Weed Science 2012 60:374–378

Germination and Emergence Characteristics of Common Beggar's-Tick (*Bidens alba*)

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Common beggar's-tick is an annual weed commonly found in citrus groves in Florida. A series of laboratory and greenhouse experiments were conducted to determine the germination response of common beggar's-tick to various environmental factors that influence seed survival, germination, and dormancy. The results suggest that common beggar's-tick germinated over a wide range of temperatures (15 to 40 C) and in both alternating light and dark and dark conditions. New seeds (collected in 2010) germinated better than the old seeds (collected in 2007) at 15/10 C; however, at temperatures above 35 C, the old seeds germinated better. The highest germination was 95% at 25 to 30 C with old seeds compared to 78 to 86% at 20 to 30 C with new seeds. Germination of common beggar's-tick was inhibited at osmotic potential above −0.6 MPa and salt concentrations of 320 mM. Highest germination in common beggar's-tick was found under neutral conditions (pH 7); germination decreased sharply under increasing acidity and alkalinity. Emergence decreased as depth of sowing increased, with greatest germination (89 to 91%) occurring when sown at the surface (0 cm) regardless of seed age. No germination was observed when seeds were buried at 10 cm. Results of this study suggest that favorable temperature and soil pH, and adequate moisture in Florida ensures the germination and continued presence of common beggar's-tick.

Nomenclature: Common beggar's-tick, *Bidens alba* (L.) D.C.
Key words: Depth of sowing, light, osmotic potential, pH, salt stress, seed age, temperature.

Common beggar's-tick [*Bidens alba* (L.) D.C.] is an annual or short-lived perennial weed commonly found in railroads, disturbed areas, and farmlands such as citrus orchards. It is a native of North America and belongs to the Asteraceae family (Hall et al. 1991). It can be found throughout the southeastern part of the United States (U. S. Department of Agriculture–Natural Resources Conservation Service 2011). Typically, emergence starts in April, flowers in summer months, and seeds are dispersed by fall. A common beggar's-tick plant produces an average of 1,205 seeds that germinate readily and can stay viable for 3 to 5 yr. Seeds of common beggar's-tick are easily dispersed by wind and water but more commonly by humans and animals due to its barbed spines that stick to clothing and animal hair or fur (Futch and Hall 2003; Hall et al 1991).

Common beggar's-tick, also commonly referred to as Spanishneedles, is a very competitive weed and is able to reduce the growth of newly established citrus trees by 10% at a density of 20 plants m^{-2} (Buker 2005). If left uncontrolled, common beggar's-tick occurs in dense monocultures making it very competitive especially with younger nonbearing citrus trees and may interfere with grove operations. Although it can be controlled by broadleaf herbicides such as 2,4-D, dicamba, glyphosate, and triclopyr, its ability to rapidly reestablish from seeds coupled with high seed production assures its year round presence in citrus groves (Hall et al. 1991).

Following repeated and extensive use of glyphosate over several years in citrus groves, growers have expressed concerns on the reduced control of several weeds including common beggar's-tick with the recommended label rate of glyphosate. Currently, efforts are underway to determine if glyphosate resistant biotypes of common beggar's-tick occur in Florida. If such biotypes of common beggar's-tick are confirmed to occur, information on the germination biology of this weed is needed to develop better weed control recommendations and predict possible spread of this weed to other areas. So far, no study has explored the impact of various environmental factors on the germination and emergence of common beggar's-tick. Therefore, this study aimed to determine the effects of various factors such as seed age, temperature, light, osmotic potential, pH, and salt concentration on germination and the effect of seed age and depth of sowing on the emergence of common beggar's-tick.

Materials and Methods

Seed Source and Preparation. Seeds of common beggar's-tick were collected in 2010 (new seeds) from a citrus grove at Lake Alfred, FL. After collection, seeds were cleaned, dried at room temperature, and stored at 5 C until initiation of the experiments. Additionally, seeds collected in 2007 (old seeds) from a citrus grove at Fellsmere, FL, were used in the studies on the effect of seed age, light, temperature, and depth of sowing. These seeds were stored at 5 C since their collection in 2007 and prior to initiation of all experiments.

