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Efficacy of sea water in combination with trifloxysulfuron and quinclorac to control weeds in salt tolerant tropical turfgrass

Md. Kamal Uddin[3], Abdul Shukor Juraimi[1*], Mohd. Razi Ismail[3], Mahfuza Begum[3]Radziah Othman[2] and Anuar Abdul Rahim[2]

[1]Department of Crop Science, Faculty of Agriculture, Universiti Putra Malaysia, 43400 Serdang, Selangor, Malaysia
[2]Department of Land Management, Universiti Putra Malaysia, 43400 Serdang, Selangor, Malaysia
[3] Institute of Tropical Agriculture

***Corresponding author: ashukor@agri.upm.edu.my**

Abstract

Research was designed to reduce herbicide use by replacing post emergence herbicides with readily available sea water to control weeds in salt tolerant tropical turfgrass. Different concentration of sea water in combination with trifloxysulfuron-sodium and quinclorac were used in this study. Maximum injury of 70-100% occurred at 21 DAT in *Sporobolus diander, Cyperus aromaticus, Cyperus rotundus,* and *Emilia sonchifolia*, except *E. atrovirens,* when treated with ¾ trifloxysulfuron-sodium{N-(4-6-Dimethoxy2-pyrimidinyl)-3-(2,2,2-rifluoroethoxy)-pyridine-2-sulfonamide sodium salt} with sea water, ¾ trifloxysulfuron-sodium with ¾ sea water, trifloxysulfuron-sodium with ½ sea water, ¾ quinclorac (3,7-dichloro-8-quinoline carboxylic acid) with sea water and ¾ quinclorac with ¾ sea water. The trifloxysulfuron-sodium and quinclorac herbicide can be effectively used for weed control in *C. dactylon* 'satiri' and *P. vaginatum* respectively; and both the herbicides can be used for effective weed control in *Z. japonica*.

Keywords: Sea water, weed, turfgrass, trifloxysulfuron-sodium, quinclorac.
Abbreviations: EC-Electrical Conductivity, LSD-Least Significance Difference DAT-Day after treatment.

Introduction

Weed causes 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*) (Blum et al., 2000; Wiecko, 2000; Unruh et al., 2006; Teuton et al., 2004). According to numerous studies, seashore paspalum exhibits exceptional salt tolerance (Kamal Uddin et al., 2009; Carrow and Duncan, 1998; Dudeck and Peacock, 1985; Duncan, 1998; Duncan and Carrow, 2000) and also bermudagrass, is listed as tolerant (Carrow and Duncan, 1998; Marcum and Murdoch, 1994, Marcum and Murdoch 1994; Kamal Uddin et al., 2011).
Most herbicides used in warm season turfgrass will not control grasses and sedges. Nonselective use of herbicides, such as glyphosate and glufosinate, provide control but injure desired turf (Hossain et el., 1999; McCarty et al., 1993). 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 (Hudtez et al., 2000; Mosdell et al., 2001; Porterfield et al., 2002; Rawls et al., 2000). 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; Wiecko, 2003). 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. 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 (Wiecko, 2003). The specific objective of this study was to evaluate the performance of sea water in combination with reduced herbicide rates on to control weed in salt tolerant turfgrass species.

Results

Effect of combinations of sea water and trifloxysulfuron on turfgrass injury

Paspalum vaginatum

Significant differences in injury level were observed at 3 days after treatment (DAT) in the different combinations of trifloxysulfuron-sodium herbicide and sea water (Table 3-supplementary data). Applications of fresh water (FW), ½ sea water (½ SW) and ¼ sea water (¼ SW) did not cause any injury to *P. vaginatum*. The treatment with ¾ sea water (¾ SW), ¼ trifloxysulfuron-sodium (¼ RT), sea water (SW), ½ trifloxysulfuron-sodium with ½ sea water (½ RT + ½ SW) and ¼ trifloxysulfuron-sodium with ¼ sea water (1/4 RT+1/4 SW) caused very light injury symptoms ranging from 5 - 10% in *P. vaginatum*. At 21 DAT, *P. vaginatum* showed no injury due to application of fresh water, sea water, ¾ sea water, ½ sea water and ¼ sea water. Trifloxysulfuron-sodium with sea water caused highest injury (40%), while trifloxysulfuron-sodium, recommended trifloxysulfuron-sodium with ¾ sea water, trifloxysulfuron-sodium with ½ sea water, ¾ trifloxysulfuron with sea water and ¾ trifloxysulfuron-sodium with ¾ sea water showed injury ranging from 31 to 35%..

