Pak. J. Agri. Sci., Vol. 51(1), 153-160; 2014
ISSN (Print) 0552-9034, ISSN (Online) 2076-0906
http://www.pakjas.com.pk

SEAWATER: AN ALTERNATIVE GRASSY WEED CONTROL METHOD FOR POST EMERGENCE HERBICIDES IN TROPICAL TURFGRASS

Md. Kamal Uddin[1,*], Abdul Shukor Juraimi[2], Mohd Razi Ismail[1], Radziah Othman[3], Muhammad Saiful Ahmad-Hamdani[2] and Anuar Abdul Rahim[3]

[1]Institute of Tropical Agriculture, University Putra Malaysia, Serdang, Malaysia; [2]Department of Crop Science, University Putra Malaysia, 43400 Serdang, Selangor, Malaysia; [3]Department of land Management, University Putra Malaysia, 43400 Serdang, Selangor, Malaysia
[*]Corresponding author's e-mail: mkuddin07@gmail.com

Research was designed to reduce herbicide use by replacing post emergence herbicides with readily available sea water to control tropical turfgrass weeds. In studies evaluating the use of saline solutions for weed control, four salinity levels (0, 24, 48 and 72 dS m^{-1}) were applied once to 30 grassy weed species, along with seashore paspalum (*Paspalum vaginatum* Swartz) (as a control) during December, 2007 to March, 2008. The results on injury ratings for salt tolerant weeds were categorized as highly susceptible, moderately susceptible and extremely tolerant. *C. dactylon*, *E. indica*, *E. virescense*, *E. unioloides* and *I. globosa* were very susceptible and found to be effectively controlled (100%) at 72 dS m^{-1} salinity treatment. However, two most serious weeds viz. wiry eragrostis (*E. atrovirens*) and lesser dropseed (*S. diander*), were found to be extremely tolerant, and were not controlled even at the highest salinity level of 72 dS m^{-1}. *P. vaginatum* and *E. atrovirens* did not show significant decrease in shoot and root dry weight at highest salinity levels (72 dS m^{-1}). The results indicate that sea water has excellent potential for sustainable control of several common grassy weeds in tropical turf.
Keywords: Weed control, turf, seashore paspalum, sea water, dry weight, landscape

INTRODUCTION

Turfs are important in human activities from functional, recreational, and ornamental standpoint (Beard, 1973). The presence of weeds in a turfgrass community disrupts the uniformity due to the variability in leaf width, color, and growth habit. Weeds also compete with the desirable turfgrass species for light, soil moisture, soil nutrients, and carbon dioxide (Floskowski and Landry, 2002). Chemical herbicides such as 2,4–D, dicamba, DSMA, MSMA and bentazone have been used to control weeds in turfgrass (Emmons, 2008). Weeds can spread rapidly in turf by means of seeds, rhizomes, stolons and various underground storage organs such as bulbs and tubers (Johns, 2004). The possibility of using salt water as a substitute for herbicides against weeds has been evaluated based on the response of plants to salinity stress (Wiecko, 2003).

Physiological growth responses of turfgrass species to salinity stress have been investigated. The results of these studies have been investigated and showed that *Paspalum vaginatum* (seashore paspalum) and *Zoysia japonica* (Japanese lawn grass) were among the most salt-tolerant warm-season turfgrass species (Uddin *et al.*, 2011, 2009a; Marcum, 2005). Seashore paspalum has the potential to be one of the most environmentally compatible turfgrasses in the near future (Duncan, 1996ab). Also, seashore paspalum has excellent wear tolerance, and good insect, disease, drought, flood and also shade tolerance (Juraimi, 2001). Herbicides that effectively control weeds in commonly used turfgrasses are readily available (Johnson and Duncan, 2000, 2001). However, application of salt water as a substitute for post emergence herbicides in salt tolerance turfgrass species could control weeds as well as reduce the amount of herbicide use. However, information on response of weed and turfgrass species to salt water (post emergence) treatments is limited in Malaysia. Therefore, the present study was designed to evaluate the efficacy of salt water for the control of weed species in the turf.

MATERIALS AND METHODS

This experiment was conducted under glasshouse conditions at Faculty of Agriculture, University Putra Malaysia (UPM) in 2007/08. 30 grasses, weeds were found in turfgrass area (Uddin *et al.*, 2009b, 2010) and evaluated for salt water susceptibility. Thirty grassy weed species (Table 1) were collected from the field, and seashore paspalum (*Paspalum vaginatum* Swartz) was used as a control. The young weeds were planted in pots (14 cm diameter by 15 cm depth), filled with a mixture of sand and peat (9:1). The grown media was sandy soil with pH 5.23, Electrical conductivity 0.3 dS/m, Organic carbon 0.69%, sand 97.93%, silt 1.89% and clay 0%. The average temperature and light intensity of glasshouse were 28.5-39.5°C and 1500-20400 lux, respectively.

