Factors Affecting the Germination of Tall Morningglory (*Ipomoea purpurea*)

Author(s) :Megh Singh, Analiza H. M. Ramirez, Shiv D. Sharma, and Amit J. Jhala
Source: Weed Science, 60(1):64-68. 2012.
Published By: Weed Science Society of America
DOI:
URL: http://www.bioone.org/doi/full/10.1614/WS-D-11-00106.1

Weed Science 2012 60:64–68

Factors Affecting the Germination of Tall Morningglory (*Ipomoea purpurea*)

Megh Singh, Analiza H. M. Ramirez, Shiv D. Sharma, and Amit J. Jhala*

Tall morningglory is an annual broadleaf vine and a problem weed in many annual and perennial crops in several countries including the United States. A better understanding of the germination biology of tall morningglory would facilitate the development of better control strategies for this weed. Experiments were conducted under greenhouse and laboratory conditions to evaluate the effects of various environmental factors, such as temperature, light, planting depth, pH, osmotic and salt stress, and flooding duration, on the germination of tall morningglory. The results suggested that the optimum day/night temperature range for the germination of tall morningglory was 20/12.5 to 35/25 C and maximum germination (89%) was observed at 30/20 C. Temperature higher and lower than the optimum range significantly reduced germination. Alternate light and dark did not have any adverse effect on the germination of tall morningglory seeds. The germination was 10% at an osmotic stress of −0.3 and −0.4 MPa, and above that, no germination was observed. Tall morningglory showed some tolerance to salt stress. The germination was 40% and 12% at salt concentrations of 50 mM and 200 mM, respectively. Germination was affected by pH levels, and maximum germination occurred at pH 6, whereas above or below that level, germination was significantly reduced. Maximum germination of seeds was 83 and 94% when sown at 0 and 2 cm depth in soil, within a week of sowing; however, germination was significantly reduced to 76% when placed at a depth of 4 cm or deeper. Under no flooding treatment, 87% of seed germinated, but flooding delayed and inhibited the germination of tall morningglory seeds. It is concluded that several environmental factors affected the germination of tall morningglory, and this information could help to predict the spread of tall morningglory in new areas such as Florida.
Nomenclature: Tall morningglory, *Ipomoea purpurea* (L.) Roth, PHBPU.
Key words: Temperature, photoperiod, osmotic stress, salt stress, depth of sowing, flooding, seedling emergence.

Tall morningglory belongs to the family Convolvulaceae. It is a summer twining or climbing vine with distinctive, heart-shaped, alternating leaves and large, showy, white to pink to dark purple flowers. Tall morningglory germinates in early summer and flowers from July through September in most tropical environments. The stems can reach 3 m in length (DeFelice 2001; Uva et al. 1997). This plant prefers rich, moist soils, but can adapt to most environments. A common weed of agronomic, horticultural, and nursery crops, it is found throughout the United States predominantly in the north-central, southeastern, and northeastern United States (Bryson and DeFelice 2009, 2010; USDA 2011).

Tall morningglory is a very competitive weed of annual crops such cotton (*Gossypium hirsutum* L.), soybean [*Glycine max* (L.) Merr.], and sunflower (*Helianthus annuus* L.)(Buchanan and Burns 1971; Crowley and Buchanan 1978; Johnson 1971; Oliver et al. 1976). Reductions of 33% in cotton seed yield have been reported with tall morningglory at a density of 16 plants 15 m^{-1} (Crowley and Buchanan 1978). In soybean, there was a 63% yield reduction when tall morningglory was planted at a density of 1 plant 15 cm^{-1} (Oliver et al. 1976). In perennial crops, such as citrus (*Citrus* spp.), tall morningglory smothers young and established trees, thereby interfering with photosynthesis. In addition, tall morningglory interferes with harvesting operations by making it difficult for harvesters to find the fruits on smothered trees and by tangling and wrapping around machinery (Elmore et al. 1990; Futch 2007; Johnson 1971). Tall morningglory, as with most morningglory species, is very difficult to control. Even with common cultural practices and POST-directed herbicides, adequate control of tall morningglory can be extremely difficult (Elam et al. 2003).