Laboratory and greenhouse experiments were conducted at the Citrus Research and Education Center, University of Florida at Lake Alfred, FL. Initial germination test indicated 97 and 90% germination for new and old seeds, respectively (data not shown). Prior to the initiation of the study, old and new seeds were surface sterilized in 0.5% sodium hypochlorite solution for 10 min, and were rinsed with running tap water for 5 min. Seeds were air dried at room temperature for 7 d and stored at 5 C.

General Procedure for Germination. Twenty-five seeds of common beggar's-tick were sown on 9-cm Petri dishes lined with filter paper (Whatman #4 filter paper, International Ltd., Maidstone, England) and 7 ml of distilled water or other germination solution was added to the Petri dishes. Petri dishes were sealed with Parafilm (American National Company, Greenwich, CT 06836) to prevent desiccation during incubation and were kept for 7 d in a germination

DOI: 10.1614/WS-D-11-00167.1
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chamber with day/night temperature of 25/20 C and 12-h photoperiod, except in the study on the effect of seed age, light, and temperature. After 7 d, the number of seeds that germinated was counted. Seeds were considered as germinated if at least 1 mm of the radicle was visible. In all studies, treatments were replicated four times and were laid out in a randomized complete block. All experiments were repeated.

Effect of Seed Age, Light, and Temperature. Seeds collected in 2010 and 2007 were used in this study. Light regimes consisted of alternating light and dark (12-h interval) and complete dark. Petri dishes were covered with two layers of aluminum foil to create the dark condition. Day/night temperatures used were 15/10, 20/15, 25/20, 30/25, 35/30, 40/35, and 45/40 C.

Effect of Osmotic Stress. Solutions with osmotic potentials of 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 8000 (Polyethylene glycol 8000, Fischer Scientific, Fair Lawn, NJ 07410) in 1 L of deionized water (Michel 1983; Shaw et al. 1991). These solutions were used as germination media.

Effect of Salt Stress. Solutions of 0, 10, 20, 40, 80, 160, and 320 mM NaCl (Sodium chloride, Fischer Scientific) were prepared according to Michel (1983) and were used as germination media.

Effect of pH. Different buffer solutions were prepared according to the method described by Gortner (1949) and Shaw et al. (1987) and used as germination media. Buffer solutions with pH 3, 4, 5, and 6 were prepared using 0.1 M potassium hydrogen phthalate (Fischer Scientific) while solutions of pH 7, 8, and 9 were prepared using 25 mM sodium borate (Fischer Science Education, 4500 Turnberry Dr., Hanover Park, IL 60133) solution.

Effect of Seed Age and Depth of Sowing. Seeds (old and new) were sown in a 17.5 by 9 cm Styrofoam cups (Master containers, Mulberry, FL) filled with Candler fine soil. Depths of sowing used in the study were 0 (sown on the surface), 1, 2, 4, 6, and 10 cm. The sand was sieved for other debris and moistened before the seeds were sown to facilitate easy wetting of soil. The experiment was conducted under greenhouse conditions. Day/night temperatures were set at 25 ± 5 C/20 ± 5 C. Styrofoam cups were initially subirrigated to field capacity and were then surface irrigated daily to maintain adequate soil moisture. Germinated seedlings were counted at 7 and 14 d after planting. Seedlings were considered emerged when the two cotyledons could be visually discerned and were removed after weekly counts.

Statistical Analysis. Data on percent germination were tested for homogeneity of variances. Data on percent germination were arcsine square root transformed to correct for variance homogeneity and subjected to ANOVA using the mixed procedure in SAS (SAS version 9.3, SAS Institute, Cary, NC) where experimental repeats were considered as random effects and the various treatments were considered as fixed effects. Treatment means were separated using Least Square Means (LSMEANS) at 5% level of significance. Untransformed data were presented with mean separation based on the transformed data.

Percent germination values at different osmotic potentials or salt concentrations were fitted to a functional three-parameter logistic model using SigmaPlot (SigmaPlot version 10.0, Systat Software Inc., 1735 Technology Drive, Suite 430 San Jose, CA 95110). The model fitted was:

$$G(\%) = G_{\max}/(1 + [X/X_{50}]^{Grate}) \quad [1]$$

Where G represents total germination (%) at osmotic potential or salt concentration x, G_{max} is the maximum germination (%), and G_{rate} is the slope.

