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EFFECTS OF VARIOUS TREATMENTS ON THE GERMINATION OF SAWGRASS, *CLADIUM JAMAICENSE* CRANTZ, SEEDS

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Abstract: The objective of this research was to test the effectiveness of several treatments at raising germination percentages of sawgrass (*Cladium jamaicense*) seeds. Sawgrass seed lots from two years (1991 and 1995) were tested in two separate germination experiments that were run from 1994 to 1995 and 1995 to 1996. Treatments aimed at breaking dormancy were abrasion with sand paper, steeping in hot water, dry heating, soaking in nitric acid or sodium hypochlorite, cold, moist stratification (for a duration of 3 days or 1 month), and supplements of exogenous chemicals (gibberellic acid or potassium nitrate). A combination treatment of wet heat followed by soaking in gibberellic acid was tested. In the 1994–1995 experiment, no treatment was effective at increasing germination over that of untreated seeds ($P>0.05$). Treatments with dry heat, abrasion, the combination treatment, and the water control significantly reduced germination. In contrast, in the 1995–1996 experiment, treatment with sodium hypochlorite (bleach) significantly increased sawgrass germination in comparison with untreated seeds. Cold, moist stratification for one month significantly increased germination over that found in the water control. The highest germination of nearly 80% was achieved in seeds that were treated with bleach. The results of this experiment suggest that the disinfectant properties of bleach may be one mechanism through which sawgrass germination is enhanced.

Key Words: sawgrass, *Cladium jamaicense*, sodium hypochlorite, scarification, stratification, disinfectant, fungus

INTRODUCTION

Sawgrass (*Cladium jamaicense* Crantz) is a member of the sedge family (Cyperaceae) and the dominant species of the Florida Everglades and similar marshes that occur in the St. Johns River Basin (Loveless 1959, St. Johns River Water Management District 1980). Although several aspects of sawgrass have been studied, including floristics, structure and development, nutrient dynamics and production, and the effects of hydrology and fire, little information is available on sawgrass germination or seedling development (Yates 1974).

Only three studies to date present data concerning *Cladium jamaicense* germination. Alexander (1971) found that the best sawgrass seed batches, collected from the Everglades in 1967, 1969, and 1970, achieved a maximum germination of 20%. As part of a larger seed bank study, Sleszynski (1991) collected *Cladium jamaicense* seeds from prairies bordering Big Cypress National Preserve in southwest Florida and documented poor germination at 0.4%. Using seeds collected from upper St. Johns River basin marshes, Ponzio et al. (1995) tested the germination of sawgrass seeds under varying hydrologic conditions and found 34% germination. All three studies indicated low to moderate germination percentages of *Cladium jamaicense* that ranged from 0.4% to 34.3%.

More in-depth studies have been conducted on *Cladium mariscus* (L.) Pohl, a species considered as the European equivalent of *Cladium jamaicense*. Goossens and Devillez (1973), Goossens and Devillez (1974), and Devillez and DeSloover (1981) conducted carefully designed experiments on the germination of *Cladium mariscus* under varying temperature regimes. Goossens and Devillez (1973) found that with no treatment, *Cladium mariscus* seeds exposed to alternating temperatures of 20 to 30 °C would only germinate to approximately 9%. Lutz (1938) and Conway (1942) also failed in their attempts to germinate *Cladium mariscus* seeds in the laboratory. Goossens and Devillez (1974) ran a reference test on freshly harvested seeds and found that 100% of the seeds were dormant.

Attempts to germinate untreated seeds of both *Cladium jamaicense* and *Cladium mariscus* have proven to be at best, only moderately successful, with germination as low as 0% and as high as 34%. In this study, several treatments to improve sawgrass germination

were tested. The goal of this experiment was to develop a treatment that would maximize germination of seeds for potential use in restoration. Treated sawgrass seeds could be used for precultivating seedlings for eventual transplantation or for direct seeding of restoration sites.

METHODS

Seed Collection and Storage

Sawgrass seeds were collected from the Blue Cypress Water Management Area—West (Latitude 273915, Longitude 803933) in Indian River County, Florida in August 1991 and 1995. The 1991 collection (referred to as the S1V seed lot) was accomplished by traversing a 1,751 ha marsh several times via airboat. Seeds that fell into the boat were scooped out and placed into a brown paper bag. The 1995 seed lot (referred to as the S4V seed lot) was collected by cutting off inflorescences and shaking or lightly brushing loose seeds into a cardboard box. Both seed lots were stored in brown paper bags at temperatures typically between 21 and 27°C, with relative humidity never exceeding 65%.

