Weed Science, 53:41–45. 2005

Factors affecting germination of hairy nightshade (*Solanum sarrachoides*) seeds

Jingkai Zhou
Corresponding author. Department of Plant Science, North Dakota State University, Fargo, ND 58105; jing.zhou@ndsu.nodak.edu

Edward L. Deckard
Department of Plant Science, North Dakota State University, Fargo, ND 58105

William H. Ahrens
Shenyang Research Institute of Chemical Industry, Pesticide Bioactivity Center, Shenyang 110021, People's Republic of China

Hairy nightshade is the most widespread nightshade species in North America. Increased knowledge of hairy nightshade germination biology would facilitate development of an optimum control program. Germination of hairy nightshade seeds as affected by environmental and chemical factors was studied under greenhouse and controlled-environment growth chamber conditions. Hairy nightshade seeds were in an innate dormant state when initially separated from the berries. Moist compared with dry storage was more effective for breaking dormancy at 4 C, but dry storage was more effective at 17 C. Hairy nightshade seeds germinated equally well under both a 14-h photoperiod and continuous darkness. These germinated at constant temperatures ranging from 19 to 39 C, with optimum germination attained between 27 and 33 C. Germination markedly declined as osmotic potential of the germination medium decreased. The optimum pH range for germination of hairy nightshade seeds was between 6 and 8, although some seeds germinated at pH 4 and 9. Maximum hairy nightshade emergence occurred with seeding depths of 2 cm or less. No emergence occurred when seeding depth reached 8 cm.

Nomenclature: Hairy nightshade, *Solanum sarrachoides* Sendtner SOLSA.

Key words: Dormancy, germination, light requirement, temperature, osmotic potential.

Nightshades (*Solanum* spp.) are common agricultural weeds in many parts of the world (Holm et al. 1977). These plants can substantially reduce yield in several major crops, but interference with harvest and reduced crop quality are probably the most important economic consequences (Crotser and Witt 2000). Livestock producers are concerned about the potential of nightshades to poison animals (Arnold 1985; Axton and Durgan 1991).

Germination is one of the most critical phases in plant development. It is the result of complex interactions between numerous internal and external controls (Bewley and Black 1994). The internal control of seed dormancy relates to the state of the seed itself. External control relates to environmental factors that relieve seed dormancy and cause germination. Seed dormancy, an attribute common to nearly all weed species, influences the persistence of seeds in soil and affects germination patterns in natural ecosystems (Benech-Arnold et al. 2000; Egley and Duke 1985). The various dormancy levels within a seed population may lead to nonsynchronous weed seed germination and cause a prolonged period of weed emergence in crops (Egley and Duke 1985). Nondormant weed seeds will not germinate unless ecophysiological factors, which are species specific, are adequate for germination (Bewley and Black 1994; Egley and Duke 1985; Taylorson 1987). Environmental factors, such as temperature and water, may be critical in regulating the occurrence and speed of germination. Light has long been known as a requirement for germination of many weed species (Bewley and Black 1994).

Hairy nightshade, introduced from South America, is one of five predominant weedy nightshades in the United States (Ogg and Rogers 1989). Season-long control of hairy nightshade in crop fields has been difficult because it germinates throughout the growing season (Ogg and Dawson 1984). Late emergence, after standard weed control practices are completed, may be a major factor in the population increase of this species. Hairy nightshade is a prolific seed producer; a single plant can produce several thousand seeds (Kempen and Graf 1981; Zollinger 2004). An understanding of the dormancy behavior and requirements for germination may help predict timing and extent of hairy nightshade emergence. This knowledge may be useful in developing more effective control programs or in achieving uniform stands for research. Therefore, the objectives of this study were to characterize hairy nightshade seed dormancy and to examine the effects of environmental and chemical factors on germination of this species.

Materials and Methods

Seed Sources

Nondormant and dormant seed lots were used to test seed germination requirements and dormancy-breaking factors, respectively. The original seeds were collected and pooled from multiple plants from three farm fields near Prosper and Mayville, ND, in September and became nondormant following afterripening at 5 C for 8 mo. Freshly harvested seeds were obtained by growing hairy nightshade in the greenhouse at 28 ± 2 C with a photoperiod of 16 h using natural sunlight supplemented with metal halide lights at 250 μmol m^{-2} s^{-1} photosynthetic photon flux (PPF).

