OPTIMUM STORAGE AND GERMINATION CONDITIONS FOR SEEDS OF

Pickerelweed

(*Pontederia cordata* L.)

FROM FLORIDA

| Lyn A Gettys and R Kasten Dumroese

ABSTRACT

Clean seeds of pickerelweed (*Pontederia cordata* L. [Pontederiaceae]) germinated best (84 to 94%) under water, even after being stored dry up to 6 mo at about 25 °C (77 °F), but germination of clean seeds under water was reduced to 43% when seeds were stored at 4 °C (39 °F) for 6 mo. Underwater germination of seeds enclosed in fruits was less effective; germination of fresh fruits or fruits stored for 3 mo ranged from 70 to 90% and was reduced to 38 to 42% when seeds were stored for 6 mo. The least effective method was burial, which significantly reduced germination in seeds or fruits stored for 3 or 6 mo. Understanding seed cleaning and germination requirements will make it even easier to propagate this attractive native perennial freshwater shoreline species.

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KEY WORDS

Pontederiaceae, aquatic, wetland, ornamental, mitigation

NOMENCLATURE

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Figure 1. Pickerelweed growing along the margin of Robert's Pond in Bainbridge, New York. Inset: Flowers of pickerelweed. Photos by Lyn A Gettys

Pickerelweed (*Pontederia cordata* L. [Pontederiaceae]) is an attractive native freshwater shoreline species frequently used in ornamental aquascapes and in wetland mitigation and restoration projects (Figure 1). Pickerelweed is hardy in USDA Zones 4 through 11 and ranges from Prince Edward Island to the Florida Keys and in Central America, Brazil, the West Indies, and Argentina (Lowden 1973; Godfrey and Wooten 1979). The showy purplish-blue or white inflorescences of this herbaceous perennial, which contain up to 250 individual flowers, make pickerelweed a prime candidate for inclusion in water gardens. Pickerelweed flowers from mid-June to mid-August in the northern extremes of the species' range, while flowering is almost continuous in southern Florida (Godfrey and Wooten 1979; Zomlefer 1994; Tobe and others 1998). Its status as a native plant provides many opportunities for use in projects where ecosystem fidelity is critical. When used in wetland mitigation or restoration, pickerelweed provides a refuge and habitat for many types of fauna. The nectar-producing flowers attract butterflies, skippers, and hummingbirds (Larson 1995; Speichert and Speichert 2001), and the fruit is an important food source for ducks and small animals (Tobe and others 1998).

Although pickerelweed reproduces sexually and vegetatively, it colonizes new areas mostly through dissemination of copious amounts of single-seeded fruits (Figure 2). The wall of the fruit is formed from the floral tube and is ridged with a dentate crest. Fruits of pickerelweed are buoyant, surrounded by light aeriferous tissue, and may float for up to 15 d (Schultz 1942; Barrett 1978). The seed housed within the fruit is filled with starchy endosperm and contains a linear embryo that runs the entire length of the seed (Martin 1946). Garbisch and McIninch (1992) report 11 000 seeds/kg (5000/lb).

Fulfillment of conditions required for germination determines the success of long-distance dispersal of pickerelweed in natural settings, but is also important for native plant producers and restoration specialists who wish to produce and outplant this species. Several environmental cues, including storage technique, stratification, quantity of light, and available moisture may affect pickerelweed germination.

Storage conditions often affect germination. For example, several authors (Muenscher 1936; Roberts and King 1980; Berjak and others 1990; Leck 1996) noted that germination percentage of seeds of some aquatic species was reduced when seeds were desiccated or stored for as little as 2 wk. However, others (Grime and others 1981; Garbisch and McIninch 1992) found that seeds of many wetland species germinated well after being stored for 1+ y.

Stratification (cool, moist conditions) may also influence germination, especially in temperate or widely adapted species such as pickerelweed. A number of authors (Muenscher 1936; Whigham and Simpson 1982; Speichert and Speichert 2001) concluded that seeds of pickerelweed require stratification to germinate.

Some research suggests that most mudflat and wetland species germinate at a higher percentage or more quickly when exposed to light rather than dark (Salisbury 1970; Grime and others 1981); but others have shown that seeds of pickerelweed are unaffected by presence or absence of light (Whigham and Simpson 1982). Germination of buried seeds of pickerelweed was reduced compared to those germinated in the presence of light; however, germination in the dark was improved by stratification (Galinato and van der Valk 1986).