DOI: 10.1614/WS-D-11-00106.1

* Professor, Postdoctoral Associate, Postdoctoral Associate, and Postdoctoral Associate, Citrus Research and Education Center, University of Florida/IFAS, 700 Experiment Station Road, Lake Alfred, FL 33850. Current address of third author: FMC Corporation, 1735 Market Street, Philadelphia, PA 19103. Corresponding author's E-mail: ahmramirez@ufl.edu

Germination is one of the most critical stages in weed establishment. Successful establishment of weeds depends heavily on the weeds' ability to germinate. Germination results from complex interactions between numerous internal and external controls (Bewley and Black 1994). Several environmental factors affect seed germination. For example, temperature may be critical in regulating the occurrence and speed of germination, as rate of emergence is closely correlated with soil temperatures (Cardwell 1984; Chauhan et al. 2006a). Another major factor in determining seed germination is soil moisture. Previous research has shown that, in some crops, germination is affected only slightly with moisture tensions of −0.05 to −0.3 MPa (Cardwell 1984). Light has long been known as a requirement for germination of many weed species (Bewley and Black 1994). The ability of weed seeds to germinate at various depths has also been widely reported (Balyan and Bhan 1986; Singh and Achhireddy 1984). The optimum environmental conditions necessary for germination vary considerably depending on the weed species (Burke et al. 2003; Chauhan et al. 2006b; Mennan and Ngouajio 2006; Taylorson 1987).

A better understanding of the seed germination and emergence behavior of tall morningglory would aid in predicting its potential behavior as it spreads into new areas, such as Florida. Furthermore, information on the effects of various environmental factors on the germination of tall morningglory would be useful in developing effective control measures. Therefore, the objective of this study was to determine the effects of temperature, light, planting depth, pH, osmotic stress, salt stress, and flooding duration on seed germination and emergence of tall morningglory.

Materials and Methods

Seed Preparation for Germination Studies and General Procedures. Tall morningglory seeds (Valley Seed Service, P.O. Box 9335, Fresno, CA 93791) were obtained from a commercial seed source and stored at 10 C before the conduct of the different studies. Seeds with visible indication of pathogen or insect damage were removed and not used in the experiments. Seeds were surface-sterilized by immersion in a 0.5% solution of sodium hypochlorite for 10 min. The sterilizing solution containing the seed was filtered; after which, seeds were rinsed with distilled water several times and allowed to dry at room temperature.

All experiments consisted of four replicates of 25 seeds placed on two sheets of filter paper (No. 4 filter paper, Whatman International Ltd., Maidstone, Kent ME14 2LE, U.K.) in 9-cm petri dishes, unless stated otherwise. The filter paper was moistened initially with 7.5 ml of distilled water or test solution. All dishes were sealed with Parafilm (American National Company, Greenwich, CT 06836) to prevent desiccation. The number of seeds that germinated was determined after 7 d, except in experiments on depth of burial and flooding duration.

Effect of Temperature. Eight temperature regimes were selected to determine the effect of temperature on the germination of tall morningglory. These temperatures reflect typical seasonal variation and the average high and low temperatures in Florida for the months of January to February, May, and June to August, and the range of effective day/night temperatures for diverse locations throughout the United States (Patterson, 1990).The petri dishes were placed in corresponding growth cabinets and maintained at day/night temperatures of 12.5/7.5, 15/10, 20/12.5, 25/15, 30/20, 37.5/25, 42.5/30, and 45/35 C. The photoperiod was set at 12/12 h (day/night), and a photosynthetic photon flux of 200 µmol m^{-2} s^{-1} was maintained during the experiment for all temperature regimes.

Effect of Light. Petri dishes containing tall morningglory seeds were exposed to different lengths of light and dark conditions, creating either complete dark (24/0 h dark/light), complete light (0/24 h dark/light), or alternating light and dark conditions (4/20, 8/16, 12/12, 16/8, or 20/4 h dark/light). A constant temperature of 30/20 C was maintained in all growth cabinets for this test.

Effect of Osmotic Stress. Solutions with osmotic potential of 0.0, −0.3, −0.4, −0.6, −0.9, and −1.3 MPa were prepared by dissolving 0, 154, 191, 230, 297, or 350 g of polyethylene glycol (PEG; polyethylene glycol 8000, Fischer Scientific, Fair Lawn, NJ 07410) in 1 L of deionized water (Michel 1983; Shaw et al. 1991); 7.5 ml of the appropriate PEG solution was added to each petri dish containing tall morningglory seeds. Petri dishes were placed in growth cabinets with temperature set at 25/20 C day/night temperatures as described by Young et al. (1983).

Effect of Salt Stress. Sodium chloride (NaCl; Fischer Scientific, Fairlawn, NJ 07410) solutions of 0, 50, 100, 150, 200, 250, and 300 mM were prepared according to Michel (1983). Petri dishes containing 7.5 ml of the appropriate salt solution were placed in growth cabinet with day/night temperatures at 28/20 C and 12 h photoperiod.