Treatments

Sawgrass seeds were subjected to several treatments designed to affect germination in a number of ways. Treatments were applied to the seeds prior to germination tests and included both mechanical and chemical scarification techniques, as well as stratification and the application of exogenous chemicals.

Sand Paper Abrasion Treatment. Each replicate of 100 dry seeds was placed in a No. 35 wire mesh sieve (mesh size 500 μm). Sand paper (150 grit) was run over the seeds with medium pressure for approximately one minute. All seeds and any associated chaff were transferred to a container with deionized water and allowed to imbibe water at room temperature (~25 °C) for 24 hours. Initial mixing was required because seeds floated on top of the chaff.

Dry Heat Treatment. Each replicate of 100 dry seeds was first placed in a drying oven at 80 °C for 24 hours. Following drying, seeds were placed in containers with deionized water to allow imbibition for an additional 24 hours at room temperature (~25 °C).

Wet Heat Treatment. Each replicate of 100 dry seeds was steeped in deionized water at 80 °C for 3 minutes. Following this procedure, all seeds were transferred to a plastic container with deionized water and allowed to imbibe water at room temperature (~25 °C) for 24 hours.

Nitric Acid Treatment. Each replicate of 100 dry seeds was steeped in 100 ml of 0.1 N nitric acid (HNO_3) solution at room temperature (~25 °C) for 12 hours. pH in the acid solution ranged between 0 and 1. Seeds were then transferred to deionized water for a 24-hour imbibition period. Resulting pH upon transfer was between 6 and 7.

Sodium Hypochlorite Treatment. Each replicate of 100 dry seeds was placed in a commercially prepared 2–3% sodium hypochlorite (bleach) solution. Seeds in solution were placed in a dark refrigerator (4–10 °C) for 72 hours. Following soaking in bleach, seeds were rinsed with tap water.

Gibberellic Acid Treatment. Each replicate of 100 dry seeds was placed in a plastic cup with deionized water for 24 hours to allow imbibition. Seeds were then soaked in a 1.5×10^{-3} M solution of gibberellic acid (GA_3) for 24 hours at room temperature (~25 °C). For both years experiments, pH in these solutions measured between 3 and 4. At the end of the 24-hour treatment period, seeds were rinsed with deionized water.

Gibberellic Acid/Wet Heat Treatment. Each replicate of 100 dry seeds was first steeped in dionized water at 80 °C for 3 minutes. Seeds were then subjected to the same procedures as with the gibberellic acid treatment.

Potassium Nitrate Treatment. Each replicate of 100 dry seeds was initially allowed to imbibe deionized water for 24 hours at room temperature (~25 °C). Seeds were then soaked in a 2.0×10^{-2} M solution of potassium nitrate (KNO_3) for 24 hours at room temperature. For both years treatment experiments, pH in these solutions was 7. At the end of the 24-hour treatment period, seeds were rinsed with deionized water.

Freezing/3-day Stratification Treatment. Each replicate of 100 dry seeds was placed in plastic bags in a freezer at ~0 °C for 25 days. After removal from the freezer, seeds were placed in tap water and held in a dark refrigerator at 4 to 10 °C for 3 days.

One-month Cold Stratification Treatment. Each replicate of 100 dry seeds was placed in tap water and stored in a dark refrigerator at 4 to 10 °C for one month.

No Treatment. Each replicate of 100 dry seeds was placed on a dry plastic weighing plate and subjected to laboratory conditions (room temperature ~ 25 °C) for 24 hours.

Water Control. Each replicate of 100 dry seeds was placed in dionized water for an imbibition period of 24 hours at room temperature (~25 °C).

