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Seed Biology and Ecology of Natalgrass (*Melinis repens*)

Courtney A. Stokes, Gregory E. MacDonald, Carrie Reinhardt Adams, Kenneth A. Langeland, and Deborah L. Miller*

Natalgrass is an invasive species that has become increasingly problematic in natural areas in Florida and other subtropical and tropical regions around the world. Natalgrass is a prolific seed producer, but little information is available regarding its seed biology and ecology. Research was conducted to determine levels of seed dormancy and to examine the effects of light, temperature, pH, water stress, and depth of burial on natalgrass seed germination. In addition, seed persistence under field conditions was examined both on the soil surface and while buried. Seeds appeared to undergo afterripening. Seed germination was not light dependent and occurred from 15 to 35 C, with optimum germination occurring at 20 to 35 C. Germination occurred at pH levels of 6 and 8 and was affected by water stress; no germination was observed at osmotic potentials less than -0.2 MPa. Seeds emerged from depths of at least 5 cm. Under field conditions, germination was reduced after burial; however, burial lengths of 3 to 15 mo did not result in differences in germination levels. Seedling numbers from seed deposits on the soil surface were greatly reduced after 1 mo, and no seedling emergence was observed after 4 mo.

Nomenclature: Glyphosate; natalgrass, *Melinis repens* (Willd.) Zizka RHYRE, formerly *Rhynchelytrum repens* (Willd.) C.E. Hubb.).

Key words: Seed germination, light, pH, depth of burial, temperature, water stress, dormancy, seed longevity.

Natalgrass is a grass native to Africa that has become a problematic weed in many tropical and subtropical regions around the world, including Florida, Mexico, the Caribbean, Central America, Brazil, and many Pacific islands (Häfliger and Scholz 1980; Haselwood and Motter 1966; Kleinschmidt and Johnson 1977). In Florida, natalgrass exists in many areas but is particularly widespread along the central Florida ridge in citrus groves and reclaimed phosphate mining areas (Kluson et al. 2000). The Florida Exotic Pest Plant Council (FLEPPC) classifies natalgrass a category I invasive in Florida, indicating that this species is considered to have caused significant ecological harm (FLEPPC 2009). For example, research shows that natalgrass invades undisturbed ecosystems, such as pine rocklands in Florida (Possley and Maschinski 2006).

Natalgrass is sometimes grown as an ornamental and was reportedly grown for this purpose in the United States as early as 1866 (Tracy 1916). Tracy (1916) also states that natalgrass was grown as a forage plant in the U.S. Department of Agriculture (USDA) trial gardens in 1878. Between 1891 and 1894, the USDA received natalgrass seeds from Natal, South Africa; Queensland, Australia; India; and Hawaii. In 1892, natalgrass was the first forage grass cultivar released by the Florida Agricultural Experiment Station (Mislevy and Quesenberry 1999). More than 12,141 ha of cultivated natalgrass were reported in central Florida in 1915. Natalgrass was often grown between rows of citrus trees (Tracy 1916), which may explain the species' current prevalence in citrus groves.

Natalgrass is an annual species that sometimes perennates in warmer climates (Häfliger and Scholz 1980; Haselwood and Motter 1966; Kleinschmidt and Johnson 1977). Although its native range in south and east Africa has a warm climate, these regions experience seasonal dry conditions and heavy grazing pressure from animals, which migrate at certain

times of the year, causing plant dieback (Klages 1942). In Florida, natalgrass will sometimes perennate in those areas of the state that do not experience freezing temperatures (MacDonald et al. 2008).

Natalgrass forms tussocks that grow up to 1 m in height. Although this species does not produce rhizomes, it can root at the nodes and sometimes develops a sprawling appearance (Haselwood and Motter 1966). Natalgrass inflorescences are panicles up to 20 cm long; initially rosy pink, the inflorescences fade to silver with age. Natalgrass produces pedicelled spikelets that are covered with dense, silky hairs, giving the plant a feathery or fluffy appearance (Häfliger 1980).