***Cynodon dcatylon* 'satiri'**

No injury symptoms were observed in species *C. dactylon* 'satiri' on day 3, 7, 14 and 21 for the treatments; fresh water, ½ sea water, ¼ sea water, ½ recommended trifloxysulfuron-sodium, ¼ recommended trifloxysulfuron-sodium, ¼ recommended trifloxysulfuron-sodium with ½ sea water and ¼ recommended trifloxysulfuron-sodium with ¼ sea water (Table 3-supplementary data). All treatments, except the recommended trifloxysulfuron-sodium with sea water alone showed low levels of injury (15%). Finally at 21 DAT it was observed that very light injury (4 to10%) was found only in six treatments *viz* ¼ trifloxysulfuron-sodium with ¾ sea water, ½ trifloxysulfuron-sodium with ½ sea water, ¾ trifloxysulfuron-sodium with ¼ sea water, ¾ trifloxysulfuron-sodium, recommended trifloxysulfuron-sodium with ¼ sea water and trifloxysulfuron-sodium with ½ sea water, while eight treatments showed light injury symptoms (12 to 29%).

Zoysia japonica

At 3 DAT the treatments ¾ trifloxysulfuron-sodium with ½ sea water, trifloxysulfuron-sodium with ¼ sea water, ¾ trifloxysulfuron-sodium, trifloxysulfuron-sodium, ¾ trifloxysulfuron-sodium with ¾ sea water, ½ trifloxysulfuron-sodium, ¼ trifloxysulfuron-sodium with sea water, sea water, ¾ sea water, trifloxysulfuron-sodium with ½ sea water, trifloxysulfuron-sodium with ¼ sea water, ¾ trifloxysulfuron-sodium with sea water and trifloxysulfuron-sodium with sea water produced 2 to 8% injury (Table 3-supplementary data). At 7 DAT the treatments ¾ trifloxysulfuron-sodium with ½ sea water, trifloxysulfuron-sodium with ¼ sea water, ¾ trifloxysulfuron-sodium, trifloxysulfuron-sodium, ¾ sea water, ¾ trifloxysulfuron-sodium, trifloxysulfuron-sodium, ¾ trifloxysulfuron-sodium with ¾ sea water, ¾ trifloxysulfuron-sodium with sea water, trifloxysulfuron-sodium with ¾ sea water, ½ trifloxysulfuron-sodium with ¾ sea water, and trifloxysulfuron-sodium with sea water and sea water caused between 2 to 10% injury, which indicated very light symptoms. At 14 DAT the treatments trifloxysulfuron with sea water and ½ trifloxysulfuron with sea water caused the highest injury (11%).

Effect of combinations of sea water and trifloxysulfuron on weed injury

Eragrostis atrovirens

The following treatments did not show any injury symptoms on *E. atrovirens* at 3, 7, 14 and 21 DAT: fresh water, ½ sea water, ¼ sea water, ¼ recommended trifloxysulfuron-sodium, ¼ trifloxysulfuron-sodium with ¾ sea water, ¼ trifloxysulfuron-sodium with ½ sea water and ¼ trifloxysulfuron-sodium with ¼ sea water. Treatments ¾ sea water, ½ trifloxysulfuron-sodium and ½ trifloxysulfuron-sodium with ¼ sea water showed no injury symptoms at 3 DAT, while ¾ sea water, and ½ trifloxysulfuron-sodium –sodium with ¼ sea water showed no injury symptoms at 7 DAT (Table 4-supplementary data). The following treatments demonstrated very light injury (4-10%) at 14 and 21 DAT: ½ trifloxysulfuron–sodium with ¼ sea water, ½ trifloxysulfuron –sodium, ¼ trifloxysulfuron –sodium with sea water, sea water, ½ trifloxysulfuron–sodium with ½ sea water, ½ trifloxysulfuron –sodium with ¾ sea water, ½ trifloxysulfuron-sodium with sea water and ¾ trifloxysulfuron-sodium with ¼ sea water. On the other hand, the following 9 treatments *viz* ¾ trifloxysulfuron –sodium with ½ sea water, trifloxysulfuron –sodium, ¾ trifloxysulfuron –sodium with ¾ sea water, trifloxysulfuron-sodium with ½ sea water, ¾ trifloxysulfuron–sodium, sea water, trifloxysulfuron–sodium with ¾ sea water, ¾ trifloxysulfuron–sodium with sea water and trifloxysulfuron–sodium with sea water showed light injury symptoms (12-25%) at 14 and 21 DAT. The trifloxysulfuron–sodium with ¼ sea water showed very light injury at day 14, while light symptoms were observed at 21 DAT.

