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Evaluation of Factors That Influence Benghal Dayflower (*Commelina benghalensis*) Seed Germination and Emergence

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A perennial species in its native range of Asia and Africa, Benghal dayflower in North America establishes annually from seed. This species has the unique ability to produce aerial and subterranean flowers and seeds. Information on how various environmental factors affect Benghal dayflower aerial and subterranean seed germination and emergence in the United States is lacking. Studies were conducted to determine the effect of temperature, planting depth, salt concentration, and pre-emergence herbicides on germination or emergence of aerial and subterranean Benghal dayflower seed. Maximum aerial seed germination occurred at 30 C, whereas maximum subterranean seed germination occurred at 30 and 35 C. Germination at 40 C was delayed relative to optimum temperatures. The seed coats in this study were mechanically disrupted to evaluate the response of seeds to temperature in the absence of physical dormancy. The physical dormancy imposed by the seed coat could require additional study. Benghal dayflower was not tolerant to ≥ 10 mM NaCl, indicating that this exotic species is not likely to become problematic in brackish marshes and wetlands of coastal plain regions. There was an inverse linear response of Benghal dayflower emergence and planting depth, with no emergence occurring at a planting depth of 12 cm. A field survey of Benghal dayflower emergence revealed that 42% of plants established from a depth of 1 cm in the soil profile, with 7 cm being the maximum depth from which seedlings plants could emerge. This suggests that PRE herbicides must remain in the relatively shallow depths of the soil profile to maximize control of germinating seedlings. Subterranean seeds were less sensitive than aerial seeds to *S*-metolachlor, the primary means of controlling this species in cotton. There were no differences between the germination of aerial and subterranean seed in response to treatment with diclosulam.

Nomenclature: Diclosulam; *S*-metolachlor; Benghal dayflower, *Commelina benghalensis* L., COMBE; cotton, *Gossypium hirsutum* L.; peanut, *Arachis hypogaea* L.

Key words: Federal noxious weed, emergence, germination, soil depth, temperature, tropical spiderwort, weed seed.

Benghal dayflower, also known as tropical spiderwort, is among the world's worst weeds, infesting 25 crops in 29 countries (Holm et al. 1977). This exotic monocot species is native to Africa and Asia (Wilson 1981) and has tolerance to glyphosate (Culpepper et al. 2004). It has become a troublesome weed of agronomic crops in the southeast Coastal Plain of the United States (Webster 2005, 2009).

The reproductive plasticity of Benghal dayflower contributes to its success in establishing into new areas (Burns 2004, 2006; Kaul et al. 2002; Webster and Grey 2008). An herbaceous perennial in tropical climates, Benghal dayflower grows as an annual in temperate regions, relying on annual establishment from seed (Faden 2000; Holm et al. 1977). Benghal dayflower produces both aerial and subterranean flowers, each with dimorphic seeds (Maheshwari and Maheshwari 1955). Previous studies from around the world have documented the variation in Benghal dayflower seed germination responses to different environments (Ferreira and Reinhardt 1999; Gonzalez and Haddad 1995; Walker and Evenson 1985b), but the response of the Georgia population of Benghal dayflower has not been characterized. Benghal dayflower has a sprawling growth habit that quickly forms a dense ground cover capable of developing adventitious roots at nodes upon soil contact (Webster et al. 2005). Also, cultivation can dissect plants into several parts that are capable of rooting at the nodes (Budd et al. 1979; Chivinge and Kawisi 1989).

