ENVIRONMENTAL FACTORS AFFECTING BENGHAL DAYFLOWER (*COMMELINA BENGHALENSIS*) SEED GERMINATION

by

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(Under the Direction of Timothy L. Grey)

ABSTRACT

Studies were conducted from 2007 to 2008 to determine the effect of temperature, salt stress and plant depth on germination of the aerial and subterranean seed of Benghal dayflower. The seed was harvested from mature pods of the plant, cleaned and allowed to dry for two days before the experiments began. Tests were conducted in the greenhouse and growth chamber. Data indicated that the aerial seed had a higher germination percent for the temperature treatment. The highest germination percent was 90% at 30°C. The 20°C treatment had a cumulative germination of only 30% indicating that emergence could still be sustained even at these low temperatures. Germination was 45 and 15 % for the 10 and 20 mM concentration, respectively. No germination occurred with the 40 mM salt concentration. The highest germination was at 0 and 1 cm plant depth. No germination occurred in the 12 cm plant depth.

INDEX WORDS: Benghal dayflower, *s*-metolachlor, diclosulam, and cumulative germination percent

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DEDICATION

I dedicate this work to my husband for his never ending support the whole time I have been in school. Thanks for helping clean and counting the dayflower seeds. You are my best friend, I can never ask for more. To my Lord and savior Jesus Christ, thank you for grace to pull this through. To God be the glory!

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Dr. Grey, thank you for all of the help, guidance and patience that you have given me. Dr. Vencill thanks for all the support and your advisement of courses. Thank you for letting me use your lab for my research. Mike, thanks for helping me set the growth chamber and finding my way in the green house. To my mum, thank you very much for leaving all your work and coming to help me with the baby. I don’t know what I would have done without you.

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CHAPTER 1

INTRODUCTION

Benghal day flower (*Commelina benghalensis*), also known as tropical spiderwort is among the worlds worst weeds and considered a weed in 25 crops in 29 countries (Holm et al. 1977). This weed is a native to Africa and Asia and some of the countries it has invaded include China, Pakistan, Taiwan, Jamaica, Kenya, Cuba and the subtropical parts south of United States of America like Georgia, Florida and North Carolina (Wilson 1981). It is an herbaceous creeping monocot and has stems that are succulent, either ascending or creeping, 20 to 90 cm in length covered with fine pubescence and dichotomously branched (Faden and Hafliger 1982). The stems will climb if supported but otherwise they creep along the ground.

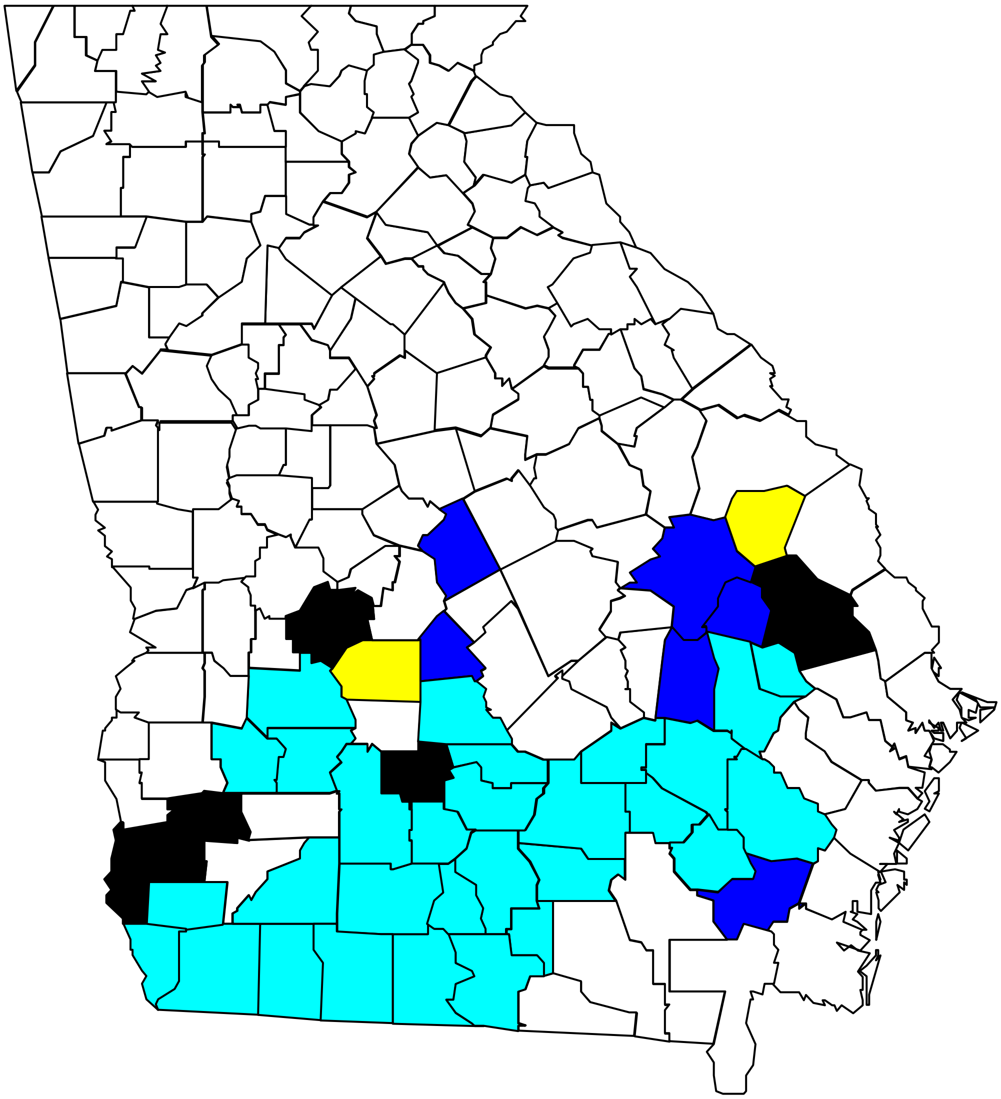
The leaves are succulent, ovate-elliptical in shape and about 3 to 7 cm in length. The leaf blades have parallel venation, entire leaf margins and pubescence on the lower and upper leaf surfaces and margins (Faden and Hilfinger 1982). Related species such as Asiatic dayflower (*Commelina communis* L) and spreading dayflower (*Commelina diffusa*) have thick waxy leaves that are relatively long and narrow (length to width ratios of 4:1 or greater) compared to the short broad leaves of Benghal dayflower (length to width ratios of 3:1 or less) [Webster et al. 2005]. Benghal dayflower has the unique ability to produce both aerial and subterranean flowers (Maheshwari and Maheshwari 1955). Aerial flowers are chasmogamous, typical open-pollinated flowers. Even though these flowers lack nectar, they are insect or self-pollinated, but never wind-pollinated (Faden 2000). They consist of three petals: two larger, purple or lavender in coloration, and one smaller white petal. The other *Commelina* species, like Asiatic and spreading dayflower, have blue flowers. The flowers desiccate rapidly opening in the morning and begin wilting by midday. There can be about 240 aerial flowers per plant and these begin forming 8 to 10 weeks after emergence (Kaul et al. 2002). Subterranean flowers are cleismogamous (self pollinating flowers that do not open) and develop on a rhizome. They are pale yellow to white in color (Walker and Everson 1985) but with a light cue, they will convert to the aerial flower form. There can be up to 19 subterranean flowers per plant that begin to form within 6 weeks after emergence (Kaul et al. 2002).

The fruit is a pyriform capsule, 4 to 6 mm in length, and usually contain three to five dimorphic seeds (Faden and Hafliger 1982). Aerial fruit contain one large and four small seed, whereas one large seed and two small seed are produced by the subterranean fruit. Plants can produce 1,600 to 16,000 seed (Faden and Hafliger 1982). The seed are rectangular, 1.6 to 3 mm in length, 1.3 to 1.8 mm in width and brownish-black in color (Faden and Halfiger 1982). They have a cap over the embryo, which is dislodged during germination. The small aerial seed account for 73 to 79 % of the total number produced.

Small aerial seed have a greater dormancy than larger seed (Budd et al 1979). In a study done by Kim et al. (1989), the aerial seed were treated with different chemical and heat treatments and the small aerial seed were also found to have a higher dormancy than the large seed. Underground seed represented less than 3% of total seed production and do not exhibit as much dormancy compared to smaller aerial seeds. Walker and Evenson (1985) reported that Benghal dayflower plants which develop from aerial seed tended to be smaller, developed aerial flowers earlier and produced greater numbers of aerial fruit relative to plants that originated from underground seed.

