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Full Length Research Paper

Application of saline water and herbicides as a method for weed control in the tropical turfgrass: Its impact on nutrient uptake and soil microbial community

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A field study was conducted at Universiti Putra Malaysia with the aim to find out a suitable environment friendly weed control method for turfgrass species in combination with different levels of sea water and herbicides. A number of three turfgrass species (*Paspalum vaginatum*, *Zoysia japonica* and *Cynodon dactylon* 'satiri') and five associative weed species (*Eragrostis atrovirens, Sporobolus diander, Cyperus aromaticus, Cyperus rotundus,* and *Emilia sonchifolia*) were treated with different doses of sea water level and two herbicides (Trifloxysulfuron –sodium and Quinclorac). The shoot uptake of Na, K, Ca, Mg were determined as a indicator of salt tolerance using Atomic Absorption Spectrophotometer. Among the three turfgrass species *C. dactylon* 'satiri' had higher tissue accumulations of Na with greater reduction of K (27%), Ca (42%), and Mg (23%). The tested five weed species showed higher Na accumulation and reduction of Na, K, Ca and Mg compared to turfgrasses. The highest Na accumulation was found in *E. sonchifolia* and *S. diander* weed species. Microbial populations were found highest in control treatment. While comparing 9 treatments, the combination of ¾ recommended herbicides, either trifloxysulfuron-sodium or quinclorac with ¾ sea water had lower reductions of uptake of K (5 to 19%), Mg (10-37%) and Ca (21-31%) in turfgrass species and exhibited higher microbial populations, which proved suitable for turfgrass weed management. In general, it may concluded that, combination of reduced doses (¾) of sea water and herbicide is the best method for weed control in tropical trufgrass species and also friendly to environment.

Key words: Turfgrass weed, bacteria, fungus, actinomycetes.

INTRODUCTION

Turfgrasses are monocot plants under the family Poaceae that act as vegetative ground cover and produce safe playing surfaces for children and adults. These grasses differ in environmental adaptation, wear tolerance, recuperative ability, and use. Differences in ecological adaptation of turf determine their obvious geographical distribution over the climatic regions of the world. Bermudagrass, Cowgrass, Serangoongrass, Zoysiagrass St. Augustinegrass, Bahiagrass, Seashore Papalum, and Centipedegrass are highly appreciated as tropical warm season turfgrass (Chapman and Peat, 1992). Among the warm season turfgrasses, *Cynodon dactylon* (bermuda satiri), *Cynodon dactylon* (bermuda tifdwarf), *Zoysia japonica* and *Paspalum vaginatum* (seashore pasplaum) are salt tolerant (Uddin et al., 2009b; 2011b) and mostly used in major turfgrass areas of Malaysia.

Weeds are a major problem in turfgrass areas and

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continue to pose problems in overall management programs for all turfgrass species (Johnson and Duncan, 1997). Weeds in turfgrass cause reduction in turf growth and quality due to competition for nutrients, light, water and CO_2 and detract uniformity and beauty of lawns due to the distinct contrast in color and texture between the desired grass plants and weeds (Turgeon, 2005). Three types of weeds are common in turfgrasss areas. These are grassy weeds, sedges and broadleaf. *Cyperus aromaticus*, *Fimbristylis dichotoma*, *Desmodium triflorum*, *Ischaemum indicum*, *Chrysopogoen aciculatus* and *Borerria repens* were more prevalent and abundant in turf grasses areas of Malaysia (Uddin et al., 2009a, 2010).

Weed control is difficult in turfgrass. Most herbicides used in warm season turfgrass may not control grasses and sedges. Nonselective use of herbicides, such as glyphosate and glufosinate, provide control but injure desired turf (Hossain et al., 1999; McCarty et al., 1993). Quinclorac is also leveled in turfgrass pre-emergence 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 is readily absorbed by shoots and roots and rapidly translocate in weeds. Growth of susceptible weeds is inhibited by trifloxysulfuron-sodium along with sea water with within 1 to 2 weeks after application (Hudetz et al., 2000; Uddin et al., 2011a). Although, several herbicide has good impact on turfgrass weed but it has adverse environmental effect. In this situation, sea water can be a good source of weed control in turfgrass land especially near to sea beach. Several golf courses have the capability to use salt water 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 required other means of control. Sea water integrated with combinations of reduced herbicide rates offer opportunities to improve weed control. However, a study on susceptibility of salt tolerant turfgrass weeds to saltwater in combination with reduced herbicide rates is lacking. In the selection of weed management strategies, the community of soil microbes is also an important issue for consideration. The soil gains importance, especially where high salinity results from irrigation practices and application of chemical treatments. This effect is always more pronounced in the rhizosphere as a result of increased water uptake by the plants due to transpiration (Tripathi et al., 1998). Turfgrass quality may suffer in the absence of beneficial microbe-plant interactions (Mueller, 2005). The adaptation of diazotrophs to osmotic stress is of great significance, because soil salinity inhibits many of the vital bacterial plant growth-promoting activities, such as nitrogen fixation and phytohormone production (Miller and Woods, 1996). The rhizobacteria often play crucial roles in increasing crop productivity, biodegradation of herbicides and also soil nutrient recycling. However, its efficiency in polluted environments is often limited due to abiotic stresses. Thus, it is essential to understand the microbial community structure in turfgrass in relation to environmental factors especially in salt stress environments. The specific objectives of this study is to evaluate the effect of sea water in combination with reduced herbicide rates on Na, K, Ca and Mg uptake of turfgrass and weed species and its effect on soil microbial community.

MATERIALS AND METHODS

Land preparation

The experiment was conducted in the field at the Turf Unit, Taman Pertanian Universiti, University of Putra Malaysia during the period from July to October, 2009. Land preparation began one month before planting. To kill insects, pathogens and weed seeds, Basamid ^{R} was mixed into the soil at 2 t/ha and fumigated for 7 days. After removal of polyethylene the soil was exposed to ‘Harmaler Cond’ for 7 days to remove the Basamid residue.