Bulk samples of ripe berries were collected from the greenhouse-grown hairy nightshade plants 10 d after berries developed a brownish color. The berries were crushed and the seeds washed out on a sieve in running water.

Germination Test

The effects of treatments on hairy nightshade germination were evaluated by evenly placing a 25-seed sample in a 58-mm-diam petri dish containing one filter paper disk moistened with 2 ml distilled water or test solution. These dishes were sealed with Parafilm[1] and incubated in a controlled-environment growth chamber at 30 C with a 14-h photoperiod and light intensity at 320 μmol m^{-2} s^{-1} PPF. A seed was considered germinated when the cotyledons and radicle emerged from the seed coat.

Treatments for Breaking Dormancy

Storage in Soil

Twenty-five freshly harvested hairy nightshade seeds were dispersed in 15 g of air-dried or moist (80% field capacity) Fargo–Ryan silty clay soil and sealed in 5- by 8-cm zip-closed plastic bags. Two fresh mature berries were mixed in 25 g moist Fargo–Ryan silty clay soil and sealed in 5- by 8-cm zip-closed plastic bags. The small bags, which contained seeds or berries, were sealed in a 17- by 17-cm zip-closed plastic bag. To minimize moisture loss from the moist-soil treatments, two pieces (about 12 cm^3) of water-saturated sponge were placed in the large bags containing these treatments.

Moist–cold and dry–cold treatments were achieved by storing seeds or berries in a refrigerator at 4 C. Moist–warm and dry–warm treatments were achieved by storing seeds or berries in an incubator at 17 C. Germination was tested every 15 d during the 150-d storage. The seeds and soil from each sample were spread evenly on filter paper in a petri dish moistened with 2.5 ml distilled water. Seeds from the nondecayed berries were obtained by crushing the berries and thoroughly rinsing the seeds with running water. Seeds from the decayed berries were obtained by sieving the soil in water.

Scarification, Gibberellic Acid, Leaching, and Berry Extract

Scarification was achieved by cutting off a small piece of seed coat opposite the radicle end. To evaluate the effect of gibberellic acid (GA_3),[2] the germination test was conducted using test solutions of GA_3 at 0, 10^{-6}, 10^{-5}, 10^{-4}, and 10^{-3} M.

To evaluate the effect of leaching on seed germination, freshly harvested hairy nightshade seeds were placed in cheesecloth bags attached to a water faucet from which water passed continuously and slowly through the bags for 0, 12, 24, 36, 48, 60, and 72 h.

Another experiment was conducted to evaluate the effect of hairy nightshade berry extract juice on its germination. A stock solution was prepared by crushing a 50-g sample of freshly mature berries in 50 ml distilled water and filtering the mixture through Whatman No. 1 filter paper. Stock solutions of 0, 25, 50, 75, and 100% (v/v) concentrations in water were used as germination media for nondormant control hairy nightshade seeds.

Effect of Environmental Factors on Germination of Nondormant Seeds

Light

Germination was tested in a controlled-environment growth chamber. The growth chamber conditions were the same as those mentioned in Germination Test. Complete dark treatment was obtained by wrapping the dishes in two layers of aluminum foil.

Temperature

The optimum temperature for hairy nightshade seed germination was determined by using a temperature gradient bar from 5 to 44 C, adapted from the designs of Barbour and Racine (1967) and Evans et al. (1970). The bar was covered with a piece of water-saturated filter paper. To maintain water saturation, the edges of the filter paper were in water-filled grooves throughout the experiment. The bar was divided into 41 sections, with a 1 C difference between consecutive sections.

Twenty-five seeds were placed in the center of each section and covered with a layer of clear plastic wrap,[3] and the entire bar was covered with a transparent Plexiglas cover. The experiment was conducted in light with a 16-h photoperiod and 250 μmol m^{-2} s^{-1} PPF. Tests were conducted three times, and each run was treated as a replicate. Runs and temperatures were considered random effects. Although the temperatures could not be randomized within replicates, the experiment was analyzed as if they were randomized.