Once established, Benghal dayflower can cause significant crop yield losses. For example, season-long Benghal dayflower interference reduced yields of cotton 40 to 60% (Webster et al. 2009) and peanut 51 to 100% (Webster et al. 2007). Using residual herbicides to control Benghal dayflower is important in weed management programs because seeds can continually germinate and emerge throughout the growing season (Prostko et al. 2005). Although many common herbicides are ineffective for controlling Benghal dayflower (Culpepper et al. 2004; Webster et al. 2006), two have been identified as potential components of weed management systems: diclosulam and *S*-metolachlor. Diclosulam, an acetolactate synthesis inhibitor, is registered for PRE and POST control of Benghal dayflower in soybean [*Glycine max* (L.) Merr.] and peanut. *S*-metolachor, a chloroacetamide herbicide that inhibits fatty acid synthesis, provides residual PRE control of Benghal dayflower and small-seeded grass and broadleaf weed species (Culpepper et al. 2004). Optimal application timing of these PRE herbicides should be based on seed emergence patterns of Benghal dayflower. Seed of this tropical species emerges later in the growing season (peak emergence in June and July) relative to most agronomic weeds of the southeast United States, suggesting warmer temperatures might be required for Benghal dayflower establishment as a weed.

Benghal dayflower is an exotic species in the United States (Faden 1993; Krings et al. 2002) and is listed on the Federal Noxious Weed List (USDA–APHIS 2010), but has not been a common or problematic species in natural areas (Kabat 2003). Other invasive weed species with a tolerance to saline soils previously have caused major disruption to natural areas through displacement of native flora (Chambers et al. 1999; Richards et al. 2008). The ability of Benghal dayflower to tolerate saline soil conditions common to marsh and coastal wetland areas is not known. Therefore, studies were conducted to determine how temperature, salinity, and depth

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of seed in the soil profile affect Benghal dayflower seed germination and emergence. Additionally, the influence of *S*-metolachlor and diclosulam rate on germination of aerial and subterranean Benghal dayflower seeds was evaluated.

Materials and Methods

Benghal dayflower plants were collected in summer of 2007 from a cotton field near Cairo, GA (30°59′20″N, 84°16′57″W) from a naturalized population. Plants were transplanted into 30-cm diameter pots filled with Tifton loamy sand (fine-loamy, kaolinitic, thermic Kandiudults) at the University of Georgia in Athens. Greenhouses were maintained with natural light supplemented by metal halide lamps (350 µmol m^{-2} s^{-1} photosynthetic photon flux) with average day/night temperatures of 30/22 C, respectively. Pots were watered daily and fertilized as needed for 3 mo prior, to produce seed necessary for the subsequent studies. Benghal dayflower has an indeterminate reproduction pattern with seed maturing over time. Therefore, prior to seed harvest, the plants were not watered for 2 to 3 wk to force desiccation. Aerial seeds then were hand-harvested from mature pods in the autumn 2007. Subterranean seeds were harvested from the same pots by excavation of the roots, and then mature fruit were removed by hand. All seeds were separated from the capsule by hand and then air-dried for 2 d at 30 C. Seeds were treated with 5% chlorine bleach solutions for 5 min to remove pathogens on the seed coat (Sermons et al. 2008). Benghal dayflower has an impermeable seed coat that restricts germination, but piercing the seed coat alleviates this condition (Budd et al. 1979; Goddard et al. 2009). Therefore, a 0.25-mm-deep incision was made to each seed coat surface by hand, using a razor blade to facilitate moisture uptake and alleviate the physical dormancy constraint.

Studies were conducted to evaluate: (1) the effect of various temperature regimes on Benghal dayflower seed germination for aerial and subterranean seeds, (2) the effect of sodium chloride concentration on germination of aerial seeds, (3) the effect of burial depth of Benghal dayflower seeds on emergence, (4) the influence of soil depth on in situ emergence frequency in the field, and (5) the influence of rates of diclosulam and *S*-metolachlor on Benghal dayflower seed germination. Unless otherwise noted, all experiments used a completely randomized design with treatments replicated five times, and repeated in time.