Planting materials: Collection and establishment

Three salt tolerant turfgrass species *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. Plugs were cut from the sod strips (15 × 15 cm) and planted. Twenty 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. All plots were fertilized fortnightly with NPK Green (15:15:15) at 50 kg N ha^{-1}.

Experimental design

The treatments were arranged in a randomized complete block design (RCBD) with three replications. The size of each plot was 2 m x 1 m. Nine potential weed control methods were selected for trifloxysulfuron-sodium (recommended rate 40 g ai ha^{-1}) and quinclorac (recommended rate 200g ai ha^{-1}) 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^{-1}) + 3/4 RT, T_5 =3/4 SW (36 dS m^{-1}) + 3/4 RT, T_6 =SW (48 dS m^{-1}) + 1/2 RT, T_7= RQ (Recommended quinclorac herbicide), T_8 = SW (48 dS m^{-1}) + 3/4 RQ, T_9 = ¾ SW (36 dS m^{-1}) + 3/4 RQ. The treatments were initiated at the 9 th week (after establishment).

Determination of turfgrass rhizosphere soil microbial populations

The bacterial, fungal and actinomycetes populations were determined according to Wollum (1982) by using Spread plate counting method in nutrient agar (NA), potato dextrose agar (PDA) and actinomycete agar plates, respectively. A liquid suspension of cells from soil samples was prepared by mixing 10 g of soil in 95 ml of sterile diluents (water). After 2 days, colonies were counted and the $\log_{10}$ number CFU per gram dry mass in the original sample was calculated using the dilution factor and dry mass correction factor. For populations of fungi and actinomycetes, plates were observed for up to one week of incubation.

Table 1. Effect of combinations of sea water and herbicide rates on shoot Na, K, Ca, Mg contents of different turfgrass species.

Treatment	Turfgrass species (Na, K, Ca, Mg contents in mg g^{-1}, dry weight)											
	P. vaginatum				*Zoysia japonica*				*C. dactylon* 'satiri'			
	Na	K	Ca	Mg	Na	K	Ca	Mg	Na	K	Ca	Mg
FW	0.78	18.74 a	3.91 a	3.77 a	1.01 e	15.39 a	2.83 a	3.54 a	1.15d	14.14 a	2.95 a	3.15 a
SW	8.01 a (10)	16.10 cd (86)	2.66 cd (68)	3.21 b (85)	10.03 a (10)	13.56 cd (88)	1.91 cd (67)	3.10 bc (88)	18.71 a (16)	8.97 de (63)	1.81 de (61)	2.66 a-c (84)
RT	1.18 e (2)	16.90 b-d (90)	3.49 ab (89)	3.55 ab (94)	1.77 e (2)	14.71 ab (96)	2.31 bc (82)	3.43 ab (97)	1.36 d (1)	11.02 bc (78)	2.59 ab (88)	2.97 ab (94)
¾ RT+SW	7.78 b (10)	16.32 c-e (87)	2.36 d (60)	3.11 b (82)	11.10 ab (11)	12.59 d (82)	1.65 d (58)	2.73 c-e (77)	16.70 b (15)	9.12 d (64)	1.52 e (52)	2.29 cd (73)
¾ RT+¾SW	5.72 d (7)	17.81 ab (95)	3.02 bc (77)	3.41 ab (90)	6.30 d (6)	13.78 c (90)	2.21 c (79)	2.97 b-d (84)	10.30 c (9)	11.98 b (85)	2.34 bc (79)	2.00 d (63)
½ RT+SW	6.56 c (8)	16.39 c-e (87)	2.54 cd (65)	3.39 ab (90)	9.90 bc (10)	12.68 d (82)	2.06 cd (73)	3.17 ab (90)	16.30 b (14)	9.74 cd (69)	1.69 de (57)	2.46 b-d (78)
RQ	1.31 e (2)	17.56 a-c (94)	3.06 bc (78)	3.49 ab (93)	1.65 e (2)	14.30 bc (93)	2.64 ab (93)	3.27 ab (92)	1.31 d (1)	12.23 b (86)	2.54 a-c (86)	2.72 a-c (86)
¾ RQ+SW	7.51 b (10)	15.56 e (83)	2.37 d (61)	2.21 c (63)	9.10 c (9)	12.39 d (81)	1.71 d (60)	2.62 de (74)	15.83 b (14)	8.57 d (61)	1.49 e (51)	2.09 d (66)
¾ RQ+¾SW	5.96 cd (8)	17.25 b-d (92)	2.83 cd (75)	3.39 ab (90)	5.90 d (6)	13.85 c (90)	2.19 c (77)	2.45 e (69)	10.90 c (9)	11.51 b (81)	2.04 cd (69)	2.13 d (68)
LSD (0.05)	0.74	1.26	0.53	0.54	1.85	0.79	0.40	0.43	1.25	1.57	0.50	0.51

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 x-fold increase relative to control (FW).

Chemical analysis

Plant samples (shoot) were dried in the oven at 70°C for 72 h. Plant samples were prepared according to method of Ma and Zua (1984). The samples were digested and were analyzed for Na, K, Ca, and Mg by Atomic Absorption Spectrophotometer (AAS) (Perkin Elmer, 5100, USA).

Statistical analysis

Data were analyzed using the ANOVA PROC with RCBD design available in SAS (2004). The treatment means were separated by protected least significance differences (LSD) at the 5% probability level.

RESULTS

Effect of combinations of sea water and herbicide rates on shoot Na, K, Ca and Mg contents of turfgrass species

Application of different combinations of sea water and herbicide produced significant variation in uptake of Na, K, Ca, Mg in turfgrass and weed species (Tables 1, 2 and 3). In control treatments, Na content in the different turfgrass species ranged between 0.78 to 1.15 mg g^{-1} (DW) (Table 1). Treatments with sea water alone caused 10 to 16 fold increases in shoot Na content in the turfgrass species. The treatments, recommended trifloxysulfuron herbicide (RT) and recommended quinclorac (RQ) alone resulted in a 2 fold increase in Na content compared to control treatments. However, with reduced doses of herbicides, that is, when ¾ recommended trifloxysulfuron-sodium and ¾ recommended quinclorac were combined with sea water; Na uptake increased between 6 to 15 fold. In general, among herbicide and sea water combination treatments; ¾ recommended trifloxysulfuron-sodium with ¾ sea water and ¾ recommended quinclorac with ¾ sea water had

Table 2. Effect of combinations of sea water and herbicide rates on shoot Na, K, Ca, Mg contents of weed species.