It has been present in the United States for more than seven decades (Faden 1993) but only recently has it become a pest in agricultural fields. In 1983, the USDA designated Benghal dayflower as a federal noxious weed (USDA-APHIS 2000). This will limit the interstate spread of the weed. It is now a noxious species of the Southern United States and has become the most troublesome weed of cotton (*Gossypium hirsutum* L.) and peanut (*Arachis hypogaea* L.) in Georgia and Florida (Webster, 2005). In 1999, Benghal dayflower was found in five counties in southern Georgia, and by 2004, it was confirmed in 29 counties. Five additional counties were added in 2005 (Flanders 2005), six more in 2006 and two more in 2007(Figure 1.1). The rapid spread of the weed in agronomic crop fields in Georgia as well as infestations in other Southern states of North Carolina and Alabama, suggest that it is spreading quickly with a potential to invade other crop producing regions.

Figure 1.1. The distribution and progressive movement of Benghal dayflower in Georgia (Prostko, 2007)



- 2004: 29 counties (light blue)
- 2005: 5 counties (black)
- 2006: 6 counties (dark blue)
- 2007: 2 counties (yellow)

CHAPTER 2

LITERATURE REVIEW

Benghal dayflower possesses a sprawling growth habit that will quickly form a dense ground cover capable of developing adventitious roots at nodes upon soil contact (Webster et al. 2005). In early planted field corn, Benghal dayflower is not a significant problem due to late emergence pattern (Prostko et al. 2005). Emergence is high when the temperatures are much higher hence not a problem in early planted crops. This weed has several physiological characteristics that contribute to its potential as a successful invasive weed. The most important aspect of this weed is its' reproductive elasticity. It is an herbaceous perennial in tropical climates, but can grow as an annual in temperate regimes (Holm et al. 1977). Moreover, it produces both aerial and subterranean flowers, each with dimorphic seeds (Figure 2.1 and 2.2). [Maheshwari and Maheshwari 1955]. It posses the ability to root at the nodes and can be propagated from cut stems. Therefore light cultivation can often break plant parts which are capable of rooting and therefore increase the area of infestation (Budd et al. 1979).

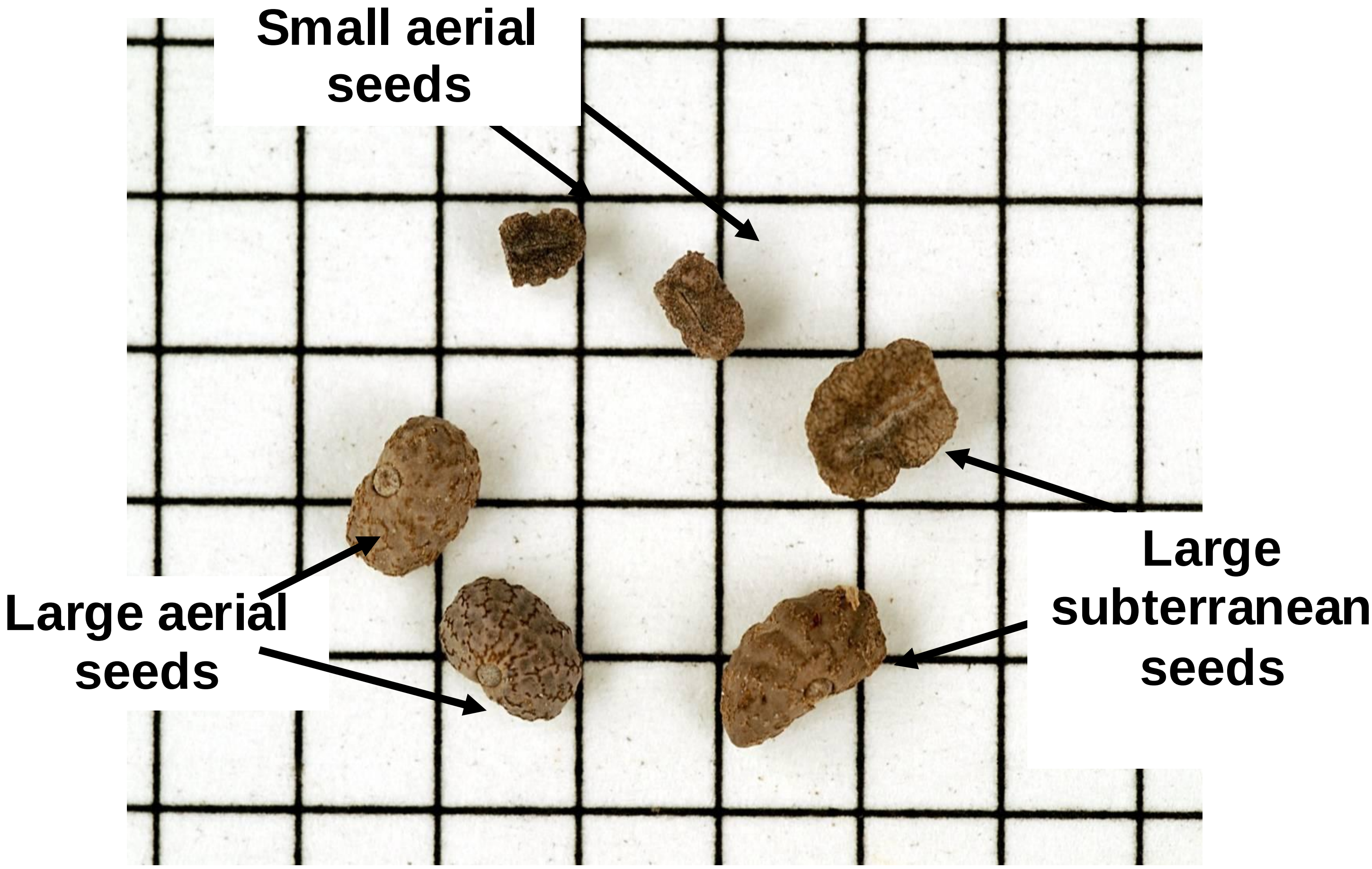
Control

Contributing to the significance of Benghal dayflower as a troublesome weed is its tolerance to glyphosate making control difficult in agronomic settings. It has a high degree of tolerance to glyphosate, which is the primary management tool used for weed control in glyphosate resistant cotton and soybean systems throughout the southeast (Culpepper et al. 2004). However, it is not equally difficult to control in all crops. Although glyphosate can control 3 to 10 cm tall Benghal dayflower, lack of residual activity resulted in less than 55% control (Culpepper et al. 2004).

Control in cotton has been difficult. Peak Benghal dayflower emergence occurs in cotton in June or July in Georgia. At 21 DAT, glyphosate applied post emergence over the top in a cotton field controlled Benghal dayflower 53%. This was attributed to newly emerged plants and suppressed growth of plants treated with glyphosate (Culpepper et al. 2004).

Figure 2.1. Benghal dayflower subterranean flower

Figure 2.2. Benghal dayflower aerial and subterranean seed



Residual control of Benghal dayflower is important in cotton weed management program because its seeds will continually germinate and emerge throughout the season (Prostko et al. 2005) and cotton yield can be reduced to up to 60% by season-long interference from Benghal dayflower. Poor control of Benghal dayflower in cotton also has an impact on subsequent rotational crops such as peanut.

In soybean (*Gossypium hirsutum* L.), control of Benghal dayflower can be achieved by shading and competition when narrower row spacing and increased soybean plant population is used. In glyphosate resistant soybean systems, glyphosate can provide about 55% control of Benghal dayflower if it is applied to plants that are 8 cm tall or less (Prostko et al. 2005).

Peanuts grown in twin row spacing rather than single spacing provide earlier canopy closure and shading which may provide greater control of Benghal dayflower (Yoder et al. 2003). The most consistent herbicide for control of Benghal dayflower has been *s*-metolachlor due to its soil residual activity. Peanut field trials conducted in Grady County GA indicated *s*-metolachlor provided 80% residual control of Benghal dayflower (Webster et al. 2006). Maximum control was observed when the application is followed by 1.3 cm of rainfall or irrigation within seven to ten days. As peanut emerges, it is recommended that metolachlor (0.80 kg ai ha^{-1}) be applied with bentazon (0.28 kg ai ha^{-1}), and paraquat (0.21 kg ai ha^{-1}) to control emerged and germinating Benghal dayflower seedlings (Prostko et al. 2005). A sequential application of imazapic (0.070 kg ha^{-1}) and *s*-metolachlor (0.80 kg ha^{-1}) is recommended POST. Paraquat provides excellent control of emerged Benghal dayflower if applied before the 5-leaf stage. Flumioxazin and diuron are good at suppressing the rate of Benghal dayflower emergence but the visual control rating did not exceed 50%. These herbicides are only beneficial when used with *s*-metolachlor.