Sporobolus diander

At 3 DAT, in *S. diander* fresh water, ½ sea water, ¼ sea water, ¼ trifloxysulfuron–sodium and ¼ trifloxysulfuron–sodium with ¼ sea water did not show any injury (Table 4-supplementary data). Fresh water and ¼ trifloxysulfuron–sodium with ¼ sea water did not show any injury at 14 DAT. The least injury (4-10%) was observed in treatments: ¼ trifloxysulfuron–sodium, ¼ sea water and ½ sea water. Maximum injury was observed in the following treatments: recommended trifloxysulfuron–sodium with ¾ sea water (52%), ½ trifloxysulfuron–sodium with sea water (52%), ¾ trifloxysulfuron–sodium with ¾ sea water (55%), ¾ trifloxysulfuron–sodium with sea water (59%) and trifloxysulfuron –sodium with sea water (73%) which indicated acceptable level of 'weed control'.

Cyperus aromaticus

At day 3, treatments with fresh water, ¾ sea water, ½ sea water, and ¼ sea water did not show any injury in *C. aromaticus* (Table 4-supplementary data). Low injury (5-10%) was observed for 11 treatments which indicated very light symptoms for the species. At 21 DAT, fresh water, ½ sea water and ¼ sea water did not affect the plants at all. Trifloxysulfuron–sodium with ½ sea water, trifloxysulfuron–sodium with ¾ sea water, ½ trifloxysulfuron –sodium with sea water, trifloxysulfuron –sodium with sea water, ¾ trifloxysulfuron–sodium with ¾ sea water and ¾ trifloxysulfuron–sodium with sea water resulted in injury levels of 55, 65, 80, 85, 85, and 93%, respectively.

Cyperus rotundus

Fresh water and ¼ recommended herbicide showed no injury symptoms in *C. rotundus* at 3 DAT (Table 4-supplementary data). At day 21, the treatments ¼ sea water, ½ sea water, ½ trifloxysulfuron –sodium with ¼ sea water, ¼ trifloxysulfuron –sodium, ¼ trifloxysulfuron –sodium with ¼ sea water, ¼ trifloxysulfuron –sodium with ½ sea water, and

½ trifloxysulfuron –sodium with ½ sea water showed injury levels ranging from 15 to 25%. Only the trifloxysulfuron –sodium with sea water showed complete control. The following treatments caused heavy injury symptoms (54-86%): ¾ trifloxysulfuron –sodium, ¾ trifloxysulfuron –sodium with ½ sea water, trifloxysulfuron –sodium with ¼ sea water, trifloxysulfuron –sodium, trifloxysulfuron –sodium with ½ sea water, ½ trifloxysulfuron –sodium with sea water, trifloxysulfuron –sodium with ¾ sea water, ¾ trifloxysulfuron–sodium with ¾ sea water and ¾ trifloxysulfuron–sodium with sea water.

Emilia sonchifolia

Fresh water and ¼ recommended trifloxysulfuron–sodium did not show any injury at 3 DAT in *Emilia sonchifolia* (Table 4-supplementary data). Finally, at 21 DAT only ½ sea water showed light injury (15%). The following treatments demonstrated moderate injury (32-50%): ¾ sea water, ¼ trifloxysulfuron –sodium with ¼ sea water, sea water, ¼ trifloxysulfuron –sodium with ½ sea water, ½ trifloxysulfuron–sodium and ¼ trifloxysulfuron –sodium with ¾ sea water. *Emilia sonchifolia* was completely controlled at day 21 by ¾ trifloxysulfuron–sodium with sea water and r trifloxysulfuron–sodium with sea water.

Effect of combinations of sea water and quinclorac on turfgrass injury

Paspalum vaginatum

Low injury levels (5-10%) were observed at 3 day in *P. vaginatum* due to applications of herbicide with ¾ sea water, quinclorac (RQ) with sea water, ¾ sea water, quinclorac and sea water, while the remaining 20 treatments did not show any injury (Table 5-supplementary data). At day 21 sea water, quinclorac with sea water and ¾ quinclorac with sea water produced light injury symptoms (5-10%) while the remaining twenty-two treatments did not show any injury in *P. vaginatum*.