Germination Experiments

Two germination experiments were conducted from September 1994 to May 1995 and September 1995 to June 1996. The first germination experiment was conducted at the St. Johns River Water Management District headquarters in Palatka, Florida using seeds collected in 1991 (S1V) with six replicates each of seven treatments and two controls: sand paper, nitric acid, dry heat, gibberellic acid, gibberellic acid with wet heat, potassium nitrate, wet heat, water control, and no treatment. Four treatments (sand paper, dry heat, gibberellic acid with wet heat, and wet heat) were excluded from the second germination test because these treatments resulted in low numbers of sawgrass seed germination in the 1994–1995 test. The gibberellic acid treatment also yielded poor germination percentages but was retained because it was expected that the hormone would work more effectively on younger seeds (Bewley and Black 1982). The discarded treatments were replaced by sodium hypochlorite, freezing/3-day stratification, and one-month cold stratification treatments. The second test was conducted in Keystone Heights, Florida (39 km NW of Palatka) with sawgrass seeds collected in 1995 (S4V) with four replicates each of six treatments and two controls: nitric acid, sodium hypochlorite, gibberellic acid, potassium nitrate, freezing/3-day stratification, one-month cold stratification, water control, and no treatment. The germination media used was a universal-type potting soil that was sterilized by heating in a drying oven for 1 to 2 hours at 200 °C to kill existing seeds and microorganisms. Average soil depth in the trays was approximately 4 cm, and the soil surface area was 206.5 cm^2. After treatments were administered, sawgrass seeds were sprinkled directly onto the moist soil surface. In both experiments, trays were randomly placed on tables in a screenhouse and watered to saturation one to three times daily and allowed to drain.

Monitoring Seed Germination

In each replicate, the total number of seedlings was counted, but seedlings were not removed. Frequency of observations varied throughout the study for each germination test. At the beginning of the study, when germination rate was rapid, counts were conducted twice per week and decreased to once every 2 weeks by the end of each experiment, when germination rates declined.

Final germination percentage, lag time, response time, and germination rate were measured for each treatment and control in each germination experiment. Calculations of germination attributes followed that of Shipley and Parent (1991) and Goodwin et al. (1995). Lag time was defined as days between beginning of experiment and commencement of germination of the first seed. Germination was considered to have occurred once the coleoptile emerged from the seed and was discernible without magnification. Response time (T_{50}) equaled the days required for 50 percent of the germinating seeds to germinate in a particular replicate. Germination rate was calculated as number of seeds that germinated per day between any two observations.

Fungal Experiment

In August 1996, three replicates each of 100 dry seeds from the S4V seed lot were subjected to either the bleach treatment or no treatment. Following treatment, seeds were sown onto moist, heat-sterilized potting soil that was first covered with mesh screening to allow easy seed retrieval. Trays were subjected to the same conditions as for the germination experiments. The experiment was conducted for a total of 4 weeks. Each Monday and Friday, ten seeds from each replicate were randomly removed from the trays and evaluated. Presence of fungal mycelia and condition of the embryo were determined by bisecting the seed longitudinally with a razor blade and inspecting it under a microscope. Condition of the seed was noted as "apparently viable" if the embryo filled the entire cavity or as "apparently non-viable" if the embryo was either shriveled and/or infected with fungi (Figure 1). Seeds that initiated germination, either by emergence of the coleoptile or differentiation of cells in the embryo, were recorded for each observation.

Statistical Analyses

Statistics were performed using the SYSTAT statistical package and Microsoft Excel. The number of germinated seeds in each treatment was compared using a one-way ANOVA, and significant differences were separated using Duncan's multiple range test. The main effect tested was treatment. Probability plots of residuals indicated that data distribution was normal and variances among the groups were equal as determined by Bartlett's Test for Homogeneity of Group Variances (Zar 1984). Significance was assumed at $P<0.05$.

In the fungal experiment, data are presented as the proportion of seeds infected with fungi and the proportion of "apparently viable" seeds. These proportions or parameters were transformed with an arcsine transformation to equalize variances and separately subjected to a two-way ANOVA (Box et al. 1978). The main effect tested was treatment, and time elapsed since the initiation of the experiment was used as a