Effect of pH. Buffered pH solutions were prepared according to the method described by Gortner (1949) and Shaw et al. (1987), using 0.1 M potassium hydrogen phthalate (Fischer Scientific, Fairlawn, NJ 07410) to obtain solutions with pH levels of 4, 5, and 6, and a 25 mM sodium borate (Fischer Science Education, 4500 Turnberry Dr., Hanover Park, IL 60133) solution to prepare solutions with pH levels of 7, 8, or 9. Twenty-five tall morningglory seeds were placed in petri dishes containing 7.5 ml of the appropriate pH solution, and the petri dishes were placed in 28/20 C day/night temperature germination cabinets, and a 12 h photoperiod was maintained. Deionized water was used as a control.

Effect of Depth of Sowing. Seeds were sown at depths of 0, 0.5, 1, 2, 4, 6, or 10 cm below the soil surface in Florida Candler fine sand contained in Styrofoam cups (Master containers, Mulberry, FL 33860; 12 cm ht and 9.5 cm diam). The sand was cleaned through a sieve for other debris and moistened before planting the seed in the Styrofoam cups to facilitate easy wetting of sand by water. The experiment was conducted under greenhouse conditions. Day/night temperatures were set at 25 ± 5/16 ± 5 C. Natural day light was supplemented with sodium vapor lamps to provide 12 h of light. Styrofoam cups were initially subirrigated to field capacity and were then surface-irrigated daily to maintain adequate soil moisture. Germinated seedlings were counted every 7, 14, and 21 d after planting. Seedlings were considered emerged when the two cotyledons could be visually discerned and were removed after weekly counts.

Effect of Flooding Duration. Seeds were planted 1 cm deep in Florida Candler fine sand contained in Styrofoam cups (12 cm height and 9.5 cm diam). Results of burial depth study indicated that maximum germination occurred when seeds were buried at this depth. Flooding durations used were 0, 4, 7, 14, and 21 d. To simulate flooding, water was maintained 2 cm above the soil surface for the above mentioned periods. After exposure to a given period of flooding, surface water was drained by poking holes at the side of the cups to drain the excess water. Thereafter, watering was done as needed to maintain adequate moisture. Greenhouse conditions were the same as that for the depth of sowing experiment. Germination was observed at 7, 14, 21, and 35 d after seed planting.

Statistical Analysis. A completely randomized design with four replications was used in all experiments. Experiments were repeated. Before analysis, the final values of the percentage of germination were arcsine square-root–transformed to correct for homogeneity of variances (Steel and Torrie 1960). The data presented were averaged across two experimental runs because there was no significant experiment-by-treatment interaction. Homogeneity of variance, according to Bartlett's test, was also analyzed. However, transformation did not improve variance homogeneity; hence, nontransformed data were subjected to ANOVA. Means were separated using Fisher's Protected LSD test at P = 0.05.

Percentage of germination values at different osmotic potential or salt concentrations were fitted to a functional two-parameter exponential decay model using SigmaPlot (Version 10.0, Systat Software Inc., 1735 Technology Drive, Suite 430, San Jose, CA 95110). The model fitted was:

$$G(\%) = G_{\max} \times \exp(-G_{rate} \times x) \quad [1]$$

where G represents germination at the osmotic potential or salt concentration x, $G_{\max}$ is the maximum germination, and G_{rate} is the slope.

Results and Discussions

Effect of Temperature. Tall morningglory germinated over a wide range of temperatures. Highest germination (86 to 89%) was observed at day/night temperatures of 25/15 C to 30/20 C (Figure 1). The germination decreased to 67 and 74% at 20/12.5 and 35/25 C, respectively. At temperatures below 20/12.5, germination was < 10%, whereas at temperatures above 35/25 C the germination was ≤ 20%. The optimum germination occurred between 20/12.5 and 35/25 C. These results were similar to those obtained by Cole and Coats (1973). They observed that germination of tall morningglory occurred from temperatures of 15 to 30 C, with lower germination at ≥ 35 C. Similarly, germination of other morningglory species, such as *Ipomoea hederacea* Jacq. var. *integriuscula* Gray and *Ipomoea hederacea* Jacq., and pitted morningglory (*Ipomoea lacunosa* L.), occurred over a wide range of temperatures (7.5 to 52.5 C), with optimum germination between 20 and 25 C (Gomes et al. 1978; Oliviera and Norsworthy 2006). Furthermore, the temperature response of tall morningglory was similar to other broadleaf weed species, such as hairy beggarticks (*Bidens pilosa* L.)(Reddy and Singh 1992), Florida pusley (*Richardia scabra* L.)(Biswas et al. 1975), and licoriceweed (*Scoparia dulcis* L.)(Jain and Singh 1989). The optimum temperature range reported for these weeds was 25 to 35 C, whereas for grass weed species, such as crowfootgrass [*Dactyloctenium aegyptium* (L.) Willd.], the optimum temperature range for germination was 15 to 40 C (Burke et al. 2003).

