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EFFECTS OF SEA WATER AND HERBICIDE FOR SALT TOELARNT WEED MANGEMENT IN TURFGRASS

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Abstract

Sea water in combination with trifloxysulfuron-sodium and quinclorac were used to observe weed injury level in turfgrass field. The weed species *viz., Sporobolus diander* (L.) R. Br., *Croton aromaticus* L., *Croton rotundus* and *Emilia sonchifolia* (L.) DC. *ex* Wight except *Emilia atrovirens* were fully controlled when treated with ¾ recommended trifloxysulfuron-sodium with sea water, ¾ recommended trifloxysulfuron-sodium with ¾ sea water, ½ recommended trifloxysulfuron-sodium with sea water, ¾ recommended quinclorac with sea water and ¾ recommended quinclorac with ¾ sea water. *Eragrostis atrovirens* (Desf.) Trin. *ex* Steud. exposed maximum (48%) injury when treated with ¾ recommended trifloxysulfuron-sodium and sea water. *Paspalum vaginatum* Sw. showed only 8% injury to sea water in combination with ¾ recommended quinclorac, indicating greater salt tolerance among the three turfgrass. *Zoysia japonica* Steud. also exposed no more than 14% injury when treated with sea water in combination with ¾ recommended trifloxysulfuron-sodium or quinclorac. *Cynodon dactylon* (L.) Pers. ''Satiri' had up to 21% salt injury with ¾ sea water in combination with ¾ recommended trifloxysulfuron-sodium.

Introduction

Weeds cause a continuous problem in management of all turfgrass species. There are numerous herbicides available for pre and post weed control in bermudagrass (*Cynodon dactylon*), seashore paspalum (*Paspalum vaginatum*) and zoysiagrass (*Zoysia japonica*) (Teuton *et al*. 2004). Seashore paspalum exhibits exceptional salt tolerance (Uddin *et al.* 2009, 2011a, 2012a) and also bermudagrass, is listed as tolerant (Carrow and Duncan 1998).

Most herbicides used in warm season turfgrass can control grasses and sedges. Non-selective use of herbicides such as glyphosate and glufosinate, provides control but injures desired turf (Hossain *et al*. 1999). Quinclorac is also leveled in turfgrass preemergence and post emergence for control of several weed species including *Digitaria sanguinalis*, *Panicum repens*, *Trifolium repens*, and *Hydrocotyle* spp. (Kelly and Coats 1999). Trifloxysulfuron-sodium, a sulfonylurea herbicide, has been developed for use in cotton, sugarcane and bermudagrass (Mosdell *et al*. 2001, Porterfield *et al*. 2002). Trifloxysulfuron-sodium was readily absorbed by shoots and roots and was rapidly translocated in weeds. Growth of susceptible weeds was inhibited by trifloxysulfuron-sodium application with complete mortality within 1 to 2 weeks after application (Hudetz *et al*. 2000).

Several golf courses have the capability to use saltwater for irrigation, and this practice is becoming more common in coastal environments (Duncan and Carrow 2000). Many weeds can be suppressed in saline conditions but salt tolerant weeds will require other means of control. Weeds are a common problem and need to be controlled in order to maintain a high quality turf.

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Furthermore, many golf courses border environmentally sensitive areas and hence chemical control of weeds is not always feasible. While sea water may control some weed species, salt tolerant weeds would require more innovative approaches for effective control. Sea water integrated with combinations of reduced herbicide rates offer opportunities for improved weed control. However, studies on susceptibility of salt tolerant turfgrass weeds to saltwater in combination with reduced rates of herbicide is lacking. The specific objective of this study was to evaluate the effect of sea water in combination with reduced herbicide rates on injury of turfgrass and weed species.

Materials and Methods

The experiment was conducted in the field at the Turf Unit, Taman Pertanian Universiti, Universiti Putra Malaysia. Among the 79 species found in the field survey, the five most salt tolerant weed species (Table 1) were selected for evaluation. They were planted in *Paspalum vaginatum* (sea shore papspalum), *Zoysia japonica* (Japanese lawn grass) and *Cynodon dactylon* 'satiri' which were maintained as the designated turfgrass species.

