GRANULAR FORMULATIONS OF SODIUM AND POTASSIUM AZIDE FOR *MESOCRICONEMA* SPP. CONTROL ON A BENTGRASS PUTTING GREEN[1]

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ABSTRACT

Wells, S.M., R.H. Walker, R. Rodríguez-Kábana, L.J. Simmons and J.L. Belcher. 2011. Granular formulations of sodium and potassium azide for *Mesocriconema* spp. control on a bentgrass putting green. Nematropica 41:39-44.

Granular formulations of sodium (NaN_3) and potassium (KN_3) azides were developed at Auburn University and evaluated for their nematicidal efficacy in an established mix of 'A1-A4' bentgrass [*Agrostis stoloniferas* L. (Huds.) Farw.] putting green in 2007 and 2008. The study site had ring nematode (*Mesocriconema* spp.) at levels which were considered damaging. Both sodium and potassium azides were impregnated in/on granular carriers consisting of Profile® and Biodac® and applied in three applications at 11.2, 5.6, and 11.2 kg ai/ha, respectively. The objectives of this research were to determine nematicidal efficacy, turf injury, and root length density for both sodium and potassium azides on both carriers. The potassium formulation was developed because many golf course superintendents are reluctant to apply additional sodium to putting greens in coastal areas. After all applications of both formulations, *Mesocriconema* spp. populations were lower than the non-treated control. Injury for both formulations was within the acceptable range until after the third application. One week after treatment of the third application of the sodium formulations were above the 30% acceptable level. However, two weeks after treatment of the third application, injury was acceptable. Potassium treatments were within the acceptable level throughout the study. Root length density was only measured in 2008 and results indicated that the potassium azide formulations produced higher root length densities than the controls.

Key words: Agrostis stoloniferas, Biodac®,creeping bentgrass, golf putting green, *Mesocriconema* spp., potassium azide, Profile®, root length density, sodium azide

RESUMEN

Wells, S.M., R.H. Walker, R. Rodríguez-Kábana , L.J. Simmons and J.L. Belcher. 2010. Formulaciones granuladas de las azidas de sodio y potasio para controlar *Mesocriconema* spp. en un campo de golf con césped Agrostis. Nematropica 41:39-44.

Se prepararon formulaciones solidas de las azidas de sodio (N_3Na) y de potasio (N_3K) en la Universidad de Auburn. El poder nematicida de las composiciones se evaluo en 2007 y 2008 en un campo de golf con césped de Agrostis [*Agrostis stoloniferas* L.(Huds.) Farw.] ; mezcla 'A1-A4' infestado con el nematodo del anillo (*Mesocriconema* spp.) a niveles considerados como dañinos de acuerdo con los umbrales económicos. Se impregnaron ambas azidas en gránulos de arcilla calcinada (Profile®) y otros de composición celulosica (Biodac®) se efectuaron tres aplicaciones en secuencia con los dos tipos de gránulos y de azidas a razón de 11.2, 5.6, y 11.2 kg i.a./ha, resoectuvanebte. Los objetivos de la investigación fueron determinar el poder nematicida, fitotoxicidad, y la densidad longitudinal de las raices [DLR] tanto para las dos azidas como para los dos tipos de gránulos portadores de las mismas. Dado que por lo general los superintendentes de los campos de golf se muestran reacios a la adición de sodio en campos en las zonas maritimas costeras se prepararon formulaciones con N_3K. Los resultados indican que después de todas las aplicaciones de ambas formulaciones, spp de *Mesocriconema* poblaciones fueron apreciablemente más bajo que el control no-tratado. La herida para ambas formulaciones setuvo dentro de la gama aceptable hasta después de la tercera aplicación. Calificaciones de herida 1 semana después de tratamiento de; la tercera aplicación del azide/Profile de sodio y formulaciones de azide/Biodac de sodio produjo que estuvo encima del 30% de nivel aceptable y fue apreciablemente. Dos semana después de tratamiento de la tercera aplicación, la herida fue aceptable. Los tratamientos con N_3K

siempre estuvieron dentro del nivel de fitotoxicidad aceptable. La DLR sólo se determinó en 2008 y los resultados indican que las aplicación de N_3K resultó en valores DLR superiores a los correspondientes al testigo y a los tratamientos con N_3Na.