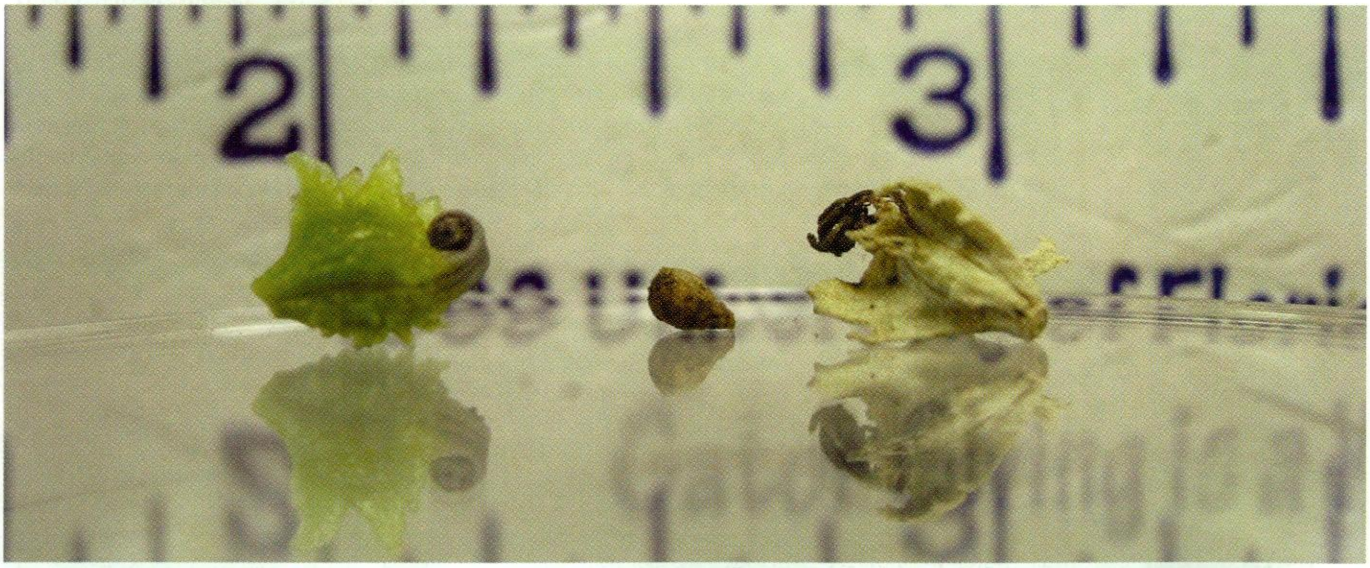

Figure 2. Fresh fruit, cleaned seed, and dried fruit of pickerelweed (shown here left to right against a one-inch scale). Photo by Lyn A Gettys

Moisture levels can affect germination as well. Williges and Harris (1995) stated that germination of pickerelweed was significantly higher in inundated treatments than in non-flooded treatments. All material used by Williges and Harris (1995), however, was collected around Lake Okeechobee and refrigerated for an unspecified length of time before germination experiments commenced, thus samples most likely were stratified. Barrett and others (1983) found that seeds germinated poorly in water at 30 to 40 °C (86 to 104 °F); only 76 seedlings were produced from 15 inflorescences, which theoretically could have produced 3000 or more seeds.

Conditions that affect germination in pickerelweed have been investigated by a number of workers, but the literature is conflicting and does not conclusively define consistent, effective storage and germination conditions (including time) for the species. Thus, the study objective was to determine optimum storage and germination conditions that favor high germination in seeds of pickerelweed from Florida.

MATERIALS AND METHODS

Collection and Storage of Fruits

Ripe open-pollinated fruits were collected during December 2003 from a population of plants grown outdoors at the University of Florida Fort Lauderdale Research and Education Center (lat 26°08'N, long 80°24'W) and were air-dried on a greenhouse bench at about 28 °C (82 °F) for 1 wk. Dried fruits were counted into lots of 100; each lot was placed in a small plastic bag and sealed. Dried fruits were stored dry at 2 temperatures (4 and about 25 °C [39 and 77 °F]) for 3 durations: 0, 3, and 6 mo. Note: at zero months storage, propagules did not experience the 4 °C temperature.