Natalgrass is a prolific producer of windborne seeds. Tracy (1916) suggests that 45.4 kg (100 lb) of seeds per 0.4 ha (1 acre) could be expected from the initial growth of a natalgrass crop. In areas where severe natalgrass infestations occur, dense layers of seeds up to 5 cm thick have been observed on the soil surface (C. A. Stokes, unpublished data). Natalgrass seeds appear to be key to the rapid spread of this species, and extensive seed deposits are likely a reason for the persistence of natalgrass in a given area. Little research, however, has been conducted on the biology of natalgrass, and no published research is available, to our knowledge, which addresses seed biology; likewise, no information is available with reference to the persistence of these seeds in the environment. If effective management plans for this species are to be developed, there is a need for better comprehension of both the environmental factors that affect natalgrass seed germination and the persistence of natalgrass seeds when buried or as part of the commonly observed surface seed deposits.

The objectives of this research were to establish levels of seed dormancy and to examine the effects of light, temperature, pH, water stress, and depth of burial on natalgrass seed germination. In addition, seed persistence under field conditions was examined both on the soil surface and when buried.

Materials and Methods

Seed Source. Natalgrass seeds were collected in November 2007 in Polk County, FL, from soil-surface deposits (duff

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layer) and from the seedheads of mature plants. Duff layer seeds were likely deposited over the previous summer and fall seasons. Additional seeds were collected from the Lake Louisa Mitigation Bank (Lake County, FL), in November 2008 from both the duff layer and the seedheads of mature plants, and again in December 2009, from only the duff layer. Both groups of seeds collected in 2008 were used for preliminary germination tests, whereas seeds from the duff layer were used for the first run of all further experiments. Duff layer seeds collected in 2009 were used when each experiment was repeated. Unless otherwise stated, seeds were stored in a paper bag at 20 C.

General Germination Test Protocol. Unless otherwise stated, natalgrass seed germination was tested with 30 seeds with intact husks, placed evenly in a 9 cm petri dish,¹ which contained 1 piece of filter paper.² The filter paper was moistened with 4 ml of deionized water (pH = 6) or test solution. Each petri dish was sealed with parafilm and placed in a growth chamber at 30 ± 1 C under constant light ($200 \mu\text{mol m}^{-2} \text{s}^{-1}$ photosynthetic photon flux density [PPFD]). Germination was visually determined after 14 d. Seeds were considered germinated when the radicle emerged from the seed coat. Any ungerminated seeds were tested for viability according to procedures described in the *Handbook on Tetrazolium Testing* (Moore 1985). In this procedure, seeds were removed from the husk and seed coat and placed in a 0.25% tetrazolium solution for 24 h in the dark. Seeds were examined under a dissecting microscope and were counted as viable if the entire embryo was stained red or pink. The number of germinated seeds was divided by the total number of viable seeds, then multiplied by 100 to calculate percentage of germination. Each petri dish was considered a replication; treatments were replicated four times, and experiments were conducted twice.

Preliminary Germination Test. Preliminary germination tests (data not shown) indicated that seeds collected from the duff layer had a much higher germination rate than seeds collected directly from seedheads, which suggests that natalgrass seeds require an afterripening period after the seeds are shed. To test this hypothesis, seeds were collected with a sweep net from mature seedheads at the Lake Louisa Mitigation Bank. A sample of these seeds was tested for germination immediately, and the seeds that remained were divided into 2 groups. One group was stored in a paper bag at 4 C and the other group in a paper bag at 25 C. Seeds from each group were tested for germination at intervals of 2, 4, 6, 8, 10, and 15 wk after collection. For dormancy tests, percentage of germination was calculated as the quotient of the number of germinated seeds divided by the total number of seeds tested at each interval. All environmental conditions were the same as described in the general germination protocol.

Light. To determine the effect of light on natalgrass seed germination, dry seeds were placed in petri dishes, which contained 4 ml water, in a dark room with only green light present to ensure that all hydration occurred in the absence of light. Dishes were immediately wrapped in two layers of aluminum foil to prevent light penetration. Seed germination was then compared with control seeds exposed to continuous

light. All other environmental conditions were the same as described in the general germination protocol.

Temperature. To determine the effects of temperature on natalgrass seed germination, seeds were placed in petri dishes. Dishes were incubated at constant temperatures of 10, 20, 25, 30, and 35 C. All other environmental conditions were the same as described in the general germination protocol.

pH. To evaluate the effects of various pH levels on natalgrass seed germination, seeds were placed in petri dishes, which contained 4 ml of buffer solutions, at pH values of 4, 6, 8, and 10. Seeds used as the control were placed in dishes with 4 ml deionized water. Buffer solutions were prepared at 25 μM and included potassium hydrogen phthalate, 2-(4-morpholino) ethanesulfonic acid (MES), *N*-2(2-hydroxyethyl)-piperazine-*N'*-2-ethanesulfonic acid (HEPES), and Tris(hydroxymethyl)-aminomethane (Tris) for pH levels of 4, 6, 8, and 10, respectively. Buffer solutions were titrated with HCl or NaOH to achieve the desired pH. All other environmental conditions were the same as described in the general germination protocol.

