Efficacy of Sodium Chloride Applications for Control of Goosegrass (*Eleusine indica*) in Seashore Paspalum Turf

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Control of goosegrass is difficult in the pan-Pacific region. No herbicides are currently labeled for selective control of goosegrass in seashore paspalum turf, a species used regularly on golf courses throughout the tropics. Sequential granular applications of sodium chloride (99% sodium chloride, 1% sodium silicoaluminate, 83% 0.5 to 0.25 mm diam) at 488 kg/ha did not effectively (> 70%) control goosegrass in this study. Goosegrass injury following sequential granular applications of sodium chloride, at 488 kg/ha, subsided at 6 wk after initial treatment (WAIT). A single application of MSMA at 2.40 kg/ha plus metribuzin at 0.56 kg/ha provided 96 and 83% control of goosegrass 8 WAIT in 2007 and 2008, respectively. Sequential applications of MSMA plus metribuzin at lower rates yielded similar results. Applications of foramsulfuron did not effectively control (> 70%) goosegrass in this study, suggesting a possible tolerance to this treatment. Applications of MSMA plus metribuzin controlled goosegrass (> 70%), but induced phytotoxic injury to seashore paspalum turf. Additional research is needed to evaluate strategies for POST control of goosegrass in seashore paspalum turf that do not induce phytotoxic turfgrass injury after application.

Nomenclature: Metribuzin; MSMA; foramsulfuron; goosegrass, *Eleusine indica* (L.) Gaertn. ELEIN; seashore paspalum, *Paspalum vaginatum* Swartz. PASVA.

Key words: Salinity, turfgrass, chlorophyll meter, chlorophyll index, seashore paspalum, herbicide, weed.

Goosegrass is one of the most difficult turfgrass weeds to control in the tropical and subtropical pan-Pacific region (Wiecko 2000). A summer annual in temperate regions, goosegrass behaves as a perennial in tropical and subtropical environments, producing new tillers during every month of the year. Environmental conditions in the pan-Pacific region also allow for the year-round germination of goosegrass seed; thus, populations at various stages of growth are present throughout the year. Considering that herbicides labeled for POST goosegrass control are often more efficacious when applied to nontillering plants, variability in goosegrass growth stage often makes POST herbicide applications less effective in tropical climates (R. Nishimoto, personal communication).

Options for selective POST control of goosegrass in turf include applications of metribuzin plus MSMA (Brennan et al. 1992; Nishimoto and Murdoch 1999), simazine plus MSMA (Murdoch and Ikeda 1974), diclofop (McCarty 1991), diclofop plus metribuzin (Nishimoto and Murdoch 1999), foramsulfuron (Nishimoto and Kawate 2003), and foramsulfuron plus metribuzin (Busey 2004). Although these products are safe for use on bermudagrass turf (*Cynodon* spp.), none are labeled for use on seashore paspalum, a turfgrass used extensively on golf courses throughout Hawaii for its aesthetic characteristics and salinity tolerance. Although morphologically and aesthetically similar to bermudagrass, seashore paspalum can tolerate salinity levels as high as 54 dS/m, a level at which most horticultural crops could not survive (Duncan and Carrow 2000).

Research has suggested that this salinity tolerance might allow for applications of sodium chloride to be used for POST control of grassy weeds in seashore paspalum (Duncan and Carrow 2000). Salt-tolerant turfgrasses like seashore paspalum are able to make osmotic adjustments following salt stress (Marcum and Murdoch 1990), whereas certain weed species cannot. Brosnan et al. (2008a) suggested that granular applications of sodium chloride could create osmotic gradients large enough to rupture the cell membranes of some grassy weed species in a manner similar to what has been reported after applications of metribuzin and MSMA.