Palabras clave: Agrostis stolonifera, azida de sodio, azida de potasio, Biodac®, campo de golf, césped tipo bent, densidad longitudinal de las raices, *Mesocriconema* spp., Profile®

INTRODUCTION

Ring nematodes (*Mesocriconema* spp.) are found commonly in Alabama golf course putting greens and the threshold limit in Alabama and Florida is 300-500/100 cm^3 soil (Sikora *et al*., 1999; Crow, 2007). Curfew® (1,3-dichloropropene), 1,3-D, is the only chemical control available for established turf. Only one application can be made annually by certified personnel in eight states including Alabama. This leaves turf managers in most locations without nematicides for established turf. Therefore, a need exists for alternative controls for established turf.

SEP-100® is a stabilized liquid formulation of sodium azide which has been extensively studied at Auburn University from 2004 to 2006 as a preplant methyl bromide replacement. Research was initiated in 2007 to investigate the potential of using reduced rates of azide impregnated on granular carriers to improve tolerance in established turfs. Sodium (NaN_3) and potassium (KN_3) azide were formulated to contain 10% active ingredient by weight. Profile® (Profile Products LLC., 750 Lake Cook Rd., Suite 440, Buffalo Grove, Il 60089) and Biodac® (Kadant Inc., One Technology Park Dr., Westford, MA 01886) were chosen as the granular carriers. Small particle size carriers were chosen so they would readily disperse into the closely mowed canopy. The granular particle range for Profile® was 0.25-1.0 mm and the particle range for Biodac® was 0.84-3.0 mm.

Profile® is fired ceramic clay which is stable and currently used as a soil amendment for golf green construction and after core aerification. The clay particles contain 39% capillary (water) pores, and 35% non-capillary (air) pores (Profile Products, 2002). Thus, Profile® permanently improve most soils by increasing water and nutrient holding capacity while also allowing for aeration and excess water drainage. The chemical composition includes 74% SiO_2, 11% Al_2O_3, 5% Fe_2O_3, and less than 5% of CaO, MgO, K_2O, Na2O, and TiO_2 (Wehtje *et al.*, 2003).

Biodac® is an absorbent granule made from paper pulp residue and is used as a carrier to deliver chemicals for use in agricultural and lawn and garden applications, and is also used as an absorbent for oil and grease. The product is a gray colored cellulose complex consisting of 47-53% paper fiber, 28-34% kaolin clay, and 14-20% calcium carbonate, and no more than 1% titanium dioxide (Ilyina *et al.*, 2000).

The most widely used cool-season turfgrass for golf course putting greens is creeping bentgrass [*Agrostis stolonifera* L. (Huds). Farw.] (Beard, 1982). During summer months in the Southeastern United States, bentgrass quality typically declines resulting in root system loss. Therefore, golf greens are frequently amended during construction or aerification to improve resiliency and nutrient and water retention (Beard, 1982). Inorganic amendments such as Profile®, having high water retention capacity are used in place of sphagnum peat moss because of resistance to biodegradation (Bigelow *et al.*, 2004). Field experiments conducted by Bigelow *et al.* (2001) evaluated creeping bentgrass response to inorganic soil amendments including Profile®. Turf establishment, turf quality, and root mass density were tested. They found that amending medium-coarse sized sand with organic amendments had significant beneficial effects on turfgrass establishment and visual quality ratings. A laboratory study of three United States Department of Agriculture sand size classes (fine, medium, and coarse) was conducted by Bigelow *et al.* (2004) to determine physical properties with and without inorganic amendments. Profile® resulted in higher total porosity and overall water retention compared to other amendments tested. Joo *et al.* (1998) evaluated the effects of soil amendments on the chemical and physical soil parameters of a 'Crenshaw' creeping bentgrass sand-based golf green. Profile® was found to be the most effective amendment for increasing cation exchange capacity of the media. Profile® also doubled the amount of exchangeable potassium and increased magnesium by approximately 50%; it also increased water retention and decreased bulk density as compared to the control.

Miller (2000) evaluated the physiological response of Tifdwarf bermudagrass (*Cynodon dactylon* x *C. transvaalensis* Burtt-Davy) grown in soil with various amendments including Profile® during drought stress. Turf grown with Profile® had the highest quality among the amendments tested. The data suggested that selected amendments can have a positive influence on soil moisture resulting in an increase in drought avoidance. In a greenhouse experiment Wehtje *et al.* (2003) used four inorganic soil amendments to improve a native soil and to evaluate Tifway bermudagrass performance. They found that neither Profile® nor any of the amendments influenced bermudagrass growth compared to non-amended soil when water and nutrients were plentiful.