Effect of Light. Exposure to light or dark had very little effect on the germination of tall morningglory. Under complete dark (24/0 h) conditions, germination was 93%, whereas exposure to continuous light (0/24 h) reduced germination to 88% (Figure 2). Exposure to alternating light and dark conditions increased germination of tall morning glory to > 95%. This suggests that tall morningglory was not sensitive to photoperiod because germination was > 85% in either complete light or dark or in alternating light and dark conditions. Varied germination responses to light have been reported among different weed species. Previous studies have suggested that, among the morningglory species, germination of ivyleaf morningglory was not affected by exposure to light, whereas pitted morningglory was sensitive to light because germination under natural light was lower than under dark conditions (Oliviera and Norsworthy 2006; Singh and Singh 2009). In other weed species, such as licoriceweed, light was required for germination (Jain and Singh 1989), whereas germination of wild oat (*Avena fatua* L.) was inhibited under light (Sharma and Vanden Born 1978).

Effect of Osmotic Potential. A two-parameter exponential decay model [G (%) = 91.94 − 6.45x; r^2 = 0.99) described the germination of tall morningglory under various levels of water stress (Figure 3). Germination decreased as osmotic potential decreased (Figure 3). Germination was very low (< 15%) at an osmotic potential of −0.3 and −0.4 MPa, beyond which, germination did not occur. This suggests that tall morningglory is extremely sensitive to low water potential and that under very dry and extreme water-stress conditions, tall morningglory will not germinate. Morningglory species had varying sensitivity to osmotic stress. Crowley and Buchanan (1978) ranked the sensitivity of morningglory species to osmotic stress from most to least tolerant as follows: ivyleaf > pitted = cotton [*Ipomoea cordatotriloba* var. *torreyana* (Gray) D. Austin] > tall = palmleaf (*Ipomoea wrightii* Gray) > cypressvine (*Ipomoea quamoclit* L.) = smallflower [*Jacquemontia tamnifolia* (L.) Griseb.] morningglories. Reddy and Singh (1992) reported that hairy beggarticks germination decreased linearly with increasing osmotic stress. However, tolerance to extreme water stress has been reported in some weed species. For example, turnipweed [*Rapistrum rugosum* (L.) All.] seed may germinate up to −1.0 MPa (Chauhan et al. 2006b), and Brassicaceae weed species germinated up to an osmotic potential of −1.2 MPa (Ray et al. 2005).

Effect of Salt Stress. A two-parameter exponential decay model [G (%) = 88.19 − 0.012x; r^2 = 0.97) described the relationship between germination of tall morningglory and salt concentration (Figure 4). Germination of tall morningglory occurred over a wide range of salt concentrations. The germination of tall morningglory was < 40% at 50 mM NaCl, whereas at 200 mM NaCl, germination decreased to < 15%. Germination was completely inhibited at 250 mM NaCl. These data suggest that tall morningglory can tolerate

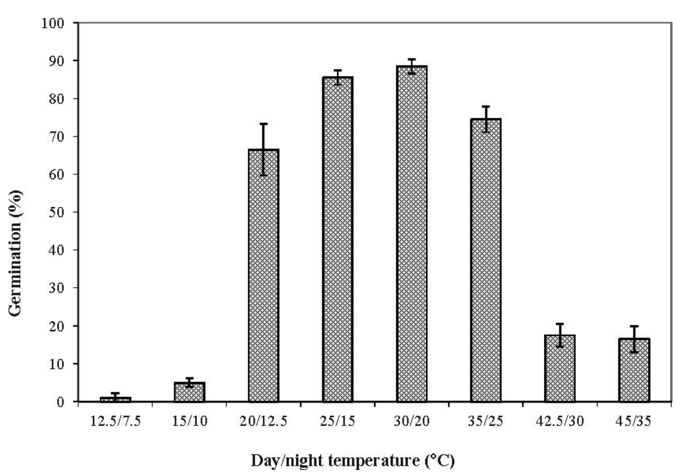

Figure 1. Germination of tall morningglory under varying day/night temperatures.