Table 1. List of five most salt tolerant weed species.

Scientific name	Common name	Weed type
Eragrostis atrovirens (Desv.) Trin. ex Steud.	Wiry eragrostis	Grass
Sporobolus diander (Retz.) P. Beauv.	Lesser dropseed	"
Cyperus aromaticus (Ridley) Mattf. & Kük.	Greater kyllinga	Sedge
Cyperus rotundus L.	Purple nutsedge	"
Emilia sonchifolia (L.) DC. *ex* Wight	Red tassel flower	Broadleaf

The soil medium was prepared by thoroughly mixing washed river sand and peat (KOSAS^R) in the ratio of 9 : 1 (v/v). Land preparation began one month before planting. The land was cultivated, leveled and constructed according to USGA Green profile. The experimental plots were laid out according to the randomized complete block design (RCBD). The size of each plot was 2 m × 1 m. The spacing between plots was 20 cm.

Three salt tolerant turfgrass species, namely *Paspalum vaginatum*, *Zoysia japonica* and *Cynodon dactylon* 'satiri' and five salt tolerant weed species *viz. Eragrostis atrovirens, Sporobolus diander, Cyperus aromaticus, Cyperus rotundus,* and *Emilia sonchifolia* were used in this study. Strips of turfgrass sods were cut with a sod cutter. Plugs were cut from the sod strips. The plug sizes were 15 cm × 15 cm. The native soil was washed from the plugs and the plugs were transplanted into the field plots. Mature plants of weed species were collected from fields around UPM, the native soil was removed, and 20 plants of each weed species were transplanted into the respective experimental plots at 20 cm × 10 cm spacing. Prior to application of treatments the transplanted weeds and turf species were irrigated with fresh water twice daily (morning and evening) for 8 weeks to allow for rooting and establishment. Weeds specimens were thinned to a final density of 20 plants per plot for each weed species.

Based on the results of the glasshouse study, five potential weed control methods were selected for trifloxysulfuron-sodium (recommended rate 40 g ai/ha) and quinclorac (recommended rate 200 g ai/ha) herbicides. Herbicides with sea water combinations evaluated in this study were: T_1 = 0 (control), T_2 = Sea water (SW), T_3 = RT (Recommended trifloxysulfuron-sodium herbicide), T_4 = SW (48 dS/m) + 3/4 RT, T_5 = 3/4 SW (36 dS/m) + 3/4 RT, T_6 = SW (48 dS/m) + 1/2 RT, T_7 = RQ (Recommended quinclorac herbicide), T_8 = SW (48 dS/m) + 3/4 RQ and T_9 = ¾ SW (36 dS/m) + 3/4 RQ.

Seawater with the EC value 48 dS/m was taken from the sea near Morib Beach, Selangor and diluted with distilled water as necessary and mixed with the selected herbicide doses to prepare the respective treatments. The treatments were initiated at the 9th week (after establishment). Treatments were applied once, at a spray volume of 450 l/ha. Trifloxysulfuron (recommended rate 40g ai/ha) and quinclorac (recommended rate 200 g ai/ha) were applied per plot at the rate of 8 mg ai/90 ml and 40 mg ai/90 ml, respectively. Weed control was visually evaluated at 3, 7, 14 and 21 days after treatment using a scale of 0 (no control) to 100 (complete control) (Burril *et al*. 1976).

At 21 DAT shoots and roots of turfgrass (15 cm × 15 cm) and weeds were harvested. The turfgrass plug sizes were 15 cm × 15 cm. Three plants of weed were collected. The plant samples were carefully washed to remove all soil particles and dried in an oven at 70ºC for 3 days until constant weight was achieved. The dry weight (g) was recorded/m^2 for each treatment. Shoot dry weights were expressed as percentages, relative to control for each species by the following formula proposed by Ashraf and Waheed (1990):

$$\text{Relative dry weight (\%)} = \frac{\text{Dry weight of salinized treatment value of a species}}{\text{Dry wight of control treatment value of that species}} \times 100$$

Data were analyzed using the ANOVA available in SAS (2004). The treatment means were separated by protected LSD at the 5% probability level.