In a study done by Steptoe (2006), Benghal dayflower visual injury by flumioxazin, metolachlor and glufosinate was found to increase with increasing soil moisture. This was because of the thick cuticle formed with low soil moisture. On the other hand, soil moisture did not affect response of Benghal dayflower to 2, 4-D, diclosulam and glyphosate.

In peanut, the critical period of weed control (CPWC) for Benghal dayflower necessary to avoid more than 5% peanut yield loss in 2004 was an interval between 316 and 607 growing degree days (GDD), which corresponds to a 24-d period beginning three weeks after peanut emergence. In 2005, the CPWC was between 185 and 547 GDD. Therefore to reduce the impact of Benghal dayflower on peanut, it is recommended that the peanut crop be free of Benghal dayflower between three to seven weeks after peanut emergence (Webster et al. 2007).

Benghal dayflower can also be an alternate host for some nematodes like southern root knot, peanut root knot and reniform nematodes (Davis et al. 2006). Nematodes are the most damaging pathogens of cotton and one of the most important pathogens of peanut (Valdez 1968). Weeds can support nematode reproduction and reduce the effectiveness of crop rotation as a management tool. *Commelina* species were a recommended ground cover in banana (*Musa balbisiana*) plantations (Kasasian 1971) until they were found to be a host for the reniform nematode and the recommendation was changed (Edmunds 1971). Benghal dayflower was also shown to be a host for the southern root knot nematode in the Philippines (Valdez 1968) and for *Pratylenchus goodeyi* in eastern Africa (Mbwana et al. 1995).

Another important weed species in the Commelinaceae family that has shown some tolerance to glyphosate is doveweed (*Murdannia nudiflora*) [Culpepper et al. 2004; York and Culpepper, 2006]. This is an invasive weed in the United States from Texas to North Carolina and is considered one of the top three major weeds species from the family Commelinaceae (Holm et al. 1997). Doveweed occurs in as many as 17 crops in about 26 countries (Wilson 1981). It is a problematic weed in turf grass in the United States but has also been found to increase in cotton and soybean. This could be because of the adoption of herbicide resistant crops hence less soil applied herbicides are used and less cultivation. York et al. (2006) determined that glyphosate can not adequately control doveweed, although it is a broad spectrum herbicide for control of both annual grasses and broad leaf weed species.

Doveweed is also a host for root-knot (*Meloidogyne* spp.) and lesion (*Pratylenchus* spp.) nematodes (Valdez 1968). It is also a host for Pythium root rot which occurs in many crops in the United States (Deep and Lipps 1996; Lee and Hoy 1992).

Weed seed germination can be affected by different environmental factors such as light, temperature and pH (Taylorson 1987). Effects exerted by environmental factors on the plant germination, growth and competition are thought to be key elements of predicting a species' potential geographical range (Patterson et al. 1999). Studies were done to see the effect of environmental factors on doveweed seed germination. The seed were found to be strongly influenced by temperature and the optimum temperature for germination was found to be 28°C. Moreover, the seed does not require light for germination. Germination of common cocklebur seed was found to be optimum at temperatures of 35°C or 40°C (Norsworthy and Oliveira 2007).

Salinity also affects the important physiological processes in plants. Sodium ions can alter the soil structure and fertility by replacing magnesium and calcium ions and this leads to nutrient and water stress (DiTommaso 2004). High salts concentration prevents water from entering the seed and this may inhibit germination. In a study done by Chauhan et al. (2006), germination of rigid ryegrass seed decreased linearly as NaCl concentration increases from 0 to 200 mM.

Studying salt tolerance of Benghal dayflower may help determine its geographical range and management practices can be put in place to avoid its spread.

The ability of Benghal dayflower to produce aerial and subterranean seed contributes to the ability of this weed to survive in various habitats. Therefore understanding the environmental factors that affect germination and emergence of Benghal dayflower is necessary so that successful control of this invasive species can be achieved. This may also provide insights for managing its growth at early developmental stages. Therefore, studies were initiated to determine how the environmental factors affect Benghal dayflower seed germination.

CHAPTER 3

MATERIALS AND METHODS

Benghal dayflower plants were obtained from a grower's field in Grady County, Georgia with a naturalized population and were transplanted to 30 cm diameter pots with field soil. Pots were transferred to a greenhouse at the University of Georgia in Athens. Pots were watered daily and fertilized as needed. The plants were under natural photoperiod in the green house and were trimmed periodically to allow for re-growth.

Prior to seed harvest, the plants were not watered for two to three weeks to allow the plants to dry completely. The aerial seed were then hand harvested from mature pods in the summer of 2007. The seeds were separated from the capsule by hand and allowed to dry for two days at 30°C. The soil in the pot was carefully evaluated by spreading in a thin layer on a table in order to harvest any subterranean seed in the soil. Additional subterranean seeds were harvested from the mature fruit that were still attached to the roots of the plant. The seeds were separated from the capsule by hand and also let to dry for two days at 30°C. Seed were treated with 5% bleach for 5 minutes to remove pathogens that may have resided on the seed coat. Benghal dayflower seed are dormant because of an impermeable seed coat (Budd et al. 1979). A 0.25 mm cut was therefore made to the seed coat surface to facilitate moisture uptake and alleviate the physical dormancy constraint.

For the salt, temperature and pH study, the experiment was performed in Petri dishes[1], 9 cm in diameter, where 20 seeds were placed on two layers of blotter paper[2] moistened with 7ml distilled water or test solution. The Petri dishes were covered to cause the condensate to flow to the sides of the container and also to retain moisture.

The effect of depth on germination of seed was conducted in the green house in 250 ml Styrofoam cups[3] with soil as the medium. Soil was a Cecil sandy loam (fine Kaolinitic, thermic typic Kanhaplidults) with organic matter of one to two percent and pH ranging from five to six, from the Plant Science farm in Oconee County, GA.

Germination test

Germination tests were conducted by placing 20 seed in a Petri dish 9 cm in diameter on layers of blotter paper moistened with water. Tests were conducted in a growth chamber[4]. Temperature was set at 30 to 35°C, with a photoperiod of 12 hours to coincide with the high temperatures of the southern United States known to provide an adequate environment for Benghal dayflower rapid growth and reproduction (Burton et al. 2003). A seed was considered to have germinated when the embryo had protruded 1mm from the seed coat.

Temperature treatment. The effect of temperature on germination was done by evenly spacing out twenty aerial and subterranean seeds in separate Petri dishes. These were wetted with 7 ml of water and incubated under constant temperatures of 20, 30, 35, and 40°C in a growth chamber. Light was provided by fluorescent bulbs set for 12 hours of light and 8 hours of darkness. Counting of the germinated seed started 5 days after experiment initiation. A seed was considered to have germinated when the embryo had protruded 1mm from the seed coat.

Salt stress study: The salt study was conducted with sodium chloride[5] solutions of 0, 10, 20, 40, 80, and 160 mM. Solutions were prepared by dissolving sodium chloride in deionized water to make 1M solution. Ten ml of this solution was measured in to a 1000 ml volumetric flask[1] and brought to volume with water to prepare the 10 mM solution. The other salt solutions, 20, 40, 80 and 160 mM were prepared using the same procedure. For the 0 mM, deionized water was used. Twenty seed were evenly spaced on a round plastic Petri dish. The sodium chloride solutions were used to moisten the blotter paper instead of water. The dishes were arranged in a growth chamber with 30°C day temperature and 25°C night temperature. The dishes were arranged in six lanes corresponding to salt treatments of 0, 10, 20, 40, 80 and 160 mM with four dishes per lane in which each dish served as a replicate. Light was provided by fluorescent bulbs set for 12 hours of light and 8 hours of darkness. Counting of the germinated seed started 5 days after experiment initiation. Germination was evaluated as previously described in the germination experiment.

Plant depth study: Above ground seed were placed in Styrofoam cups and filled with soil. Ten Benghal dayflower seed were planted separately in the pots at depths of 0 (soil surface), 1, 2, 4, 6, 9 and 12 cm. The columns were surface irrigated to maintain adequate moisture and placed in a greenhouse with temperatures ranging from 30 to 40°C under natural photoperiod. A seed was considered to have germinated when the cotyledon emerged from the soil surface.

Statistical analysis

All experiments had five replications and were repeated twice. The cumulative germination data for all the experiments were subjected to analysis of variance and linear regression. The experiments were combined for the analysis. Most of the treatments showed a difference and hence a Tukey HSD test was performed to determine which treatments were different.