Water Stress. To determine the effects of water stress on natalgrass seed germination, seeds were placed in petri dishes with aqueous solutions of polyethylene glycol (PEG 600) with osmotic potentials of -0.2 , -0.4 , -0.6 , -0.8 , and -1.0 MPa. Control seeds were placed in dishes with deionized water. A vapor-pressure osmometer,³ calibrated with aqueous solutions of sodium chloride was used to confirm water potential. All other environmental conditions were the same as described in the general germination protocol.

Depth of Burial. To determine the effects of burial depth on natalgrass seedling emergence, seeds were planted in a wooden box filled with field soil (Apopka sand: loamy, siliceous, subactive, hyperthermic Grossarenic Paleudults) collected from the Lake Louisa Mitigation Bank (Clermont, FL). Ten seeds were planted at each depth of 0, 0.25, 0.5, 1.0, 1.5, 2.0, 2.5, 3.0, 4.0, and 5.0 cm. Seeds were placed in the greenhouse under natural light supplemented with 16 h of 600 to $1,000 \mu\text{mol m}^{-2} \text{s}^{-1}$ PPFD. The greenhouse was maintained at 35/28 C day/night temperatures, and plants received irrigation as needed to maintain adequate soil moisture. Seedlings were counted 21 d after planting, and the percentage of emergence was calculated.

Seed Burial. Duff-layer material that included large numbers of seeds was collected from a single field site within the Lake Louisa Mitigation Bank (Lake County, FL) in November 2008. Field soil (Apopka sand: loamy, siliceous, subactive, hyperthermic Grossarenic Paleudults) was collected from the same site after the surface seed layer was completely removed. To determine if natalgrass seeds were present in the collected soil, trays of soil were placed in the greenhouse, and seedling emergence was monitored. The seed bank was determined to be negligible because of the complete lack of natalgrass seedlings and the low levels of seedling emergence for all other species (data not shown).

Material collected from the duff layer comprised seeds (approximately 50% of the total volume), soil (approximately 10% of the total volume), and other debris, such as small

twigs and stems (about 40% of the total volume). It proved to be difficult to separate the seeds from the other duff layer contents because of the fluffy hairs present on the husk, which clung to the other materials present. As a result, seeds for each replication of this study were not counted. Instead, duff layer material was mixed evenly and then divided by weight, such that each sample (1.2 g) contained approximately 60 seeds.

Polyvinyl chloride (PVC) pipe with a diameter of 10.16 cm (4 in) was cut into 30-cm-long segments and used to create seed burial tubes. Each tube was cut in half lengthwise, and five 0.5 cm holes were drilled in each half, evenly spaced and running in a line lengthwise down the center of each half. Nylon mesh fabric was folded in half to form a packet and filled with a mixture of 10 g field soil and 1.2 g of the duff layer material. The halves of the PVC pipe were filled with field soil and reassembled with the mesh packet centered between the halves. The halves were secured together with duct tape⁴ and window screen⁵ was placed over each end to prevent the loss of field soil from the tube. The end product was a 10.16-cm-diam tube filled with field soil, with a mesh fabric packet of both field soil and seeds suspended within the field soil in the center of the tube and stretched the 30-cm length of the tube. The holes drilled in the sides and the screen placed over the ends allowed the maximum moisture and gas exchange possible between the soil inside the tube and the outside environment. The contents (seeds and soil) of the tubes were kept dry at all times to prevent water imbibition and possible germination before the tubes were placed in the field.

One hundred tubes were buried in 10 groups of 10 tubes each, randomly distributed within a 37.6-ha study area, at the Lake Louisa Mitigation Bank (Lake County, FL), in June 2009. The tubes were buried on end, with the top end level with the ground surface. Each location was marked with a flag, and the global positioning system coordinates were recorded.