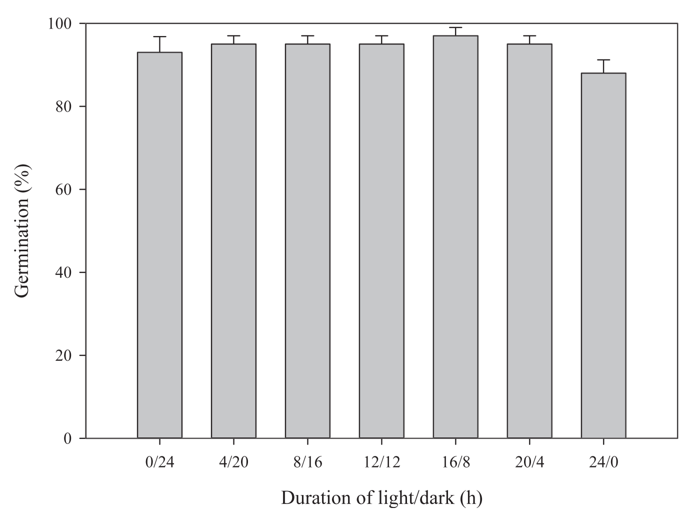

Figure 2. Germination of tall morningglory under different durations of light and dark.

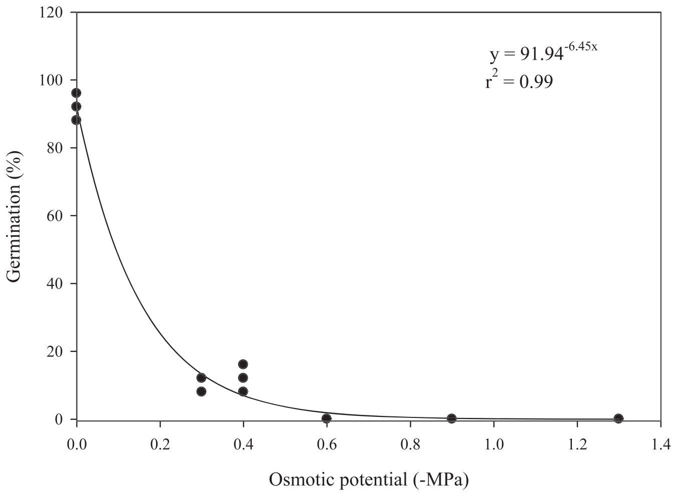

Figure 3. Effect of osmotic stress on the germination of tall morningglory.

some level of salt stress and that a proportion of tall morningglory seed may still germinate even at salinity levels up to 200 mM. This could be an important parameter for successful adaptation in the saline areas (Rengasamy 2002). Other weed species are known to tolerate salt stress during germination. Chauhan et al. (2006c) reported that 7% of annual sowthistle (*Sonchus oleraceus* L.) germinated at a salt concentration of 160 mM, whereas 11% of turnipweed and Brassicaceae seed germinated at a concentration of 160 mM (Chauhan et al. 2006b).

Effect of pH. Maximum germination (75%) was observed at pH 6, whereas 31% germination was observed at pH 5 (Figure 5). At pH 7, 8, and 9, the germination of tall morningglory was minimal (12%), and there was no germination at pH 4. In contrast, Oliviera and Norsworthy (2006) reported that pitted morningglory germination was observed at pH 3, with optimal germination from pH 6 to 8. Other morningglory species, such as smallflower morningglory, were able to germinate at high pH, with maximum germination occurring at pH 8 (Shaw et al. 1987). These results suggest that seeds of tall morningglory cannot survive in very acidic conditions and that a pH above 7 was not favorable for tall morningglory germination. This indicates a narrow range of pH for optimum tall morningglory germination.