Seed Cleaning Treatments

After each storage duration, dried fruits containing seeds were either left intact or seeds were removed by rubbing fruits over a rubber-covered rub board to remove the "husk" surrounding the seed. Hereafter, "fruits" refers to seeds enclosed within intact fruits, "seeds" refers to seeds removed from fruits, and "propagules" refers to "seeds" and "fruits" collectively.

Germination Environment

For each storage duration, storage temperature, and seed cleaning treatment, propagules were exposed to 3 germination environments: under water, on the soil surface, or buried 5 mm (0.2 in) in soil.

Propagules germinated under water were placed in 250 ml (8.5 oz) glass bottles and covered with about 5 cm (2 in) of tap water, with water added as needed throughout the course of the study to maintain a constant depth. Propagules germinated on or below "soil" were placed in propagation flats filled to a depth of 5 cm (2 in) with premoistened Metro-Mix® 500 (Sun Gro Horticulture Canada Ltd, Seba Beach, Alberta, Canada), a commercially available growing substrate that contains 40 to 50% composted pine bark, 20 to 35% horticultural grade vermiculite, and 12 to 22% Canadian *Sphagnum* peat moss by volume with a nutrient charge and pH adjustment. Planted flats were maintained under a mist irrigation system (duration 5 s, interval 10 min). Flats and jars were placed in a greenhouse (air temperature range 23 to 30°C [73 to 86°F]) at the University of Florida Fort Lauderdale Research and Education Center.

Data Collection

Once propagules were placed into the germination environments, they were monitored weekly for 12 wk. Plumule emergence was considered evidence of germination. Germinated propagules were removed from the study as they appeared and were recorded.

Statistical Analysis

Each combination of storage duration, storage temperature, seed cleaning, and germination environment was replicated 4 times with 100 propagules per replicate. Because some seeds of aquatic plants lose viability quickly when stored dry, each storage duration (0 [fresh], 3, and 6 mo) was analyzed separately. Therefore, for 3 and 6 mo of storage, the experimental design was a 2 storage temperature x 2 seed cleaning x 3 germination environment factorial randomized design; for fresh propagules that lacked the 4 °C (77 °F) treatment, data were analyzed as a 2 seed cleaning x 3 germination environment randomized design. Cumulative germination data collected after 12 wk were converted to percentage and arcsine transformed (Steel and others 1997). Multivariate analysis of variance was conducted using PROC GLM, and pairwise comparisons were conducted using MEANS/LSD statements under PROC GLM (SAS Institute 2007) with $\alpha = 0.05$.

RESULTS

Fresh Propagules

Seed treatment significantly affected germination ($P = 0.0012$), with an average of 53% of clean seeds germinating compared to 43% of seeds remaining inside fruits (Figure 3). Germination environment also significantly affected germination ($P < 0.0001$). Propagules placed on the surface of soil had similar germination to those buried (28% and 26%, respectively), which was significantly less than those germinated under water (84%). The interaction between seed treatment and germination environment was not significant ($P = 0.0621$).

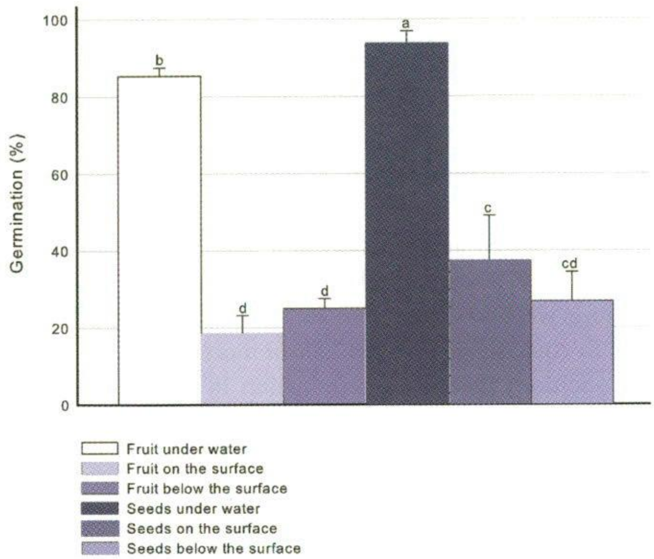

Figure 3. Percentage germination of fresh propagules of pickerelweed. Bars represent the mean of 4 replicates of 100 propagules for each treatment and error bars represent one standard deviation from the mean. Treatments coded with the same letter are not significantly different at $P = 0.05$.