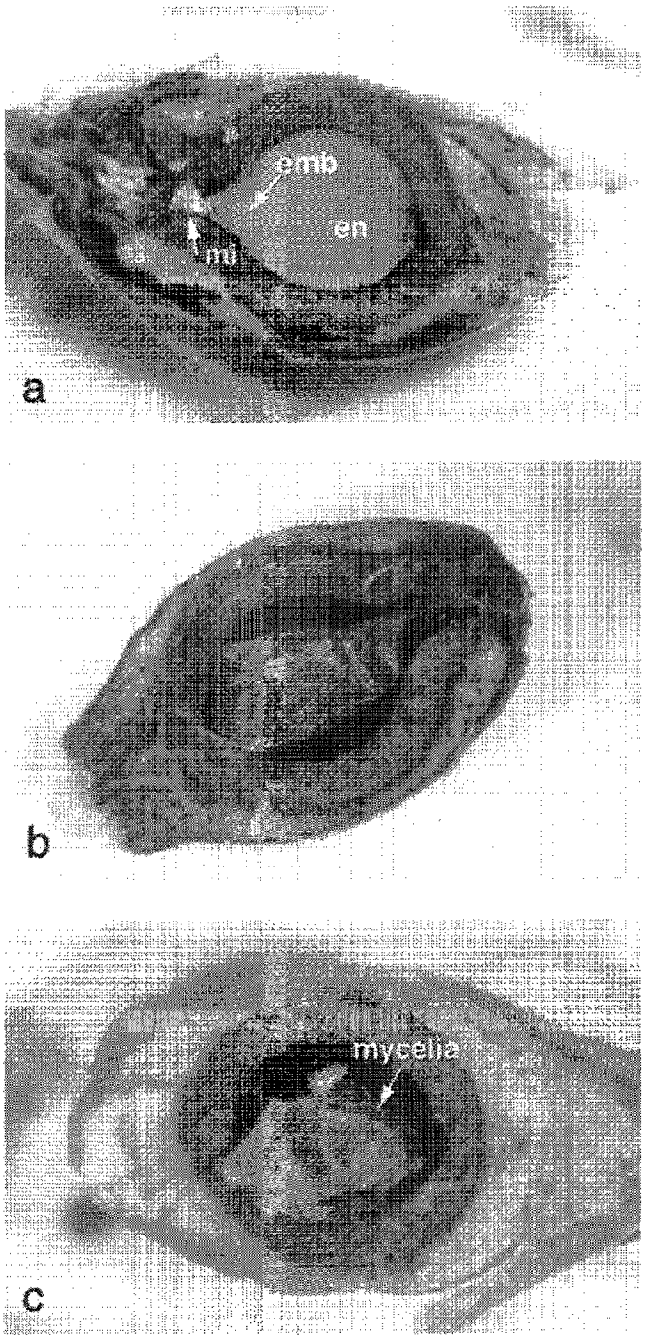

Figure 1. Longitudinal section of three *Cladium jamaicense* seeds. a) Apparently viable seed with the embryo and endosperm filling the entire cavity en=endosperm, emb=embryo, mi=micropyle); b) apparently non-viable seed with shriveled embryo and endosperm; c) apparently non-viable seed with shriveled embryo covered in fungal mycelia—seed had lost its shiny appearance. Magnification ranges from 17 to 28 times larger (average length of seeds is 2.9 mm).

Table 1. ANOVA of sawgrass germination compared within and between treatments for the 1994–1995 germination experiment with S1V seeds and for the 1995–1996 germination experiment with S4V seeds. Significance is assumed at $P < 0.05$.

Source of Variation	d.f.	Mean Square	*f*	*P*
1994–1995 Germination Test with S1V Seeds:				
Between Treatments	8	194.00	5.93	<0.0001
Within Treatment Error	45	32.70	—	—
1995–1996 Germination Test with S4V Seeds:				
Between Treatments	7	536.82	17.58	<0.0001
Within Treatment Error	24	30.53	—	—

covariable in the model. Data from the fungal experiment had a normal distribution as determined by probability plots of the residuals. For ease of presentation, data are expressed as the untransformed proportions in tables, figures, and text. Significance for all tests was assumed at $P<0.05$.

RESULTS

1994–1995 Germination Test

Final Germination Percentage. There was a significant difference in final germination percentage among treatments (Table 1). The nitric acid treatment resulted in the greatest germination at 54.8%, which was significantly higher than that of seeds in three other treatments (dry heat, gibberellic acid/wet heat, and sand paper abrasion) and the water control (Table 2). However, the nitric acid treatment was ineffective at raising germination significantly over that observed in seeds that had no treatment. Seeds treated with dry heat had the worst germination. Order of treatments and controls from highest to lowest germination percentages was nitric acid>no treatment>potassium nitrate>wet heat>gibberellic acid>water control>sand paper abrasion>gibberellic acid/wet heat>dry heat. The overall average germination achieved by sawgrass seeds was 47.9%.

Lag Time and Response Time. S1V seeds typically began to germinate 2 to 4 weeks after initiation of the experiment. The shortest mean lag time was observed for seeds in the gibberellic acid treatment and the water control when the first seeds began germinating after 14.0 days (Table 2). Seeds in the gibberellic acid/wet heat treatment had the longest mean lag time, with the first seeds germinating after 23.0 days.