Table 1. List of weed species used in this experiment

Scientific name	Common name
Paspalum vaginatum	Seashore paspalum
Axonopus affinis	Narrow leaf carpetgrass
Bothriochloa intermedia	Sandhor
C. dactylon x *C. transvaalensis*	Hybrid bermudagrass
Chrysopogon aciculatus	Pilipiliula
Cynodon dactylon	Bermudagrass
Dactyloctenium aegyptium	Egyptian grass
Digitaria ciliaris	Southern crabgrass
Digitaria didactyla	Serangoon grass
Digitaria fuscescens	Yellow crabgrass
Digitaria longiflora	Indian crabgrass
Digitaria sanguinalis	Large crabgrass
Echinochloa colona	Junglerice
Eleusine indica	Goosegrass
Eragrostis atrovirens	Wiry eragrostis
Eragrostis malayana	Doubtfulgrass
Eragrostis tenella	Feathery lovegrass
Eragrostis unioloides	Chinese lovegrass
Eragrostis virescens	Mexican lovegrass
Eragrostis viscosa	Sticky lovegrass
Imperata cilíndrica	Cogon grass
Isachne globosa	Rounded Isachne
Ischaemum timorense	Stalkleaf murainagrass
Ischaemum indicum	Smutgrass
Ischaemum muticum	Droughtgrass
Leersia hexandra	Southern cutgrass
Paspalum conjugatum	Sour paspalum
Sacciolepis indica	Short spiked sacciolepis
Sporobolus diander	Lesser dropseed
Sporobolus indicus	Common dropseed
Stenotaphrum secundatum	St. Augustinegrass

The temperature was measured by thermometer and light intensity was measured by Heavy duty light meter (Extech ® model 407026). All pots were fertilized with a complete fertilizer (15 N: 15 P_2O_5: 15 K_2O) @ 50 kg N/ ha / month and applied fortnightly. The transplanted species were irrigated with fresh water for 8 weeks to allow for rooting and recovery from transplanting. Plants were gradually thinned to a final density of 3 plants per pot. All species of weeds and turfgrass (seashore paspalum) were treated in four different saline water (seawater) concentrations namely EC 0, 24, 48, and 72 dSm^{-1}. The seawater (EC 48 dSm^{-1}) in this experiment was taken from the sea in Morib Beach, Selangor, Malaysia. Common salt (sodium chloride [NaCl]) was used to increase the seawater concentration to EC 72 dSm^{-1}, whereas the seawater was diluted with distilled water to 50% concentration to get EC 24 dSm^{-1} saline treatment. The treatments were applied using hand sprayer with 1L capacity to wet the whole plants parts including leaf, inflorescence, stem, node, internodes, as well as the planting medium. The volume of spray was 450 L/ha and applied once.

Visual assessments of plant injury were made 3, 7, 14 and 21 days after initial saltwater exposure using a scale of European System of Weed Control and Crop Injury Evaluation (Burrill *et al*., 1976). A rating scale of 0 to 100% was used, where 0 = no injury, >70%= acceptable control and 100 = completely killed (Table 2). All plants were harvested 21 days after treatment. Shoots and roots of turfgrass and weeds were separated, washed, oven-dried at 70^{o}C for 72 h, and weighed. The experimental design was a complete randomized design with 5 replications per treatment. Data were analyzed using Analysis of Variance (ANOVA) and LSD test was performed at the 5% probability level (SAS, 2004).

Table 2. Injury rating scale of weed and turf

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

Source: Burrill *et al*. (1976)

RESULTS

Effect of salt water on plant injury at 3 day after treatment (DAT): At 24 dSm^{-1} salinity level, a significant difference in injury was observed among the weed species irrespective of weed types (Table 3). Nine weed species *Imperata cylindrica*, *Ischaemum timorense*, *Ischaemum indicum*, *Ischaemum muticum*, *Leersia hexandra*, *Sporobolus diander*, *Digitaria sanguinalis*, and *Eragrostis atrovirens*; and the control turfgrass species *Paspalum vaginatum* were unaffected, expressing by no injury (Table 3). Three species *Isachano globosa* (28%), *Cynodon dactylon* (14%) *Eleudine indica* (11 showed light symptoms and injury levels were between 11-30%. The remaining species showed minimum injury level (1-10%).