Treatment	**Turfgrass weed species (Na, K, Ca, Mg contents in mg g^{-1}, dry weight)**											
	Eragrostis atrovirens				***Sporobolus diander***				***Cyperus aromaticus***			
	Na	**K**	**Ca**	**Mg**	**Na**	**K**	**Ca**	**Mg**	**Na**	**K**	**Ca**	**Mg**
FW	1.91 f	41.20 a	2.61 a	2.67 a	1.56 e	45.41 a	2.47 a	2.64 a	2.65 e	40.42 a	3.01 a	3.33 a
SW	21.44 bc	35.43 e	2.31 c	2.44 b	24.24 c	35.31 d	2.11 cd	2.21 c	29.16 b	30.31 d	2.69 bc	2.77 d
	(11)	(86)	(88)	(91)	(16)	(77)	(85)	(84)	(11)	(75)	(89)	(83)
RT	2.51 f	39.16 bc	2.45 b	2.54 ab	2.73 e	42.49 b	2.33 ab	2.37 b	2.95 e	38.16 b	2.83 ab	2.95 bc
	(1)	(95)	(94)	(95)	(2)	(91)	(94)	(90)	(1)	(94)	(94)	(89)
¾ RT+SW	22.41 b	33.44 f	2.05 e	2.06 cd	26.16 b	32.10 g	1.65 f	1.67 f	30.21 ab	30.01 d	2.24 ef	2.44 f
	(12)	(81)	(79)	(77)	(17)	(71)	(66)	(63)	(11)	(74)	(74)	(73)
¾ RT+¾SW	18.34 e	38.19 cd	2.11 de	2.17 c	22.25 d	36.51 d	1.81 ef	1.89 d	23.25 c	28.30 e	2.41 de	2.55 ef
	(10)	(93)	(81)	(81)	(14)	(80)	73)	(72)	(9)	(70)	(80)	(77)
½ RT+SW	20.25cd	34.71 ef	2.01 e	2.07 cd	25.44 bc	34.90 e	1.70 f	1.71 ef	29.73 b	31.25 cd	2.29 ef	2.81 cd
	(11)	(84)	(77)	(78)	(16)	(77)	(69)	(65)	(11)	(77)	(76)	(84)
RQ	2.52f	40.20 ab	2.45 b	2.51 b	2.69 e	40.57 c	2.25 bc	2.47 b	3.11 e	37.41 b	2.53 cd	3.01 b
	(1)	(98)	(94)	(94)	(2)	(89)	(91)	(94)	(1)	(93)	(84)	(90)
¾ RQ+SW	24.48a	34.12 ef	1.78 f	1.98 d	28.19 a	30.13 h	1.93 de	1.81 de	31.16 a	27.45 e	2.02 g	2.42 f
	(13)	(83)	(69)	(74)	(18)	(66)	(78)	(69)	(12)	(68)	(67)	73)
¾ RQ+¾SW	19.16 de	37.40 d	2.19 cd	2.11 cd	21.32 d	33.16 f	2.05 cd	1.90 d	20.20 d	32.16 c	2.17 fg	2.67 de
	(10)	(91)	(84)	(79)	(14)	(73)	(83)	(72)	(8)	(80)	(72)	(80)
LSD (0.05)	1.85	1.72	0.12	0.14	1.37	0.85	0.20	0.11	1.14	1.41	0.19	0.16

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 x-fold increase relative to control (FW).

lower Na accumulation (6 to 9 folds) in turfgrass species. Among the three turfgrass species, *P. vaginatum* and *Z. japonica* had lower average Na accumulation (about 6 fold), while *C. dactylon* 'satiri' had greater Na accumulations (about 9 fold).

A significant variation in K uptake in shoots were observed among the turfgrass species (Table 1). In control treatments, K uptake in turfgrass species ranged from 14.14 to 18.74 mg g^{-1} (DW). Treatment with sea water alone caused 79 to 88% decreases in shoot K content in the turfgrass species. The treatments recommended trifloxysulfuron-sodium (RT) and recommended quinclorac (RQ alone resulted in maximum K uptake of 22 and 14%, respectively. However, when reduced doses of ¾ recommended trifloxysulfuron-sodium and ¾ recommended quinclorac were combined with sea water, the decreases in K uptake ranged between 61-87%. In general, among the herbicide and sea water combination treatments, ¾ recommended trifloxysulfuron-sodium with ¾ sea water and ¾ recommended quinclorac with ¾ sea water had lower K reductions (5 to 19%). Among the three turfgrass species, *P. vaginatum* had lower average K reduction (10%) followed by *Z. japonica* (12%), while *C. dactylon* 'satiri' had greater reduction (27%).

There was significant variation in Ca content in shoots of the different turfgrass species due to the different treatments. In control treatments, Ca contents in turfgrass species ranged between 2.83 to 3.91 mg g^{-1} (DW) (Table 1). Treatment with sea water alone, caused 61 to 68% decrease in shoot Ca contents in the turfgrass species.

The treatments, recommended trifloxysulfuron herbicide (RT) and recommended quinclorac (RQ) alone gave maximum decreases of 18 and 22%, respectively compared to control treatments. However, when reduced doses of ¾ recommended trifloxysulfuron-sodium and ¾ recommended quinclorac were combined with sea water; decreases in Ca uptake ranged between 52 to 77%. In general, among the combination treatments; ¾ recommended trifloxysulfuron-sodium with ¾ SW and ¾ recommended quinclorac and ¾ sea water had lower Ca reductions (21-31%) in turfgrass species; among the three turfgrass species, *Z. japonica* had lower average Ca reduction (26%) followed by *P. vaginatum* (28%), while *C. dactylon* had greater Ca reduction (42%).