The nitric acid treatment showed the most rapid response time, where 50% of the seeds that germinated in all replicates had done so within 26.0 days (Table

Table 2. Germination attributes (mean lag time, response time, maximum germination rate, and final germination percentage) of *Cladium jamaicense* in two germination tests for several treatments. The number of germinated seeds in each treatment was compared using a one-way ANOVA, and significant differences were separated using Duncan's multiple range test. The main effect tested was treatment. Significance was assumed at $P < 0.05$. Significant differences in final germination percentages between treatments are denoted by different letters.

Treatment	Mean Lag Time (days)	Response Time T_{50} (days)	Maximum Germination Rate (seeds/day)	Final Germination Percentage (%)
1994–1995 Germination Test with S1V Seeds:				
Sand Paper Abrasion	15.2	27.8	1.7	43.5 bcd
Nitric Acid	15.2	26.0	2.8	54.8 a
Water Control	14.0	30.5	1.7	44.2 bcd
Dry Heat	17.5	28.7	2.0	39.5 d
Gibberellic Acid	14.0	27.8	1.9	48.5 abc
Gibberellic Acid/ Wet Heat	23.0	32.0	2.0	42.5 cd
Potassium Nitrate	17.5	31.2	2.0	53.2 a
No Treatment	17.5	31.2	2.6	54.5 a
Wet Heat	21.0	33.0	2.4	50.3 ab
Minimum	14.0	26.0	1.7	39.5
Maximum	23.0	33.0	2.8	54.8
Mean	17.2	29.8	2.1	47.9
1995–1996 Germination Test with S4V Seeds:				
Nitric Acid	21.3	38.3	2.9	56.0 bc
Sodium Hypochlorite	17.0	35.3	5.5	79.3 a
Water Control	21.0	46.0	2.1	50.8 cd
Gibberellic Acid	16.5	52.3	1.6	47.8 cd
Potassium Nitrate	15.0	44.8	1.6	54.5 bc
No Treatment	17.8	47.8	3.3	57.0 bc
Freezing/3-day Stratification	17.8	47.5	1.6	40.8 d
One-month Cold Stratification	31.5	42.0	3.3	64.3 b
Minimum	15.0	35.3	1.6	40.8
Maximum	31.5	52.3	5.5	79.3
Mean	19.7	44.3	2.7	54.0

2). In comparison, the wet heat treatment had the longest response time at an average of 33.0 days.

Germination Rate. The fastest germination rate of sawgrass seeds was observed in the nitric acid treatment at 2.8 seeds/day (Table 2). However, seeds with no treatment had the second most rapid germination rate of 2.6 seeds/day. The slowest germination rate was observed in both the sand paper abrasion treatment and the water control at 1.7 seeds/day.

1995–1996 Germination Test

Final Germination Percentage. There was a significant difference in final germination percentage among treatments (Table 1). The bleach treatment resulted in the greatest germination at 79.3%, which was significantly higher than that of seeds in all other treatments and controls (Table 2). The bleach treatment was the only treatment that yielded germination percentages significantly greater than those found with no treatment. Both bleach and one-month stratification treatments showed significantly greater germination than in the water control. Seeds treated with freezing/3 day stratification had the worst germination. Order of treatments and controls from highest to lowest germination percentages was bleach>one-month cold stratification>no treatment>nitric acid>potassium nitrate>water control>gibberellic acid>freezing/3-day stratification. The overall average germination achieved by sawgrass seeds was 54.0%.

Lag Time and Response Time. S4V seeds typically began to germinate 2 to 4 weeks after initiation of the experiment. The shortest mean lag time was observed for seeds in the potassium nitrate treatment, when the first seeds began germinating after 15.0 days (Table 2). Seeds in the one-month cold stratification treatment had the longest mean lag time, with the first seeds germinating after 31.5 days.

Seeds in the bleach treatment had the most rapid response time, with 50 percent of the seeds germinating in all replicates within 35.3 days (Table 2). In comparison, the gibberellic acid treatment had the longest response time at an average of 52.3 days.

Germination Rate. The fastest germination rate of sawgrass seeds was observed in the bleach treatment at 5.5 seeds/day (Table 2). The seeds with no treatment and those cold stratified for one month had the second most rapid germination rate of 3.3 seeds/day. The slowest germination rate was observed in three treatments (gibberellic acid, potassium nitrate and freezing/3-day stratification) at 1.7 seeds/day.