Variable Temperature. Germination tests were conducted to establish seed response using variable temperatures. Twenty-five aerial or subterranean seeds were placed in a 100 by 15 mm Petri dish (Fisher Scientific International, Inc., Hampton, NH 03842) onto layers of blotter paper (Anchor Paper Company, St. Paul, MN 55101) moistened with 7 ml of deionized water. The effect of constant temperature regimes of 20, 30, 35, and 40 C on aerial and subterranean seed germination was evaluated in growth chambers (Conviron, Pembina ND 58271) with 12/12 hr light/darkness. Seeds were evaluated every 3 d for 39 d. Seeds were considered germinated when the embryo had protruded 3.0 mm from beyond the seed coat; germinated seed were counted and then discarded. Temperature data were converted to growing degree days (GDD), following the suggestion of Forcella (1997). Previous studies on Benghal dayflower indicated no germination occurred at 10 C (Gonzalez and Haddad 1995), with limited germination at 15 C (Walker and Evenson 1985b). Therefore, a base temperature of 15.5 C was selected for calculation of daily GDD for germination, similar to one developed for Benghal dayflower growth (Webster et al. 2009).

Salt Concentration. The effect of salt on Benghal dayflower aerial seed germination was evaluated with sodium chloride (NaCl) (J. T. Baker Chemical Co., Phillipsburg, NJ 08865) solutions of 0, 10, 20, 40, 80, and 160 mM, following previous methodologies (Chauhan et al. 2006; Koger et al. 2004). Twenty aerial seeds were evenly spaced on a Petri dish, and then 7 ml of each NaCl solution was used to moisten the blotter paper. Petri dishes were arranged in a growth chamber with alternating 30/25 C day/night temperatures, with light supplementation as described previously. Germination was evaluated daily for 21 d beginning 5 d after initiation, using previously described criteria.

Depth of Emergence. Surveys of in situ emergence depth were conducted in Grady County, GA in a field with a naturalized population of Benghal dayflower. Depth of Benghal dayflower seed germination in the field was evaluated by sampling 100 established seedlings, marking the soil surface on the stem, excavating down to the seed that was still attached to the seedling, and measuring the soil depth of that seed. Owing to its strength, the seed coat does not rupture during germination. Instead, the seedlings emerge through the micropyle region (Goddard et al. 2009), leaving the seed coat intact, attached to the seedling, and easily recovered. Depth of emergence was surveyed May 23, June 21, August 11, 2006 and June 4 and June 25, 2007.

In greenhouse studies, the effect of planting depth was evaluated on Benghal dayflower aerial seed. Foam cups (250 ml) were filled with soil (Cecil sandy loam, fine Kaolinitic, thermic typic Kanhaplidults) obtained from the Plant Science Research Farm in Oconee County, GA with an organic matter content of 1% and pH of 5.6. Ten seeds were planted separately in foam cups to depths of 0 (soil surface), 1, 2, 4, 6, 9, and 12 cm. Soils were surface-irrigated to maintain adequate moisture and placed in a greenhouse with temperatures ranging from 30 to 40 C under natural photoperiod (13.5 hr average of daylight during time of study). Establishment of Benghal dayflower was considered successful when the cotyledon emerged from the soil surface.

Herbicide Dose Response. The effects of diclosulam and *S*-metolachlor on germination were evaluated in growth chamber experiments as previously described. Aerial and subterranean seeds were evaluated with *S*-metolachlor concentrations of 0, 5, 10, 100, and 1,000 parts per million (ppm) and diclosulam concentrations of 0, 1, 10, 100, and 500 ppm; all were mixed with deionized water. Herbicide solutions were used to moisten the filter paper. Germination was evaluated as previously described. The experiment was a completely randomized design with four replications and was repeated in time.

Statistical Analysis. Cumulative germination data for all experiments were subjected to analysis of variance using the GLMX procedure of SAS (SAS Institute 1999). Repetitions of the studies were regarded as random factors whereas aerial and subterranean seed, salt concentrations, temperature regimes, and herbicide concentrations were considered fixed effects. Regression models were fit to Benghal dayflower germination/