Results and Discussion

Significant differences were observed among tested turfgrass species regarding their sensitivity to the treatment combinations (Table 2). Application of sea water (SW) alone gave 2 - 5% injury in *P. vaginatum* at 21 DAT, while 5 - 10% and 10 - 20% injuries were recorded in *Z. japonica* and *C. dactylon* 'satiri', respectively. Application of RT alone resulted in 18-32%, 4-9%, and 6 - 10% injuries to *P. vaginatum*, *Z. japonica* and *C. dactylon* 'satiri', respectively. In contrast, application of RQ alone had 0 - 10% and 24 - 56% injuries to *P. vaginatum* and *C. dactylon* 'satiri', respectively. Whereas, *Z. japonica* had no injury with RQ alone. When reduced doses of 3/4 RQ + SW) were applied, *P. vaginatum* showed only 0 - 8% injury, while *C. dactylon* 'satiri had 25 - 76% injury and *Z. japonica* had intermediate levels of injury (0 - 12%). Due to 3/4 RT+SW, *P. vaginatum*, *Z. japonica* and *C. dactylon* 'satiri showed 20 - 37%, 0 - 10% and 8 - 36% injury, respectively. Overall, ½ or ¾ RT with SW or ¾ SW caused 10% injury in *Z. japonica*, while ¾ RQ with SW or ¾ SW gave 10% or less injury in *P. vaginatum*. Combination of RQ and SW gave less injury in *P. vaginatum* and *Z. japonica* while the combination of RT and SW resulted in low injury only in *Z. japonica*.

Application of sea water (SW) alone showed 6-25% injury in *E. atrovirens* at 21 DAT, while 10 - 34, 5 - 27, 7 - 40 and 12 - 49% injuries were observed in *S. diander*, *C. aromaticus*, *C. rotundus* and *E. sonchifolia*, respectively.At 21 DAT, application of recommended trifloxysulfuron-sodium (RT) alone caused 10 - 30, 10 - 55, 20 - 48, 19 - 55 and 15 - 65% injury in *S. diander*, *C. aromaticus*, *C. rotundus* and *E. sonchifolia*, respectively. In contrast application of recommended quinclorac (RQ) alone caused 8 - 30, 10 - 49, 8 - 50, 18 - 50 and 17 - 56% injury in *S. diander*, *C. aromaticus*, *C. rotundus* and *E. sonchifolia*, respectively. Injury level dramatically increased in combination treatments. Reduced doses of recommended quinclorac combined with sea water (3/4 RQ + SW) in *S. diander*, *C. aromaticus*, *C. rotundus* and *E. sonchifolia* gave 13 - 48, 26 - 29, 30 - 100, 35 - 100 and 36 - 100% injury, respectively. On the other hand, the same reduced doses with recommended quinclorac when combined with sea water in *S. diander*, *C. aromaticus*, *C. rotundus* and *E. sonchifolia* resulted in 15 - 42, 20 - 80, 20 - 85 and 22 - 82% injury, respectively. Overall, ½ or ¾ RT with sea water or ¾ sea water resulted in 10 - 40, 21 - 84, 20 - 88, 20 - 87 and 23 - 94% injury in *S. diander*, *C. aromaticus*, *C. rotundus* and *E. sonchifolia*, respectively. In contrast ¾ recommended quinclorac with sea water, or ¾ sea water resulted in 10-42, 17 - 80, 15 - 85, 20 - 77 and 20 - 82% injury in *S. diander*, *C. aromaticus*, *C. rotundus* and *E. sonchifolia*, respectively, while combination of recommended quinclorac with sea water or¾ sea water resulted 10 - 42, 17 - 80, 15 - 85, 20 - 77 and 20 - 82 injury in *S. diander*, *C. aromaticus*, *C. rotundus* and *E. sonchifolia*, respectively.

Table 2. Effect of sea water application in combination with reduced rates of herbicide on turfgrass species injury.