CHAPTER 4

RESULTS AND DISCUSSION

Temperature. There was a significant effect of temperature ($p < 0.0001$) on Benghal dayflower germination (Figure 4.4). Tukey HSD test showed a difference in germination of the above and below ground seed. The highest germination was 90% at 30°C for the aerial seed and 75% for the subterranean seed (Figure 4.1 and 4.2). The lowest germination percent was 10% at 20°C for the aerial seed and 5% for subterranean seed (not shown), indicating some sensitivity to cooler temperatures. Germination of the aerial and subterranean seed was 80% and 50 % at 35°C (Figure 4.3) and 50% and 25% at 40°C (not shown). In a study done by Gonzalez and Haddad (1995), peak germination of the aerial seed of Benghal dayflower was between 25°C and 30°C. Doveweed, a closely related species, germination declined rapidly with increasing and decreasing temperatures above and below the optimum of 28°C (Wilson Jr. et al. 2006). In a study done on Tropical soda apple (*Solanum viarum*) it was shown that tropical soda apple seed were photoblastic with light and temperature stimulating germination (Akanda et al. 1996). In a similar research with eclipta seed (*eclipta prostrate*) the highest germination was 83% at 35°C. The eclipta seed were also found to be strongly photoblastic and light stimulated germination (Altom and Murray 1996). Other two agronomically important weeds, sicklepod (*Cassia obtusifolia*) and prickly sida (*Sida spinosa*), were found to have maximal growth at an aerial temperature of 36°C (Tungate et al. 2006). Another study found Palmer amaranth (*Amaranthus palmeri*) to have rapid growth at even higher temperatures (Wright et al. 1999).

Salt treatment. There was a significant difference in the salt concentration used indicated by a p-value of <0.0001. A HSD test showed that salt concentration of 10 and 20 were different form each other and also different from the 40, 80 and 160 mM (Table 4.3). The 40, 80 and 160 mM salt concentration gave germination percentages that were not different form each other. The highest germination was 45% at 10 mM (Figure 4.4), 20% for the 20 mM (Figure 4.5) and zero for the 40, 80 and 160 mM. This shows that at high soil salinity, Benghal dayflower seed may not germinate as opposed to Texasweed seed where germination at 40 mM was 52% and 27% at 160 mM (Koger et al. 2004). In ryegrass, seed germination was greater than 50% in 40 mM NaCl concentration and some germination occurred even at 160 mM. However, germination was completely inhibited by 320 mM NaCl (Chauhan et al. 2006).

Depth. Germination of Benghal dayflower seed ranged from 0 to 90 % in the plant depths used (Figure 4.5). The highest germination percentage was at 0 and 1 cm plant depth. There was 0% germination at 12 cm plant depth. A Tukey HSD test showed that there was no difference in the germination percentage at 0, 1 and 2 cm (Table 4.1). There was a difference in the germination percentage at 4, 6, 9 and 12 cm, with the lowest percentage being at 9 and 12 cm. Matsuo et al. (2004) reported large aerial seed of Benghal dayflower emerged from depth of 5 cm while the small aerial seed failed to emerge from depths greater than 1 cm. Doveweed emergence was noted from depths of 0 to 6 cm with emergence decreasing as seed burial depth increased (Wilson Jr. et al. 2006). In previous research, tropical signal grass (*Urochloa subquadripara*) emergence was highest when the seed was placed on the surface and no emergence from seed placed below 7 cm (Teuton et al. 2004). In all the treatments, the subterranean seed have always germinated faster.

Conclusion

Benghal dayflower has the ability of spreading very fast if not checked and therefore poses a serious threat especially to cotton and peanut growers. Germination of the seed was highest at 30°C and lowest at 20°C and 40°C. Spread of Benghal dayflower will therefore be faster in temperatures around 30°C because of the higher germination of the seed at this temperature. Although germination at 20°C and 40°C was not high, control of the weed once established will be hard because of the increase of leaf cuticle formed in low or high temperatures as a way of preserving water in the plant. Metabolic processes in the plant are slow in very low or high temperatures making control of the weed with systemic herbicides hard. Webster et al. (2006) also found that peak Benghal dayflower emergence in cotton occurred in June or July where the temperature is about 30°C or higher. Cotton planted early will have an advantage because of the canopy closure prior to emergence of the weed. There was also a difference in the germination of the aerial and subterranean seed where the aerial seed had a higher germination percent and can therefore spread fast and perform better in the field.

In considering the potential success of Benghal dayflower, we should also consider that models of global warming predict an increase in temperature of the southeastern U.S. by as much as 5°C during the next century (IPCC 2001). Warmer temperatures will mean an expanded season for germination and growth of Benghal dayflower and many other problematic weed species increasing competitiveness with many of the major crop species.

Emergence of Benghal dayflower in the 10 mM salt concentration was 45%. This was higher than the germination in the rest of the salt concentrations used. A high salt concentration in the soil causes soil moisture stress. Control of Benghal dayflower in such soils can be hard because of the increase in leaf waxy cuticle and trichomes formed in plants growing in soils with moisture stress.

Benghal dayflower germination was high at 0, 1, and 2 cm plant depth. This could be due to availability of sunlight, aeration as well as ease of the radicle and shoot to make its way in the soil. Benghal dayflower emergence prefers warm soil temperatures (Steptoe et al. 2006). It is also possible that the high germination % at 0, 1 and 2 cm was because the soil in the upper soil surface was warmer than deep in the soil, though this would depend on the season. The low germination % observed in the plant depth of 9 and 12 cm could have been due to lack of sunlight and difficulty of the shoot to reach the surface but could as well be the low soil temperatures deep in the soil. Seeds buried deep in the soil will not pose any threat as far as spread of the weed unless they are brought to the surface by mechanical or other forms of tillage. This also explains why conventional tillage has been shown to help alleviate Benghal dayflower problems. The key to minimizing the impact of this weed is to employ rigorous Bengal dayflower control programs especially in newly infested areas.