***Cynodon dactylon* 'satiri'**

There was no visual injury at day 3, 7, 14 and 21 in *C. dactylon* 'satiri' due to application of ½ sea water, ¼ sea water and ¼ quinclorac (Table 5-supplementary data). At day 21 low injury levels (5-10%) with light symptoms was observed in ¾ sea water and ½ quinclorac, while maximum injury (75-79%) with heavy damage symptoms was observed in ¾ quinclorac with sea water and quinclorac with sea water. Fairly heavy damage symptoms were observed in quinclorac (55%), quinclorac with ¼ sea water (55%), ¾ quinclorac with ¾ sea water (59%), quinclorac with ½ sea water (61%) and quinclorac with ¾ sea water (69%), which indicated acceptable control. Moderate injury (31-50%) were observed in ¼ quinclorac with sea water, ½ quinclorac with sea water, ¾ quinclorac with ¼ sea water and ¾ recommended quanclorac with ½ sea water.

Zoysia japonica

At 3 DAT the following eight treatments showed very light injury (5-10%) symptoms in *Z. japonica*: ¾ quinclorac with ½ sea water, quinclorac with sea water, ¾ quinclorac with ¾ sea water, ¾ sea water, sea water, ¾ quinclorac with sea water, ¼ quinclorac with sea water and quinclorac (Table 5-supplementary data). At 14 DAT only ¾ quinclorac with sea water showed light injury symptoms (12%), while ¾ sea water, ¾ quinclorac with ¾ sea water, sea water and ¼ quinclorac with sea water demonstrated very light symptoms (6-10%).

Effect of combinations of sea water and quinclorac on weed injury

Eragrostis atrovirens

At 3 DAT, the ¾ recommended quinclorac with ¼ sea water, recommended quinclorac and ¼ sea water treatments resulted in injury levels of between 12 to 15% in *E. atrovirens* (Table 6-supplementary data). There was no injury recorded on day 21 in treatments with ½ sea water, ¼ sea water, ½ quinclorac, and ¼ quinclorac with ¼ sea water. Only ¾ sea water showed very light injury (10%). The following treatments showed moderate injury symptoms (32-44%): ½ quinclorac with ¾ sea water, quinclorac with ½ sea water, ¾ quinclorac with sea water, ½ quinclorac with sea water, quinclorac with ¾ sea water and quinclorac with sea water.

Sporobolus diander

At day 3, no injury was observed in treatments ½ sea water, ¼ sea water and ¼ quinclorac with ¼ sea water (Table 6-supplementary data). Quinclorac with sea water caused 100% injury at day 21, while ¼ sea water caused no injury. The treatments ½ quinclorac with ¾ sea water, quinclorac with ¼ sea water, quinclorac with ½ sea water, ½ with sea water, ¾ quinclorac with ½ sea water, ¾ quinclorac with ¾ sea water, ¾ quinclorac with sea water and quinclorac with ¾ sea water resulted in injuries of 52, 52, 55, 60, 62, 65, 71 and 74%, respectively.

Cyperus aromaticus

At 3 DAT low injury levels (5-30%) were observed in all treatments. Among the treatments ½ sea water and ¼ sea water showed no injury (Table 6-supplementary data). At 7 DAT no injury was observed in ½ sea water and ¼ sea water treatments. At 21 DAT, ½ sea water and ¼ sea water showed no injury. Only the ¼ quinclorac with ¼ sea water showed very light injury (10%), while rquinclorac with sea water showed very heavy damage (91%). The following treatments resulted in heavy damage: ¾ quinclorac with ¾ sea water (70%), ½ quinclorac with sea water (74%), ¾ quinclorac with sea water (79%) and quinclorac herbicide with ¾ sea water (84%).