Research investigating the efficacy of sodium chloride applications for POST control of goosegrass in seashore paspalum is limited. Wiecko (2003) reported that six sequential applications of saline ocean water (electrical conductivity [EC] = 55 dS/m) induced severe (> 90%) phytotoxic injury to goosegrass plants 10 d after initial treatment (DAIT); however, injury decreased to almost 48% at 30 DAIT. Pool et al. (2005) reported that applications of 54 dS/m saline water provided greater than 70% control of goosegrass in a greenhouse study. Brosnan et al. (2008a) suggested that sequential applications of sodium chloride at 488 kg/ha are required for POST control of grassy weeds and that carrier volumes required to deliver rates as large as 488 kg/ha render commercial spray applications impractical. In the same study, Brosnan et al. (2008a) reported that sequential applications of granular sodium chloride at 488 kg/ha provided greater than 90% control of sourgrass (*Paspalum conjugatum* Berg.) in seashore paspalum turf.

The efficacy of granular applications of sodium chloride for POST control of goosegrass in seashore paspalum has not been investigated. The objective of this research was to determine the efficacy of granular applications of sodium

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chloride for POST control of goosegrass in seashore paspalum turf.

Materials and Methods

Studies were conducted on a 'Salam' seashore paspalum driving range tee at Coral Creek Golf Course (Ewa Beach, HI) in October 2007 and a Salam seashore paspalum turfgrass stand at Kapiolani Park (Honolulu, HI) in January 2008. Seashore paspalum turfgrass at Coral Creek was established on a Mamala stony, silty, clay loam soil (clayey, parasesquic, isohyperthermic Lithic Haplocambids), whereas seashore paspalum turfgrass at Kapiolani Park was established on a Jaucas sand soil (carbonatic, isohyperthermic Typic Ustipsamments). Turfgrass was maintained at 3.8 cm height at each facility. Plot size was 2.1 by 0.9 m. Soil testing before initiation of each experiment revealed no nutrient deficiencies at either site and soil pH values of 7.3 and 7.5, respectively. Rainfall in each experiment was monitored with a virtual weather station managed by ZedX Inc. (Bellefonte, PA).

Treatments were as follows: (1) granular sodium chloride[1] at 488 kg/ha, followed by granular sodium chloride at 488 kg/ha 7 d later, followed by granular sodium chloride at 488 kg/ha 7 d later; (2) MSMA[2] at 1.12 kg /ha, followed by MSMA at 1.12 kg /ha 14 d later; (3) MSMA at 2.4 kg /ha; (4) MSMA at 1.12 kg/ha plus metribuzin[3] at 0.28 kg/ha, followed by MSMA at 1.12 kg/ha plus metribuzin at 0.28 kg/ha 14 d later; (5) MSMA at 2.4 kg/ha plus metribuzin at 0.56 kg/ha; (6) foramsulfuron[4] at 0.027 kg/ha followed by foramsulfuron at 0.027 kg/ha 14 d later; (7) foramsulfuron at 0.043 kg/ha; (8) untreated check. The MSMA formulation evaluated included a surfactant. The granular sodium chloride treatment was applied from a shaker jar. All other treatments were applied by a CO_2-powered boom sprayer calibrated to deliver 374 L/ha with one flat-fan 8004E nozzle at 275 kPa configured to provide a 0.9-m spray swath.

Treatments were initiated on October 9, 2007 at Coral Creek and January 23, 2008 at Kapiolani Park. Plots were rated 1, 2, 3, 6, and 8 wk after initial treatment (WAIT). The percentage of goosegrass in each plot was determined visually, with changes in the percentage of goosegrass in each plot used to calculate percent control; greater than 70% control was considered acceptable. Seashore paspalum and goosegrass injury were assessed quantitatively through measurements of relative chlorophyll index (R840/R700) with a CM-1000 chlorophyll meter[5] according to the methods of Mangiafico and Guillard (2005). The CM-1000 chlorophyll meter measures chlorophyll content by analyzing ambient and reflected light at two wavelengths (700 and 840 nm); results are expressed on a relative index of 0 (no chlorophyll present) to 999 (maximum measurable chlorophyll content). This device has been used by other researchers to quantify herbicide injury (Teuton et al. 2008).