One tube from each group of 10 was exhumed at intervals of 0, 3, 6, 9, 12, and 15 mo after burial. The tubes were split in half lengthwise, and the mesh packets were opened so that the contents were not disturbed. Each tube was then placed in the greenhouse and irrigated as needed to maintain adequate soil moisture. After 2 wks, the number of natalgrass seedlings present was noted, as well as the number of seedlings in each segment of the tube divided into depths of 0 to 5, 5 to 10, 10 to 15, 15 to 20, 20 to 25, and 25 to 30 cm.

Seed Exclusion. Ten areas within the study site at the Lake Louisa Mitigation Bank were chosen as plots based on these criteria: the presence of a duff layer natalgrass seed deposit, and an area of at least 1 m² containing no vegetation. In April 2009, each plot was outlined with a square wooden frame (1 m by 1 m) secured to the ground. Each frame was covered with screen⁵ to exclude the entrance of any additional seeds into the plot, and hardware cloth⁶ was used to prevent damage from birds or other animals. Half of the plots remained undisturbed for the duration of the experiment, whereas half were tilled to a depth of 3 cm at 6 mo after frame installation. The number of natalgrass seedlings growing in each plot was counted 1, 2, 3, 4, 5, 6, 8, 10, and 12 mo after the frames were installed. After each seedling count, a 1% solution of glyphosate⁷ was applied as needed to remove all plants emerged in the plot.

Statistical Procedures. Unless otherwise stated, seed experiments were conducted twice with a completely randomized

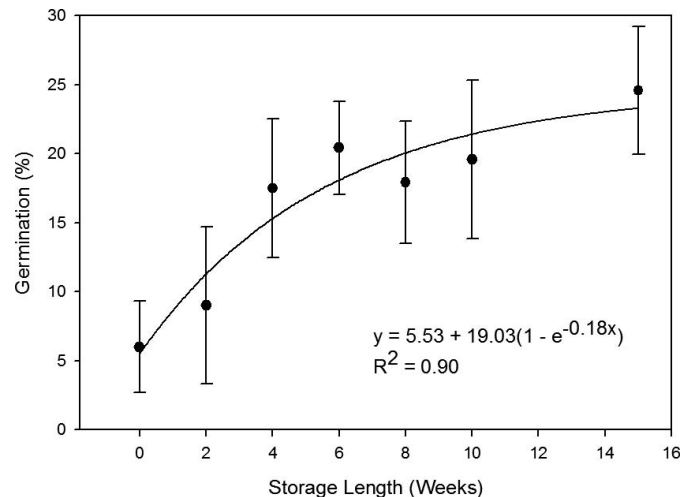


Figure 1. Effects of storage length on natalgrass germination. Values represent the mean of eight replications with standard error.

design with four replications of each treatment. Data were subjected to ANOVA. There was no significant ($P > 0.05$) trial-by-treatment interaction for each experiment; data were, therefore, pooled for analysis. Means were separated with 95% confidence intervals. Germination is reported as the percentage of germination \pm 95% confidence interval. Regression analysis was used to explain the response of natalgrass seed emergence to various temperatures and depths of burial. The field seed-burial study and the seed-exclusion study were conducted with a completely randomized design, and 10 replications were located across a 37.6-ha infested site. Data were subjected to ANOVA, and means were separated with 95% confidence intervals.

Results and Discussion

Preliminary Germination Test. Seed collected from the duff layer had an initial germination rate of $49 \pm 4\%$, whereas seed collected directly from seedheads had a germination rate of $6 \pm 5\%$. There was no difference ($P > 0.05$) between the germination rates of seed stored at 4 C and the seed stored at 25 C, so data were pooled for analysis. Percentage of germination increased over time to $25 \pm 5\%$ after 15 wks of storage (Figure 1). These results indicate that natalgrass may require a period after seed shed to ripen to maximum potential for germination. *Afterripening* is defined as the loss of a dormant state, over time, through exposure of seeds after maturation and separation from the parent plant to a set of environmental conditions (Simpson 1990). Afterripening has been observed in a number of grass species and is well documented in wild oat (*Avena fatua* L.) and African red rice (*Oryza punctata* Kotschy ex Steud.) (Foley 1994; Leopold et al. 1988; Quail and Carter 1969). Afterripening can be influenced by environmental conditions, such as moisture status and temperature; the conditions that best facilitate afterripening vary with species (Foley 2001). Although the results from this experiment suggest that afterripening does occur in natalgrass, further research is required to better characterize the afterripening mechanism. This could provide useful information to land managers who attempt to control natalgrass infestations. Because dense seed deposits can form on the ground surface in areas where infestations occur,