Ilyina *et al.* (2000) evaluated Biodac® as a possible carrier for microorganisms that are used for bioremediation applications. They reported the possible side effects on soil capacity to retain moisture and influence plant growth and found Biodac® to be hydrophilic, porous and to absorb water at 1.15 ml/g due to the high cellulose content. The best plant height and heaviest plants were observed in Biodac®-treated soils. The objectives of this research were to determine nematicidal efficacy, turf injury, and root length density (RLD) of both sodium and potassium azide sources and Profile® and Biodac® carriers in a creeping bentgrass putting green.

MATERIALS AND METHODS

Laboratory Methods

Profile® and Biodac® carriers were impregnated with NaN_3 and KN_3 following procedures developed by Rodrigo Rodríguez-Kábana (2005), Department of Entomology and Plant Pathology, Auburn University. For each formulation, 1760 grams of either Profile® or Biodac® was placed in a stainless steel mixer and pulsed to break up clumps. In a separate beaker, 40 grams of anhydrous Na_2CO_3 was mixed with 700 ml of demineralized water until totally dissolved. One hundred fifty grams of a technical grade (10% ai) NaN_3 or KN_3 was added to the Na_2CO_3 solution and mixed. Demineralized water was then added to bring the solution to 800 ml. Aliquots of 100 ml of this solution were added to the granules as the drum mixer rotated until all of the solution and granules were mixed. The wetted granules were poured onto flat trays, spread thin and dried with a fan. During the drying process, the mixture was stirred to prevent clumping. After drying, the azide granules were placed in air-tight, light-excluding containers.

Field Studies

Research was conducted at FarmLinks Golf Club in Sylacauga, Alabama on number 17 putting green which had a mature stand of 'A1-A4' bentgrass mixture. The green was constructed in 2002 and was a USGA specification green with 85% sand and 15% Profile®. The initial soil pH was 7.2. Field trials were initiated 25 September 2007 and 14 July 2008. Separate plots were used in 2008 located adjacent to previous year plots. Regular scheduled maintenance to include mowing, irrigation, fertility, pesticide, and aerification practices were conducted on this green during the course of the study by golf course personnel.

This experiment was a small-plot randomized complete block design with four replications in 2007 and six replications in 2008. The plot size was 1.2 x 3 m. Treatments were applied three times at approximately 2-week intervals between treatment 1 and 2, and a 4-week interval between treatments 2 and 3. In 2007, the first treatments were applied on 25 September and consisted of 11.2 kg ai/ha each and of sodium azide and potassium azide on both Profile® and Biodac® carriers and a non-treated control. The second application was applied 9 October and consisted of 5.6 kg ai/ha each of sodium azide and potassium azide on Profile® and Biodac® carriers, and a non-treated control. The third application was made 11 November and used the same rates as the first treatment. Applications were made with a 0.91-m Gandy® (Gandy Company, 528 Gandrud, Owatonna, MN 55060) drop spreader with a single pass in one direction. The turf was irrigated immediately after application with 0.6 centimeters of water and an additional 0.6 centimeters within a 6-hour period. In 2008 applications were made 14 July, 29 July, and 12 August and rates of treatments and irrigation were the same as for 2007.

Soil samples were collected for nematode assays prior to each application and 1 week after the final application. Six cores, 1.9 cm-diameter by 10.16 cm-deep, were collected randomly to form a composite sample from each plot. Nematodes were extracted from 100 cm^3 of soil using a modified funnel technique, (Rodríguez-Kábana and Pope, 1981).

Turf injury was visually evaluated for phytotoxic effects using a scale of 0 to 100% where 0 was no injury and 100 was plant death. An injury rating of 1-30% was considered slight and within the acceptable range for turfgrass, 31-69% moderate, and >70% severe injury. Turf injury was evaluated until symptoms were within the acceptable level (<30%). Injury symptoms were chlorosis (yellowing).

