Effects of Environmental Factors on Germination and Emergence of Siam Weed (Chromolaena odorata)

Lu Ping¹, Bai Yamei¹, Xiao Tongyu¹, Li Tianzhu¹

¹School of Resources and Environment, Northeast Agricultural University, Harbin 150030, China
Wei_Lu2123@163.com

Abstract

Laboratory and greenhouse studies were conducted to determine the effect of several environmental factors on seed germination and seedling emergence of Siam weed (Chromolaena odorata). Seeds germinated over a range of 10 to 35 °C with optimum germination at 25 °C. Low temperature markedly restricted germination, with no germination occurring at 5 °C. Siam weed was moderately photoblastic, with 38% germination occurring in the dark. Germination decreased with increasing water potential, and germination was totally inhibited at osmotic stress higher than -0.8 MPa. Germination was greater than 65% at less than 50 mM NaCl and greater than 20% at 200 mM NaCl, with no germination at 300 mM NaCl. Maximum emergence occurred when seeds were planted on the soil surface. No seedlings emerged when planted 3.5 cm deep. These results suggest that the future range of Siam weed in China will be restricted largely to the Southern China.

Keywords: Invasive weed, Siam weed, Environmental factors, Germination

Introduction

Siam weed (Eupatorium odoratum), native to the neotropics from the eastern USA to northern Argentina[1], has become a major weed of crops, plantations, savannas and natural forests in many parts of the world[2]. It is a perennial shrub forming dense tangled bushes 1.5-2.0 m in height, occasionally reaching 6 m as a scrambler up trees. Seed production is prolific, the achenes bears a small stiff pappus and are wind-dispersed[3], so it has great potential to increase in distribution and density.

Siam weed was first recorded in the southern parts of Yunnan and Hainan provinces of China in 1934, it has spread extremely rapidly, now it prevails in Yunnan and Hainan provinces, and has expanded its distribution to the southwestern part of Guangxi province, the coast south of Guangdong province. It also tends to be a sporadic problem in Hongkong city, Guizhou and Taiwan provinces[4]. The weed decreases the carrying capacity and species diversity in both grassland and forest[5]. It is one of the top 9 alien invader plants in China[6], and attract significant attention because of threats they pose to local diversity and economics.

1878-0296 © 2011 Published by Elsevier Ltd. Open access under CC BY-NC-ND license. Selection and/or peer-review under responsibility of Conference ESIAT2011 Organization Committee. doi:10.1016/j.proenv.2011.09.273
Unfortunately, Siam weed is extremely difficult to control or eradicate. It is generally recognized that biocontrol remains the only way to bring Siam weed to manageable levels[2], but Chinese scientists are still trying to find a suitable biological enemy[7]. Considerable effort is being put forward to find new and innovative methods for integrative management for Siam weed, which should be based on a detailed understanding of weed biology and ecology[7].

Although Siam weed has received considerable attention and research[1,3,6], most of these researches have focused on population dynamics[8], biological control[9], allelopathic effect[10], potential distribution[3] and genetic structure[6], information about Siam weed germination is limited[8]. Little is known about the effects of environmental factors on seed germination of this species.

Seed germination is one of the most critical events for the success of any weed because it represents the first stage at which the weed can compete for an ecological niche[11]. An understanding of germination and emergence of Siam weed seeds would help to predict its potential spread into new areas and would be useful in developing effective control measures. The information may help explain why Siam weed has successfully invaded such a large area of southern China. Therefore, the purpose of this research was to determine the effects of temperature, light, water stress, salt stress and planting depth on Siam weed seed germination and seedling emergence.

**Material and Methods**

Siam weed seeds were collected from Lancang, China (22°34’N, 99°56’E), on May 12, 2007. Seeds which were obviously filled were retained while the empty seeds were discarded. The seeds were dried for 7 days at room temperature, and then stored in paper bags at room temperature (20±5 °C) for 1 wk until the experiment started.

**General Information.** Fifty seeds were placed on two sheets of filter paper in 9-cm petri dishes. The filter paper was moistened initially with 4 ml of distilled water or test solution. If necessary, 1 to 3 ml of the appropriate solution was added to maintain adequate moisture. All dishes were sealed with Parafilm to reduce loss of water. They were placed in the growth chamber with diurnal 10-h light/ 14-h dark regime, the light period had a photon irradiance rate 250 μmol m⁻² s⁻¹. A preliminary study indicated that maximum germination of Siam weed seeds occurred at approximately 25 °C. Therefore, all germination experiments, excluding those measuring the effects of temperature, were conducted at 25 °C. Germinated seed (seed were considered germinated when the radicle had emerged 1 mm) were counted and removed daily for a period of 35 days. No further germination was observed at 42 days after the start of any experiment. Seed was tested for viability with the use of 1% tetrazolium chloride solution before each trail.

**Effect of Temperature.** Siam weed seeds were placed in petri dishes and incubated at constant temperatures of 5, 10, 15, 20, 25, 30, 35, and 40 °C to evaluate the response to a wide range of germination temperatures.

**Effect of Light.** Petri dishes were covered with double layers of aluminum foil to ensure no light penetration or left uncovered to allow continuous light exposure (250 μmol m⁻² s⁻¹ PPFD) in order to determine the effect of light on germination. Dishes assigned to dark treatments remained unopened until the final day of the experiment. The experiment was set in a dark room with a safe green light.

**Effect of Water Stress.** Siam weed seeds were moistened using solutions of PEG 6000 with known water potentials. The PEG solutions were prepared according to the equations of Michel and Kaufmann[12]. The water potentials were set to 0, -0.1, -0.2, -0.3, -0.4, -0.5, -0.6, -0.7, -0.8, -0.9, and -1.0 MPa. Germination of seeds and the level of PEG solutions were assessed daily. Once a reduction in the level of PEG solution was detected, all filter papers and solutions were replaced using PEG solutions prepared on the day of replacement.