Table 3. Effect of different salt water concentration on grassy weed injury at three days after treatment in Malaysia, 2007

Weed species	**Plant injury level (%) Salt concentration (dSm^{-1})**				**LSD (0.05)**
Grasses	**0**	**24**	**48**	**72**	
Paspalum vaginatum	0 a	0 a	0 a	5 b	0
Axonopus affinis	0 a	13 b	34 c	50 d	11
Bothriochloa intermedia	0 a	4 a	16 b	30 c	5
C. dactylon x *C. transvaalensis*	0 a	5 b	32 c	50 d	4
Chrysopogon aciculatus	0 a	6 b	44 c	49 d	4
Cynodon dactylon	0 a	14 b	23 c	38 d	6
Dactyloctenium aegyptium	0 a	7 b	19 c	35 d	5
Digitaria ciliaris	0 a	5 a	23 b	35 c	7
Digitaria didactyla	0 a	4 b	6 c	29 d	3
Digitaria fuscescens	0 a	5 b	17 c	43 d	4
Digitaria longiflora	0 a	10 b	20 c	30 d	6
Digitaria sanguinalis	0 a	0 a	10 b	30 c	6
Echinochloa colona	0 a	6 b	13 c	46 d	5
Eleusine indica	0 a	11 b	32 c	41 d	6
Eragrostis atrovirens	0 a	0 a	9 b	12 c	2
Eragrostis malayana	0 a	3 a	10 a	30 b	7
Eragrostis tenella	0 a	9 b	30 c	44 d	5
Eragrostis unioloides	0 a	8 b	33 c	45 d	7
Eragrostis virescens	0 a	5 a	23 b	59 c	6
Eragrostis viscosa	0 a	8 b	25 c	50 d	8
Imperata cilíndrica	0 a	0 a	0 a	28 b	3
Isachne globosa	0 a	28 b	61 c	73 d	6
Ischaemum timorense	0 a	0 a	9 b	41 c	4
Ischaemum indicum	0 a	0 a	11 b	43 c	4
Ischaemum muticum	0 a	0 a	39 b	50 c	5
Leersia hexandra	0 a	0 a	15 b	30 c	5
Paspalum conjugatum	0 a	4 a	10 b	35 c	5
Sacciolepis indica	0 a	6 b	12 c	41 d	3
Sporobolus diander	0 a	0 a	7 b	28 c	4
Sporobolus indicus	0 a	3 a	6 ab	14 c	4
Stenotaphrum secundatum	0 a	4 a	6 ab	23 b	4

Means within rows followed by the same letter are not significantly different at P =0.05 (LSD test).

At 48 dSm^{-1} salinity level, most plant species were affected by the salt stress. More than 60% injury level was recorded for weed species *F. ovata* (60%), *Isachne globosa* (61%) which showed fairly heavy damage. However eight (7) species *viz*. *Sporobolus indicus*, *Stenotaphrum secundatum*, *Digitaria didactyla*, *S. diander*, *E. atrovirens*, *I. timorense*, *D. sanguinalis*, *Eragrostis malayana*, and the control species *P. vaginatum* were less affected with injury level less than 10%.

At the highest salinity level (72 dSm^{-1}), all species were affected including the control species *P. vaginatum* which exhibited 5% injury. Four weed species (*C. dactylon x C. transvaalensis*, *Eragrostis viscosa*, *I. muticum*, and *Axonopus affinis* recorded 50% injury, indicating medium damage. Moderate injury levels of 31 to 49% were found for 13 species. *I. globosa*, species exhibited >70% injury level which indicated acceptable control.

***Effect of salt water at day 21*:** Twenty one days after treatment, *P. vaginatum*, weed species *E. atrovirens* were still unaffected by 24 dS m^{-1} salinity treatment, while low injury level (1-10%) was observed in several species *viz. I. cilíndrica*, *I. indicum*, *S. diander*, and *I. muticum* (Table 4). Meanwhile, high level of injury was observed *I. globosa*, showed high level of injury, 86%. With the 48 dSm^{-1} salinity treatment, *I. globosa* species and *A. affinis* were completely controlled at day 21 day. Three (5) species of grasses, namely *Echinochloa colona* (30%), *Sacciolepis indica* (30%), *E. atrovirens* (27%), showed low injury symptom.