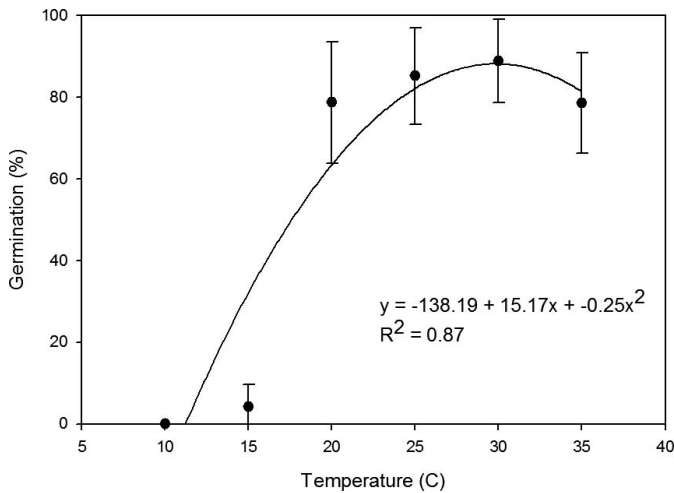


Figure 2. Effects of temperature on natalgrass germination. Values represent the mean of eight replications with standard error.

management should not end when all emerged plants have been eliminated. A better comprehension of natalgrass afterripening could result in a prediction of how long germination should be expected from duff-layer deposits following seed rain.

Light. No difference ($P > 0.05$) was observed between the rate of natalgrass seed germination in the light and in the dark. The rate of germination was $90 \pm 6\%$ in light and $74 \pm 17\%$ in dark. These results suggest that light is not required for natalgrass seed germination. Based on these results, experiments to determine the effects of varying light quality (phytochrome-based studies) were not performed.

Temperature. Natalgrass seed germination did not occur at a constant temperature of 10 C, and only $4 \pm 5\%$ germination occurred at 15 C (Figure 2). Seed germination was greater than 78% at temperatures from 20 to 35 C. The highest level of germination observed was $89 \pm 10\%$ at 30 C, although there was no significant difference among germination rates at 20 to 35 C. This outcome was not surprising because many tropical species have optimum germination rates above 20 C (Teuton et al. 2004; Wilder 2009). These results could explain why natalgrass has not become invasive in U.S. states other than Florida and Hawaii and why natalgrass has not spread to areas outside the southern United States.

pH. Natalgrass seed did not germinate at pH 4 or 10. The rate of natalgrass seed germination at pH 6 was $96 \pm 6\%$, and at pH 8, it was $91 \pm 5\%$. Germination rates at pH 6 and 8 were not significantly different ($P > 0.05$). These results indicate that natalgrass seeds do not successfully germinate at acidic or basic pH levels. Natalgrass is most often a problem in disturbed areas, such as reclaimed phosphate mine areas and newly cultivated soils; however, populations appear to decline over time. This decline could possibly be a result of increased soil acidity as soil pH reverts back to natural pH levels closer to 5 (Adjei and Rechcigl 2004).

Water Stress. Natalgrass seed germination was greatly affected by water stress. Germination was $85 \pm 15\%$ in deionized water, whereas seeds placed in the -0.2 MPa test

solution had a germination rate of 98%. At osmotic potentials less than -0.2 MPa, no germination was observed. These results indicate that natalgrass seed germination is dependent on adequate soil moisture. Bradford (1990) described seed germination as the process of initiated growth of a previously quiescent or dormant embryo, which usually begins with the imbibition of water. The rates of water imbibition and seed germination are generally very sensitive to changes in soil water potential. Evans and Etherington (1990) found that some species that are adapted to dry or well-drained habitats, germinate well even in soil with osmotic potentials as low as -1.5 MPa. Other research has shown that some species that are adapted to dry conditions, such as yankeeweed (*Eupatorium compositifolium* Walt.), germinate at low osmotic potentials (MacDonald et al. 1992). However, Evans and Etherington (1990) found that a number of species that are typically located in dry or well-drained areas did not germinate in dry soils. They suggested that this may be a response that confers an ecological advantage to species in dry conditions. If seeds from these species germinate in soils with very low water potentials, seedling establishment failures may occur if dry conditions continue. Instead, if the seeds do not germinate until higher levels of moisture are present in the soil, there is a greater chance that the seedlings will survive. This response may allow natalgrass to successfully germinate and reach maturity in the dry, sandy areas in which it is typically found. Because natalgrass germination is so dependent on available soil moisture, it may also be possible to predict, based on current rainfall patterns in an area, when and where large numbers of seeds will germinate in the field.