Cyperus rotundus

At 3 DAT, there was no visual injury with application of ¼ sea water (Table 6-supplementary data). Low injury levels of 6 to 10% were obtained in ¼ quinclorac with ¼ sea water, ¼ quinclorac, ¼ quinclorac with ½ sea water, ¼ quinclorac with ¾ sea water, ½ quinclorac with ½ sea water, ½ sea water and ½ with ¼ sea water treatments. At 21 DAT, no injury was observed in *Cyperus rotundus* due to the application of ¼ sea water. Low injury (10%) was observed in ¼ quanclorac and ¼ quinclorac with ¼ sea water, while maximum injury (98%) with very heavy damage was observed in quinclorac with sea water. Fairly heavy damage symptoms were obtained in the following treatments: sea water (51%), quinclorac with ¼ sea water (52%), ¾ quinclorac with ¼ sea water (55 quinclorac with ¼ sea water (56%), quinclorac (59%), ¾ quinclorac with ½ sea water (61%), ¾ quinclorac with ¾ sea water (65%), ½

Table 1. List of salt tolerant weed species

Scientific name	*Common name*	*Weed type*
Eragrostis atrovirens	Wiry eragrostis	Grass
Sporobolus diander	Lesser dropseed	Grass
Cyperus aromaticus L.	Greater kyllinga	Sedge
Cyperus rotundus	Purple nutsedge	Sedge
Emilia sonchifolia	Red tassel flower	Broadleaf

quinclorac with ¾ sea water (71%), quinclorac with ½ sea water (76%), ¾ quanclorac with sea water (82%), ½ quinclorac with sea water (85%) and quinclorac with ¾ sea water (87%).

Emilia sonchifolia

At 3 DAT, ¼ sea water, ½ quinclorac, ¼ quinclorac and ¼ quinclorac with ¼ sea water recorded 8 to 10% injury, while ¾ quinclorac with sea water, quinclorac with ¾ sea water, ¾ quinclorac with ½ sea water and quinclorac with sea water resulted in 33 to 40% injury (Table 6-supplementary data). At 21 DAT, 100% injury was recorded in quanclorac with sea water and ½ quinclorac with sea water, while ¾ quinclorac with sea water (93%) and the quinclorac with ¾ sea water (95%) caused very heavy damage. The following treatments showed fairly heavy to heavy damage: ¼ quinclorac with sea water (55%), ¾ quinclorac with ¼ sea water (65%), ¾ quinclorac (65%), ½ quinclorac with ½ sea water (70%), quinclorac (80%), ½ quinclorac with sea water (80%), ¾ recommended quinclorac with ½ sea water (82%), quinclorac with ¼ sea water (85%), ¾ quanclorac with ¾ sea water (86%) and qunclorac with ½ sea water (88%).

Discussion

Application of sea water (SW) alone or in combination with herbicide resulted different levels of injury to turfgrass species viz, *P. vaginatum*, *Z. japonica* and *C. dactylon* 'satiri'. Application of ¾ recommended dose of RT plus sea water or ¾ sea water increased the injury level in *P. vaginatum* by 21-34%, while that in *Z. japonica* and *C. dactylon* 'satiri' were 4-8% and 8-31%, respectively. Sea water alone resulted in 10-25%, 10-38%, 5-30%, 10-43% and 21-45% injury in *E. atrovirens*, *S. diander*, *C. aromaticus*, *C. rotundus* and *E. sonchfolia*, respectively. The sea water plus ¾ RT and sea water produced 12-25%, 23-91%, 33-93%, 20-95% and 22-100%, injury in *E. atrovirens*, *S. diander*, *C. aromaticus*, *C. rotundus* and *E. sonchfolia* respectively. Application of ¾ sea water plus ¾ RT had injury levels of 10-20%, 20-85%, 25-85%, 16-86% and 20-90%, in *E. atrovirens*, *S. diander*, *C. aromaticus*, *C. rotundus* and *E. sonchfolia* respectively. The result revealed that there is no difference in injury level that caused with ¾ RT plus sea water alone or ¾ RT plus ¾ sea water for each of the weed species. It was also found from the result that *E. atrovirens* showed higher tolerant to the herbicide plus sea water than other four weed species. In the glasshouse study, ¾ of RQ with sea water gave less injury in *P. vaginatum*, *Z. japonica* and *C. dactylon* 'satiri', while the ¾ RQ with ¾ sea water produced 0, 5-8 and 20-59% injury, respectively. In the case of weed species the treatment with ¾ of RQ and sea water resulted in highest injuries of 10-35%, 20-85%, 20-79%, 20-82% and 33-93% in *E. atrovirens*, *S. diander*, *C. aromaticus*, *C. rotundus* and *E. sonchfolia*, respectively, while the ¾ RQ with ¾ sea water resulted in injuries of 8-30%, 20-7%5, 15-70%, 22-65% and 30-86%, respectively. Grass weeds (*Poa annua*, *Lolium perenne*), sedges (*Cyperus rotundus*, *Cyperus globulosa*, *Cyperus compressus*, *Cyperus 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 Unruh, 2002; 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 *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.