Figure 4.1. Effect of time on aerial seed germination at 30°C

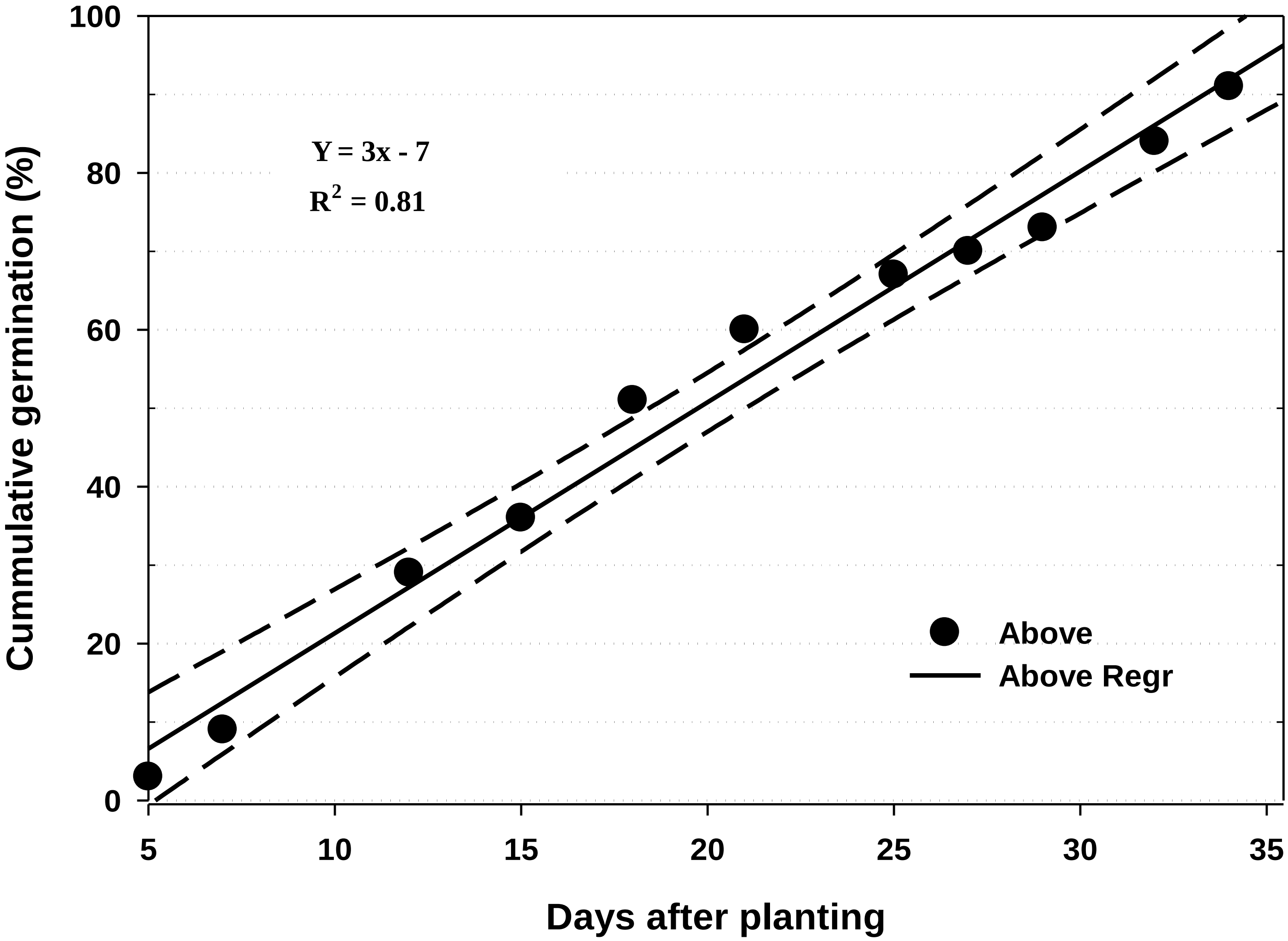


Figure 4.2. Effect of time on subterranean seed germination at 30°C

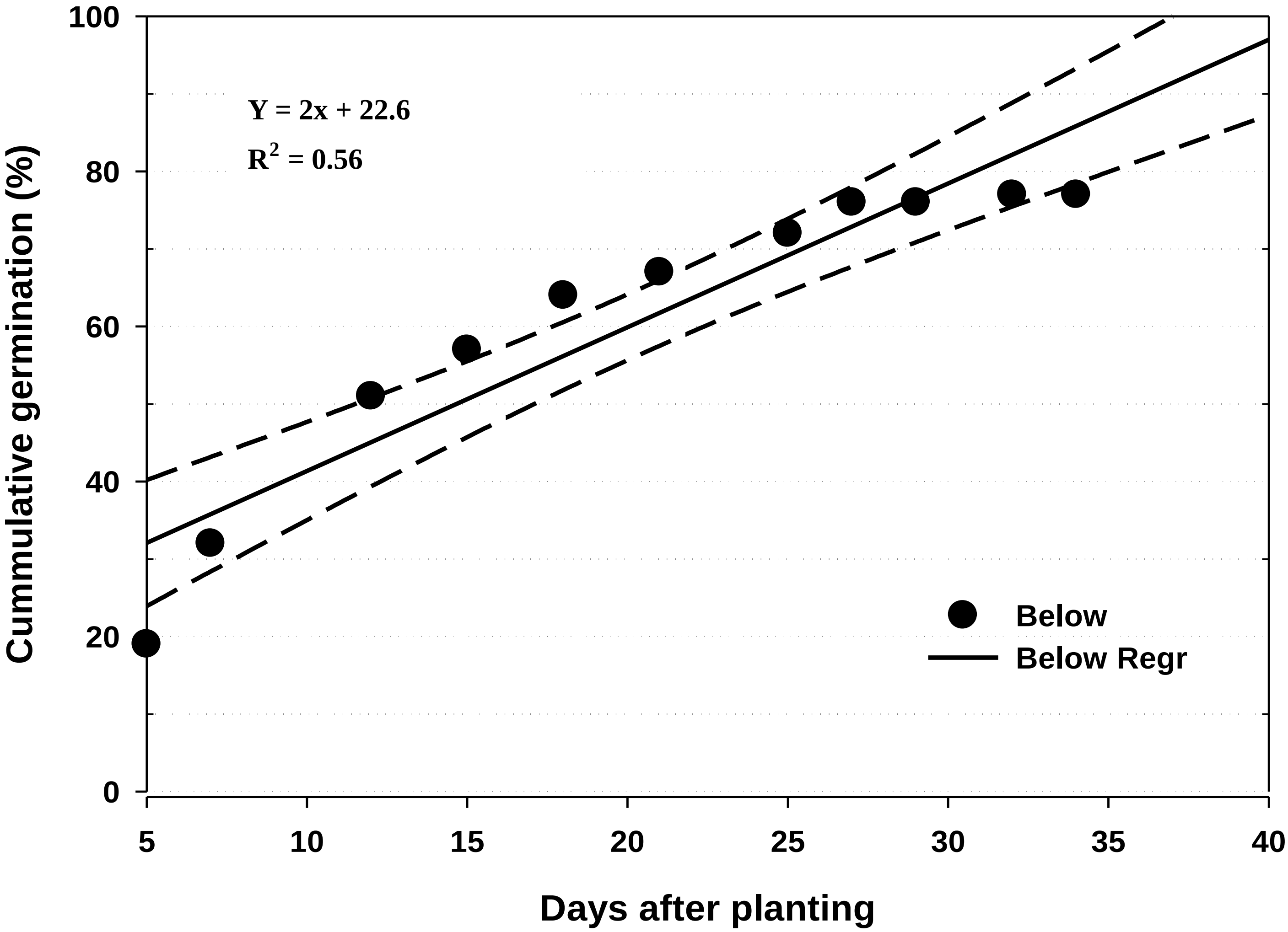


Figure 4.3. Effect of time on aerial and subterranean seed germination at 35°C

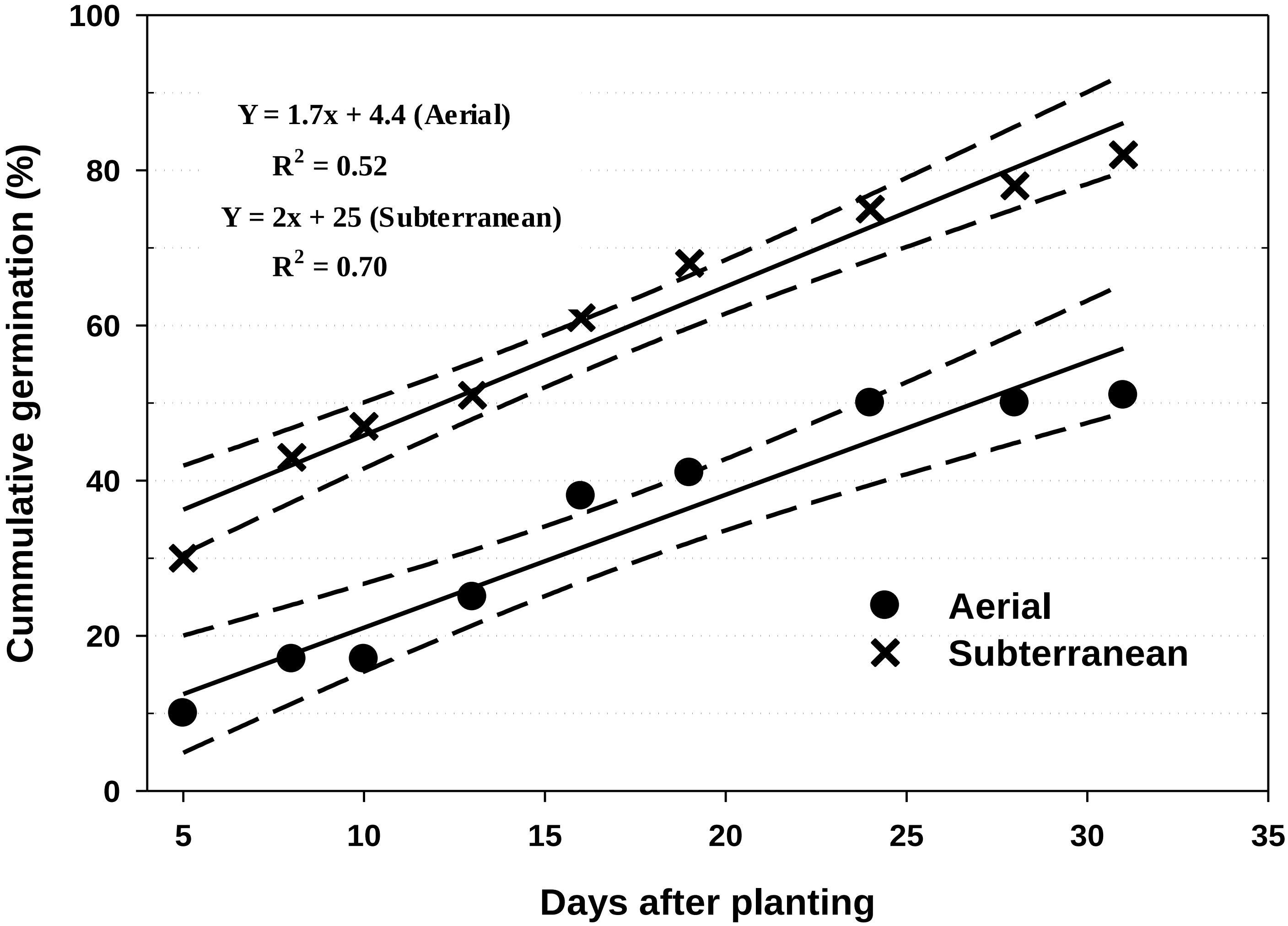


Figure 4.4. Effect of temperature on Benghal dayflower seed germination

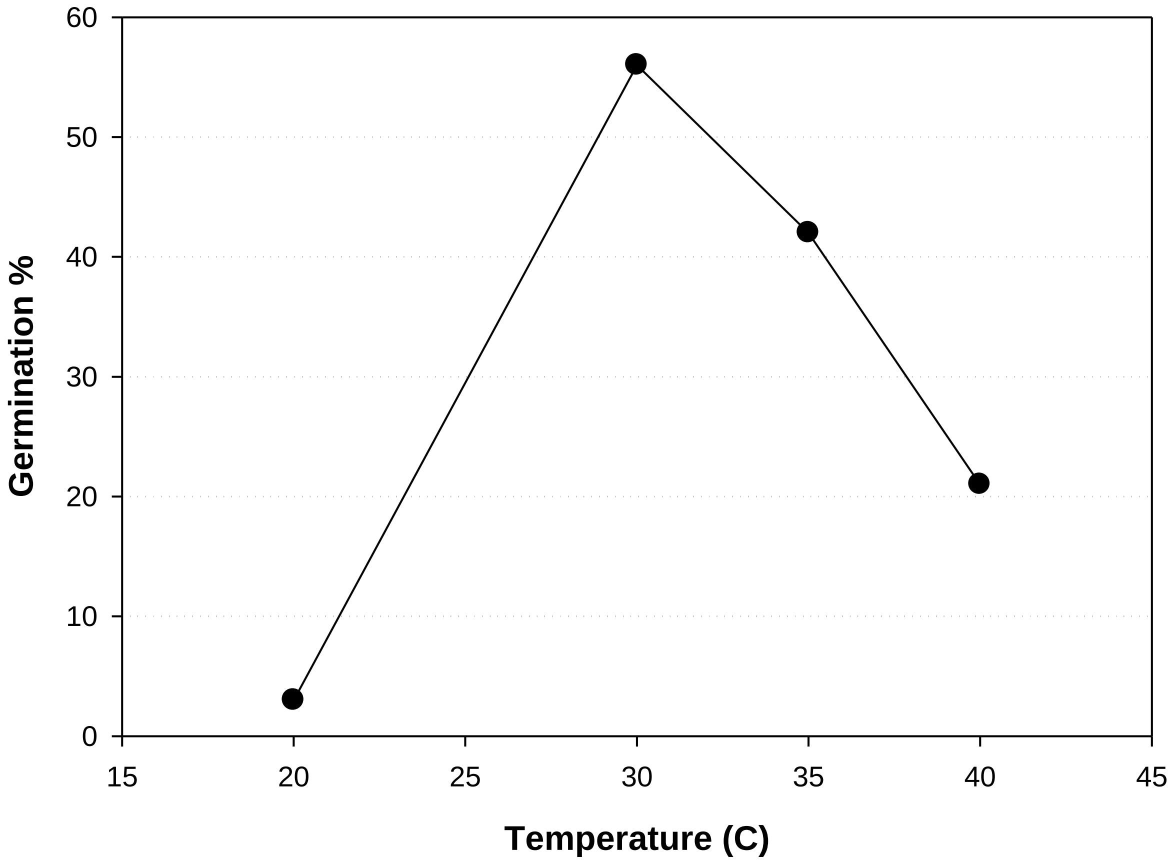
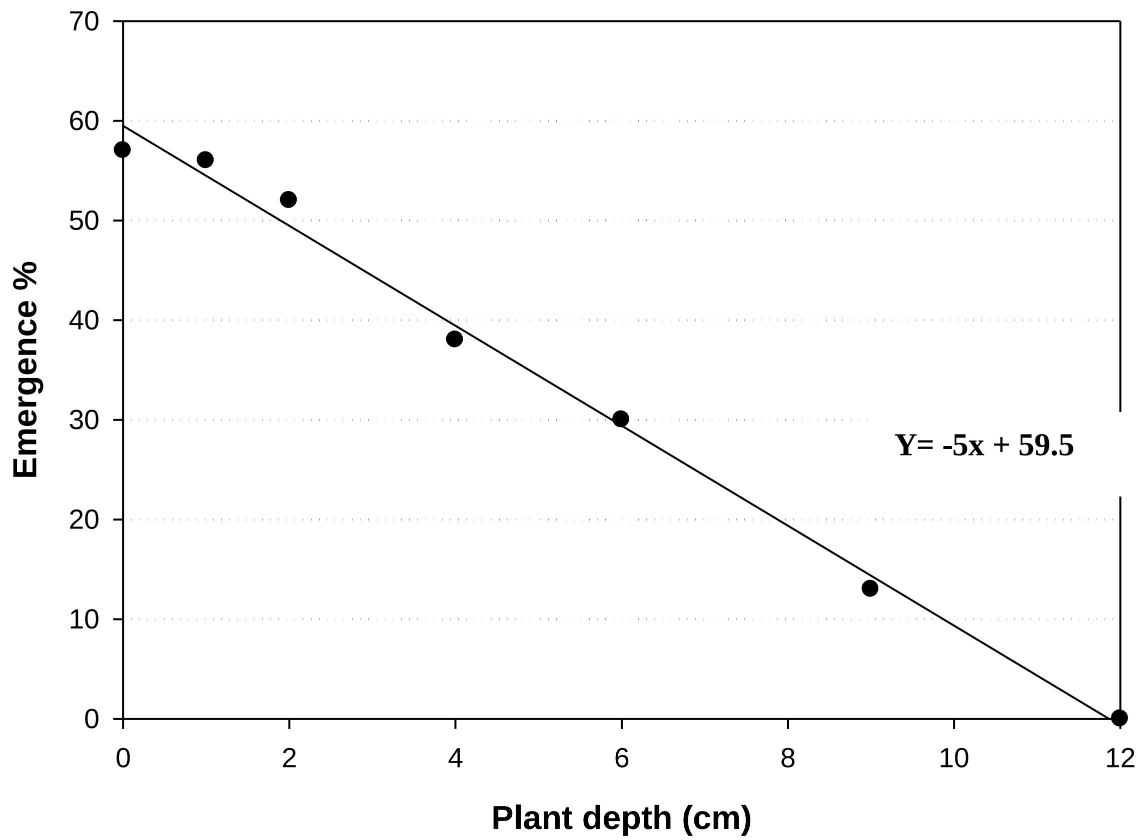


Table 4.1. Benghal dayflower germination in different salt concentrations

Salt concentration Mm	Mean % germination
0	57a
10	23b
20	10c
40	1d
80	0d
160	0d

Means within a column followed by the same letter do not differ significantly at 5% probability level.

Figure 4.5. Effect of plant depth on Benghal dayflower seed germination



CHAPTER 5

RESPONSE OF AERIAL AND SUBTERRANEAN SEED OF BENGHAL DAYFLOWER TO *S*-METOLACHLOR AND DICLOSULAM

Abstract

Studies were conducted to determine the response of aerial and subterranean seed of Benghal dayflower to metolachlor and diclosulam. The seed was harvested from mature pods of the plant, cleaned and allowed to dry for two days before the experiment began. Tests were conducted in the lab at room temperature (25°C). The seed were placed on the Petri dish on a layer of filter paper and the herbicide solutions were used for moisture. Data indicated that the subterranean seed was less sensitive to metolachlor than the aerial seed. There was no significant difference in the response of the aerial and subterranean seed in diclosulam.

Introduction

Benghal dayflower (*Commelina benghalensis*), also known as tropical spiderwort, is one of the most troublesome weeds in peanut as well as cotton in Georgia and Florida and has now become a significant pest (Webster 2005). It is an important weed in the warm temperate regions of Africa, Asia and South America (Holm et al 1977). Benghal dayflower was present in Georgia in 1997 but was not considered a troublesome weed (Dowler 1998). It has now become problematic and was ranked the ninth most troublesome weed in Georgia and Florida cotton by 2001 (Webster 2001). It is estimated that greater than 80,000 ha in GA are infested with

Benghal dayflower and it continues to spread. This weed has also been identified in Alabama, Louisiana and North Carolina (Faden 1993).