Propagules Stored 3 mo

Germination was unaffected ($P = 0.9637$) by storage temperature (4 versus 25 °C [39 and 77 °F]). Seed treatment, however, significantly ($P = 0.0009$) affected germination, with an average of 52% of clean seeds germinating compared to only 40% of the seeds retained inside fruits (Figure 4). Moreover, germination environment also significantly ($P < 0.0001$) affected germination; propagules under water germinated significantly better (83%) than propagules on the soil surface (44%), which germinated significantly better than buried propagules (11%). The seed treatment x germination environment interaction was also significant ($P = 0.0009$). Seeds on the soil surface germinated better than fruits on the soil surface (59% versus 28%). No difference was observed between seeds and fruits under water (86% versus 80%) or between buried seeds and fruits (11% versus 12%).

Propagules Stored 6 mo

Storage temperature significantly affected ($P < 0.0001$) germination of propagules. Germination of propagules stored at 25 °C (77 °F) averaged 41% compared to only 29% for those stored at the colder temperature (Figure 5). Removing seeds from the fruits resulted in significantly ($P = 0.0152$) more germination (38%) than those retained inside fruits (31%). Although germination of propagules under water and on the soil surface was similar (52% and 47%, respectively), these germination values were significantly ($P < 0.0001$) greater than that of buried propagules (5%).

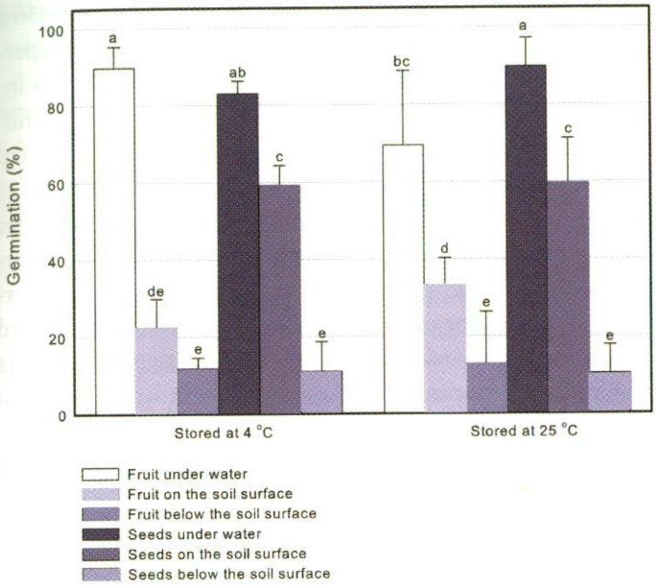

Figure 4. Percentage germination of propagules of pickerelweed stored for 3 mo. Bars represent the mean of 4 replicates of 100 propagules for each treatment and error bars represent one standard deviation from the mean. Treatments coded with the same letter are not significantly different at $P = 0.05$.

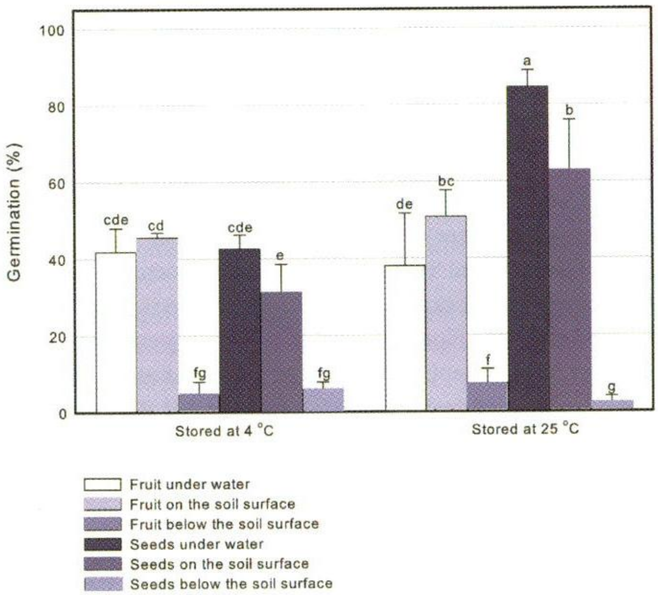

Figure 5. Percentage germination of propagules of pickerelweed stored for 6 mo. Bars represent the mean of 4 replicates of 100 propagules for each treatment and error bars represent one standard deviation from the mean. Treatments coded with the same letter are not significantly different at $P = 0.05$.