Materials and methods

Selection of weed species

Five salt tolerant weed species (Table 1) were selected for evaluation in this experiment. They were planted in *Paspalum vaginatum* (seashore papspalum), *Zoysia japonica* (Japanese lawn grass) and *Cynodon dactylon* 'satiri' which were maintained as the designated turfgrass species.

Soil Media preparation

The soil media was prepared by thoroughly mixing washed river sand and peat (Peatgrow^R, KOSAS) in the ratio of 9:1 (v/v). The prepared media was pulverized and inert materials, visible insect pests and plant propagules were removed.

Planting materials: Collection and establishment

The adhering native soil on turfgrass and weed samples were removed by thorough washing. Depending on the species, weeds and turfgrass were transplanted into pots vegetatively using rhizomes or stolons or tillers. Plants were irrigated every morning and evening. The transplanted weeds and turf species were irrigated with fresh water for 8 weeks to allow for rooting and recovery from transplanting. Weeds were thinned to a final density of 3 plants per pot. The aerial reproductive structures of annual weeds were removed weekly to prevent the weeds from completing their life cycle.

Cultural practices

All pots were fertilized fortnightly with NPK Green (15:15:15) @ 50 kg N/ ha. The amount of fertilizer per pot was 513 mg and applied fort- nightly. The pot area was 0.0154 m^2 (14 cm diameter). Grasses were clipped weekly using a pair of scissors at a cutting height of 15 mm for course leaf and 5 mm for narrow leaf species.

Table 2. Injury rating scale

Scale	Injury (%)	Effects on weeds and turf
1	0	No effect (all foliage green and alive)
2	1-10	Very light symptoms
3	11-30	Light symptoms
4	31-49	Symptoms not reflected in yield
5	50	Medium
6	51-70	Fairly heavy damage
7	71-90	Heavy damage
8	91-99	Very heavy damage
9	100	Complete kill (dead)

Source: Burril et al., 1976

Application of treatments

Upon full establishment, 8- week- old all weed and turfgrass species were subjected to different sea water concentrations in combination with different herbicide doses. Seawater in this experiment was taken from the sea near Morib Beach, Selangor, Malaysia. The EC of sea water was 48 dS m^{-1}. Sea water was diluted with distilled water to prepare the lower (12, 24 and 36 dS m^{-1}) salinity level treatments.

The five salinity treatments used in this study were designated as:

S_0=0 (control)
S_1=12 dS m^{-1} (1/4 sea water)
S_2=24 dS m^{-1} (1/2 sea water)
S_3=36 dS m^{-1} (3/4 sea water)
S_4=48 dS m^{-1} (sea water)

The two herbicides *viz.* trifloxysulfuron (rate 40g ai /ha) and quinclorac (rate 200g ai/ha) were used at the following doses:

H_0 = control (no herbicide)
H_1 = RR (Recommended rate of herbicide)
H_2 = ¾ RR (3/4 Recommended rate of herbicide)
H_3 = ½ RR (1/2 Recommended rate of herbicide)
H_4 = ¼ RR (1/4 Recommended rate of herbicide)

There were a total of 25 treatment combinations for each herbicide. The pot area was 0.0154 m^{-2}. Trifloxysulfuron-sodium (recommended rate 40g ai /ha) and quinclorac (recommended rate 200g ai/ha) were applied per pot 0.06 mg ai/0.70 ml and 0.31 mg ai/0.70 ml respectively.

Determination of plant injury level

Injury symptoms were visually evaluated as an indicator to show condition of weeds and turfgrasses at 3, 7, 14 and 21 days after initial saltwater exposure using the European Weed Control and Crop Injury Evaluation system (Burrill et al., 1976). The rating scale of 0 (no injury) to 100 % (complete kill) is described in Table 2).

Experimental design and statistical analysis

The experimental design was a randomized complete block design with 4 replications. The treatments were randomly distributed in each block. The data were analyzed using the analysis of variance procedure in SAS (SAS Institute, 2004). Treatment means were separated by protected LSD test at P = 0.05.

Conclusion

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. 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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