Benghal dayflower has a sprawling growth habit that quickly forms a dense ground cover. It is capable of producing adventitious roots at nodes upon contact with the soil (Webster et al. 2005). Moreover, it produces aerial and subterranean flowers leading to viable seeds being produced both above and below ground (Maheshwari and Maheshwari 1955). Studies have shown that Benghal dayflower is more competitive than peanut when grown in replacement series greenhouse studies (Chivinge and Kawisi 1990). In the midst of other weeds, Benghal dayflower can reduce cotton and peanut yields up to 62% (Paulo et al. 2001).

The spread of Benghal dayflower through agricultural fields in Georgia and Florida is associated with high input agricultural production. Benghal dayflower has a higher growth rate as well as biomass under high nutrient availability (Burns 2004), and irrigation. Another factor contributing to its spread is its tolerance to many commonly used herbicides, especially glyphosate (Culpepper et al. 2004). The use of glyphosate resistant crops has allowed growers to reduce the use of soil–applied herbicides in cotton (Culpepper and York 1998). Glyphosate is effective against common weed populations. However, it is not effective for Benghal dayflower management providing less than 55% control. Benghal dayflower has some level of glyphosate tolerance and its continuous germination throughout the growing season assures proliferation (Prostko et al. 2005). Elimination of herbicides with residual soil activity may have played a role in the rapid spread of Benghal dayflower for these cropping systems. Consistent control and suppression of Benghal dayflower has been accomplished with *s*-metolachlor (Webster et al. 2006). Due to its residual activity, *s*-metolachlor has provided greater than 90% control of Benghal dayflower. Diclosulam is a soil applied herbicide which provides control of a number of troublesome annual broadleaf weeds in peanut and soybean (Bailey et al. 1999). Ducar-Tredaway et al. 2006 reported 100% control of smooth pigweed and 95% control of common lambsquater with diclosulam. Benghal dayflower control with Diclosulam at 0.45 oz/A applied 17 days after planting (DAP) was 90% when observed at 69 DAP but reduced to 75% by 117 DAP (Prostko et al. 2004).

Previous field studies have established that diclosulam and *s*-metolachlor provide residual efficacy for Benghal dayflower (Webster et al. 2006). However, the exact herbicide concentration and sensitivity of Benghal dayflower to these herbicides has not been established. The objective of this research was to examine aerial and subterranean Benghal dayflower seed response to *s*-metolachlor and diclosulam using Petri dish evaluations.

Materials and Methods

Benghal day flower seed source was from Grady county Georgia. These had been planted in the green house of the University of Georgia and were being watered everyday. The seed were hand harvested from the nursery in the summer of 2007. The seed were separated from the capsule by hand and allowed to dry for two days at 30°C. Seed were treated with 5% bleach for 5 minutes to sterilize. Benghal dayflower seed are dormant because of an impermeable seed coat (Budd et al. 1979). A 0.25 mm cut was therefore made to the seed coat surface to facilitate moisture uptake.

The experiments were performed in Petri dishes, 9 cm in diameter, where 10 seeds were placed on two layers of filter papers moistened with 5 ml of test solution. The Petri dishes were covered to cause the condensate to flow to the sides of the container and also to retain moisture.

Metolachlor study: The *s*-metolachlor herbicide concentrations used were 0 (tap water), 5, 10, 100 1000 mg/L. The studies were conducted at room temperature (25°C). Ten aerial seeds were evenly spaced on a 9 cm diameter plastic Petri dish. The herbicide solutions were used to moisten the filter paper instead of water. The dishes were arranged on a bench in the lab with 25°C day and night temperatures. The dishes were arranged in six lanes corresponding to the herbicide doses of 0, 5, 10, 100 and 1000 mg/L with four dishes per lane in which each dish served as a replicate. The same was done for the subterranean seeds. Counting of the germinated seeds started 5 days after experiment initiation. A seed was considered to have germinated when the embryo had protruded 1mm from the seed coat.

Diclosulam study: The herbicide concentrations used were 0, 1, 10, 100 and 500 mg/L. The study was done in the lab in room temperature (25°C). For the 0 mg/L, tap water was used. 10 aerial seeds were evenly spaced on a round plastic Petri dish. The herbicide solutions were used to moisten the filter paper instead of water. The dishes were arranged on a bench in the lab with 25°C day and night temperatures. The dishes were arranged in six lanes corresponding to the herbicide treatments of 0, 1, 10, 100 and 500 mg/L with three dishes per lane in which each dish served as a replicate. The same was done for the subterranean seed. Counting of the germinated seeds started 5 days after experiment initiation. A seed was considered to have germinated when the embryo had protruded 1mm from the seed coat.

Statistical analysis

The two experiments had four replications and were repeated twice. The cumulative germination data for all the experiments were subjected to analysis of variance and regression using the log logistic regression according to Seedfeldt 1993. The experiments were combined for the analysis.

Results and Discussion

Metolachlor study: The highest germination was 65% for the aerial seed at 5mg/L and 70% for the subterranean seed. The lowest germination percent was 10% and 40% at 100mg/L for the aerial and subterranean seed respectively (data not shown). None of the seeds germinated in 1000mg/L herbicide solution. A dose response curve for the metolachlor data showed that the subterranean seed had a higher germination percent than the aerial seed. The ED_{50} for the aerial seed was 58mg/L and for the subterranean seed was 119mg/L (Figure 5.1). More herbicide is needed to have 50% less germination of the aerial seed of Benghal dayflower than for the subterranean seed. Therefore, both the aerial and subterranean seed would most likely germinate with the recommended field applications which are normally much lower. In another research, the ED_{50} of imazethapyr and nicosuluron in giant foxtail (*Setaria faberi*) was 32.2 and 1.9 g/ha respectively (Volenberg et al. 2001). This indicates that there can be good control of the plants from aerial seed by inhibiting germination of the aerial seed. Unless, the subterranean seed remain buried deep in the soil, germination is unlikely as was indicated by the plant depth study. If this seed is brought to the surface by tillage mechanisms, control will be hard as shown by the high ED_{50}.

Diclosulam study: There was a slight difference in the germination of the aerial and subterranean seed in diclosulam with the subterranean seed being slightly higher (Figure 5.2). Germination at 1mg/L was 72% and 82% for the aerial and subterranean respectively while germination at 500mg/L was 80% for both the aerial and subterranean seed. A dose response curve also showed the subterranean seed to be slightly less responsive to diclosulam than the aerial seed (Figure 5.3). However the analysis of variance showed no significant difference.

Conclusion

The data shows that the aerial seed is more susceptible to metolachlor than the subterranean seed. More herbicide is needed to have 50% less germination for the subterranean seed than for the aerial seed. An herbicide dose that would inhibit germination of the aerial seed will not necessarily inhibit germination of the subterranean seed and these may re infest an area if the environmental conditions are suitable. This also indicates that the subterranean seed is able to withstand control by metolachlor than the aerial seed.

There was no significant difference in the germination of the aerial and subterranean seed in diclosulam. A high germination % was still sustained even in the highest concentration of diclosulam solution and is possible that diclosulam promoted Benghal dayflower seed germination. Although diclosulam may have promoted germination of the seed, it is possible that seedling growth maybe inhibited. In a study done by Egley and Williams (1978), germination of redroot pigweed (*Amaranthus retroflexus* L.) seeds was stimulated by glyphosate while paraquat inhibited germination of barnyardgrass (*Echinocloa crus-galli*) and Johnsongrass (*Sorghum halepense*).

In metolachlor and diclosulam studies, the subterranean seed germinated faster than the aerial seed. This shows that the subterranean seed has a greater vigor than the aerial seed and expected to perform better in the field than plants from the aerial seed.