At the highest salinity treatment (72 dS m^{-1}), again, *P. vaginatum* was found to be the most tolerant species to

Table 4. Effect of different salt water concentration on grassy weed injury at 21 days after treatment in Malaysia, 2007

Weed species	Plant injury level (%) Salt concentration (dSm^{-1})				LSD (0.05)
Grasses	**0**	**24**	**48**	**72**	
Paspalum vaginatum	0 a	0 a	0 a	0 a	0
Axonopus affinis	0 a	32 b	74 c	92 d	4
Bothriochloa intermedia	0 a	16 b	57 c	66 d	6
C. dactylon x *C. transvaalensis*	0 a	19 b	65 c	93 d	8
Chrysopogon aciculatus	0 a	20 b	73 c	89 d	6
Cynodon dactylon	0 a	41 b	71 c	100 d	5
Dactyloctenium aegyptium	0 a	19 b	55 c	65 d	7
Digitaria ciliaris	0 a	20 b	50 c	92 d	9
Digitaria didactyla	0 a	16 b	19 b	62 d	7
Digitaria fuscescens	0 a	29 b	55 c	79 d	6
Digitaria longiflora	0 a	30 b	54 c	63 d	9
Digitaria sanguinalis	0 a	15 b	50 c	56 c	7
Echinochloa colona	0 a	22 b	30 c	93 d	5
Eleusine indica	0 a	28 b	79 c	100 d	7
Eragrostis atrovirens	0 a	0 a	27 b	29 b	4
Eragrostis malayana	0 a	28 b	50 c	81 d	5
Eragrostis tenella	0 a	33 b	50 c	94 d	6
Eragrostis unioloides	0 a	46 b	50 b	98 c	5
Eragrostis virescens	0 a	28 b	52 c	100 d	5
Eragrostis viscosa	0 a	25 b	53 c	100 d	5
Imperata cilíndrica	0 a	10 b	20 c	73 d	8
Isachne globosa	0 a	86 b	95 c	100 d	4
Ischaemum timorense	0 a	24 b	49 c	79 d	5
Ischaemum indicum	0 a	9 b	66 c	82 d	5
Ischaemum muticum	0 a	9 b	72 c	91 d	5
Leersia hexandra	0 a	19 b	41 c	63 d	7
Paspalum conjugatum	0 a	19 b	48 c	98 d	5
Sacciolepis indica	0 a	28 b	30 c	83 d	8
Sporobolus diander	0 a	9 b	36 c	50 d	6
Sporobolus indicus	0 a	18 b	40 c	65 d	7
Stenotaphrum secundatum	0 a	16 b	36 c	52 d	6

Means within rows followed by the same letter are not significantly different at P =0.05 (LSD test).

salinity. Meanwhile, *E. indica*, *E. virescense*, *E. unioloides* and *I. globosa* weed species were completely killed. High level of injury between 91-98% was observed in 9 species. Two species *E. atrovirens* (29%) and *S. diander* (50%) appeared to be most salt tolerant with injury level less than 50%.

***Effect of salinity treatments on shoot dry weight*:** Shoot dry weight (SDW) of most of the grassy weed species were significantly affected by salinity levels (Table 5). The lowest SDW was observed in weeds treated with the highest concentration of salt water (72 dSm^{-1}). SDW of the turfgrass species *P. vaginatum* was between 15.38 to 13.59 g. At this level of growth, this species is considered as not affected by the salt concentrations though there was a proportional decrease in weight with increase in salinity level. Among the grass weeds, SDW of *E. atrovirens* was unaffected by salt stress. SDW of *P. conjugatum* remain unchanged of up to 48 dSm^{-1} salinity, but substantially decreased at 72 dSm^{-1}. SDW of 14 grass species *viz*, *B. intermedia*, *C. acicultus*, *D. ciliaris*, *D. fuscescens*, *E. malayana*, *E. unioloides*, *E. virescens*, *I. cylindrica*, *I. globosa*, *I. timorense*, *I. indicum*, *I. muticum* , *S. indicus* and *S. secundatum* were not affected by 24 dS m^{-1} salinity treatment, but declined at higher salinity levels. SDW of *Echinochloa colona.* and *E. indica* remain unchanged of up to 48 dSm^{-1} salinity treatment, but declined at 72 dSm^{-1}. *P. vaginatum* and *E. atrovirens* by highest salt concentration showing not significant decrease in SDW with increasing salt concentration.