Osmotic Potential

Solutions with osmotic potentials ranging from 0 to −1.1 MPa were prepared by dissolving Carbowax PEG 6000 (polyethylene glycol) in distilled water as described by Michel and Kaufman (1973).

pH

Buffer solutions with pH values of 4, 5, 6, 7, 8, and 9 were prepared as described by Reddy and Singh (1992). Potassium hydrogen phthalate buffer solution was adjusted to pH 4 with HCl. 2-(*N*-Morpholino)ethanesulfonic acid solution was adjusted to pH 5 and 6 using NaOH. *N*-(2-Hydroxymethyl)piperazine-*N*′-(2-ethanesulfonic acid) solution was adjusted to pH 7 and 8 with NaOH. *N*-Tris(hydroxymethyl)methylglycine (Tricine) solution was adjusted to pH 9 with NaOH. Distilled water (pH 6.8) was used as a control.

Effect of Seeding Depth on Seedling Emergence

Twenty-five nondormant hairy nightshade seeds were planted in soil (Fargo–Ryan silty clay) in 1-L plastic pots at depths of 0.5, 1, 2, 3, 4, 5, 6, 7, 8, and 9 cm. The soil was watered to field capacity daily. The pots were wrapped with aluminum foil to prevent light penetration through the sides. The greenhouse conditions were the same as those mentioned in Seed Sources. A seedling was considered emerged when the cotyledons were visible.

Statistical Analysis

All experiments were conducted two times (runs) using a completely randomized design with four replicates. There were no run by treatment interactions; therefore, data were pooled over runs for analysis. Data were subjected to analysis of variance, and mean separation was made using Fisher's

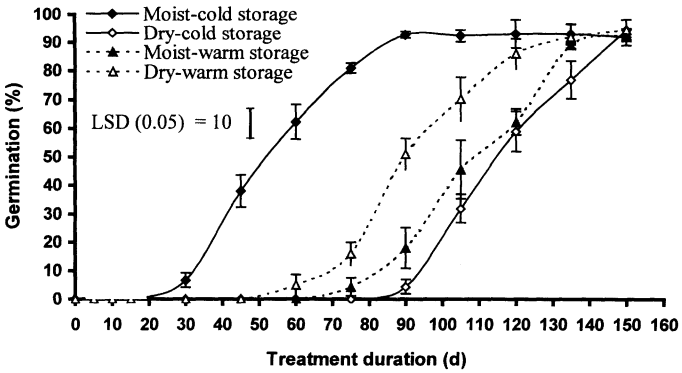

FIGURE 1. Effect of storage moisture and temperature on germination of freshly harvested hairy nightshade seeds. Vertical bars represent standard errors of the means.

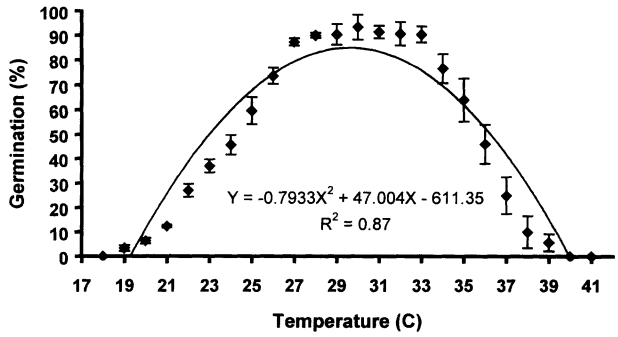

FIGURE 2. Effect of constant temperature on germination of hairy nightshade seeds. Vertical bars represent standard errors of the means.

Protected LSD test at the 0.05 level of significance. Nonlinear regression analysis was used to determine the effect of pH, temperature, and osmotic stress on germination and planting depth on emergence.

Results and Discussion

No germination occurred in freshly harvested seeds, whereas 93% of nondormant control seeds germinated (data not shown), indicating that freshly harvested hairy nightshade seeds were innately dormant, as reported previously (Bithell et al. 2002; Roberts and Boddrell 1983). In contrast, freshly harvested black nightshade (*Solanum nigrum* L.) seeds germinated almost 100% (Roberts and Lockett 1978).