Depth of Burial. There was no significant difference among treatments; emergence was fairly uniform across all the depths tested. These results indicate that natalgrass can emerge from depths of up to 5 cm. Additional research is required to determine the depth at which natalgrass emergence is impeded.

Seed Burial. There was no significant difference ($P > 0.05$) in the number of seedlings counted within the areas corresponding to different burial depths; therefore, only the total number of seedlings per burial tube is discussed. The control group (tubes buried for 0 mo) had a mean of 50 ± 8 seedlings per tube (Figure 3). There was no significant difference ($P > 0.05$) among the mean number of seedlings from tubes buried for 3, 6, 9, 12, and 15 mo; however, these values were significantly lower than the mean at 0 mo, and there was an indication of a decline in natalgrass germination after burial. The lowest mean number of seedlings observed was 13 ± 5 after 9 mo of burial. However, after the initial decline, germination levels remained relatively consistent, which indicates possible dormancy.

There are a number of causes for increased dormancy during burial and decreased seed germination after burial. Several studies have demonstrated that seeds can become light-sensitive after burial, even when germination of the same seeds was not previously light-dependent (Taylorson 1970; Wesson and Wareing 1969). In addition, several studies have suggested the increase in dormancy and decrease in overall germination observed after burial could be caused by toxic metabolites produced by anaerobic respiration that occurs in hypoxic conditions (Benvenuti and Macchia 1995; Holm

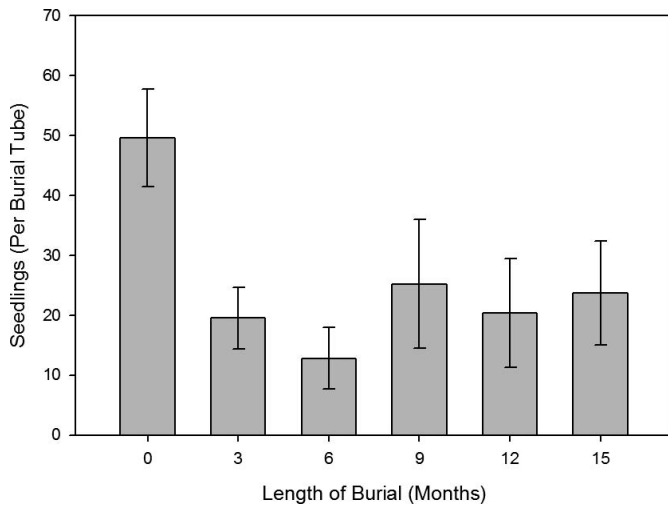


Figure 3. Effects of burial on natalgrass seedling emergence. Values reflect the mean of 10 replications with 95% confidence intervals.

1972). Finally, decreased seed germination can occur because of seed mortality. This mortality can be a result of predation, failed germination, increase in seed age, or attack from pathogens (Baskin and Baskin 1998). Seed burial studies are often criticized because the conditions created may coincide with accelerated seed mortality. Van Mourik et al. (2005) found that when high densities of seeds are buried in mesh bags during seed burial studies, attack from pathogenic fungi often causes an overestimation of the rate of soil seed bank depletion. However, when lower densities of seeds were mixed with soil inside the mesh bags, mortality was significantly lower. Based on the conclusions of Van Mourik et al. (2005), the decision was made to mix field soil with natalgrass seed samples before burial in this study to more closely mimic natural conditions. Because the study methods were designed in such a way as to limit artificial acceleration of seed mortality, decreased germination over the course of the study can more positively be attributed to an increase in dormancy.

These data suggest increased dormancy after burial is consistent with the observations of Tracy (1916), who instructed growers to plow under natalgrass fields in the winter and then cultivate again in the spring to induce new growth. Land managers should be mindful of this potential for new growth if they use tillage in natural areas to control natalgrass or other species when natalgrass is present.