***Effect of salinity treatments on root dry weight*:** It was evident from the results that salinity significantly influenced

Table 5. Effect of different salt water concentration on shoot dry weight of turfgrasses and weeds in Malaysia, 2007

Species	**Shoot dry weight (g)/pot salt concentration (dSm^{-1})**				**LSD (0.05)**
Grasses	**0**	**24**	**48**	**72**	
Paspalum vaginatum	15.38 a	14.60 a	14.56 a	13.59 a	1.83
Axonopus affinis	3.68 a	3.47 a	2.77 b	2.56 b	0.38
Bothriochloa intermedia	5.05 a	4.54 b	2.54 c	1.84 d	0.30
C. dactylon x *C. transvaalensis*	3.03 a	2.93 a	1.94 b	1.76 b	0.30
Chrysopogon aciculatus	4.15 a	3.96 b	3.46 c	2.47 d	0.02
Cynodon dactylon	3.12 a	2.99 a	2.00 b	1.91 b	0.30
D. aegyptium	5.55 a	5.04 ab	3.04 c	2.33 d	0.31
Digitaria ciliaris	7.56 a	6.52 b	5.52 c	4.32 d	0.19
Digitaria didactyla	4.13 a	3.98 a	3.00 b	2.92 b	0.30
Digitaria fuscescens	5.23 a	5.01 b	4.01 c	2.02 d	0.02
Digitaria longiflora	6.55 a	6.52 a	3.53 b	2.34 c	0.19
Digitaria sanguinalis	6.24 a	6.02 a	3.04 b	1.84 c	0.56
Echinochloa colona	6.12 a	5.53 a	5.31 a	3.13 b	1.07
Eleusine indica	8.17 a	7.87 a	7.49 a	4.69 b	0.81
Eragrostis atrovirens	3.06 a	2.96 a	2.85 a	2.56 a	0.53
Eragrostis malayana	3.64 a	3.44 b	3.08 c	2.02 d	0.12
Eragrostis tenella	5.57 a	4.98 ab	4.15 b	2.08 c	1.16
Eragrostis unioloides	2.77 a	2.52 b	2.32 c	1.82 d	0.01
Eragrostis virescens	2.58 a	1.49 b	1.33 c	1.21 c	0.16
Eragrostis viscosa	4.74 a	4.59 b	4.31 c	3.89 d	0.12
Imperata cilíndrica	3.82 a	3.68 b	3.54 c	3.04 d	0.04
Isachne globosa	2.95 a	2.25 b	1.93 c	1.73 d	0.03
Ischaemum timorense	3.45 a	3.29 b	2.99 c	2.02 d	0.01
Ischaemum indicum	4.66 a	4.42 b	3.42 c	2.83 d	0.09
Ischaemum muticum	4.98 a	3.36 b	3.13 b	2.64 b	0.73
Leersia hexandra	5.1a	4.71 a	3.85 b	3.62 b	0.65
Paspalum conjugatum	6.74 a	5.62 ab	5.23 b	4.02 c	1.36
Sacciolepis indica	6.28 a	5.98 a	5.76 a	3.76 b	0.87
Sporobolus diander	4.88 a	4.68 a	3.78 b	3.48 b	0.78
Sporobolus indicus	4.38 a	4.18 b	3.78 c	3.28 d	0.01
Stenotaphrum secundatum	6.57 a	5.98 ab	5.14 b	3.08 c	1.15

Means within rows followed by the same letter are not significantly different at P =0.05 (LSD test).

root dry weight (RDW) of 30 weed species (Table 6). RDW of the control species *P. vaginatum* was not significantly affected at the highest salt treatments (72 dSm^{-1}). Five (5) species, namely *E. indica*, *E. atrovirens*, *I. cylindrica*, *I. timorense*, and *S. diander* showed no reduction in their RDW with salinity treatments of up to 48 dSm^{-1}. RWD of 14 grasses remain unchanged with salinity treatments of up to 24 dSm^{-1}.