The storage temperature x seed treatment x germination environment interaction was also significant ($P < 0.0001$). In general, fruits and seeds stored at 4 °C (39 °F) had similar ger- mination percentages whether placed under water or on the soil surface, and this germination percentage was similar to fruits stored at 25 °C (77 °F) and germinated with similar conditions. Germination percentage was increased, however, for seeds stored at 25 °C (77 °F) and placed on the soil surface, and the best overall germination was achieved for seeds stored at 25 °C (77 °F) and germinated under water.

DISCUSSION

In this study, highest germination percentage was noted in seeds of pickerelweed germinated under water. These results support the work of Williges and Harris (1995), who stated that germination percentage of pickerelweed was significantly higher in inundated than in non-flooded treatments. This preference for flooded conditions during germination has been reported in other aquatic plants, including American wildcelery (*Vallisneria americana* Michx. [Hydrocharitaceae]) (Campbell 2005) and arrowhead (*Sagittaria lancifolia* L. [Alismataceae]) (Collon and Velasquez 1987). Also, Bliss and Zedler (1998) found that species richness in vernal pool communities in California increased after inundation and identified several species that germinated only under anaerobic conditions. This preference (or requirement) for inundated conditions may be a mechanism to ensure that seeds germinate in an environment that meets the requirements for their successful establishment and growth.

Propagules stored for 3 or 6 mo and placed on the soil surface germinated to a higher percentage than those under soil. These results are similar to those of Galinato and van der Valk (1986), who found that seed burial reduced germination percentage. This phenomenon has been noted in other aquatic species as well. For example, germination percentage of seeds of Eurasian watermilfoil (*Myriophyllum spicatum* L. [Haloragaceae]) is significantly reduced when seeds are covered by more than 2 cm (0.8 in) of sediment (Hartleb and others 1993).

Germination percentage decreased with increasing seed age, but a significant reduction in germination percentage was not detected in seeds stored for 3 mo at 25 °C (77 °F). Storage temperature also played a role in viability, because germination percentage was lowest in seeds stored at 4 °C (38 °F). Muenscher (1936) observed that seeds of many aquatic species failed to germinate after 2 to 5 mo of dry storage at 25 °C or 1 to 3 °C (77 °F or 34 to 38 °F), but those stored in tap water at 1 to 3 °C remained viable and germinated quickly when incubated at 18 to 21 °C (64 to 70 °F). Muenscher (1936) further stated that dry storage of pickerelweed seeds induced dormancy, but that germination percentages of 51 to 71% could be realized if dry-stored seeds were subjected to cold water stratification for 30 d prior to incubation under water. Propagules used in our experiment were stored dry, so it is possible that dormancy was induced in propagules stored for 3 or 6 mo. However, germination percentages of stored propagules in our experiment were reasonably high; for example, 84.5% of seeds stored at 25 °C for 6 mo and incubated under water germinated 12 wk after being moved to the incubation environment. Thus, it is unlikely that dormancy played a role in the outcome of this experiment. Although the effects of stratification were not examined in this study, the reasonably high germination percentages achieved without stratification suggests that stratification is not necessary to induce germination of pickerelweed seeds.

These results for this Florida source of pickerelweed suggest that the best germination occurs for seeds removed from the fruits and germinated under water at about 27 °C (80 °F). For short-term storage (< 3 mo), dried seeds may be kept at either 4 or 25 °C (39 or 77 °F), but for storage of 3 to 6 mo, the warmer temperature appears to better retain seed viability. Therefore, storing dried seeds at room temperature regardless of storage duration may be preferred. These results may be specific for Florida sources but should be a useful starting point for nursery managers desiring efficient production of pickerelweed seedlings for use as ornamentals in water gardens or as native flora in restoration projects.

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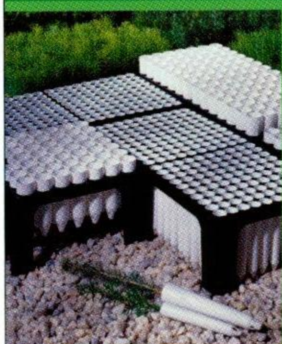

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