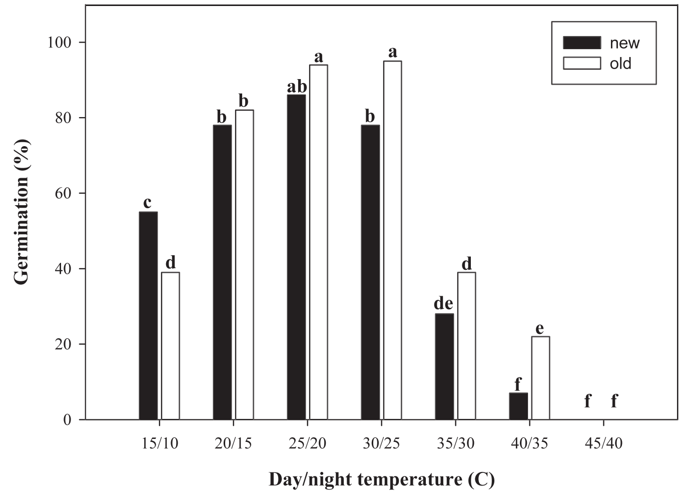

Figure 1. Effect of seed age and temperature on germination of common beggar's-tick. Bars within a temperature regime followed by the same letter(s) are not significantly different at α = 0.05.

Results and Discussion

Effect of Seed Age, Light, and Temperature. The analysis of variance revealed that there was no significant three-way interaction among seed age, light, and temperature (data not shown). Germination of common beggar's-tick was influenced significantly by the interactions of seed age and temperature (Figure 1), and light and temperature (Figure 2). Germination of old and new seeds of common beggar's-tick occurred at a wide range of temperatures regardless of light conditions (Figure 1). Optimum temperature for germination of old and new seed was between 25 and 30 C and between 20 and 30, respectively. Germination of both seeds was < 60% at temperature below 20 C and above 30 C. New seeds germinated better than the old seeds at 15/10 C, while at temperatures at or above 35 C the old seeds germinated better than the new seeds. The highest germination (95%) was observed at 25 to 30 C for old seeds while for new seeds, highest germination (78 to 86%) occurred at 20 to 30 C. Varied germination response to temperature and seed age was also observed in barnyardgrass [*Echinochloa crus-galli* (L.) Beauv.]. Martinkova et al. (2006) reported that older barnyardgrass seeds required a lower temperature for germination than newly harvested seeds.

These results suggest that under cooler conditions during early spring months, newly added seeds in the seed bank have slightly higher germination than seeds that have been in the

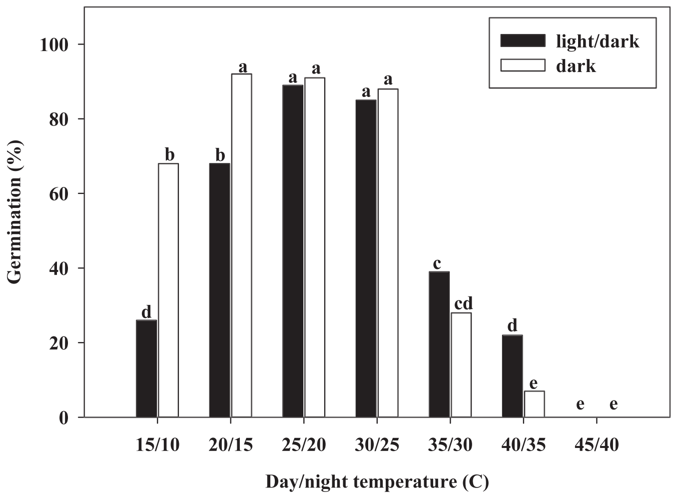

Figure 2. Germination response of common beggar's-tick to varying light and temperature regimes. Bars followed by the same letter within a temperature regime are not significantly different at $\alpha = 0.05$.