DISCUSSION

Alternative methods of weed control have received considerable attention in the past decade because no herbicides are currently labeled for selective control of goosegrass (*Eleusine indica*) in seashore paspalum, a turfgrass species used regularly on golf courses throughout the tropics (Brosnan *et al.*, 2009). Readily available sea water application could be an alternative of post emergence herbicides to control weeds in turfgrass and accordingly, present study was designed to evaluate this issue. A significant difference was observed among the tested weed plants at 3rd day after saline sea water (24 dS m^{-1}) treatments (Table 3). Out of 30 weed species, 8 species and the control (*Paspalum vaginatum)* were unaffected at the same salinity levels. In contrast, at the highest salinity level (72 dSm^{-1}) all species were affected including the control, *P. vaginatum* (5% injury) after 3 days treatments. Interestingly, 5% injury was noticed at 3 days after application, which was disappeared at 14 days after application (data not shown). The result suggested that the species has the capacity to recover salt injury after a certain time. Being halophyte, 72 dSm^{-1} salinity was applied at a time which might be imposed a sudden osmotic shock to the turfgrass species (*P. vaginatum)*. With the passing of exposure time, it may

Table 6. Effect of different salt water concentration on root dry weight of turfgrasses and weeds in Malaysia, 2007

Species	Root dry weight (g)/pot salt concentration (dSm^{-1})				LSD (0.05)
Grasses	**0**	**24**	**48**	**72**	
Paspalum vaginatum	5.90 a	5.38 a	5.03 a	4.97 a	1.11
Axonopus affinis	2.22 a	2.12 a	1.22 b	1.12 b	0.43
Bothriochloaintermedia	2.05 a	1.88 a	1.00 b	0.80 b	0.22
C.dactylon x *C. transvaalensis*	1.73 a	1.62 a	1.11 b	1.03 b	0.23
Chrysopogon aciculatus	2.09 a	1.68 b	1.19 c	1.05 c	0.32
Cynodon dactylon	1.62 a	1.52 a	1.01 b	0.92 b	0.23
D. aegyptium	2.16 a	1.99 a	1.10 b	0.88 c	0.21
Digitaria ciliaris	2.29 a	2.07 a	1.28 b	0.89 c	0.33
Digitaria didactyla	2.63 a	2.52 a	2.02 b	1.74 b	0.38
Digitaria fuscescens	2.15 a	2.03 a	1.63 b	1.43 c	0.16
Digitaria longiflora	2.09 a	1.88 a	1.10 b	0.70 c	0.32
Digitaria sanguinalis	1.94 a	1.75 a	0.95 b	0.58 c	0.32
Echinochloa colona	2.53 a	2.23 b	2.06 c	1.16 d	0.12
Eleusine indica	4.17 a	3.85 a	3.37 ab	2.91 b	0.86
Eragrostis atrovirens	1.55 a	1.45 a	1.39 ab	1.22 b	0.18
Eragrostis malayana	1.61 a	1.42 b	1.02 c	0.92 d	0.01
Eragrostis tenella	1.85 a	1.45 b	1.36 b	0.86 c	0.30
Eragrostis unioloides	1.45 a	1.07 b	0.92 bc	0.62 c	0.32
Eragrostis virescens	1.36 a	0.96 b	0.68 c	0.50 d	0.10
Eragrostis viscosa	1.72 a	1.57 b	1.44 c	1.31 d	0.02
Imperata cilíndrica	1.93 a	1.83 a	1.62 a	1.02 b	0.41
Isachne globosa	1.02 a	0.72 b	0.62 c	0.49 d	0.05
Ischaemum timorense	1.41 a	1.26 a	1.14 a	0.72 b	0.35
Ischaemum indicum	1.83 a	1.63 a	1.13 b	0.83 c	0.19
Ischaemum muticum	2.17 a	1.74 b	1.49 b	1.05 c	0.32
Leersia hexandra	1.61 a	1.51 ab	1.31 b	0.94 c	0.23
Paspalum conjugatum	2.37 a	2.17 b	1.69 c	1.56 d	0.04
Sacciolepis indica	1.76 a	1.46 ab	1.27 b	0.83 c	0.41
Sporobolus diander	1.23 a	1.22 a	1.02 a	0.80 b	0.21
Sporobolus indicus	1.53 a	1.37 b	1.10 c	0.64 d	0.14
S.secundatum	2.05 a	1.85 ab	1.56 b	1.07 c	0.44

Means within rows followed by the same letter are not significantly different at P =0.05 (LSD test).

overcome the osmotic shock and recover salt injury. Previously, Wiecko (2003) also reported that *P. vaginatum* was injured by 10% by 10 days after treatment of 55 dSm^{-1} salinity. Again, at the highest salinity level (72 dSm^{-1}), *E. viscosae* species were completely (100%) killed on the 14th day (data not shown). A differential doses (0, 24, 48, 72 dSm^{-1} seawater) dependent response of 30 weed species was also observed at 7 days after treatment (data not shown). To avoid repeating results alike fashion, we only showed 3 and 21 days results and excluded 7 and 14 days data.