One soil core (10 by 8.9 by 1.9 cm) was removed from each plot at 8 WAIT and analyzed for sodium adsorption ratio (SAR) and electrical conductivity (EC_e) according to the methods of Sparks (1996). Voids remaining after cores were removed were filled with silica sand.

The experimental design was a randomized complete block with three replications. Data were subjected to analysis of variance. Fisher's protected LSD values are reported for comparisons at the $\alpha = 0.05$ level. Significant interactions were detected between years and treatments; thus, data from each year are presented individually.

Results and Discussion

Sodium Chloride Treatments. Granular applications of sodium chloride did not effectively (> 70%) control goosegrass in this study. Sequential applications of granular sodium chloride at 488 kg/ha (treatment 1) provided 58 and 54% control of goosegrass 8 WAIT in 2007 and 2008, respectively (Table 1). This response differs from what was reported by Brosnan et al. (2008a) evaluating the use of granular sodium chloride applications for sourgrass (*Paspalum conjugatum* Berg.) control.

However, sequential granular applications of sodium chloride at 488 kg/ha (treatment 1) induced phytotoxic injury to goosegrass plants. Goosegrass chlorophyll index values 1, 2, and 3 WAIT in 2008 measured 181, 109, and 146 for treatment 1, respectively, compared with 250, 213, and 246, respectively, for the untreated check (Table 2). A similar response was observed in 2007 as well. Similar to the findings of Wiecko (2003), injury subsided 30 d after treatment, in that goosegrass chlorophyll index values were not statistically different from the untreated check at 6 and 8 WAIT in both 2007 and 2008 (Table 2).

In both 2007 and 2008, sequential applications of granular sodium chloride at 488 kg/ha (treatment 1) yielded soil SAR values that were higher than the untreated check; treatment 1 yielded an SAR value of 3.3 in 2007 and 2008, compared with values of 1.4 and 1.2, respectively, for the untreated check (Table 3). Similar to what was reported by Brosnan et al. (2008a), SAR values in this study are well below threshold levels that would negatively affect seashore paspalum turfgrass quality. Sequential applications of granular sodium chloride at 488 kg/ha (treatment 1) had no effect on soil EC_e values in this study.

Herbicide Treatments. Sequential applications of MSMA plus metribuzin effectively (> 70%) controlled goosegrass in this study. Applications of MSMA at 1.12 kg/ha plus metribuzin at 0.28 kg/ha, followed by MSMA at 1.12 kg/ha plus metribuzin at 0.28 kg/ha 14 d later (treatment 4) provided 92 and 77% control of goosegrass 8 WAIT in 2007 and 2008, respectively (Table 1). A similar response was observed after a single application of MSMA plus metribuzin at rates of 2.40 and 0.56 kg/ha (treatment 5), respectively, in both 2007 and 2008 (Table 1). Goosegrass control following applications of MSMA plus metribuzin has been reported by other researchers (Brennan et al. 1992; Busey 2004; Johnson 1980; Nishimoto and Murdoch 1999).

Applications of foramsulfuron (treatments 6 and 7) did not effectively (> 70%) control goosegrass in this study. Goosegrass tolerance to applications of foramsulfuron has been observed in Hawaii, with tolerant goosegrass populations exhibiting sensitivity to applications of MSMA plus metribu-

Table 1. Goosegrass control means for sodium chloride and herbicide treatments in 2007 and 2008.[a]

Treatment	Rate	Goosegrass control[b]									
		1 WAIT		2 WAIT		3 WAIT		6 WAIT		8 WAIT	
		2007	2008	2007	2008	2007	2008	2007	2008	2007	2008
	kg/ha	%									
1. Granular sodium chloride + granular sodium chloride (7 d later) + granular sodium chloride (7 d later)	488 488 488	6	0	19	9	19	15	79	67	58	54
2. MSMA+ MSMA (14 d later)	1.12 1.12	5	0	6	0	6	0	15	7	19	17
3. MSMA	2.40	0	0	4	0	4	2	46	12	19	33
4. MSMA+ metribuzin + MSMA (14 d later) + metribuzin (14 d later)	1.12 0.28 1.12 0.28	5	1	0	0	17	0	86	92	92	77
5. MSMA + metribuzin	2.40 0.56	0	0	27	4	27	11	94	95	96	83
6. Foramsulfuron + foramsulfuron (14 d later)	0.027 0.027	0	0	22	3	30	18	49	24	60	50
7. Foramsulfuron	0.043	5	1	19	3	3	0	40	46	58	63
8. Untreated check	0	0	0	0	0	0	0	0	0	2	
LSD (0.05)	NS	NS	26	5	26	21	42	19	44	38	