Treatments for Breaking Dormancy

Storage in Soil

Moist–cold storage was more effective than dry–cold storage for breaking dormancy; however, dry–warm storage was more effective than moist–warm storage (Figure 1). Germination of hairy nightshade seeds occurred after 30 d of moist–cold storage (cold stratification), 60 d of dry–cold storage, 75 d of dry–warm storage, and 90 d of moist–warm storage.

Hairy nightshade berries decayed after 45 d of moist–cold storage or 20 d of moist–warm storage. Seeds started to germinate after 60 d of moist–cold storage (15 d after berry decay) and 45 d of moist–warm storage (25 d after berry decay) (data not shown). In contrast to bare seeds, seeds with berries started germinating much earlier under moist–warm conditions than under moist–cold conditions. These results indicate that specific products from hairy nightshade berry decay enhanced seed dormancy breaking.

Scarification, GA_3, Leaching, and Berry Extract

No germination occurred in freshly harvested hairy nightshade seeds when GA_3 was added to germination medium. This result differed from that of Bithell et al. (2002).

Leaching with water up to 72 h did not affect germination of freshly harvested seeds. The addition of juice extracted from hairy nightshade berries to the germination medium did not inhibit germination of nondormant seeds but inhibited seedling root development (data not shown).

Cotyledons emerged from the seed coat in a few scarified freshly harvested hairy nightshade seeds, but no root system formed; thus, they were not counted as germinated. This observation suggests that dormancy of freshly harvested hairy nightshade seeds is due to prevention of root development.

Effect of Environmental Factors on Germination of Nondormant Seeds

Light

Hairy nightshade seeds germinated equally well (93%) under both a 14-h photoperiod and continuous darkness (data not shown), indicating that hairy nightshade seeds are not photoblastic. Similarly, silverleaf nightshade (*Solanum elaeagnifolium* Cav.) and black nightshade have been reported to germinate in light as well as dark (Ogg and Dawson 1984; Thullen and Keeley 1982). However, light enhances eastern black nightshade (*Solanum ptycanthum* Dun.) germination (Thomson and Witt 1987). Our results may help explain why shallow tillage at monthly intervals had no effect on hairy nightshade emergence (Ogg and Dawson 1984).

Temperature

Hairy nightshade seeds required temperatures greater than 19 C but less than 39 C for germination (Figure 2). Optimum germination occurred from 27 to 33 C. Germination at these temperatures was similar and exceeded 90%. Germination decreased at temperatures greater than and less than this range. The optimum temperatures for hairy nightshade germination are similar to those reported for black nightshade (Thullen and Keeley 1982).

Germination speed of hairy nightshade seeds increased with increasing temperatures within the range of 20 to 34 C (data not shown). Maximum germination percentages were reached at 6, 5, and 5 d at constant temperatures of 24, 27, and 31 C, respectively. Germination speed declined as temperature increased more than 34 C.

Osmotic Potential

Hairy nightshade germination was 93, 84, and 17% at osmotic potentials of 0, −0.3, and −1.0 MPa, respectively (Figure 3). Optimum germination occurred at osmotic potentials between 0 and −0.2 MPa, where germination exceeded 90%. This result helps explain the association be-

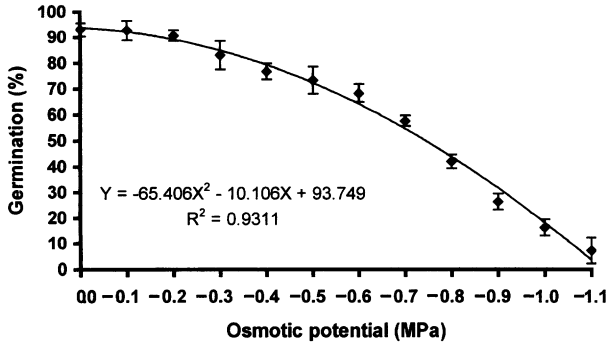

FIGURE 3. Effect of osmotic potential on germination of hairy nightshade seeds. Vertical bars represent standard errors of the means.