The various treatments had significant influence on shoot Mg content (Table 1). Magnesium contents in different turfgrass species varied from 3.15 to 3.77 mg g^{-1} (DW) in the control treatment. Treatment with seawater alone, caused 84 to 88% decreases in shoot Mg contents in the turfgrass species. Treatments recommended trifloxysulfuron-sodium (RT) and recommended quinclorac (RQ) alone gave maximum Mg content decreases of 6 and 14% compared to control treatments. However, with reduced doses of ¾ recommended trifloxysulfuron-sodium and ¾ recommended quinclorac in combination with seawater resulted in decreases in Mg uptake ranging between 18 to 37%. In general, ¾ recommended trifloxysulfuron-sodium with ¾ SW and ¾ recommended quinclorac with ¾ sea water resulted in lower Mg reductions (10-37%) in turfgrass species; among the three turfgrass species, *P. vaginatum* had lower average Mg reduction (14%) followed by *Z. japonica* (16%), while *C. dactylon* 'satiri' showed higher Mg reduction (23%).

Effect of combinations of sea water and herbicide rates on shoot Na, K, Ca and Mg content of weed species

The sodium content in shoots of different weed species varied significantly (Tables 2 and 3). The shoot Na contents in the different turfgrass weed species ranged between 1.56 to 4.11 mg g^{-1} (DW). Treatment with seawater alone, caused 9 to 16 fold increases in shoot Na contents in the weed species. The recommended trifloxysulfuron-sodium (RT) and recommended quinclorac (RQ) alone showed maximum 2 fold increases in Na contents compared to control treatments. However, ¾ recommended trifloxysulfuron-sodium and ¾ recommended quinclorac when combined with seawater resulted in Na increases ranging between 10 to 18 fold. In general, ¾ recommended trifloxysulfuron-sodium with ¾ sea water and ¾ recommended quinclorac herbicide with ¾ sea water had lower Na accumulations (6 to 14 fold) in the weed species. Among the five weed species, *E. atrovirens* and *C. aromaticus* had lower average Na accumulations (about 8 fold), while *S. diander* and *E. sonchifolia* showed higher Na accumulations (about 9 fold) followed by *C. rotundus*.

The content of potassium (K) in shoots of different weed species differed significantly between the various treatments (Tables 2 and 3). The results showed that in the control treatments, the highest K contents was found in *S. diander* (45.41 mg g^{-1} DW) and *E. sonchifolia* showed the lowest K content (29.10 mg g^{-1}). Treatments with seawater alone, caused 70 to 86% decreases in shoot Na content among the weed species. Compared to the controls, the recommended trifloxysulfuron-sodium (RT) and recommended quinclorac (RQ) alone resulted on maximum K decreases of 9% and 11%, respectively. However, ¾ recommended trifloxysulfuron-sodium and ¾ recommended quinclorac when combined with sea water; resulted in decreases in K uptake ranging between 62 to 83%. In general, ¾ recommended trifloxysulfuron-sodium with ¾ sea water and ¾ recommended quinclorac with ¾ sea water had lower K reductions (7 to 30%) in the weed species. Among the five weed species, *E. atrovirens* had lower average K reduction (11%) followed by *C. rotundus* (18%), while *E. sonchifolia* had slightly higher reduction (27%) followed by *S. diander* (22%) and *C. aromaticus* (21%).

There were significant differences in Ca content among weed species due to different treatments (Table 2 and 3). In the control treatments, *C. aromaticus* had the highest (3.01 mg g^{-1}DW) while *E. sonchifolia* had the lowest (2.41 mg g^{-1}DW) Ca content. Treatment with sea water alone, caused 77-91% decreases in shoot Ca content among species. Compared to the controls, the recommended trifloxysulfuron-sodium (RT) and recommended quinclorac (RQ) alone resulted in maximum Ca decreases of 8 and 16%, respectively. However, ¾ recommended trifloxysulfuron-sodium and ¾ recommended quinclorac when combined with sea water resulted in Ca; decreases ranging between 66 to 79%. In general, ¾ recommended trifloxysulfuron herbicide with ¾ sea water and ¾ recommended quinclorac with ¾ sea water had lower K reductions (16 to 35%) in weed species; among the five weed species, *E. atrovirens* and

Table 3. Effect of combinations of sea water and herbicide rates on shoot Na, K, Ca, Mg contents of weed species.

Treatment	**Turfgrass weed species (Na, K, Ca, Mg contents in mg g^{-1}, dry weight)**							
	Cyperus rotundus				***Emilia sonchifolia***			
	Na	**K**	**Ca**	**Mg**	**Na**	**K**	**Ca**	**Mg**
FW	2.78 d	36.40 a	2.74 a	2.91 a	4.11 e	29.10 a	2.41 a	2.21 a
SW	25.16 b (9)	28.10 d (77)	2.49 b (91)	2.54 c (87)	44.82 e (11)	20.41 c (70)	1.85 c (77)	1.91 cd (86)
RT	3.15 d (1)	34.50 b (95)	2.61 ab (95)	2.73 b (94)	4.36 e (1)	26.81 b (92)	2.23 b (92)	2.01 bc (91)
¾ RT+SW	26.50 a (10)	25.35 e (70)	2.11 cd (77)	2.19 ef (75)	45.11 a (11)	18.15 d (62)	1.60 ef (66)	1.67 e (76)
¾ RT+¾SW	18.31 c (7)	30.16 c (83)	2.23 c (81)	2.33 d (80)	34.40 c (8)	21.29 c (73)	1.81 cd (75)	1.82 d (82)
½ RT+SW	24.60 b (9)	31.12 c (85)	2.08 d (76)	1.99 g (68)	44.10 ab (11)	16.45 e (57)	1.71 de (71)	1.71 e 77)
RQ	3.41 d (1)	33.90 b (93)	2.51 b (92)	2.59 c (89)	4.81 e (1)	27.91 ab (96)	2.11 b (88)	2.03 b (92)
¾ RQ+SW	27.31 a (10)	27.19 d (75)	1.91 e (70)	2.13 f (73)	43.11 b (10)	18.51 d (63)	1.41 g (59)	1.42 g (64)
¾ RQ+¾SW	17.16 c (6)	28.12 d (77)	2.17 cd (79)	2.27 de (78)	32.51 d (8)	20.34 c (70)	1.57 f (65)	1.53 f (69)
LSD (0.05)	1.32	1.45	0.15	0.11	1.35	1.19	0.13	0.10

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 x-fold increase relative to control (FW).