[a] Abbreviations: NS = not significant at the $\alpha = 0.05$ level; WAIT = weeks after initial treatment.

[b] Visual assessment of the change in percentage of goosegrass per plot.

zin (Brosnan et al. 2008b; J. DeFrank, personal communication). Busey (2004) observed goosegrass response to applications of foramsulfuron alone to be quite variable; at only two out of five experimental sites did applications of foramsulfuron alone provide greater than 68% goosegrass control. Goosegrass populations that have developed tolerance to foramsulfuron are sensitive to tank-mix applications of MSMA and metribuzin (J. DeFrank, personal communication). Data collected in this study supports these observations, in that a single application of MSMA at 2.40 kg/ha plus metribuzin at 0.56 kg/ha provided 96 and 83% control of goosegrass 8 WAIT in 2007 and 2008, respectively, whereas a single application of foramsulfuron at 0.043 kg/ha only provided 58 and 63% control 8 WAIT in 2007 and 2008, respectively (Table 1).

Herbicide treatments that effectively (> 70%) controlled goosegrass in this study injured seashore paspalum turf for 3 WAIT in both 2007 and 2008. Seashore paspalum chlorophyll index values after an application of MSMA at 2.40 kg/ha plus metribuzin at 0.56 kg/ha (treatment 5), were

Table 2. Goosegrass chlorophyll index values for sodium chloride and herbicide treatments in 2007 and 2008.

Treatment	Rate	Goosegrass chlorophyll index[a]									
		1 WAIT[b]		2 WAIT		3 WAIT		6 WAIT		8 WAIT	
		2007	2008	2007	2008	2007	2008	2007	2008	2007	2008
	kg/ha	R840/R700									
1. Granular sodium chloride + granular sodium chloride (7 d later) + granular sodium chloride (7 d later)	488 488 488	228	181	201	109	176	146	316	216	426	173
2. MSMA + MSMA (14 d later)	1.12 1.12	158	235	123	240	134	244	221	244	415	146
3. MSMA	2.40	163	219	131	175	132	217	276	207	438	148
4. MSMA + metribuzin + MSMA (14 d later) + metribuzin (14 d later)	1.12 0.28 1.12 0.28	148	170	133	89	113	110	213	215	386	212
5. MSMA + metribuzin	2.40 0.56	110	158	101	87	119	88	287	191	478	153
6. Foramsulfuron + foramsulfuron (14 d later)	0.027 0.027	179	223	167	161	153	163	246	235	401	198
7. Foramsulfuron	0.043	194	230	159	169	151	154	246	214	452	168
8. Untreated check		225	250	251	213	265	246	327	227	519	164
LSD (0.05)		30	27	28	16	23	23	45	23	57	34

[a] Relative chlorophyll index measured at two wavelengths—840 and 700 nm (R840/R700)—according to the methods of Mangiafico and Guillard (2005).

[b] Abbreviation: WAIT = weeks after initial treatment.

Table 3. Soil sodium adsorption ratio (SAR) and electrical conductivity means 8 weeks after initial treatment for sodium chloride and herbicide treatments in 2007 and 2008.