Natalgrass plants are easily controlled by cultivation (Tracy 1916), but the effects of seed burial as a result of cultivation or other disturbance were, to our knowledge, unknown before this study. The results from this research suggest that, if a subsequent cultivation or other disturbance brings natalgrass seeds back to the soil surface, they have the potential to germinate at least 1 yr after initial burial. Land managers that cultivate as a control method for natalgrass should expect germination to recur if they repeat tillage operations within this period.

Seed Exclusion. The mean number of natalgrass seedlings per square meter was 521 ± 354 after 1 mo of seed exclusion from the plots (Figure 4). This number decreased to 6 ± 7 seedlings after 2 mo and to 0 seedlings after 4 mo of seed exclusion. No further germination was observed in any of the plots, even after disturbance. These results suggest that seeds

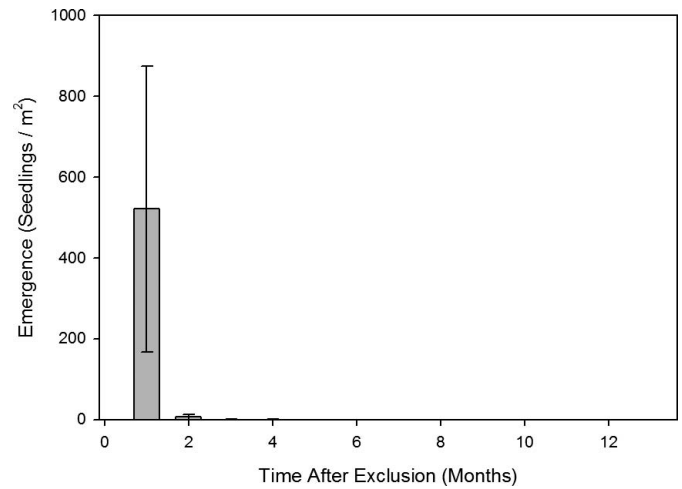


Figure 4. Effects of length of seed exclusion on the number of natalgrass seedlings per square meter. Values reflect the mean of 10 replications with 95% confidence intervals.

deposited in the duff layer over the summer and fall months have largely concluded afterripening by April, when the study began. *Afterripening* is the loss of a dormant state, over time, through exposure of seeds after maturation and separation from the parent plant to a set of environmental conditions (Simpson 1990).

With rainfall and warm temperatures in the month of April, most of the seeds present in the seed bank during this study germinated at once. These results are consistent with results from the seed biology studies that show that most natalgrass germination occurs at temperatures higher than 15 C and in conditions with adequate moisture available. These conditions existed at the study site in April 2009 (FAWN 2010). These results suggest that if land managers can prevent further seed deposition in the spring, active management of emerged seedlings for several months should result in a significant reduction of new natalgrass growth.

Collectively, these studies provide a more comprehensive understanding of natalgrass germination and seed longevity under field conditions. Natalgrass can germinate under both light and dark conditions and germinate from depths of at least 5 cm. Temperatures of 20 C or greater are needed for optimum germination, and germination requires neutral to slightly basic conditions and good moisture availability. Natalgrass appears to require an afterripening period following seed shed to reach maximum germination potential. Although natalgrass can form dense seed deposits in infested areas, the seed bank appears to quickly become depleted when conditions are favorable for germination and further seed rain is prevented. This information provides land managers with a more comprehensive knowledge of seed germination characteristics that can enhance management strategies for this increasingly problematic species.

Sources of Materials

¹ Fisherbrand petri dishes, Fisher Scientific, 2000 Park Lane Drive, Pittsburgh, PA 15275.

² Fisherbrand P8 filter paper, Fisher Scientific, 2000 Park Lane Drive, Pittsburgh, PA 15275.

³ Wescor vapor pressure osmometer, Model 5500, Wescor, Inc., 459 S. Main Street, Logan, UT 84321.

⁴ All-Purpose duct tape, Shurtape Technologies, LLC, 1506 Highland Ave NE, Hickory, NC 28601.

⁵ Fiberglass screen wire, PHIFER Inc., P.O. Box 1700, Tuscaloosa, AL 35403.

⁶ 3 Mesh galvanized hardware cloth, TWP Inc., 2831 Tenth Street, Berkeley, CA 94710.

⁷ Roundup WeatherMax herbicide, Monsanto Company, 800 N. Lindbergh Blvd, St. Louis, MO 63167.

Acknowledgments

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