At the highest salinity level (72 dSm^{-1}), 5 species were completely killed after 21 days of treatment in the current study. The result was in agreement with Pool *et al*. (2005), which reported that salinity levels of 54 and 41 dSm^{-1} provided greater than 70% control of large crabgrass (*Digitaria sanguinalis*) and goosegrass, respectively. Sequential application of sodium chloride at 488 kg/ha provided 90% control of grassy weeds in seashore paspalum (Brosnan *et al.*, 2009b). Again, only two weed species, *E. atrovirens* and *S. diander*, showed good tolerance at 72 dSm^{-1} seawater treatment after 21 days treatment (Table 5). The tolerance of these weeds may be related to their extensive rhizomes which allowed the plant to recover quickly and grow again after each application of seawater.

The present study showed that a very few weeds showed tolerance (<50% injury) to salt stress, some showed moderate tolerance (<70% injury) and most of them showed high sensitivity (>70% injury) when treated with salt water of 48 dSm^{-1} concentration. Thus the result indicated that salt water can provide effective control for most of the weed species, except for *E. atrovirens,* and *S. diander.* None of the salinity treatments severely injured *P. vaginatum*. This species recorded low injury (5%) at day 3 when treated with 72 dSm^{-1}, but in all instances, the plants recovered when watered with fresh water. The exceptionally high salt tolerance of seashore paspalum has been reported in previous studies (Uddin and Juraimi, 2012; Azwa *et al*., 2011; Uddin *et al*., 2009, 2011).

Growth parameters such as shoot growth and root mass (Marcum and Murdoch, 1990) have been reported to be excellent criteria to determine salinity tolerance in turfgrass. Significant differences were observed in shoot and root dry weight of turfgrass species *P. vaginatum*. Both shoots and roots experienced reductions in dry weight when irrigated with saline water. Shoot dry weight decreased with increase in salinity level of up to 48 dSm^{-1} but at higher salinity (72 dSm^{-1}) no significant reduction was observed. Shoot dry weight reduction (as compared to control) were recorded as 5.0, 6.0 and 12.4% at 24, 48 and 72 dSm^{-1}, respectively, but a maximum root dry weight reduction of only 16.2% (as compared to control) was recorded at the highest salinity level (72 dSm^{-1}). In most of the cases, both shoot and root dry weights were gradually decreased with increase in salinity. In general, increased levels of salinity caused depletion in energy needed for growth, and less turgor and reduction in photosynthetic area results in reduced growth and ultimately less shoot and root dry matter. Moreover, accumulation of salts in cell wall as a consequence of high salinity would also effectively reduce cell turgor and ultimately reduce growth (Flowers and Yeo, 1986). Reduced shoot and root growth due to salinity stress might be a consequence of leaf injuries like necrosis, leaf firing, and wrinkled leaf, which reduce the process of photosynthesis resulting lower shoot and root dry matter production. Detrimental effects of increased salinity on shoot and root growth of different turfgrass species has also been reported by other researchers (Murat *et al*., 2010; Alshammary *et al*., 2008; Lee *et al*., 2004a,b; Qian *et al*., 2001).

***Conclusion*:** Based on the present study, weeds can be categorized as highly susceptible, moderately susceptible and highly tolerant to salinity. Highly susceptible weeds were *C. dactylon*, *E. indica*, *E. virescense*, *E. unioloides* and *I. globosa.* Moderately susceptible weed species were *A. affinis, E. colonoa, Eragrostis tenella*, *Eragrostis unioloides*, *I. muticum, P. conjugatum, D. ciliaris* and *E. indica*. The fairly tolerant group *E. atrovirens*, *S. diander* and *P. vaginatum* were found to be highly tolerant to salt water treatments (72 dSm^{-1}). Hence, it can be concluded that sea water could be used as an alternative to herbicides for weed control in turfgrass species *Paspalum vaginatum.*

***Acknowledgement*:** This research project is funded by the Malaysian Government Research Grant (Science fund 05-01-04 SF0302) and Graduate Research Fellowship, Universiti Putra Malaysia (UPM).

REFERENCES

Alshammary, S.F., G. Hussain and Y.L. Qian. 2008. Response of warm season grasses to salinine irrigation water under arid climate. Asian J. Plant Sci. 7: 619–627.

Azwa, N.Z., A.S. Juraimi, M.K. Uddin, M. Begum, M.S. Mustapha, S.M. Amrizal and N.H. Samsuddin. 2011. Use of saline water for weed control in seashore paspalum. Aust. J. Crop Sci. 5:523-530.