Effect of Depth of Sowing. Emergence of tall morningglory decreased with an increase in seeding depth. At 7 d after sowing (DAS), there was higher emergence (83 and 94%) at 0 and 2 cm depth (Figure 6). The germination of tall morningglory decreased significantly when seeds were sown deeper than 4 cm, and at 10 cm, germination was further reduced to 50%. Germination beyond 7 DAS was limited to 8 and 3% germination at a 10-cm depth 14 DAS and at 0.5 cm depth 21 DAS, respectively (data not shown). These results were similar to the results obtained by Cole (1976) and Wilson and Cole (1966). Both studies reported that tall morningglory emergence was delayed and reduced as planting depths increased from 1.3 to 5.0 cm. Reduced seedling emergence with increasing seeding depth has also been reported in other morningglory species and several weed species (Benvenuti et al. 2001; Chauhan 2006a; Gomes et al. 1978). These results indicate that, although emergence was reduced at deeper seed burial, a significant amount of seeds (50%) could still emerge, suggesting that burying seeds through tillage to reduce tall morningglory density may not significantly improve control of this species.

Effect of Flooding Duration. Flooding drastically reduced and delayed the emergence of tall morningglory, and 4 d of flooding limited and delayed germination to 2 and 6% at 28 and 35 d after flooding, respectively. Under normal (no flooding) conditions, emergence was > 85% (data not shown). No seedling emergence was observed in any other treatments at any other observation period. This indicated that tall morningglory was sensitive to flooding and may not be able to persist in flooded areas for long periods. Emergence of other morningglory species, such as palmleaf morningglory and pitted morningglory, was also inhibited at flooding depths of 1 cm (Gealy 1998). Other weed species, such as Virginia buttonweed (*Diodia virginiana* L.) and stranglervine [*Morrenia odorata* (Hook. & Arn.) Lindl.], were not affected by flooding (Baird and Dickens 1991; Singh and Achhireddy 1984).

Results of this study indicate that tall morningglory can germinate under a wide range of temperatures and salt

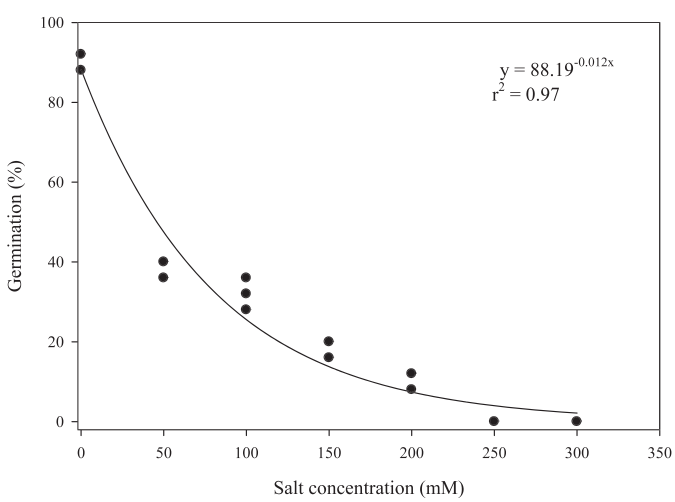

Figure 4. Effect of salt stress on the germination of tall morningglory.

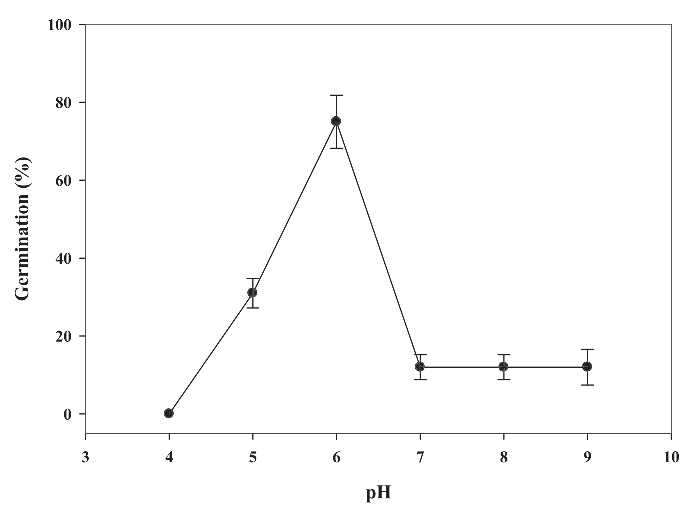

Figure 5. Germination of tall morningglory under different pH levels.