C. rotundus had lower average Ca reductions (17%) followed by *C. aromatcus* (20%) and *S. diander* (20%), while *E. sonchifolia* had slightly higher Ca reduction (26%).

Magnesium content in shoot of different weed species differed significantly (Table 2 and 3). The results indicate that in the control treatments, the highest Mg content was found in *C. aromaticus* (3.33 mg g^{-1} DW) and the lowest (2.21 mg g^{-1}) was found in *E. sonchifolia*. Treatment with sea water alone, caused 83 to 91 percent decreases in shoot Mg contents among the weed species. Compared to control, the recommended trifloxysulfuron-sodium (RT) and recommended quinclorac (RQ) alone had maximum decreases in Mg content of 11%. However, ¾ recommended trifloxysulfuron-sodium and ¾ recommended quanclorac when combined with sea water; resulted in decreases in Mg uptake ranging between 23 to 37%. In general, ¾ recommended trifloxysulfuron-sodium with ¾ sea water and ¾ recommended quinclorac with ¾ sea water had lower Mg reductions (18-31%) among weed species; among the five weed species, *E. atrovirens* had lower average Mg reduction (16%) followed by *C. aromatcus* (19%), *C. rotundus* (19%) and *E. sonchifolia* (20%), while *S. diander* had slightly higher Mg reduction (24%).

Effect of combinations of sea water and herbicide rates on turfgrass rhizosphere bacteria population

Control treatments (Fresh water) always had higher bacterial colony counts [Ranged between 6.90 to 7.27 cfu × 10^{5} g^{-1} soil (DW)] compared to all other treatments irrespective of turfgrass species and sampling time

Table 4. Effect of combinations of sea water and herbicide rates on turfgrass rhizosphere bacteria population.

Treatment	Bacteria											
	Paspalum vaginatum				***Zoysia japonica***				***Cynodon dactylon* ‘satiri’**			
	3rd day	**7th day**	**14th day**	**21th day**	**3rd day**	**7th day**	**14th day**	**21th day**	**3rd day**	**7th day**	**14th day**	**21th day**
FW	6.95a	6.98a	7.13a	7.27a	6.98a	7.02a	7.09a	7.13a	6.90a	6.95a	7.08a	7.10a
SW	6.77c	6.87bc	6.91c	6.93c	6.84cd	6.77cd	6.87c	6.96d	6.84b	6.77c	6.85b	6.86b
RT	6.35f	6.39f	6.44e	6.67e	6.39g	6.50f	6.59e	6.73g	6.75d	6.69de	6.64ef	6.76c
¾ RT+ SW	6.61e	6.72e	6.78d	6.82d	6.87bc	6.81c	6.94b	6.98c	6.80c	6.71d	6.59f	6.73cd
¾ RT+¾ SW	6.63e	6.81d	6.79d	6.86d	6.90b	6.96a	6.93b	7.00b	6.72ef	6.61g	6.75cd	6.89b
½ RT+ SW	6.70d	6.69e	6.78d	6.83d	6.81de	6.76cd	6.84cd	6.89e	6.83bc	6.88b	6.79bc	6.85b
RQ	6.80bc	6.82cd	6.75d	6.88cd	6.71f	6.63e	6.80d	6.88f	6.51g	6.75c	6.68de	6.75c
¾ RQ+ SW	6.82b	6.88b	6.96bc	7.02b	6.76ef	6.72d	6.84cd	6.96d	6.71f	6.65f	6.58f	6.69d
¾ RQ+¾ SW	6.83b	6.85bd	7.03b	7.07b	6.86bd	6.88b	6.92bc	6.98c	6.74de	6.68e	6.62ef	6.78c
LSD $_{0.05}$	0.03	0.05	0.08	0.06	0.05	0.06	0.05	0.01	0.02	0.02	0.07	0.05

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). CFU×10^5 per gram soil at day 3, 7, 14, 21.

(Table 4). In treatments with seawater, recommended trifloxysulfuron-sodium (RT) and recommended quinclorac (RQ) alone; colony counts varied among the trufgrass species. In *P. vaginatum*, sea water and recommended quinclorac (RQ) had similar and greater colony counts (6.93 cfu × 10^5 g^{-1} soil DW) compared to recommended trifloxysulfuron-sodium (RT) irrespective of sampling times, while in *Z. japonica* and *C. dactylon* ‘satiri’, sea water alone had greater colony counts (6.96 cfu × 10^5 g^{-1} soil and 6.86 cfu × 10^5 g^{-1} soil) compared to recommended trifloxysulfuron-sodium (RT) and recommended quinclorac (RQ) alone; however, these were variable with sampling time. In *P. vaginatum* rhizosphere, the treatment ¾ recommended quinclorac with ¾ sea water had greater colony counts (7.07 cfu × 10^5 g^{-1} soil DW) compared to ¾ recommended trifloxysulfuron-sodium with ¾ sea water, while for *Z. japonica* and *C. dactylon* ‘satiri’, the results were variable.