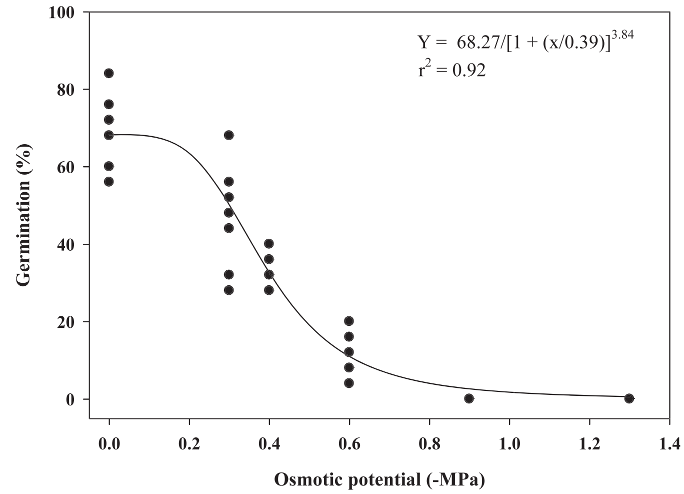

Figure 3. Germination of common beggar's-tick under varying levels of osmotic stress.

seed bank for a longer time. The optimum temperature for germination of both old and new seeds coincide with the typical temperature during spring and summer months in Florida as well as in the southern United States indicating that common beggar's-tick can germinate throughout the year in Florida.

Germination of common beggar's-tick was influenced greatly by light and temperature (Figure 2). Regardless of seed age, seeds exposed to dark condition had higher germination than seeds exposed to alternating light and dark at 15/10 and 20/15 C. At 25 to 35 C, germination of seeds incubated in the dark was similar with those incubated in alternating light and dark. However, at temperatures above 35 C, germination of seeds incubated in alternating light and dark was higher than those incubated in the dark. Optimum temperature for germination of seeds incubated in the dark occurred between 20 and 30 C, while optimum temperature for germination under alternating light and dark conditions was 25 to 30 C. Germination was $<$ 50% at temperatures below 20 C for seeds incubated in alternating light and dark and at temperatures above 30/25 C under both light regimes. The highest germination was 88 to 92% for seeds incubated in the dark while for seeds incubated in alternating light and dark condition, the highest germination was 85 to 88%. These results indicate that common beggar's-tick is not sensitive to light since germination occurred at both alternating light and dark and dark conditions and at cooler temperatures germination in the dark is favored.

Plants of the genus *Bidens* exhibited varying germination responses to light. Seeds of bur beggar's-tick (*B. tripartite* L.) and smooth beggartick [*B. laevis* (L.) B. S. P.] do not germinate in the dark (Benvenuti and Macchia 1997; Leck et al. 1994), while hairy beggar's-tick (*B. pilosa* L.) was reported to germinate under dark conditions in East Africa (Fenner 1980) or in both 12-h photoperiod and dark conditions in Florida (Reddy and Singh 1992). Furthermore, optimum temperature for germination of hairy beggar's-tick was between 25 and 35 C under 12-h photoperiod (Reddy and Singh 1992).

Effect of Osmotic Stress. A functional three-parameter logistic model described the relationship of common beggar's-tick germination and osmotic stress (Figure 3). The equation was $G = 68.27/(1 + [x/0.39])^{3.84}$ ($r^2 = 0.92$). The osmotic concentration that can cause 50% germination was -0.30 MPa. Germination of common beggar's-tick decreased as osmotic potential of the germinating medium increases such that no germination occurred at osmotic potential beyond -0.6 MPa. Germination was reduced from 68% at 0 MPa (water) to 50, 33, and 12% as osmotic potential was increased from 0 to -0.3, -0.4, and -0.6 MPa, respectively. This indicates that under severe water stress, germination of common beggar's-tick will be inhibited. Sensitivity to water stress has also been reported in many weed species. Reddy and Singh (1992) reported that germination of hairy beggar's-tick decreased linearly with increasing osmotic potential such that at -0.75 MPa, germination was reduced to 3%. Similarly, other weed species such as licoriceweed (*Scoparia dulcis* L.) (Jain and Singh 1989), stranglervine [*Morrenia odorata* (Hook. & Arn.) Lindl.] (Singh and Achhireddy 1984), dogfennel [*E. capillifolium* (Lam.) Small] and yankeeweed (*Eupatorium compositifolium* Walt.) (MacDonald et al. 1992) showed varying sensitivity to water stress.