Treatment	Injury (%)											
	Paspalum vaginatum				*Zoysia japonica*				*Cynodon dactylon* 'Satiri'			
	3 d	7 d	14 d	21d	3 d	7 d	14 d	21 d	3 d	7 d	14 d	21d
FW	0 e	0 d	0 d	0 d	0 d	0 d	0 d	0 e	0 d	0 g	0 d	0 h
SW	5 de	5 cd	5 cd	2 d	5 c	8 bc	10 ab	10 b	10 bc	15 de	20 c	15 f
RT	18 c	23 b	27 b	32b	4 c	7 c	9 bc	8 bc	10 bc	12 ef	6 e	8 g
¾ RT+ SW	30 a	30 a	35 a	37 a	8 ab	10 ab	10 ab	6 cd	12 b	17 d	18 c	36d
¾ RT+¾ SW	25 ab	28 ab	32 ab	36 a	6 bc	9 ab	7 c	4 d	8 c	13 f	12 d	21e
½ RT+ SW	20 bc	24 b	30 ab	31b	0 d	0 d	0 d	0 e	10 bc	10 ef	13 cd	18ef
RQ	10 d	10 c	0 d	0 d	0 d	0 d	0 d	0 e	24 a	28 c	45 b	56c
¾ RQ+ SW	0 e	7 c	7 c	8 c	10 a	12 a	12 a	14 a	27 a	37 a	55 a	76a
¾ RQ+¾ SW	0 e	0 d	0 d	0 d	8 b	8 bc	10 ab	10 b	25 a	32 b	48 b	61b

FW = Fresh water, RT = Recommended trifloxysulfuron-sodium herbicide, SW = Seawater, RQ = Recommended quinclorac herbicide. Means within columns followed by same letter are not significantly different at p = 0.05 (LSD test).

Significant differences in sensitivity to different treatments were observed among the tested weed species (Table 3).

Shoot dry weights (SDW) of turfgrasses were significantly reduced by different salt and herbicide treatments and varied greatly between different turf species (Table 4). In control treatments (fresh water), shoot dry weight of the different turfgrass species ranged between 278.70 and 662.83 g/m^2. On average in all turf species, sea water alone resulted in 14% SDW reduction. Treatments RT and RQ alone and ¾ RT + SW and ¾ RQ + SW caused about 25% reduction in SDW. Among the sea water - herbicides combination treatments, ¾ RT + SW and ¾ RT + ¾ SW caused greater SDW reductions (about 30%) in *P. vaginatum*, while treatments of ¾ RT + SW, ¾ RQ + SW and ¾ RQ + ¾ SW had greater SDW reductions (about 50%) in *C. dactylon* 'satiri'. None of the treatments were found to be effective against *Zoysia japonica*, where only about 10% reduction in SDW was recorded in the ¾ RT + SW treatment.

Shoot dry weights (SDW) of weed species significantly reduced due to different salt and herbicide treatment applications and greatly varied between different turf species (Table 5). In control treatments (fresh water application), shoot dry weight of different weed species ranged between 15.18 to 48.30 g/m^2. On average sea water alone caused about 21% SDW reduction and treatments of RT, RQ, ¾ RT + SW and ¾ RQ + SW resulted in 25, 29, 38 and 45% reductions, respectively. Among the sea water - herbicide combination treatments, ¾ RT + SW and ¾ RT + ¾ SW caused greater SDW reductions (about 44%) in *C. rotunduss* followed by *S. diander* (42%) and *E. sonchifolia* (about 39%), while lower reductions were recorded in *C. aromaticus* (about 22%), followed by *E. atrovirens* (about 25%). The treatments of ¾ RQ + SW and ¾ RQ + ¾ SW resulted in greater SDW reductions (about 55%) in *C. rotundus* followed by *S. diander* (50%) and *E. sonchifolia* (about 44%), while lower reductions were observed in *E. atrovirens* (about 26%) followed by *C. aromaticus* (30%).

Table 3. Effect of sea water application in combination with reduced rates of herbicide on weed species injury.