Fungal Experiment

Significant differences in the proportion of seeds infected with fungi and the proportion of "apparently viable" seeds occurred between the treatments (Table 3). Bleached seeds had significantly lower fungal infection than untreated seeds at 13% versus 34%, respectively (Table 4). Time elapsed since the beginning of the experiment did not affect either the proportion

Table 3. Two-way ANOVA of fungal and viability characteristics of sawgrass seeds for bleached and unbleached treatments. Time elapsed since the initiation of the experiment was used as a covariable in the model. Significance is assumed at $P < 0.05$.

Source of Variation	d.f.	Mean Square	f	P
Seeds infected with fungus:				
Treatment	1	0.663	11.54	0.002
Time Elapsed	7	0.040	0.688	0.681
Treatment*Time Elapsed	7	0.030	0.520	0.812
Error	32	0.057	—	—
Apparently viable seeds:				
Treatment	1	0.621	13.15	<0.001
Time Elapsed	7	0.047	0.994	0.453
Treatment*Time Elapsed	7	0.051	1.079	0.399
Error	32	0.047	—	—

of seeds infected with fungi or the proportion of "apparently viable" seeds, indicating that there was no trend of degradation over the course of the experiment (Table 3). The percentage of seeds that was considered "apparently viable" (no shriveled embryos and/or presence of fungus) for the bleach treatment and no treatment was 79% and 59%, respectively. These percentages closely match the final germination percentages obtained in the germination experiment (79.3% and 57.0%) (Table 4).

Some seeds began to germinate or cells in the embryo began to differentiate during the third and fourth weeks of the experiment. The number of seeds that germinated or differentiated in the bleached and unbleached treatments was 36 and 39, respectively. Of the 75 seeds that initiated germination, seven had fungal mycelia present (four in the bleach treatment and three in the untreated seeds).

DISCUSSION

Germination Tests

Several researchers have had success in breaking seed coat-imposed dormancy of seeds by mechanical and chemical scarification (Roberts 1963a, Frank and Larson 1970, Clemens et al. 1977, Ahmad 1978, Msanga and Maghembe 1989). In this study, scarification did not improve germination of either 3-year-old or freshly harvested sawgrass seeds. This provides evidence that these sawgrass seeds did not require scarification in order to germinate and that these seeds did not demonstrate seed coat-imposed dormancy. In fact, three of the treatments involving scarification (sand paper, gibberellic acid/wet heat, and dry heat) resulted in significantly lower germination in 3-year-old seeds. The negative effect may have been due to injury of the embryo, as observed by Msanga and Maghembe (1989) in *Vangueria infausta* seeds. They found that complete removal of the seed coat caused rapid imbibition of water, which caused the endosperm to fracture and burst. Poor germination could therefore be due to physical injury in addition to a probable loss of nutrients and hormones from the endosperm and cotyledons through the fractures.

Table 4. Fungal and viability characteristics of bleached and untreated *Cladium jamaicense* seeds. Percentages with different letters are significantly different ($P < 0.05$). Germination data are presented for comparison.

Treatment	Seeds Infected With Fungus (%)	Apparently Viable Seeds (%)	Germination (%)
Bleach	13 a	79 a	79.3
No Treatment	34 b	59 b	57.0

Nitrate ions and gibberellic acid have been found to stimulate germination by releasing embryonic or physiological dormancy (Roberts 1963a, Roberts 1963b, Sondheimer and Galson 1966, McBride and Dickson 1972, and Gendel et al. 1977). However, these exogenous chemicals did not affect germination in both 3-year-old and freshly harvested sawgrass seeds. The lack of effect of gibberellic acid may indicate that both seed lots did not show embryonic dormancy.

The two stratification treatments showed quite different results. Storage of dry seeds for 25 days at low temperatures followed by 3 days moist stratification decreased germination in freshly harvested seeds. Goossens and Devillez (1973) found that cold stratification that was not preceded by warm stratification resulted in the pronounced deterioration of *Cladium mariscus* seeds while in storage. They proposed that immature sawgrass seeds were not resistant to cold shock. In contrast, those seeds that were subjected to the one-month cold stratification treatment (moist, cool temperatures for one month) in this study produced the second best germination results. The fact that seeds were not moist or allowed to imbibe water before freezing in the freezing, 3-day stratification treatment could account for the differences observed between the two stratification treatments. Bewley and Black (1982) indicated that chilling or stratification was only beneficial in hydrated seeds.