Effect of Salt Stress. A functional three-parameter logistic model described the impact of salt concentration on germination of common beggar's-tick (Figure 4). The equation that best described this relationship was G (%) = 66.63/(1 + [x/91.64])$^{2.53}$ ($r^2 = 0.91$). The salt concentration that would cause 50% germination was calculated to be 64 mM. Germination of common beggar's-tick occurred over a wide range of salt concentrations (10 to 160 mM NaCl) suggesting that common beggar's-tick could tolerate some level of salinity. At 10 mM NaCl, germination of common beggar's-ticks was similar to germination under no salt stress. Increasing the salt concentration resulted to a steady decline in germination such that at 320 mM NaCl germination was completely inhibited. Similarly, germination of hairy beggar's-tick (Reddy and Singh 1992) and tall morningglory [*Ipomoea purpurea* (L.) Roth] (Singh et al. 2011) were also inhibited at salt concentrations $\geq$ 200 mM; however, a small proportion of seeds still germinated at salt concentrations $\geq$ 100 mM.

Effect of pH. Germination of common beggar's-tick was greatly impacted by pH of the germination solution

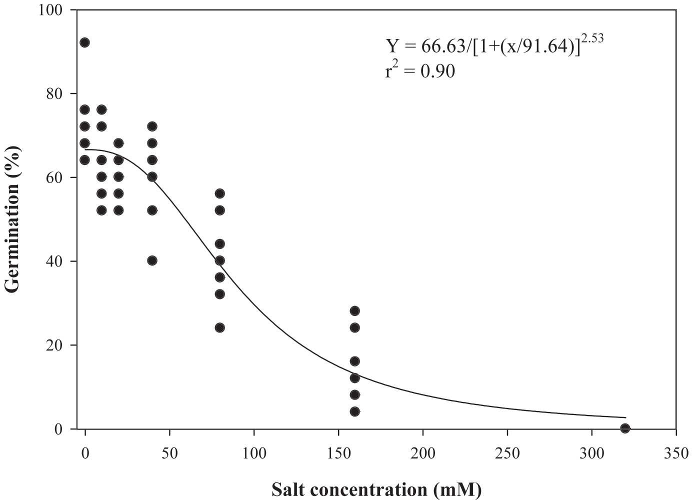

Figure 4. Germination of common beggar's-tick under varying salt concentrations.

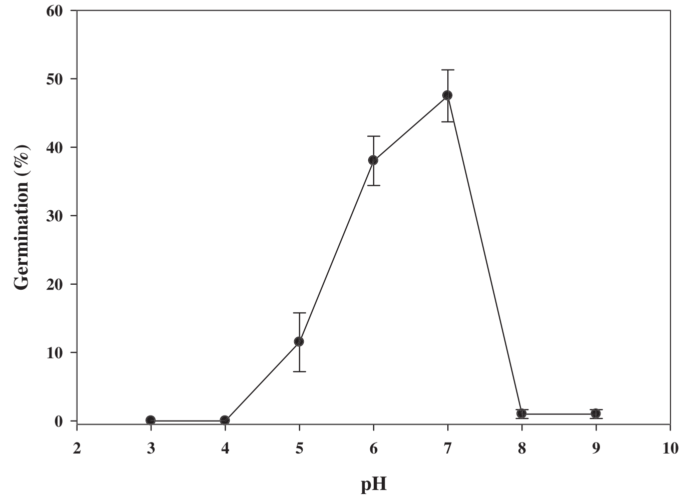

Figure 6. Seedling emergence of new and old seeds of common beggar's-tick sown at 14 dafter sowing and at varying depths. Vertical bars represent standard error of the mean.