Root length densities (RLD) were determined by dividing total root length in centimeters by the volume of the soil sampler in cubic centimeters and were measured only in 2008. Soil samples were collected 1 month after final application. A soil profiler, measuring 9 cm^3, was used to collect four samples per plot. Roots were placed in polyethylene bags and cooled until returning to the laboratory. Roots were refrigerated at 4°C and prepared for analysis within a 1-week period. The roots were placed in a 2 mm wire mesh screen and tap water was run over roots to remove soil. Roots were separated from the thatch layer and washing continued until all soil and extraneous material passed through the sieve. The clean roots were placed in sample bottles containing tap water and stored at 4°C until scanned the following week. Before scanning, the roots were placed on a sieve and rinsed with tap water. The roots were then placed on a Comair® root scanner (Commonwealth Aircraft Corporation Limited, Melbourne, Australia) and suspended in water. The scanner was calibrated to known lengths and widths and has a built-in algorithm to calculate root length. All data were analyzed using general linear model procedures with analysis of variance ($P < 0.05$) using SAS version 9.2 (SAS Institute, Carry, NC).

Table 1. *Mesocriconema* spp. numbers on a bentgrass putting green as affected by sodium (NaN_3) and potassium (KN_3) azide on granular carriers and application number for 2007 and 2008. Nematode samples were collected before treatment and 2 weeks after each treatment.

	Application number[y]			
	Nematodes/100 cm^3 soil[z]			
Treatment	0	1	2	3
Control	2039 a	3413 a	2382 a	1211 a
NaN_3 Profile®	2706 a	523 b	125 b	33 b
NaN_3 Biodac®	2863 a	858 b	110 b	63 b
KN_3 Profile®	2014 a	447 b	78 b	53 b
KN_3 Biodac®	2767 a	395 b	150 b	22 b
LSD(0.05)	1227	1079	1168	241
P-value	0.5389	<.0001	0.0025	<.0001

[z]Means followed by the same letter in a column are not significantly different according to Fisher's Protected LSD (P<0.05). Means averaged across 2 years.
[y]Respective treatment formulations applied at 11.2, 5.6, and 11.2 kg ai/ha for application 1, 2, and 3. Pretreatment = 0.

Table 2. Percent turf injury on a bentgrass putting green as affected by multiple applications of sodium (NaN_3) and potassium (KN_3) azide on granular carriers for 2007 and 2008.

		% Injury[w]				
Treatment	Kg ai/ha[y]	1 WAT 1[x]	1 WAT 2	1 WAT 3	2 WAT 3	3 WAT 3
Control	0	0 b[z]	0 c	0 c	0 c	0 b
NaN_3 Profile®	11.2, 5.6, 11.2	9 a	9 a	39 a	25 a	10 a
NaN_3 Biodac®	11.2, 5.6, 11.2	10 a	8 ab	35 a	19 b	4 b
KN_3 Profile®	11.2, 5.6, 11.2	10 a	7 ab	29 b	16 b	1 b
KN_3 Biodac®	11.2, 5.6, 11.2	11 b	7 ab	29 b	15 b	0 b
LSD(0.05)		1.98	1.82	4.3	4.2	3.9
P-value		<.0001	<.0001	<.0001	<.0001	0.0001

[w] % injury scale; 0-30 = slight, 31-70 = moderate, 71-100 = severe.
[x]WAT = week after treatment number 1, 2 and 3.
[y]Rates applied at 1, 2, and 3 application, respectively.
[z]Means followed by the same letter in a column are not significantly different according to Fisher's Protected LSD (P< 0.05). Means averaged across 2 years.

RESULTS

Ring nematode numbers were not significantly different before the first application for both years. After each treatment, year was not significant; therefore, data was pooled for both years. Nematode counts indicated no differences between plots before the first application. However, after treatment there were higher nematode counts in non-treated controls than in treated plots. After one application for a total of 11.2 kg ai/ha of azide formulations, nematodes were numerically reduced compared to non-treated controls. After the second application (total of 16.8 kg ai/ha) and the third application (total of 28 kg ai/ha) for both formulations, ring nematodes were numerically below the threshold level and reduced compared to non-treated controls (Table 1). However, there were no differences among treatment formulations.

Turf injury data collected for sodium and potassium azide formulations were within the

Table 3. Root Length Density (RLD) on a bentgrass putting green as affected by sodium (NaN_3) and potassium (KN_3) azide and granular carriers, 2008.