Effect of combinations of sea water and herbicide rates on turfgrass rhizhosphere actinomycetes population

Control treatments (Fresh water) always had greater actinomycetes colony counts [Ranged between 5.00-6.32 cfu × (10^4-10^5) g^{-1} soil (DW)] compared to all other treat-ments irrespective of turfgrass species and sampling time (Table 5). In treatments with seawater, recommended trifloxysulfuron-sodium (RT) and recommended quinclorac (RQ) alone; colony counts varied among the turfgrass species. In *P. vaginatum*, ¾ recommended quinclorac (RQ) with sea water and ¾ recommended quanclorac (RQ) with ¾ sea water had similar and greater colony counts (6.27 cfu × 10^5 g^{-1} soil DW) compared to recommended trifloxysulfuron-sodium (RT) irrespective of sampling times, while in *Z. japonica* ¾ recommended trifloxysulfuron-sodium with ¾ sea water had greater colony counts (6.15 cfu × 10^5 g^{-1} soil DW) compared to recommended trifloxysulfuron-sodium (RT) and recommended quinclorac (RQ) alone; however, counts were variable with sampling time. In *C. dactylon* ‘satiri’ ½ recommended trifloxysulfuron-sodium with sea water had greater colony counts (6.08 cfu × 10^5 g^{-1} soil DW) compared to all other treatments.

Effect of combinations of sea water and herbicide rates on turfgrass rhizhosphere fungi population

Control treatments (Fresh water) always had greater fungal colony counts [ranged between 4.88-5.08 cfu × 10^5 g^{-1} soil (DW)] compared to all other treatments irrespective of turfgrass species and sampling time (Table 6). In treatments with seawater, recommended trifloxysulfuron-sodium (RT) and recommended quinclorac (RQ) alone; colony counts varied between trufgrass species.

Table 5. Effect of combinations of sea water and herbicide rates on turfgrass rhizosphere actinomycetes population.

Treatment	Actinomycetes											
	Paspalum vaginatum				***Zoysia japonica***				***Cynodon dactylon*** **('satir'iSatiri)**			
	3rd day	**7th day**	**14th day**	**21th day**	**3rd day**	**7th day**	**14th day**	**21th day**	**3rd day**	**7th day**	**14 d**	**21 d**
FW	5.09a	5.25a	6.29a	6.32a	5.00a	5.18	6.22a	6.30a	5.08a	5.14a	6.10a	6.18a
SW	5.04a	4.96cd	6.11b	6.20b	4.85bc	5.00bc	6.08bc	6.18c	4.88bc	4.84bc	5.79d-f	6.01ab
RT	4.64f	4.48f	5.71d	5.85d	4.71de	4.78d	5.85e	5.80f	4.79c-e	4.91bc	5.85c-e	5.97a-c
¾ RT+SW	4.78de	4.91cd	5.86cd	5.90cd	4.90ab	5.08b	6.03cd	6.20bc	4.91b	4.85bc	5.89bd	5.85bc
¾ RT+¾SW	4.91bc	4.86d	5.80cd	5.80d	4.91ab	5.04b	6.14ab	6.26ab	4.91b	4.85bc	5.95bc	5.99ab
½ RT+SW	4.85cd	5.00c	5.89c	5.86cd	4.77cd	5.00bc	6.04cd	6.15cd	4.85bd	4.95b	6.00ab	6.08ab
RQ	4.71ef	4.63e	5.78cd	5.97c	4.62e	4.78d	5.86e	5.96e	4.76de	4.65d	5.71fg	5.73cd
¾ RQ+SW	4.90bc	5.11b	6.18ab	6.23ab	4.72de	4.86d	5.96d	6.08d	4.61f	4.49e	5.61g	5.74cd
¾ RQ+¾SW	5.00ab	5.16ab	6.20ab	6.27ab	4.79bd	4.95c	6.04c	6.15cd	4.70ef	4.78cd	5.73eg	5.51d
LSD $_{0.05}$	0.09	0.10	0.17	0.11	0.12	0.08	0.08	0.07	0.09	0.13	0.14	0.24

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). CFUx10^4 per gram soil at day 3, 7. CFUx10^5 per gram soil at day 14, 21.

In *P. vaginatum*, ¾ recommended trifloxysulfuron herbicide with sea water and ¾ recommended quinclorac with ¾ sea water had greater colony counts (4.69 cfu × 10^5 g^{-1} soil and 4.95 cfu × 10^5 g^{-1} soil) compared to recommended trifloxysulfuron-sodium (RT) and recommended quanclorac irrespective of sampling time, while in *Z. japonica* ¾ recommended trifloxysulfuron-sodium with ¾ sea water and ¾ recommended quanclorac with ¾ sea water had greater colony counts (4.95 cfu × 10^5 g^{-1} soil and 4.91 cfu × 10^5 g^{-1} soil) compared to recommended trifloxysulfuron-sodium (RT) and recommended quinclorac (RQ) alone; however, counts were variable with sampling time. In *C. dactylon* 'satiri' ½ recommended trifloxysulfuron-sodium with sea water had greater colony counts (4.77 cfu × 10^5 g^{-1} soil) compared to recommended trifloxysu lfuron-sodium (RT) and recommended quinclorac alone.

DISCUSSION

Application of sea water alone or in combination with herbicide (trifloxysulfuron-sodium or quinclorac) influenced uptake of mineral nutrient composition in weed and turf grass species, and showed significant changing effect on soil microbial community. In the present study the turfgrass and weed species response to different salinity level and herbicides varied with type of treatments and levels and so on. It is known that salinity results an imbalance soil ionic environment with enrichment of Na uptake and concomitant reduction of K, Ca, and Mg in the plant tissues (Rubinigg et al., 2003; Uddin et al., 2011c). The incidence of reduction of K, Ca, and Mg in plant tissue is more in susceptible plant, where as resistant plant shows less uptake of Na and less reduction of these nutrients elements. The increased uptake of Na and higher reduction of K, Ca, Mg in the tested weeds compared to turfgrass proved its susceptibility over treated turfgrass species and confirm the ability to use of salt water for turfgrass weed management. As high salinity level imposes Na toxicities and there is an ionic balance subsists between Na and K uptake in plants so combination of sea water and herbicide reduce this adverse effect of salinity and increased K, Ca, and Mg uptake compared to only sea water treatments. It was found that, recommended ¾ herbicides with ¾ sea water had lower K, Ca, and Mg reduction in turfgrass species and proved salinity tolerance compared to weed species. Therefore it is clear that sea water plus reduced rate of herbicide can be use in turfgrass area to control weeds.