Treatment	Rate	Sodium adsorption ratio[a] 2007	Sodium adsorption ratio[a] 2008	Electrical conductivity 2007	Electrical conductivity 2008
	kg/ha	SAR		dS/m	
1. Granular sodium chloride + granular sodium chloride (7 d later) + granular sodium chloride (7 d later)	488 488 488	3.3	3.3	2.0	1.6
2. MSMA + MSMA (14 d later)	1.12 1.12	1.4	1.2	2.6	1.5
3. MSMA	2.40	1.2	1.2	3.0	1.4
4. MSMA + metribuzin + MSMA (14 d later) + metribuzin (14 d later)	1.12 0.28 1.12 0.28	2.0	1.2	2.0	1.4
5. MSMA + metribuzin	2.40 0.56	1.4	1.1	2.5	1.3
6. Foramsulfuron + foramsulfuron (14 d later)	0.027 0.027	1.4	1.1	2.1	1.5
7. Foramsulfuron	0.043	1.5	1.1	2.3	1.3
8. Untreated check		1.4	1.2	2.0	1.3
LSD (0.05)		0.8	0.6	NS[b]	NS

[a] Soil SAR and electrical conductivity measured according to the methods of Sparks (1996).

[b] Abbreviation: NS = not significant at the $\alpha = 0.05$ level.

139, 162, and 217 compared with 316, 335, and 358 for the untreated check at 1, 2, and 3 WAIT, respectively, in 2007 (Table 4). Similar responses were observed after applying this treatment in 2008 and after sequential applications of MSMA plus metribuzin at lower rates (treatment 4) in both 2007 and 2008. These results support the findings of Busey (2004) and Duncan and Carrow (2000), who reported that applications of MSMA plus metribuzin at similar rates can injure both 'Tifway' hybrid bermudagrass (*Cynodon dactylon* × *Cynodon transvaalensis*) and seashore paspalum turf.

Additional research is needed to evaluate strategies for POST control of goosegrass in seashore paspalum turf that do not induce significant phytotoxic turfgrass injury after application.

Sources of Materials

[1] Granular sodium chloride, Morton International Inc., Chicago, IL 60606.

[2] MSMA 6 Plus, Drexel Chemical Inc., Memphis, TN 38113.

Table 4. Seashore paspalum chlorophyll index values for sodium chloride and herbicide treatments in 2007 and 2008.

Treatment	Rate	1 WAIT[b] 2007	1 WAIT[b] 2008	2 WAIT 2007	2 WAIT 2008	3 WAIT 2007	3 WAIT 2008	6 WAIT 2007	6 WAIT 2008	8 WAIT 2007	8 WAIT 2008
		Seashore paspalum chlorophyll index[a]									
	kg/ha	R840/R700									
1. Granular sodium chloride + granular sodium chloride (7 d later) + granular sodium chloride (7 d later)	488 488 488	300	269	288	270	294	322	393	304	489	311
2. MSMA + MSMA (14 d later)	1.12 1.12	236	372	178	306	245	338	317	301	442	208
3. MSMA	2.40	231	315	195	230	261	265	357	267	449	180
4. MSMA + metribuzin + MSMA (14 d later) + metribuzin (14 d later)	1.12 0.28 1.12 0.28	207	271	241	219	159	260	329	303	367	295
5. MSMA + metribuzin	2.40 0.56	139	260	162	163	217	202	363	276	449	233
6. Foramsulfuron + foramsulfuron (14 d later)	0.027 0.027	265	248	274	206	274	231	325	272	412	260
7. Foramsulfuron	0.043	275	315	242	237	213	231	357	289	406	284
8. Untreated check		316	333	335	308	358	334	345	304	422	224
LSD (0.05)		37	26	26	28	22	26	24	19	33	28

[a] Relative chlorophyll index measured at two wavelengths—840 and 700 nm (R840/R700)—according to the methods of Mangiafico and Guillard (2005).

[b] Abbreviation: WAIT = weeks after initial treatment.

[3] Sencor 75DF, Bayer Environmental Sciences, Research Triangle Park, NC 27709.

[4] Revolver 0.19SC, Bayer Environmental Sciences, Research Triangle Park, NC 27709.

[5] CM-1000 chlorophyll meter, Spectrum Technologies Inc., East Plainfield, IL 60585.

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