Cold stratification has been credited for breaking both morphological (seed coat-imposed) dormancy and physiological (embryonic) dormancy (Copeland 1976, Bewley and Black 1982). In *Cladium mariscus* seeds, the effect of cold stratification was attributed to the lifting of embryonic dormancy (Goossens and De-

villez 1973). The results of this investigation suggest that freshly harvested *Cladium jamaicense* seeds did not show a similar embryonic dormancy.

The bleach treatment was the best treatment in the 1995–1996 germination test. This treatment significantly increased final germination percentages over all other treatments. In addition, seeds treated with bleach had the quickest germination rate and the shortest response time.

The mechanism by which bleach enhances germination is unclear. Several researchers who have observed the same effect of bleach on *Stipa viridula* Trin., *Scirpus paludosus* A. Nels., *S. acutus* Mulh., *S. lacustris* L., and *S. maritimus* L. have either attributed the positive effect to seed coat scarification and/or seed disinfection (Frank and Larson 1970, O Neill 1972, Clevering 1995, Lacroix and Mosher 1995). However, because no other scarification treatment yielded the same positive results as treatment in bleach, the results of this study suggest that the positive effect on germination may be due to the disinfecting action of bleach.

Two other possible explanations focus on the oxidizing properties of bleach. Bewley and Black (1982) suggested that the ability of bleach to oxidize inhibitory chemicals in the seed coat may be responsible for its positive action on germination. However, Roberts (1964) postulated that any treatment that decreases the respiratory competition for oxygen speeds up the breaking of dormancy. He postulated that cytochrome oxidase has a very high affinity for oxygen, and therefore, inhibition of this enzyme would remove competition for oxygen and would make it more available for the oxidation reaction necessary for breaking dormancy. However, he also stated that the provision of alternative hydrogen acceptors that can be used in respiratory processes, such as nitrate or nitrite, can act in a similar manner by reducing competition for oxygen. The results of this study suggest that because treatment in potassium nitrate did not yield the same positive results as treatment in bleach, the promotion of germination may be due to some mechanism other than a reduction in the competition for oxygen.

Fungal Experiment

This experiment was conducted in an attempt to identify the mechanism by which bleach enhanced germination. Bleaching seeds was an effective technique for either killing fungi or preventing fungal infection in sawgrass seeds. Results of this experiment suggest that the disinfectant properties of bleach may be one mechanism through which sawgrass germination is enhanced.

However, at the end of the experiment when sawgrass began germinating, some seeds were infected with fungus. This indicates that the presence of fungi does not necessarily preclude germination. Level of infection, species of fungus present, and area of the seed that is infected may influence the ability to germinate. Although no one genus of fungus was isolated from within infected seeds when cultured, three genera of fungi were found to be either in or on the seed (*Cladosporium* sp., *Aureobasidium* sp., and *Penicillium* sp.). Both *Aureobasidium* sp. and *Penicillium* sp. have been shown to cause damage in seeds of crop species (Neergaard 1977). However, in most cases these types of fungi occur on necrotic tissue, and it is unknown whether the fungi kills the embryo or infects the embryo after it has already died. Conway (1942) documented the presence of several fungi in *Cladium mariscus* but indicated there was no evidence that serious diseases were caused by any of them. Nevertheless, both the germination experiment and the fungal experiment indicate that the disinfectant action of bleach may be responsible for the positive effect on sawgrass germination.

CONCLUSIONS

Both 3-year-old and freshly harvested sawgrass seeds appeared to show no dormancy. Treatments expected to lift physiological and morphological dormancy did not result in increased germination percentages. However, treatment with bleach enhanced sawgrass germination by as much as 40% over that found in untreated seeds, and bleached seeds had the most rapid response time and the greatest germination rate. Bleach significantly reduced the number of seeds that were infected with fungus by killing the pathogen and disintegrating fungal mycelia. The results of this study suggest that the disinfectant properties of bleach may be one mechanism through which sawgrass germination is enhanced.

Bleach may be used to treat seeds either before direct seed distribution into restoration areas or for producing greenhouse-grown plants for eventual transplantation into these areas. Results of this experiment show that it is possible to use this treatment to more efficiently grow seedlings in the greenhouse. The efficacy of using the bleach treatment on seeds that are to be directly distributed into restoration properties is an area for future research.

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