Sensitive weeds are killed by herbicide. This is because the normally competent protective

Table 6. Effect of combinations of sea water and herbicide rates on turfgrass rhizosphere fungi population.

Treatment	Fungi											
	Paspalum vaginatum				***Zoysia japonica***				***Cynodon dactylon* ‘Satiri’**			
	3rd day	**7th day**	**14th day**	**21th day**	**3rd day**	**7th day**	**14th day**	**21th day**	**3rd day**	**7th day**	**14th day**	**21th day**
FW	4.90 a	5.00 a	4.98a	5.08a	4.94a	4.93a	5.00a	5.05a	4.91a	4.88a	4.94a	5.05a
SW	4.70 cd	4.79 bc	4.95bd	5.00b	4.71c	4.84ac	4.84cd	4.87bd	4.71ab	4.70ab	4.60c	4.76ab
RT	4.60 d	4.69 c	4.61f	4.59h	4.71c	4.61d	4.78d	4.78d	4.60bc	4.48c	4.37d	4.59bc
¾ RT+ SW	4.70 cd	4.77 bc	4.71e	4.69g	4.79bc	4.81bc	4.85cd	4.79d	4.76ab	4.77ab	4.68bc	4.70b
¾ RT+¾ SW	4.77 bc	4.70 bc	4.77de	4.77f	4.85ab	4.89ab	4.95ab	5.00a	4.69b	4.66bc	4.33d	4.63b
½ RT+ SW	4.70 bc	4.8 4b	4.80cd	4.85de	4.78bc	4.71cd	4.78d	4.77d	4.77ab	4.69b	4.79ab	4.77ab
RQ	4.72 cd	4.70 c	4.78ce	4.77ef	4.70c	4.80bc	4.84cd	4.77d	4.46c	4.25d	4.32d	4.49bc
¾ RQ+ SW	4.77 bc	4.77 bc	4.86bc	4.90cd	4.84ab	4.80bc	4.90bc	4.82cd	4.63bc	4.47c	4.78b	4.30c
¾ RQ+¾ SW	4.85 ab	4.85 b	4.91ab	4.95bc	4.84ab	4.82ac	4.91ac	4.94ac	4.69b	4.71ab	4.71bc	4.62bc
LSD $_{0.05}$	0.12	0.10	0.08	0.07	0.11	0.13	0.09	0.12	0.19	0.18	0.15	0.32

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). CFUx10^5 per gram soil at day 3, 7, 14, 21.

systems are unable to cope with the excessive demands induced or promoted by herbicide. In other words, the detoxification processes are overtaxed and unable to prevent cellular damage and death (Dodge, 1994). Na and K content in the leaf of turfgrass species changed slightly due to herbicide. The result indicated that herbicide (photosensitizer) decreased growth mainly by impairing photosynthetic mechanism and salinity affects plant growth and development by imposing osmotic challenge, Na toxicity and K deficiency (Duncan and Carrow, 2000;). Several researchers showed that salinity induced swelling of thylakoids in rice (Rahman et al., 2000), barley (El-banna and Attia, 1999) and a slight destruction of chloroplast envelope. However, exogenously applied photosensitizer, such as herbicide leads to generate singlet oxygen and chlorophyll bleaching (Dodge, 1994).

Sea water and herbicide showed some adverse effects on soil bacteria, fungi and actinomycetes population. Reduction in bacteria, fungi and actinomycetes populations in soil were lower in sea water or ¾ sea water in combination with reduced rate of herbicides than full strength of sea water or herbicide alone. Omar et al. (1994) reported that total count of bacteria, fungi and actinomycetes were decreased at 5% NaCl concentration. However, recommended quinclorac exerted less effect on soil microbial population compared to recommended trifloxysulfuron-sodium alone or in combination with sea water. Mekwanakaran and Sivasitthamparam (1987) also reported that the numbers of bacteria decreased for glyphosate herbicide application. Sapundjieva et al. (2003) also found that high herbicide concentrations reduced the number of bacteria and actinomycetes in soil. The population density of bacteria was inversely proportional to the concentration of salts (Yahya and AL-Azawi, 1989). Increase in herbicide doses tends to amplify its negative effect on microorganisms. There are some evidences that high concentrations of herbicide reduce the number of nodules in symbiotic nitrogen-fixing microorganisms, nitrogenase activity, dry matter in plants, and inhibition of ATP synthesis (Govedarica et al., 1993). High doses of atrazine and alachlor caused decreases in the total number of bacteria, (ammonifiers and azotobacters) and their dehydrogenase activity (Konstantinoviã et al., 1999). Herbicide application also inhibits the activity of symbiotic bacterium *Bradyrhizobium japonicum* reflected as reduced the nodulation rate (Milosevia et al., 2000). In this situation saline water in combination of reduced dose of herbicide can ensure better microbial environment compare to herbicide alone.

Conclusion

The recommended trifloxysulfuron-sodium and quinclorac in combination with sea water can be effectively used for weed control in *C. dactylon* ‘satiri’, *P. vaginatum* and *Z. japonica.* Herbicides alone decreased the microbial activities more compared to herbicide and sea water combined treatments. The combination of ¾ herbicides recommended dose with ¾ sea water minimized weed populations; maintain soil microbial community, nutrient uptake and strongly recommended as a suitable method of weed control in turfgrass for safe environment.

REFERENCES

Chapman GP, Peat WE (1992). An Introduction to the Grasses. CAB International, Wallingford.

Dodge A (1994). Herbicide action and effects on detoxification processes. In. Causes of photooxidative stress and amelioration of defense systems in plants. edt. Foyer CH and Mullineaux PM. CRC Press, pp. 219– 236.