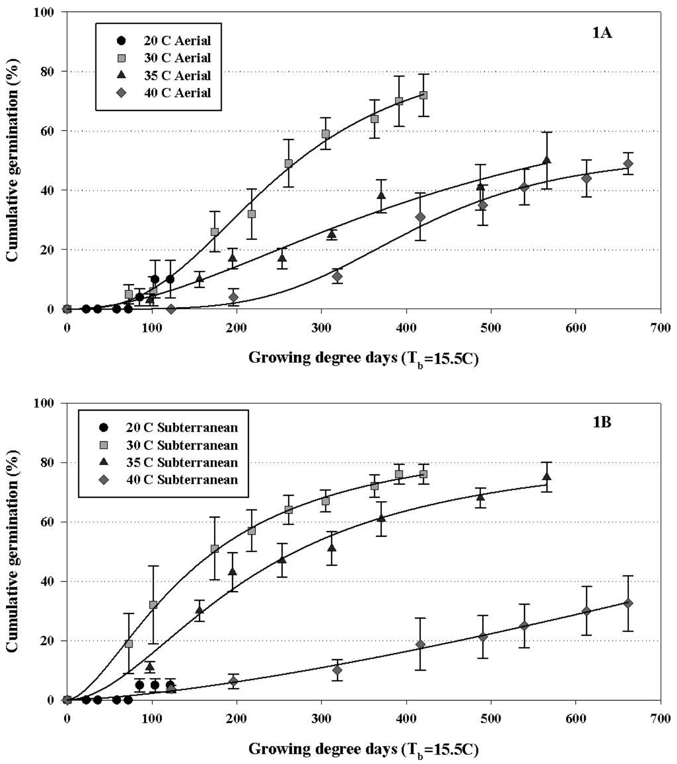

Figure 1. Germination of Benghal dayflower aerial seed (a) and subterranean seed (b) under variable temperature regimes with standard errors bars and logistic sigmoidal regression fit to the data.

$$30\text{ C Aerial seed: } y = \frac{89.7}{1+\left(\frac{x}{250.5}\right)^{-2.75}},\ r^2 = 0.77,\ \mathrm{P} < 0.0001$$

$$35\text{ C Aerial seed: } y = \frac{79.0}{1+\left(\frac{x}{437.1}\right)^{-1.92}},\ r^2 = 0.68,\ \mathrm{P} < 0.0001$$

$$40\text{ C Aerial seed: } y = \frac{52.9}{1+\left(\frac{x}{407.0}\right)^{-4.43}},\ r^2 = 0.75,\ \mathrm{P} < 0.0001$$

$$30\text{ C Subterranean seed: } y = \frac{90.1}{1+\left(\frac{x}{152.0}\right)^{-1.65}},\ r^2 = 0.81,\ \mathrm{P} < 0.0001$$

$$35\text{ C Subterranean seed: } y = \frac{85.5}{1+\left(\frac{x}{224.2}\right)^{-1.85}},\ r^2 = 0.89,\ \mathrm{P} < 0.0001$$

$$40\text{ C Subterranean seed: } y = \frac{694.3}{1+\left(\frac{x}{5325.5}\right)^{-1.44}},\ r^2 = 0.57,\ \mathrm{P} = 0.0001$$

emergence data as a function of: GDD (sigmoidal regression models), depth of emergence (linear regression), salt concentration (hyperbolic decay model), and field depth of emergence (hyperbolic decay). Cumulative germination data, expressed as a percentage of the nontreated control, were regressed against the $\log_{10}$ rates of *S*-metolachlor and diclosulam (Seefeldt et al. 1995). Regression models were selected based on the minimum root mean square (Mayer and Butler 1993; Schutte et al. 2008).