Beard, J.B. 1973. Turfgrass: Science and Culture. Prentice Hall Engle wood Cliffs, N.J.

Brosnan, J.T., J. Defrank, S.W. Micah and G.K Breeden. 2009. Efficacy of sodium chloride applications for control of goosegrass (*Eleusine indica*) in seashore paspalum turf. Weed Technol. 23: 179–183.

Burril, L.C., J. Cardenas and E. Locatelli. 1976. Field Manual for Weed Control Research. International Plant Protection Center, Oregon State University, Corvallis.

Duncan, R.R. 1996a. The environmentally sound turfgrass of the future. USGA Green Section Record 34: 9–11.

Duncan, R.R. 1996b. Seashore paspalum: The next generation turf for golf courses. Golf Course Manag. 65: 49–51.

Emmons, R.D. 2008. Turfgrass Science and Management, 4th Ed. Delmar Thompson Learning, Inc., New York.

Flowers, T.J. and A.R. Yeo. 1986. Ion relations of plants under drought and salinity. Aust. J. Plant Physiol. 13: 75–91.

Johns, R. 2004. Turfgrass Installation, Management and Maintenance. McGraw-Hill Companies, Inc.

Johnson, J.B. and R.R. Duncan. 2000. Timing and frequency of ethofumesate plus flurprimidol treatments on bermudagrass (*Cynodon* spp.) suppression in seashore paspalum (*Paspalum vaginatum*). Weed Technol. 14: 675–685.

Johnson, J.B. and R.R. Duncan. 2001. Effects of herbicide treatments on suppression of seashore paspalum (*Paspalum vaginatum*) in bermudagrass (*Cynodon* spp.). Weed Technol. 15: 163–169.

Juraimi, A.S. 2001. Turfgrass: Types, uses and maintenance. Garden Asia 8: 40–43.

Lee, G., R.R. Duncan and R.N. Carrow. 2004a. Salinity tolerance of seashore paspalum ecotypes: Shoot growth responses and criteria. HortScience 39: 1138–1142.

Lee, G., R.R. Duncan and R.N. Carrow. 2004b. Salinity tolerance of selected seashore paspalums and bermudagrasses: Root and verdure responses and criteria. HortScience 39: 1143–1147.

Marcum, K.B. 2005. Relative salinity tolerance of 21 turf type desert salt grasses compared to bermudagrass. HortScience 40: 827–829.

Marcum, K.B. and C.L. Murdoch. 1990. Growth responses, ion relations, and osmotic adaptation of eleven C_4 turfgrasses to salinity. Agron. J. 82: 892–896.

Murat, A.T., A.H.A. Elkarim, N. Taban and S. Taban. 2010. Effect of salt stress on growth and ion distribution and accumulation in shoot and root of maize plant. Afr. J Agric. Res. 584–588.

Pool, N.B., B.J. Brecke, J.B. Unrah, G.E MacDonald, L.E. Trenholm and J.A. Ferrel. 2005. Managing weeds in seashore paspalum using saline irrigation. Presented at the Florida Weed Science Society 28th Annual meeting, February, 2005, Lake Alfred FL, USA.

Uddin, M.K. and A.S. Juraimi. 2012. Using sea water for weed mangement in turfgrass. ISBN 978-3-8473-7389-6, 2012, p.1-281, LAP LAMBERT Academic Publishing GmbH & Co. KG.

Uddin, M.K., A.S. Juraimi, M.R. Ismail and J.B. Brosnan 2010. Characterizing weed populations in different turfgrass sites throughout the Klang valley of Western Peninsular Malaysia. Weed Technol. 2: 173–181.

Uddin, M.K., A.S. Juraimi, M.R. Ismail, M.A. Rahim and O. Radziah. 2009a. Growth response of eight tropical turfgrass to salinity. Afr. J. Biotech. 8: 5799–5806.

Uddin, M.K., A.S. Juraimi, M.R. Ismail, M.A. Rahim and O. Radziah and B. Mahfuza. 2009b. Floristic composition of weed community in turfgrass area of West Peninsular Malaysia. Int. J. Agric. Biol. 11: 13–20.

Uddin, M.K., A.S. Juraimi, M.R. Ismail, M.A. Rahim and O. Radziah. 2011. Relative salinity tolerance of warm season turfgrass species. J. Environ. Biol. 32: 309-312.

Wiecko, G. 2003. Ocean water as a substitute for post emergence herbicides in Tropical turf. Weed Technol. 17: 788–791.