Treatment	Rate kg ai/ha[x]	RLD cm roots/cm3 soil[y]
Control	0	467 c[z]
NaN_3 Profile®	11.2, 5.6, 11.2	576 bc
NaN_3 Biodac®	11.2, 5.6, 11.2	562 c
KN_3 Profile®	11.2, 5.6, 11.2	729 ab
KN_3 Biodac®	11.2, 5.6, 11.2	870 a
LSD(0.05)		158
P-value		<.0001

[x]Rates applied at 1, 2, and 3 application, respectively.
[y]Samples collected 9/19, 1 month after third application. Application dates 7/14, 7/29, and 8/19/2008.
[z]Means followed by the same letter in a column are not significantly different according to Fisher's Protected LSD ($P < 0.05$). Means averaged across 2 years.

acceptable range until 1 week after treatment (WAT) of the third application (Table 2). At this rating time, the sodium/Profile® formulation produced 39% injury and the sodium/Biodac® formulation produced 35% injury, which were both above the acceptable level of 30%. Injury ratings for the sodium formulations were higher than the potassium formulations which both resulted in 29% injury, slightly below the acceptable range. Injury ratings for both formulations were higher than the non-treated control. However, two WAT of the third application, injury ratings for sodium azide formulations moderated to within the acceptable range.

Root length densities were measured only in 2008. Results indicated that the RLD in the plots treated with potassium formulations were higher than the sodium azide treatments and the non-treated controls (Table 3). The plots receiving the potassium azide/Biodac® formulation produced the highest RLD.

DISCUSSION

Profile® and Biodac® proved to be excellent granular carriers for both sodium and potassium azide. Preparation of the granular formulations was relatively easy and the granules appeared to have excellent shelf life. Additionally, both granules quickly disappeared into the turf canopy after irrigation. However, mowing studies need to be conducted to determine if any of the granules will be collected in the clippings following application and irrigation. Release characteristics for each carrier also need to be investigated.

Creeping bentgrass turf injury, overall chlorosis, was generally unacceptable 1 week after the third application, of all formulations which totaled 28 kg ai/ha (11.2, 5.6, 11.2 kg ai/ha); however, the turf recovered and was generally acceptable after two weeks. Turf injury symptoms were an overall chlorosis (yellowing). There was also a trend for sodium azide formulations to be more injurious than both potassium azide formulations. This was confirmed with the RLD data for 2008 which showed generally higher root length density for the potassium azide formulation. Additional experimentation needs to be conducted to determine if a system using only a 5.6 kg ai/ha rate would provide acceptable nematode reduction.

Disclaimer

The use of trade, firm, or corporation names in this publication is solely for the purpose of providing specific information and does not imply endorsement or recommendation by the authors or Auburn University.

LITERATURE CITED

Beard, J. B. 1982. Turf management for golf courses. Pp 102-118. MacMillian Publishing Co. New York, NY.

Bigelow, C. A., D. C. Bowman, and D. K. Cassel. 2004. Physical properties of three sand size classes amended with inorganic materials or sphagnum peat moss for putting green rootzones. Crop Science 44:900-907.

Bigelow C. A., D. C. Bowman, K. K. Cassel and T. W. Rufty. 2001. Creeping bentgrass response to inorganic soil amendments and mechanically induced subsurface drainage and aeration. Crop Science 41:797-805.

Crow, W. T. 2007. Nematode management for golf courses in Florida. University of Florida Cooperative Extension Service Fact Sheet ENY-008 (IN124). University of Florida, Gainesville, Florida.

Ilyina, A. D., S. J. Villarreal, R. E. Rivera, G. Y. Garza, and M. J. Rodriguez. 2000. Using of biodac (absorbent granules produced from paper industry residues) as carrier to microorganisms for soil inoculation. Biocatalysis 41(6):135-138.

Joo, Y. K., N. E. Christian, D. Li, and D. D. Minner. 1998. Effects of soil amendments on the chemical and physical soil parameters of a sand-based golf green. Iowa Turfgrass Research Report.

Miller, G.L. 2000. Physiological response of bermudagrass grown in soil amendments during drought stress. HortScience 35(3):213-216.

Profile Products. 2002. The best way to amend your sand. www.profileproducts.com.

Sikora, E. J., E. A. Guertal, and K. L Bowen. 1999. Golf course nematodes–the hidden enemy. Highlights of Agricultural Research 46(3)10-11.

Rodríguez-Kábana, R., 2005. Azide method and composition for controlling deleterious organisms. Patent No: U.S. 6,878,389 B2.

Rodríguez-Kábana, R., and M. H. Pope. 1981. A simple incubation method for the extraction of nematodes from soil. Nematropica 11(2):175-185.

Wehtje, G. R., J. N. Shaw, R. H. Walker and W. Williams. 2003. Bermudagrass growth in soil supplemented with inorganic soil amendments. HortScience 38(4): 613-6.

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