Figure 5.1. Benghal dayflower seed response to Metolachlor

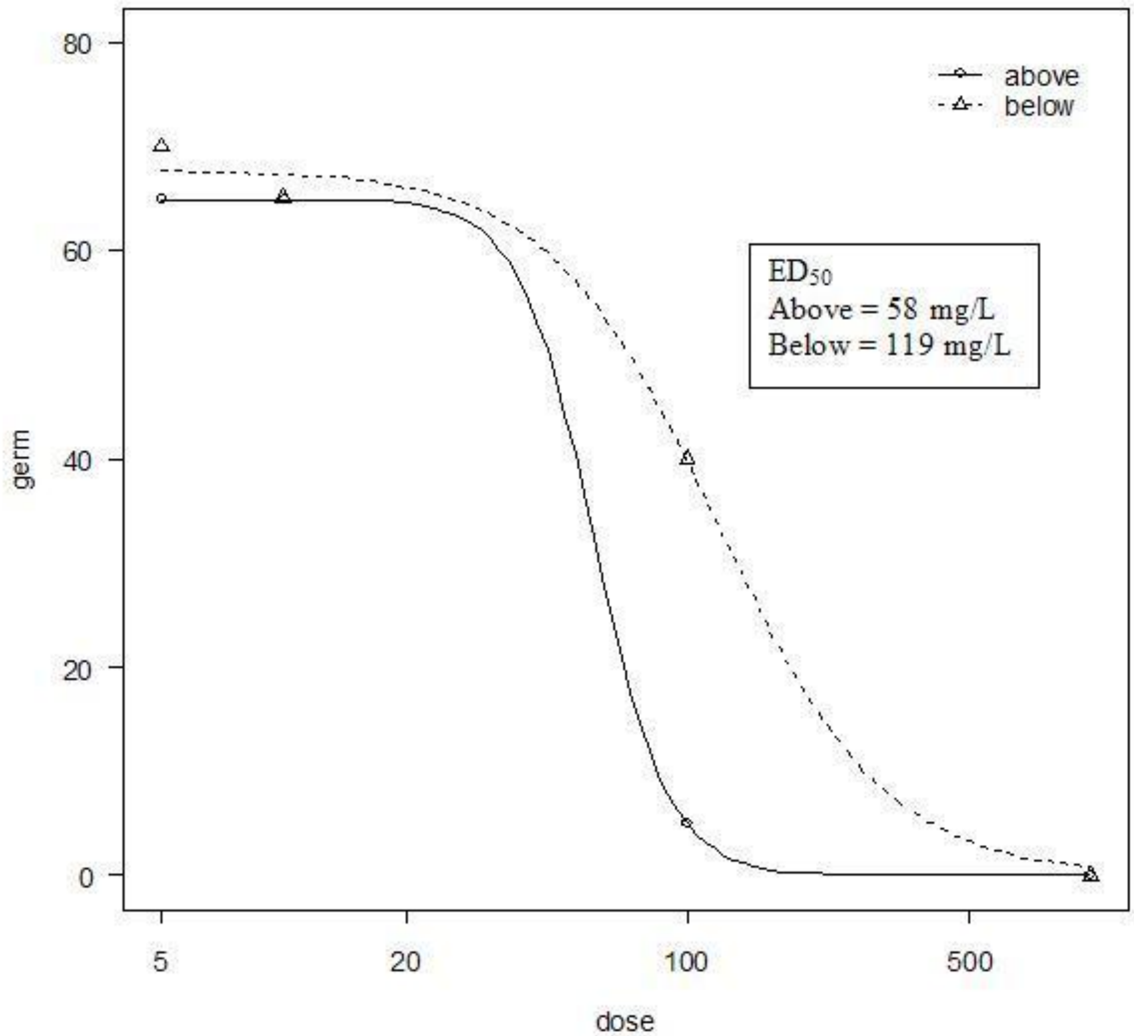


Figure 5.2. Aerial and subterranean seed response to diclosulam

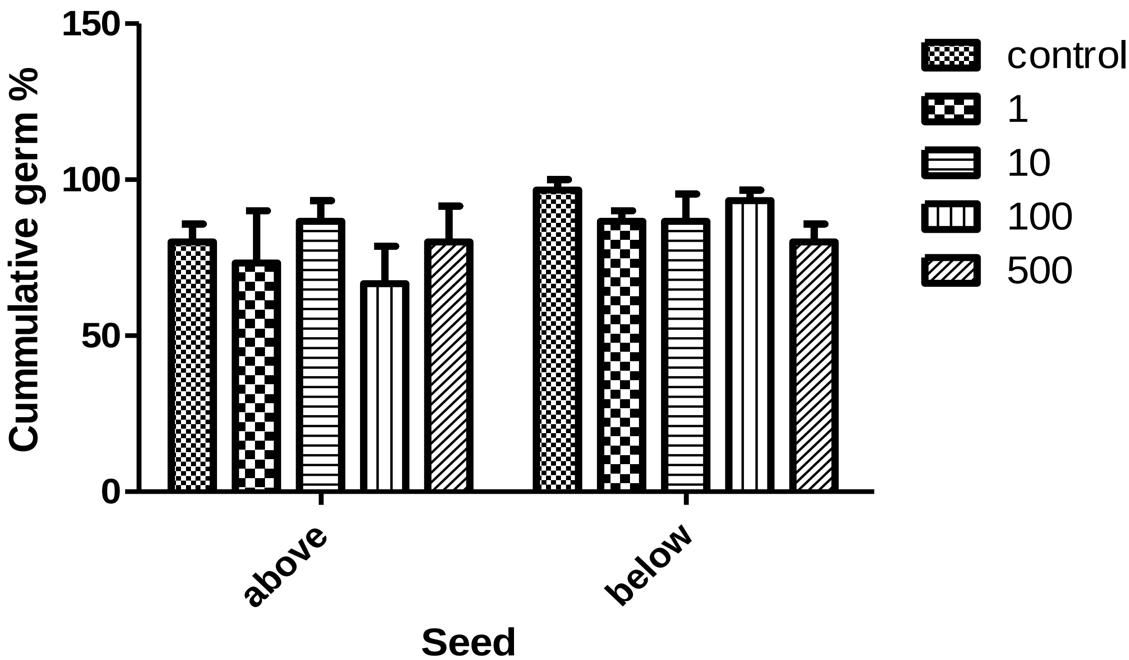
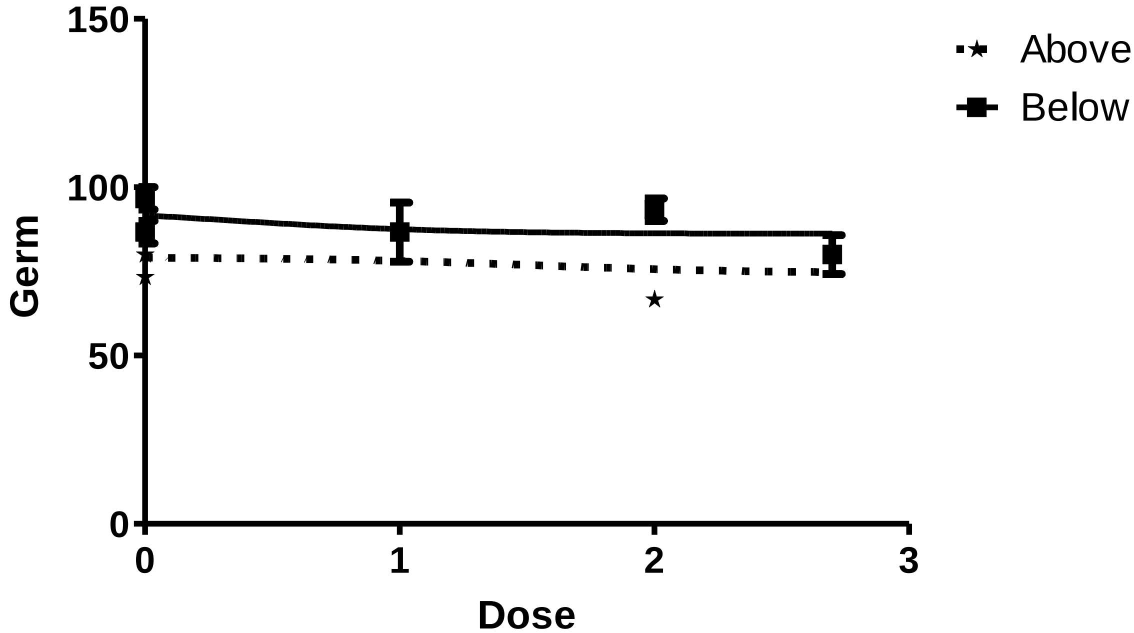


Figure 5.3. Benghal dayflower response to Diclosulam



SOURCES OF MATERIALS

[1]Supplies by Fisher Scientific International Inc. Liberty Lane, Hampton, NH 03842.

[2]Blotter paper by Anchor Paper Company 480 Broadway, St. Paul, MN 55101

[3]Styrofoam cups by Bay paper Company Inc.

[4]Growth chamber by Conviron 222 South 5th street, Pembina ND 58271

[5]Supplies by J.T Baker Chemical Co. Phillipsburg, NJ 08865

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