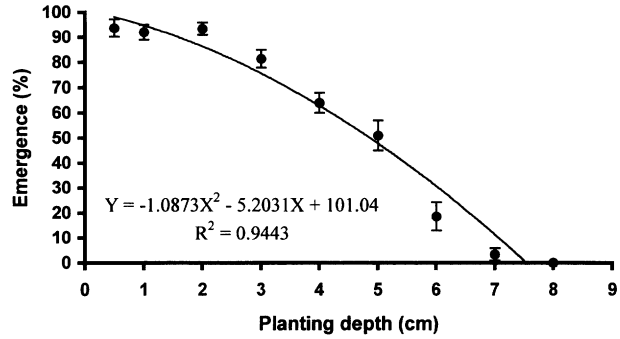

FIGURE 5. Effect of planting depth on emergence of hairy nightshade seeds. Vertical bars represent standard errors of the means.

tween rain events and flushes of hairy nightshade in the field (Zollinger 2004). Hairy nightshade was able to germinate at −1.1 MPa, whereas soybean (*Glycine max* L.) was not (Hoveland and Buchanan 1973; Thomson and Witt 1987). Hairy nightshade may have a competitive advantage over soybean under low–soil moisture conditions.

pH

The optimum pH range for hairy nightshade germination was between 6 and 8 (Figure 4). A marked decrease in germination occurred when pH was outside this range. About 31 and 48% of hairy nightshade seeds germinated at pH 4 and 9, respectively; however, radicles of the germinating seeds were often discolored and shorter than those of seeds incubated in solutions of optimum pH.

Effect of Seeding Depth on Seedling Emergence

Maximum emergence of hairy nightshade seeds occurred with planting depths of 2 cm or less (Figure 5). Emergence of seedlings decreased with increased seeding depth when the depths were more than 2 cm. No emergence occurred when seeding depth reached 8 cm.

In summary, freshly harvested hairy nightshade seeds were dormant, and scarification, GA_3, and leaching treatments did not break this dormancy. Seeds did not germinate at temperatures less than 19 C and more than 39 C, and optimum germination occurred between 27 and 33 C. This relatively high temperature requirement for germination is a reason why hairy nightshade emerges later in the growing season than many other weed species. Hairy nightshade seeds are not photoblastic; thus, night tillage will not help reduce hairy nightshade populations. The ability of hairy nightshade to germinate over a wide pH range can help explain why this species is widespread in North America (Ogg and Rogers 1989). The fact that hairy nightshade is especially abundant on irrigated lands in the West (Ogg and Rogers 1989) is likely because of its moist-soil requirement for optimum germination.

Weed ecotypes can vary in dormancy characteristics and germination requirements. Thus, inferences drawn from these experimental results are most relevant to the North Dakota weed population tested.

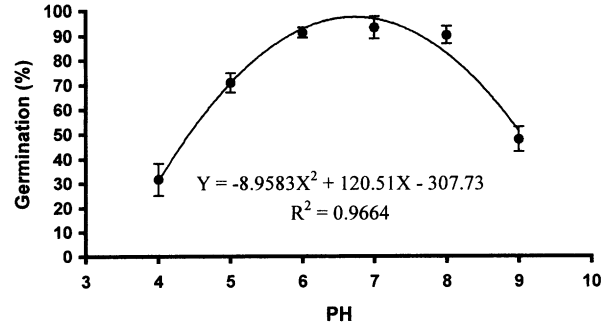

FIGURE 4. Effect of pH on germination of hairy nightshade seeds. Vertical bars represent standard errors of the means.

Sources of Materials

[1] Parafilm, American National Can, 101 Merritt, Greenwich, CT 06836.

[2] Gibberellic acid, Sigma-Aldrich Corp., 3050 Spruce Street, St. Louis, MO 63178.

[3] Clear Plastic Wrap, Albertson's Inc., General Office, 6560 Federal Way, Boise, ID 83726.

Acknowledgments

The authors are grateful for the assistance of Drs. Murray Duysen and Calvin Messersmith. This article is based on work supported by the Cooperative State Research, Education, and Extension Service, U.S. Department of Agriculture, under Agreement 2002-34361-11781.