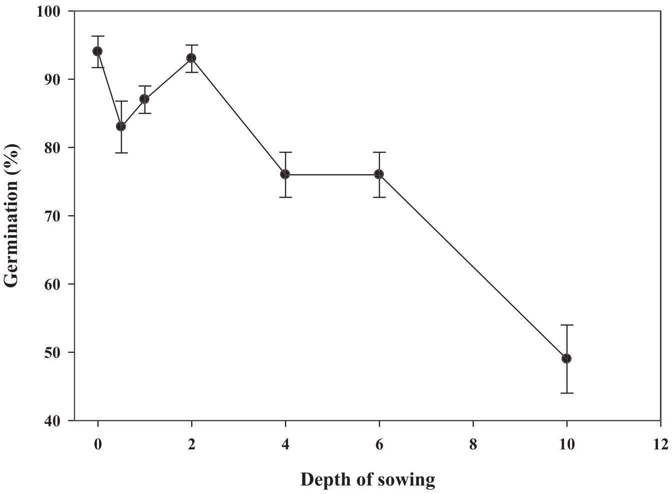

Figure 6. Effect of depth of sowing on the germination of tall morningglory 7 d after sowing.

concentrations. Germination was not affected by light. However, germination was significantly reduced when seeds were buried beyond 2 cm depth, at soil pH levels < 4 and > 7, and under water-stressed conditions (low water and prolonged flooding). These results suggest that tall morningglory can establish well under Florida conditions, which are characterized by humid and warm temperatures throughout the year, sufficient moisture, and drained, slightly acidic soil conditions.

Literature Cited

Baird, J. H. and R. Dickens. 1991. Germination and emergence of Virginia buttonweed (*Diodia virginiana*). Weed Sci. 39:37–41.

Balyan, R. S. and V. M. Bhan. 1986. Germination of horse purslane (*Trianthema portulacastrum*) in relation to temperature, storage conditions, and seedling depths. Weed Sci. 34:513–515.

Benvenuti, S., M. Macchia, and S. Miele. 2001. Quantitative analysis of emergence of seedlings from buried weed seeds with increasing soil depth. Weed Sci. 49:528–535.

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

Biswas, P. K., P. D. Bell, J. L. Crayton, and K. B. Paul. 1975. Germination behavior of Florida pusley seeds, I: effect of storage, light, temperature, and planting depths on germination. Weed Sci. 23:400–403.

Bryson, C. T. and M. S. DeFelice, eds. 2009. Weeds of the South. Athens, GA: University of Georgia Press. 175 p.

Bryson, C. T. and M. S. DeFelice, eds. 2010. Weeds of the Midwestern United States and Central Canada. Athens, GA: University of Georgia Press. 195 p.

Buchanan, G. A. and E. R. Burns. 1971. Weed competition in cotton, I: sicklepod and tall morningglory. Weed Sci. 19:576–579.

Burke, I. C., W. E. Thomas, J. F. Spears, and J. H. Wilcut. 2003. Influence of environmental factors on after-ripened crowfootgrass (*Dactyloctenium aegyptium*) seed germination. Weed Sci. 51:342–347.

Cardwell, V. B. 1984. Seed germination and crop production. Pages 53–92 *in* M. B. Teaser, ed. Physiological Basis of Crop Growth and Development. Madison, WI: American Society of Agronomy.

Chauhan, B. S., G. Gill, and C. Preston. 2006a. Seedling recruitment pattern and depth of recruitment of 10 weed species in minimum tillage and no-till seeding systems. Weed Sci. 54:891–897.

Chauhan, B. S., G. Gill, and C. Preston. 2006b. Factors affecting turnipweed (*Rapistrum rugosum*) seed germination in southern Australia. Weed Sci. 54: 1032–1036.

Chauhan, B. S., G. Gill, and C. Preston. 2006c. Factors affecting seed germination of annual sowthistle (*Sonchus oleraceus*) in southern Australia. Weed Sci. 54:854–860.

Cole, A. W. 1976. Tall morningglory response to planting depth. Weed Sci. 24:489–492.

Cole, A. W. and G. E. Coats. 1973. Tall morningglory germination response to herbicides and temperature. Weed Sci. 21:443–446.

Crowley, R. H. and G. A. Buchanan. 1978. Competition of four morningglory (*Ipomoea* spp.) species with cotton (*Gossypium hirsutum*). Weed Sci. 26:484–488.

DeFelice, M. S. 2001. Tall morningglory, *Ipomoea purpurea* (L). Roth—flower or foe? Roth—flower or foe? Weed Technol. 15:601–606.

Elam, S., S. Wright, and L. Banuelos. 2003. Tall annual morningglory control studies in Acala cotton. Pages 58–62 *in* Proceedings of the 55th Annual Conference of California Weed Science Society. Salinas, CA: CWSS.

Elmore, C. D., H. R. Hurst, and D. F. Austin. 1990. Biology and control of morningglories (*Ipomoea* spp.). Rev. Weed Sci. 5:83–114.