Results and Discussion

Temperature Response. There were sigmoidal relationships between cumulative germination and thermal time ($r^2 = 0.57$ to 0.89, $\mathrm{P} < 0.0001$) for aerial and subterranean seeds (Figure 1). Aerial and subterranean seeds at 20 C accumulated 122 GDD during the study and had a maximum of 5% germination (Figure 1). Greatest germination occurred in response to the 30 C treatment. Seeds in the 30 C treatment accumulated 420 GDD during the study and had 72 and 77% germination for aerial and subterranean seeds, respectively. Subterranean seeds at 35 C had high levels of germination (maximum germination of 82%), whereas the aerial seeds (which are smaller) were not as responsive (maximum germination of 50%). In spite of greater accumulation of GDD at the 40 C treatments (662 GDD), Benghal dayflower germination was slower than at lower temperatures and had maximum germination of 33 and 49% for subterranean and aerial seeds, respectively. Previous studies on Benghal dayflower have documented a range of germination responses to temperature at various locations around the world. Walker and Evenson (1985b) reported 55 to 83% germination at 20 C of Benghal dayflower naturalized to Australia, whereas Benghal dayflower seed naturalized to North Carolina did not germinate at 20 C (Sermons et al. 2008). Peak emergence for the Australian Benghal dayflower occurred between 24 and 31 C, with subterranean seeds having a broader optimum temperature range for germination (Walker and Evenson 1985b). In Brazil, maximum germination of aerial Benghal dayflower seeds occurred between 25 and 30 C (Gonzalez and Haddad 1995), whereas a population in North Carolina had maximum emergence between 30 and 35 C (Sermons et al. 2008). A naturalized population in South Africa had optimum germination between 21 and 28 C for subterranean seeds and 18 and 25 C for aerial seeds (Ferreira and Reinhardt 1999).

There is a similar optimum temperature range for germination of Benghal dayflower in Georgia and for other common agronomic weeds of the Southeast Coastal Plain, including Florida pusley (*Richardia scabra* L.), broadleaf signalgrass [*Urochloa platyphylla* (Nash) R.D. Webster], sicklepod [*Senna obtusifolia* (L.) H. S. Irwin & Barneby], coffee senna [*Senna occidentalis* (L.) Link], Florida beggarweed [*Desmodium tortuosum* (Sw.) DC.], smallflower morningglory [*Jacquemontia tamnifolia* (L.) Griseb.], prickly sida (*Sida spinosa* L.), arrowleaf sida (*Sida rhombifolia* L.), and wild poinsettia (*Euphorbia heterophylla* L.) (Biswas et al. 1975; Brecke 1995; Burke et al. 2003; Cardina and Hook 1989; Eastin 1983; Norsworthy and Oliveira 2006; Smith et al. 1992; Webster and Cardina 2004). In spite of the similarity in germination response among Benghal dayflower and these weed species in the laboratory, Benghal dayflower emergence in the field (in situ) typically occurs later in the season than other common weeds, with less than 40% of Benghal dayflower emergence occurring prior to June 1 (Webster et al. 2006, 2009). It is likely that other unknown factors are critical components, along with temperature, in regulating field emergence of Benghal dayflower.

One potential factor regulating emergence might be the physical dormancy of Benghal dayflower enforced by an impermeable seed coat. Previous studies have documented that mechanical, chemical, or heat scarification of the seed coats improved Benghal dayflower germination (Budd et al. 1979; Goddard et al. 2009; Kim et al. 1990; Sermons et al. 2008). In the current study, the integrity of the seed coat was mechanically compromised, so the germination response to temperature does not reflect the in situ response. Instead, this study reflects Benghal dayflower emergence patterns of seed in which the physical dormancy has been relieved. Future research on the dynamics of the Benghal dayflower seed coat could provide a greater understanding of Benghal dayflower seed germination and emergence.

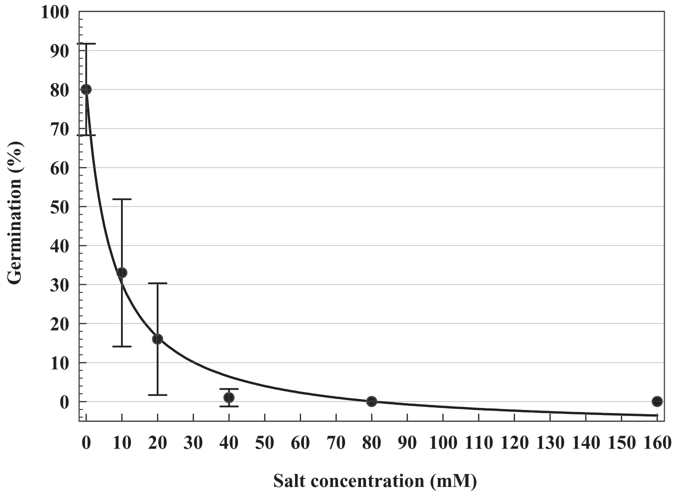

Figure 2. Benghal dayflower aerial seed germination under variable NaCl concentrations with a hyperbolic decay regression fit to the data. Data points are the means of replications with bars indicating the standard error of the mean. $y = -7.5 + \left(\frac{659.3}{7.5+x}\right)$, P < 0.0001.