Literature Cited

Arnold, S. J. 1985. Eastern black nightshade—an increasing concern for soybean and forage producers. Crops Soils Mag. 37(9):29–31.

Axton, L. M. and B. R. Durgan. 1991. Plants Poisonous to Livestock. St. Paul, MN: Minnesota Extension Service Bull. AG-FO-5655.

Barbour, M. G. and C. H. Racine. 1967. Construction and performance of a temperature gradient bar and chamber. Ecology 48:861–863.

Benech-Arnold, R. L., R. A. Sanchez, F. Forcella, B. Kruk, and C. M. Ghersa. 2000. Environmental control of dormancy in weed seed banks in soil. Field Crops Res. 67:105–122.

Bewley, J. D. and M. Black. 1994. Seeds: Physiology of Development and Germination. 2nd ed. New York: Plennum. Pp. 273–290.

Bithell, S. L., B. A. McKenzie, G. W. Bourdot, G. D. Hill, and S. D. Wratten. 2002. Germination requirements of laboratory stored seeds of black nightshade and hairy nightshade. Pages 222–227 *in* 55th Conf. Proc. (2002) New Zeal. Plant Prot. Soc. 55:222–227.

Crotser, M. P. and W. W. Witt. 2000. Effect of *Glycine max* canopy characteristics, *G. max* interference, and weed-free period on *Solanum ptycanthum* growth. Weed Sci. 48:20–26.

Egley, G. H. and S. O. Duke. 1985. Physiology of weed seed dormancy and germination. Pages 27–64 *in* S. O. Duke, ed. Weed Physiology. Volume I. Reproduction and Ecophysiology. Boca Raton, FL: CRC.

Evans, R. A., J. A. Young, R. Henkel, and G. J. Klomp. 1970. A low

temperature-gradient bar for seed germination studies. Weed Sci. 18: 575–576.
Holm, L. G., D. L. Plucknett, J. V. Pancho, and J. P. Herberger. 1977. *Solanum nigrum* L. Pages 430–434 *in* The World's Worst Weeds—Distribution and Biology. Honolulu, HI: University of Hawaii Press.
Hoveland, C. S. and G. A. Buchanan. 1973. Weed seed germination under simulated drought. Weed Sci. 21:133–138.
Kempen, H. M. and J. Graf. 1981. Weed seed production. Proc. West. Soc. Weed Sci. 34:78–81.
Michel, B. E. and M. R. Kaufman. 1973. The osmotic potential of polyethylene glycol 6000. Plant Physiol. 51:914–916.
Ogg, A. G., Jr. and J. H. Dawson. 1984. Time of emergence of eight weed species. Weed Sci. 32:327–335.
Ogg, A. G., Jr. and B. S. Rogers. 1989. Taxonomy, distribution, biology, and control of black nightshade and related species in the United States and Canada. Rev. Weed Sci. 4:25–58.
Reddy, K. N. and M. Singh. 1992. Germination and emergence of hairy beggarticks (*Bidens pilosa*). Weed Sci. 40:195–199.
Roberts, H. A. and J. E. Boddrell. 1983. Field experiments and temperature requirements for germination in *Solanum sarrachoides* Sendt. Weed Res. 23:247–252.
Roberts, H. A. and P. M. Lockett. 1978. Seed dormancy and field emergence in *Solanum nigrum* L. Weed Res. 18:231–241.
Taylorson, R. B. 1987. Environmental and chemical manipulation of weed seed dormancy. Rev. Weed Sci. 3:135–154.
Thomson, C. E. and W. W. Witt. 1987. Germination of cutleaf groundcherry (*Physalis angulata*), smooth groundcherry (*Physalis virginiana*), and eastern black nightshade (*Solanum ptycanthum*). Weed Sci. 35:58–62.
Thullen, R. J. and P. E. Keeley. 1982. The effects of some environmental conditions on the germination of black nightshade and ivyleaf morning glory. Proc. West. Soc. Weed Sci. 35:76–82.
Zollinger, R. K. 2004. North Dakota Weed Control Guide. Fargo, ND: North Dakota State University. Extension Service Circ. W-253.

Received June 2, 2004, and approved August 11, 2004.