Weed species	Treatment	Injury (%)			
		3 d	7 d	14 d	21 d
(*Eragrostis atrovirens*)	FW	0 d	0 f	0 d	0 f
(Wiry eragrostis)	SW	6 c	10 e	15 e	25 e
	RT	10 bc	12 de	20 c	30 de
	¾ RT+ SW	13 ab	30 a	40 a	48 a
	¾ RT+¾ SW	10 bc	22 b	30 bc	40 bc
	½ RT+ SW	10 bc	16 cd	25 cd	35 cd
	RQ	8 c	10 e	25 cd	30 de
	¾ RQ+ SW	15 a	20 bc	35 ab	42 ab
	¾ RQ+¾ SW	10 bc	14 de	30 bc	37 bc
(*Sporobolus diander*)	FW	0 e	0 f	0 g	0
(Lesser dropseed)	SW	10 d	15 ef	22 g	34 f
	RT	10 d	23 de	40 e	55 e
	¾ RT+ SW	26 a	50 a	65 a	95 a
	¾ RT+¾ SW	23 ab	40 b	57 b	84 b
	½ RT+ SW	21 b	30 c	50 cd	73 cd
	RQ	10 d	20 ef	40 e	49 e
	¾ RQ+ SW	20 bc	29 cd	55 bc	80 bc
	¾ RQ+¾ SW	17 c	25 c-e	45 de	70 d
(*Cyperus aromaticus*)	FW	0 e	0f	0 h	0 f
(Greater Kyllingia)	SW	5 de	10 e	18 g	27 e
	RT	20 bc	25 cd	40 e	48 de
	¾ RT+ SW	30 a	50 a	75 a	100 a
	¾ RT+¾ SW	25 ab	40 b	65 b	88 b
	½ RT+ SW	20 bc	30 c	45 d	78 c
	RQ	8 d	20 d	35 f	50 d
	¾ RQ+ SW	20 bc	38 b	55 c	85 b
	¾ RQ+¾ SW	15 c	28 c	44 de	74 c
(*Cyperus rotundus*)	FW	0 e	0 f	0 g	0 g
(Purple nutsedge)	SW	7 d	12 e	28 f	40 f
	RT	19 c	27 cd	45 d	55 e
	¾ RT+ SW	35 a	45 a	77 a	100 a
	¾ RT+¾ SW	25 b	38 b	65 b	87 b
	½ RT+ SW	20 bc	30 cd	55 c	84 c
	RQ	18 c	28 cd	35 e	50 e
	¾ RQ+ SW	25 b	32 bc	56 c	77 c
	¾ RQ+¾ SW	20 bc	25 d	45 d	70 d
(*Emilia sonchifolia*)	FW	0 g	0 f	0 d	0 h
(Red tessel flower)	SW	12 f	30 de	40 c	49 g
	RT	15 e	25 e	50 b	65 e
	¾ RT+ SW	36 a	50 a	66 a	100 a
	¾ RT+¾ SW	30 b	41 bc	55 b	94 b
	½ RT+ SW	23 c	35 cd	48 bc	84 c
	RQ	17 de	25 e	40 c	56 f
	¾ RQ+ SW	22 cd	42 b	65 a	82 c
	¾ RQ+¾ SW	20 c-e	37 bc	52 b	75 d

FW = Freshwater, RT = Recommended trifloxysulfuron-sodium herbicide, SW = Seawater, RQ = Recommended quinclorac herbicide. Means within columns followed by same letter are not significantly different at p = 0.05 (LSD test).

Table 4. Effect of combinations of sea water and herbicide rates on shoot dry weight of turfgrass species.

Treatment	Turfgrass species (shoot dry weigh gt/m^2)			Average decrease over all species (%)
	P. vaginatum	*Zoysia japonica*	*C. dactylon* 'satiri'	
FW	100	100	100	
SW	96a	96bc	67c	86
RT	77bc	93cd	61d	77
¾ RT+ SW	69d	90ab	52e	77
¾ RT+¾ SW	66d	98ab	86b	83
½ RT+ SW	76c	96bc	82b	85
RQ	87b	91d	51e	76
¾ RQ+ SW	87b	97ab	45e	76
¾ RQ+¾ SW	97a	97ab	55ce	83

FW = Freshwater, RT = Recomendad trifloxysulfuron-sodium herbicide, SW = Seawater, RQ = Recomendad quinclorac herbicide. Means within columns followed by the same letter are significantly different at p = 0.05 (LSD test). Values within parenthesis indicate per cent of control (FW).