Duncan RR, Carrow RN (2000). Soon on golf courses: New seashore paspalum. Golf Course Manag., 68: 65–67.

El-Banna Y, Attia T (1999). Root tip meristematic cell and leaf chloroplast structure in three barley (*H. vulgare* L.) genotypes exposed to salinity stress. Cytologia, 64: 69-76.

Govedarica M, Jarak M, Miloševia N (1993). Mikroorgani-zmi i pesticidi. Poglavlje u monografiji Teški metali i pesticidi u zemljištima, Polj. fakultet, Institut za ratarstvo i povrtarstvo, Novi Sad, Voj-vodine, 107–111.

Hossain MA, Ishimine Y, Akamine H, Murayama S, Moslem Uddin SM, Kuniyoshi K (1999). Effect of burial depth on emergence of *Panicum repens*. Weed Sci., 47: 651–656.

Hudetz M, Foery W, Wells J, Soares JE (2000). CGA362622, a new low rate Novartis post-emergence herbicide for cotton and sugarcane. Proc. South. Weed Sci. Soc., 53: 163–165.

Uddin KM, Juraimi AS, Ismail MR, Rahim MA, Radziah O (2011). Effect of salinity stress on nutrient uptake and chlorophyll in tropical turfgrass species. Aust. J. Crop Scil., 11: 13–20.

Johnson BJ, Duncan RR (1997). Tolerance of Four Seashore Paspalum (*Paspalum vaginatum*) Cultivars to Postemergence Herbicides. Weed Technol., 11: 689–692.

Uddin KM, Juraimi AS, Ismail MR, Brosnan JB (2010). Characterizing weed populations in different turfgrass sites throughout the Klang valley of Western Peninsular Malaysia. Weed Technol., 2: 173–181.

Uddin KM, Juraimi AS, Ismail MR, Rahim MA, Radziah O (2009). Floristic composition of weed community in turfgrass area of West Peninsular Malaysia. Inter. J. Agric. Biol., 11: 13–20.

Uddin KM, Juraimi AS, Ismail MR, Begum M, Rahim MA, Radziah O (2011a). Effecacy of sea water in combination with trifloxisulfuron and quinclorac to control weeds in salt tolerant tropical turfgrass. Aust. J. Crop Sci., 5: 1305–1310.

Uddin KM, Juraimi AS, Ismail MR, Rahim MA, Radziah O (2009b). Growth response of tropical turfgrass species to salinity. Afr. J. Biotech., 8: 5799–5806.

Uddin KM, Juraimi AS, Ismail MR, Rahim MA, Radziah O (2011b). Relative salinity tolerance of warm season turfgrass species. J. Envron. Biol., 32: 309–312.

Uddin KM, Juraimi AS, Ismail MR, Rahim MA, Radziah O (2011c). Effect of salinity stress on nutrient uptake and chlorophyll content of tropical turfgrass. Aust. J. Crop Sci., 5: 620–629.

Kelly ST, Coats GE (1999). Weed control in warm season turfgrass with quinclorac. Proc. South. Weed Sci. Soc., 52: 69–70.

Konstantinoviã B, Govedarica M, Jarak M, Milosevia N (1999). Herbicide efficiency and their impact on microbiological activity in soil. Research Progress in Plant Protection and Plant Nutrition, AAM, China Agriculture Press, Beijing, pp. 228–232.

Ma TS, Zua Z (1984). Micro-Kjeldhal determination of nitrogen. A new indicator and an improved rapid method. Ind. Eng. Chem., (Analytical edition) 14: 280–282.

McCarty LB, Higgins JM, Colvin DL (1993). Selective torpedograss (*Panicum repens*) control in bermudagrass (*Cynodon* spp) turf. Weed Technol., 7: 911–915.

Mekwanakaran P, Sivastithamparam K (1987). Effect of certain herbicides on soil microbial populations and their influence on saprophytic growth in soil and Pathogenicity of take-all fungus. Biol. Fertil. Soil, 5: 175–180.

Miller KJ, Woods JR (1996). Osmoadaptation by rhizosphere bacteria. Ann. Rev. Microbiol., 50: 101–136.

Milosevia N, Govedarica M, Dukia D, Mandia L (2000). Uticaj herbicida na mikrobiolosku aktivnost zemljista. Zimska kola za agronome, 4: 101–107.

Mueller SR (2005). Biostimulator influences on turfgrass microbial communities and creeping bentgrass putting green quality. Hortic. Sci., 40: 1904–1910.

Omar SA, Abdel Sater MA, Khalil AM, Abd-Alla MH (1994). Growth and enzyme activities of fungi and bacteria in soil salinized with sodium chloride. Folia Microbiol., 39 : 23–28.

Rahman MS, Matsumuro T, Miyake H (2000). Salinity-induced ultrastructural alterations in leaf cells of rice (*Oryza sativa* L.). Plant Prod. Sci., 3: 422–429.

Rubinigg M, Posthumus F, Ferschke M, Elzenga JTM, Stulen I (2003). Effects of NaCl salinity on ^{15}N-nitreate fluxes and specific root length in the halophyte *Plantago martima* L. Plant Soil, 250: 201–213.

Sapundjieva K, Kouzmanava J, Kartalaska Y (2003). Effect of trophy (acetochlor) herbicide upon soil microbiolgical activity. J. Environ. Protec. Ecol., 3: 631–635.

SAS Institute (2004). 9.1.3 Procedures guide, 2(1): 4. Cary, NC: SAS Institute Inc.

Turgeon (2005). Turfgrass management (7th Edition). Pretice Hall.New Jersy 07458, USA. pp. 179-219.

Wollum AG II (1982). Cultural methods for soil microorganisms. In A.L. Page *et al.*, (ed.) methods of soil analysis part 2. 2nd ed. Agron. Monogor. 9. A.S.A. and SSSA, Madison, WI. pp. 781–801.

Yahya AI, Al-Azawi SK (1989). Occurrence of phosphate-solubilizing bacteria in some Iraqi soils. Plant Soil, 117: 135–141.