Salt Treatment. The relationship between Benghal dayflower germination and salt concentration was described by a hyperbolic decay regression model (Figure 2). At the lowest salt concentration tested (10 mM NaCl), Benghal dayflower germination was reduced to 33% (from 80% in the nontreated control), with $<$ 1% germination at 40 mM NaCl and complete inhibition of Benghal dayflower germination at 80 mM. Other weed species common to the southern United States have been found to tolerate high levels of salinity. Texasweed [*Caperonia palustris* (L.) St. Hil.] and rigid ryegrass (*Lolium rigidum* Gaudin) had $>$ 50% germination at 40 mM NaCl and $>$ 25% at 160 mM NaCl (Chauhan et al. 2006; Koger et al. 2004). Eclipta [*Eclipta prostrata* (L.) L.] germination was 83% at 150 mM NaCl and 37% at 200 mM (Chauhan and Johnson 2008). Buffalobur (*Solanum robustum* H. L. Wendl.) had excellent tolerance to salinity with 95 and 52% germination at 40 and 160 mM NaCl, respectively (Wei et al. 2009). A specific biotype of common reed [*Phragmites australis* (Cav.) Trin. ex Steud.] required a salt concentration of 300 mM to reduce growth 50%, allowing this exotic species to invade brackish coastal salt marshes of the United States (Vasquez et al. 2006). By definition, salinity of salt marshes range between 18 and 35 parts per thousand (ppt) (308 to 590 mM), whereas oligohaline and mesohaline marshes have salinity ranges of 0.5 to 5 ppt (8.6 to 86 mM) and 5 to 18 ppt (86 to 308 mM), respectively (Odum 1988). The data from the current study suggest that Benghal dayflower does not pose a major invasion threat to saline soil habitats, such as coastal brackish marshes and wetlands.

Depth of Emergence Studies and Survey. In the greenhouse study, there was an inverse linear relationship between Benghal dayflower emergence and depth of aerial seed placement in the soil (Figure 3). Maximum emergence (71%) occurred with seed at the soil surface, with an approximate 6% reduction in emergence for every 1 cm increase in planting depth. Benghal dayflower failed to emerge from a depth of 12 cm. In Brazil, there was a negative linear relationship between Benghal dayflower emergence and soil depth, with no emergence occurring below 8 cm, using a sand substrate (Dias et al. 2009).

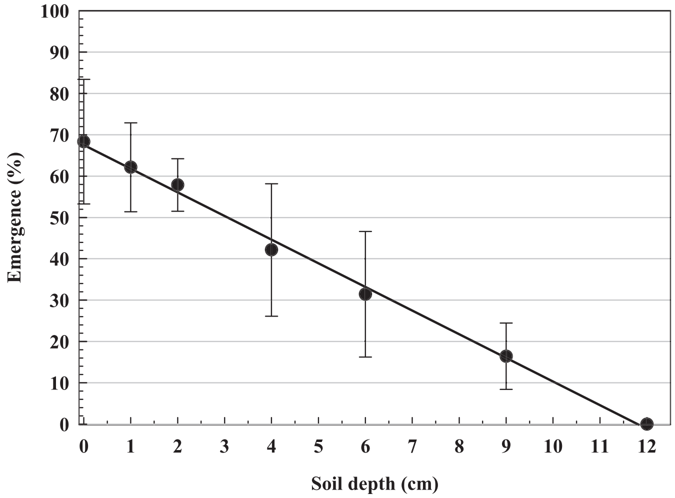

Figure 3. The inverse linear relationship between Benghal dayflower aerial seed germination and planting depth. Data points are the means of replications with bars indicating the standard error of the mean. $y = 67.5 - 5.7x$, $r^2 = 0.80$, P < 0.0001.