Table 5. Effect of combinations of sea water and herbicide rates on shoot dry weight of different weed species.

Treatment	Weed species (shoot dry weight g/m^2)					Average decrease over all species (%)
	Eragrostis atrovirens	*Sporobolus diander*	*Cyperus aromaticus*	*Cyperus rotundus*	*Emilia sonchifolia*	
FW	100	100	100	100	100	100
SW	86	75	78	76	82	79
RT	88bc	80c	82b	71c	54f	75
¾ RT SW	75d	50f	75e	53f	56f	62
¾ RT+¾SW	75d	66d	80c	58e	65d	69
½ RT+SW	79cd	82b	73f	67d	69c	74
RQ	95ab	73c	63i	52f	71c	71
¾ RQ+SW	73d	41g	69h	42h	51d	55
¾ RQ+¾SW	75d	58e	71g	47g	60e	62

FW = fresh water, RT = recommended trifloxysulfuron-sodium herbicide, SW = seawater, RQ = recommended quinclorac herbicide. Means within columns followed by the same letter are significantly different at p = 0.05 (LSD test). Values within parenthesis indicate per cent of control (FW)

Application of sea water alone or in combination with herbicide (trifloxysulfuron-sodium and/ or Quinclorac) influenced injury level, shoot dry weight of weed and turf grass. Grass weeds (*Poa annua*, *Lolium perenne*), sedges (*Cyperus rotundus*, *C. globulosa*, *C. compressus*, *C. esculentus*) and broadleaf (*Diodia virginiana*) can be controlled by single or sequential applications of trifloxysulfuron-sodium (Monument®) at 10 to 50g ai/ha (Belcher *et al*. 2002, Brecke and Mosdell *et al*. 2001, Walker and Belcher, 2002). Brecke (2000) reported that trifloxysulfuron-sodium at the rate of 0.025 to 0.074 kg a.i./ha provided better *Panicum repens* control when efficacy assessments were made 3 weeks after treatment (90 to 100%) compared to 11 day after treatment (80 to 90%). Stephenson *et al*. (2006) reported that sequential applications of trifloxysulfuron-sodium (75 g ai/ha) or quinclorac + diclofop-methyl (840 g ai/ha) provided 87 and 84% control of *Panicum repens*, respectively. Therefore, salt tolerant weed species *viz. E. atrovirens*, *S. diander*, *C. aromaticus*, *C. rotundus* and *E. sonchfolia* could be controlled effectively by application of sea water plus ¾ RT or ¾ RQ. Application of sea water along with reduced rate of RT and RQ resulted in controlling of salt resistance weed species in turf. Similar result has been reported by Uddin *et al.* (2011b), Uddin and Juraimi (2012b), Azwa *et al*. (2011), and Brosnan *et al.* (2009). The present study revealed that sea water and herbicide at reduced rate has the synergistic effect in controlling weeds.

Among the tufgrass species *P. vaginatum* was found to be highly sensitive in terms of injury to recommended trifloxysulfuron herbicide with different concentrations of sea water. There was no visual injury in *Z. japonica* due to the application of recommended quinclorac and ½ recommended trifloxysulfuron with sea water. Maximum injury of 70 - 100% occurred at 21 DAT in all weed species, except *E. atrovirens,* when treated with ¾ recommended trifloxysulfuron-sodium with sea water, ¾ recommended trifloxysulfuron-sodium with ¾ sea water, recommended trifloxysulfuron-sodium with ½ sea water, ¾ recommended quinclorac with sea water and ¾ recommended quinclorac with ¾ sea water. The recommended trifloxysulfuron-sodium and quinclorac can be effectively used for weed control in *C. dactylon* 'satiri'and *P. vaginatum*, respectively; while both of the herbicides can be used for effective weed control in *Z. japonica*.

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