(Figure 5). Germination was observed from pH 5 to 7, with highest germination at pH 7. Germination was inhibited in very acidic and slightly alkaline conditions since no germination was observed at pH ≤ 5 and ≥ 8. Contrary to this, other weeds species such as hairy beggar's-tick and licoriceweed were able to germinate under a wide range of pH (pH 4 to 10) (Jain and Singh 1989; Reddy and Singh 1992). On the other hand, seeds of wild bushbean [*Macroptilium lathyroides* (L.) Urb.] did not germinate at any pH from 4 to 9 (Adkins et al. 1985; Singh and Sharma 2001). These results indicate that common beggar's-tick seeds germinate at pH common to soils used for agricultural production and could also explain why common beggar's-tick is widely distributed in Florida since pH of typical Florida soil range from 5 to 6 (Shober et al. 2008).

Effect of Seed Age and Depth of Sowing. Seedling emergence of common beggar's-tick varied by the seed age and depth of sowing and occurred over a wide range of depths (0 to 6 cm). Highest seedling emergence (89 to 91%) was observed when seeds were sown at the surface regardless of the seed age (Figure 6). Emergence of common beggar's-tick decreased as depth of seeding increased. For old seeds, sowing at 2 cm significantly reduced seedling emergence to 79%, and at 10 cm depth seedling emergence was completely inhibited. The same trend was observed for newly harvested seeds; however, there was an abrupt decline in emergence (from 85 to 60%) when seeds were sown at 1 cm. A small proportion (< 1%) of seedlings from the newly harvested seeds was able to emerge at 10 cm. A similar response to depth of sowing has been reported in small seeded Oriental mustard (*Sisymbrium orientale* Torn.); at a depth of 2.5 mm seedling emergence was greatly reduced, and at 10 mm no seedling emergence was observed (Chauhan et al. 2006). Other weed species commonly found in Florida such as Florida pusley (*Richardia scabra* L.) (Biswas et al. 1975), dogfennel, yankeeweed (MacDonald et al. 1992), and strangler vine (Singh and Achhireddy 1984) exhibited the same response to depth of sowing as common beggar's-tick. Highest germination for these species was observed when seeds were sown on the surface or up to a depth of 2 cm. The results of this study suggest that when seeds of common beggar's-tick were buried deeper than 2 cm, establishment of this weed could be minimized since emergence at 6 cm was < 20%. Plowing seeds under 2 cm can be used to manage common beggar's-tick.

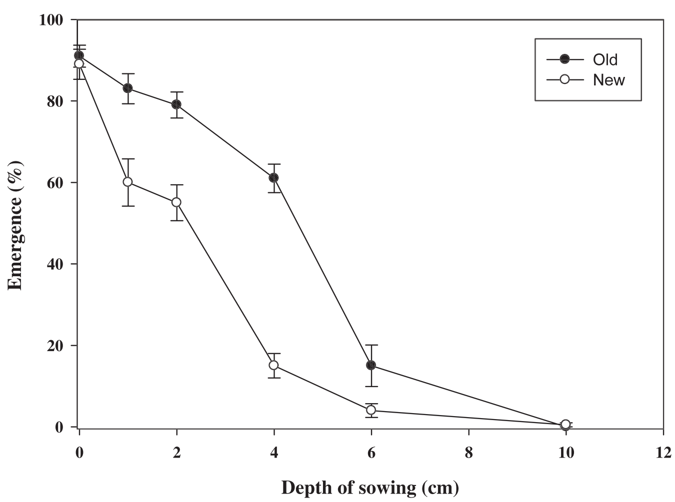

Figure 5. Germination of common beggar's-tick under varying levels of pH. Vertical bars represent standard error of the mean.

Overall, the results of this study indicate that germination of common beggar's-tick can occur at a wide range of temperatures, pH, and salt concentrations. Germination is inhibited at highly acidic and moderately alkaline soils and extreme water stress. Cultivation could be an additional method in preventing common beggar's-tick from establishing since seedling emergence was reduced significantly when seeds were buried at depths greater than 2 cm. The occurrence of a favorable temperature and soil pH and adequate moisture in Florida ensures the germination and continued presence of common beggar's-tick. This information will aid in developing predictive models of seedling emergence of common beggar's-tick in the field and better weed management recommendation for the control of common beggar's-tick in Florida citrus.

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Received October 7, 2011, and approved January 11, 2012.