Futch, S. H. 2007. Vine Weeds of Florida Citrus. Gainesville, FL: Horticultural Sciences Department, Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida, http://edis.ifas.ufl.edu/pdffiles/HS/ HS31800.pdf. Accessed: June 6, 2011.

Gealy, D. 1998. Differential response of palmleaf morningglory (*Ipomoea wrightii*) and pitted morningglory (*Ipomoea lacunosa*) to flooding. Weed Sci. 46:217–247.

Gomes, L. F., J. M. Chandler, and C. E. Vaughan. 1978. Aspects of germination, emergence and seed production of three *Ipomoea* taxa. Weed Sci. 26:245–248.

Gortner, R. A., Jr. 1949. Outlines of Biochemistry. 3rd ed. New York: J. Wiley. Pp. 82–87.

Jain, R. and M. Singh. 1989. Factors affecting goatweed (*Scoparia dulcis*) seed germination. Weed Sci. 37:766–770.

Johnson, R. J. 1971. Effect of weed competition on sunflower. Weed Sci. 19:378–380.

Mennan, H. and M. Ngouajio. 2006. Seasonal cycles in germination and seedling emergence of summer and winter populations of catchweed bedstraw (*Galium aparine*) and wild mustard (*Brassica kaber*). Weed Sci. 54:114–120.

Michel, B. E. 1983. Evaluation of the water potentials of solutions of polyethylene glycol 8000 both in the absence and presence of other solutes. Plant Physiol. 72:66–70.

Oliver, L. R., E. R. Frans, and R. E. Talbert. 1976. Field competition between tall morningglory and soybean. Weed Sci. 24:482–488.

Oliviera, M. J. and J. K. Norsworthy. 2006. Pitted morningglory (*Ipomoea lacunosa*) germination and emergence as affected by environmental factors and seeding depth. Weed Sci. 54:910–916.

Patterson, D. T. 1990. Effects of day and night temperature on vegetative growth of Texas panicum (*Panicum texanum*). Weed Sci. 38:365–373.

Ray, J., R. Creamer, J. Schroeder, and L. Murray. 2005. Moisture and temperature requirements for London rocket (*Sisymbrium irio*) emergence. Weed Sci. 53:187–192.

Reddy, K. N. and M. Singh. 1992. Germination and emergence of hairy beggarticks (*Bidens pilosa*). Weed Sci. 40:195–199.

Rengasamy, P. 2002. Transient salinity and sub soil constraints to dryland farming in Australian sodic soils: a review. Aust. J. Exp. Agric. 42:351–361.

Sharma, M. P. and W. H. Vanden Born. 1978. The biology of Canadian weeds, 27: *Avena fatua* L. Can. J. Plant. Sci. 58:141–157.

Shaw, D. R., R. E. Mack, and C. A. Smith. 1991. Redvine (*Brunnichia ovata*) germination and emergence. Weed Sci. 39:33–36.

Shaw, D. R., H. R. Smith, A. W. Cole, and C. E. Snipes. 1987. Influence of environmental factors on smallflower morningglory (*Jacquemontia tamnifolia*) germination and growth. Weeds Sci. 35:519–523.

Singh, M. and N. R. Achhireddy. 1984. Germination ecology of milkweedvine (*Morrenia odorata*). Weed Sci. 32:781–785.

Singh, S. and M. Singh. 2009. Effect of temperature, light and pH on germination of twelve weed species. Indian J. Weed Sci. 41:113–126.

Steel, R.G.D. and J. H. Torrie. 1960. Principles and Procedures of Statistics. New York: McGraw-Hill. 158 p.

Taylorson, R. B. 1987. Environmental and chemical manipulation of weed seed dormancy. Rev. Weed Sci. 3:135–154.

[USDA] U.S. Department of Agriculture. 2011. PLANTS database. http://plants.usda.gov/java/profile?symbol=IPPU2. Accessed: May 31, 2011.

Uva, R. H., J. C. Neal, and J. M. DiTomaso. 1997. Identification of weeds. Pages 214–216 *in* Weeds of the Northeast. Ithaca, NY: Cornell University Press.

Wilson, H. P. and A. W. Cole. 1966. Morningglory competition in soybeans. Weeds 14:49–51.

Young, J. A., R. A. Evans, B. Roundy, and G. Cluff. 1983. Moisture Stress and Seed Germination. Oakland, CA: U.S. Department of Agriculture–Agricultural Research Service Report ARM-W-36.

Received June 27, 2011, and approved August 31, 2011.