In Australia, aerial seed emergence was $\geq$ 35% at 5-cm planting depth, with some seeds capable of emerging from 15 cm from a 1 : 4 mixture of river sand and krasnozem soil (deep, gradational, red clay loam) (Walker and Evenson 1985b). Large aerial seed of Benghal dayflower naturalized to Japan emerged from depth of 5 cm, but not from 10 cm, whereas the small aerial seed failed to emerge from depths greater than 1 cm, using a commercial organic culture soil (Matsuo et al. 2004). Emergence of doveweed [*Murdania nudiflora* (L.) Brenan], a related species of the Commelinaceae family, was noted from depths of 0 to 6 cm with emergence decreasing as seed burial depth increased in a Norfolk loamy sand (Wilson et al. 2006). Based on the data in the current study, seeds buried deep ($>$ 12 cm) in the soil profile will not emerge and establish as weeds, unless the seeds are brought to the surface by tillage. Studies in Florida have found emerged Benghal dayflower population densities to be lower in conventional tillage when compared to reduced tillage systems in a Red bay fine loamy sand (Brecke et al. 2005). Differences among depth-of-emergence studies is due to the various soil types and media utilized; sand soils exhibited Benghal dayflower emergence from the greatest depth (Dias et al. 2009; Walker and Evenson 1985b; Wilson et al. 2006), and an organic-based medium had the shallowest emergence depth (Matsuo et al. 2004).

In the field survey, Benghal dayflower emergence decreased as soil depth increased, with 7 cm as the maximum soil depth from with seedlings emerged (Figure 4). The most-commonly encountered soil depth from which Benghal dayflower emergence occurred was 1 cm (42% of the samples). Emergence from 2 to 4 cm occurred in 10 to 17% of the samples, with less than 6% of the emergence samples occurring at 5 to 7 cm. Based on these data, PRE herbicides, such as the water-soluble *S*-metolachlor, need to remain in a relatively shallow zone to ensure efficacy. Movement of herbicides out of this zone by rainfall or irrigation could compromise successful control.

Herbicide Dose Response. Germination of Benghal dayflower seed was reduced as rate of *S*-metolachlor increased.

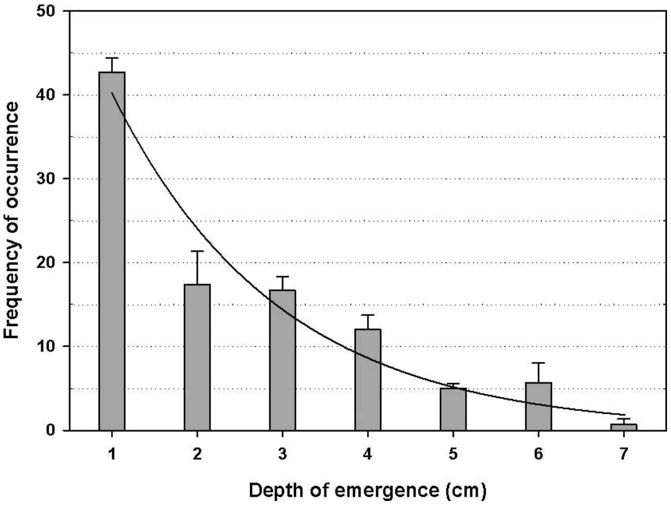

Figure 4. Depth of emergence of Benghal dayflower seedlings sampled in a naturalized field population in Grady County, GA. Data points are the means of five sampling dates with bars indicating the standard error of the mean. $y = 67.2e^{(-0.514x)}$, $r^2 = 0.91$, $P < 0.0001$.

Maximum germination was 65 and 70% for the aerial seed and subterranean seed at 5 ppm of *S*-metolachlor, respectively, and germination was reduced to 10 and 40% at 100 ppm for the aerial and subterranean seed, respectively. Germination of Benghal dayflower seed was inhibited by 1,000 ppm *S*-metolachlor. Aerial seed germination had a greater sensitivity to *S*-metolachlor ($GR_{50} = 58$ ppm) than did subterranean seed ($GR_{50} = 119$ ppm) (Table 1). The difference in response to *S*-metolachlor rate between the seed types might be attributed to seed size; subterranean seeds (3.51 and 8.81 mg $seed^{-1}$ for small and large subterranean seeds, respectively) are 1.8 to 4.6 times larger than aerial seeds (Santos et al. 2001). Weed seed size often is related to *S*-metolachlor efficacy and selectivity. Previous research has indicated that *S*-metolachlor provides PRE control of Benghal dayflower (Culpepper et al. 2004; Webster et al. 2006). The half-life for *S*-metolachlor is relatively short (field half-life $<$ 25 d in southern soils, based on bioassay) compared to other herbicides (Parker et al. 2005; Senseman 2007) with dissipation increasing with warm moist soils, which characterize farms with irrigation in the southeast coastal plain. The differential effect of *S*-metolachlor on subterranean and aerial seeds complicates Benghal dayflower management, but the high ratio of aerial seeds to subterranean seeds (Kim 1998; Walker and Evenson 1985a; Webster and Grey 2008) helps temper the significance of this differential response.

There was no detectable relationship between Benghal dayflower germination and rate of diclosulam for either aerial or subterranean seeds (Table 1). Benghal dayflower germination was 72 and 82% at 1 ppm diclosulam for the aerial and subterranean seed, respectively, whereas germination was 80% for the 500 ppm concentration of diclosulam for both aerial and subterranean seed (data not shown). These data indicate that diclosulam did not prevent germination, supporting previous conclusions that POST application of diclosulam provides better control Benghal dayflower than PRE applications (Flanders and Prostko 2004).

Table 1. Herbicide rate required to reduce germination rate (GR) for aerial and subterranean Benghal dayflower seed by 50% (GR_{50}) for *S*-metolachlor and diclosulam based on regression using log-logistic dose-response curves.

Seed type	*S*-metolachlor GR_{50}	Diclosulam GR_{50}
	ppm	
Aerial	58 a[a]	> 500 NS[b,c]
Subterranean	119 b	> 500 NS

[a] Values followed by the same letter do not differ significantly for Fisher's Protected LSD ≤ 0.05.

[b] Analysis of data indicated a nonfit for log-logistic dose-response model.

[c] Abbreviation: NS, not significant.

In conclusion, Benghal dayflower in North America establishes annually from seed; therefore, greater understanding of the factors that regulate germination and establishment will help improve effective management strategies. Maximum aerial seed germination occurred at 30 C, whereas maximum subterranean seed germination occurred at both 30 C and 35 C. Germination at 40 C was delayed relative to optimum temperatures. These responses in the laboratory are similar to what is observed with other weed species common to the Southeast Coastal Plain. However, in field situations, Benghal dayflower typically emerges later in the season than these other weeds. The seed coats in this study were mechanically disrupted to evaluate the response of seeds to temperature in the absence of physical dormancy. The physical dormancy imposed by the seed coat might account for these differential results between field and lab. Benghal dayflower was not tolerant to ≥ 10 mM NaCl, indicating that this exotic species is not likely to become problematic in the brackish wetlands and natural areas of the coastal plain. There was an inverse linear response of Benghal dayflower emergence and planting depth, with no emergence occurring at a planting depth of 12 cm. A field survey of emergence depths revealed that 42% of plants established from a depth of 1 cm in the soil profile, with a maximum depth of 7 cm. This suggests that PRE herbicides must remain in the relatively shallow depths of the soil profile to maximize control of germinating seedlings. Subterranean seeds were less sensitive than aerial seeds to *S*-metolachlor, the primary means of controlling this species in cotton. There were no differences between the germination of aerial and subterranean seed in response to treatment with diclosulam. Future research concerning the factors that govern the physical dormancy imposed by the seed coat could allow for a greater understanding of germination and emergence of this species.

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