**Effect of Salt Stress.** Salt effects on germination were studied using solutions of 0, 50, 100, 150, 200,
250, and 300 mM sodium chloride.

**Effect of Planting Depth.** Seeds were planted in sand-peat medium (90% sand and 10% peat moss, v/v) in plastic pots (19-cm diam by 16-cm depth) at depths of 0, 0.5, 1.0, 1.5, 2.0, 2.5, 3.0, and 3.5 cm below the soil surface. Greenhouse temperatures were 30 ± 3 °C during the day and 20 ± 5 °C during the night, and natural 12- to 13-h photoperiods (200 to 700 μmol m^{-2} s^{-1} PPFD) were used. Pots were watered throughout the study as needed to maintain adequate moisture. Seedlings were considered to have emerged when cotyledons were visible. Emergence counts were recorded daily and removed daily for a period of 35 days. No further germination was observed at 42 days after the start of any experiment.

**Statistical Analysis**

All experiments were conducted using a completely randomized design with four replicates. We conducted each experiment twice. Because trails of each duplicated experiment resulted in the same trend, the results were combined. Regression analysis was used to determine the effect of salt stress, water stress and planting depth on seed germination. Data met all normality conditions; therefore, data transformation was not required.

**Results and Discussion**

**Temperature.** Siam weed seed germination increased from 6% to 84% between 10 and 25 °C, and then declined to 46% at 35 °C (Fig.1A). No germination occurred at a constant temperature of 5 and 40 °C. Low temperatures were more detrimental to germination than high temperatures. Siam weed was primarily found in the southern parts of Yunnan and Hainan provinces of China, where adaptation to high temperature could be beneficial. Low temperature (≤ 10°C) markedly inhibited germination, which indicates that Siam weed seed can only germinate at relatively warm temperature, consequently, spread of this weed may be restricted to warm regions. Kritcos et al. [13] reported that Siam weed (vegetative plants) could survive in a temperature range of (2 ~36°C). So we predict that the future range of Siam weed in China will be restricted largely to the Southern China, including major parts of Yunnan and Hainan provinces, the southwestern part of Guangxi province, the coast south of Guangdong and Fujian provinces.

**Water Stress.** As osmotic stress increased, Siam weed seed germination decreased (Fig.1B). Siam weed germination was 78, 74, 68, 64 and 63% at osmotic potential of 0, -0.1, -0.2, -0.3 and -0.4 MPa,
respectively. Only 29, 15 and 5% of seed germinated at osmotic potentials of -0.5, -0.6 and -0.7 MPa, respectively. No germination occurred at an osmotic potential higher than -0.8 MPa. Optimum germination occurred at osmotic potentials between 0 and -0.4 MPa, where germination exceeded 60%. This result helps explain the association between rain events and flushes of Siam weed in the field, which occurs during the rain season (May to October) in south China. Several weedy species, such as *Bidens pilosa* [14], *Ipomoea pandurata* [15], have shown similar sensitivity to osmotic stress. However, Siam weed germination is more sensitive to osmotic stress than *Cucurbita foetidissima* [15], *Solanum sarrachoides* [16] and *Solanum viarum* [17]. Therefore, Siam weed germination is dependent on adequate soil moisture. This may partially explain why Siam weed has established and is spreading along riparian zones at river valleys of HengDuan Mountains in Yunnan province. Although the plant occupies areas in moist to dry river valley, it is restricted to river banks in hot-dry valleys, where infestations are sporadic. Within the evaluated seed population, tolerance to water stress differed immensely among individual seeds. Only a small percentage of seeds were capable of tolerating severe water stress, as evidenced by 5% germination at -0.7 Mpa. These differences in germination tolerance to water stress within a population is an important survival tactic, which permits proportionally fewer seeds to germinate in a stressed environment because of limitations in available soil moisture, which would hinder growth and ultimately reproduction.

**Salt Stress.** Germination of Siam weed seeds was inversely related to NaCl concentration (Fig 2A). Germination was greater than 65% at less than 50 mM NaCl and greater than 20% at 200 mM NaCl, with no germination at 300 mM NaCl. These data suggest that even at high soil salinity, Siam weed seed may germinate. Decreased germination due to increased salt concentration has been reported in *Campsis radicans* [18], *Bidens pilosa* [14], and *Caperonia palustris* [19]. Siam weed seems to have salt tolerance greater than *Campsis radicans* [18], *Bidens pilosa* [14], and *Caperonia palustris* [19].

![Fig. 2](image-url)  
**Fig. 2.** Effect of NaCl concentration (A) and planting depth (B) on germination and emergence of Siam weed seeds. Vertical bars represent standard errors of the means.

**Light and Planting depth.** When Siam weed seeds were exposed to continuous darkness, the germination was 38%. This was significantly lower \((P < 0.05)\) than the 76% germination under 10-h photoperiod. This shows that Siam weed seeds are light-sensitive, and our results may help explain why it usually invades areas that experience frequent disturbance, particularly where soils are bare and exposed. This suggests that successful Siam weed germination and establishment require a high light environment. A light requirement for seed germination is common, especially in species that have small seeds [20]. However, since some Siam weed seeds also germinated in complete darkness, this could explain why germination occurs in dense, shaded areas such as closed canopy tropical rain forests [21].
Emergence of Siam weed seedlings decreased rapidly with increased planting depth. Emergence was greater than 65% for seeds placed on the soil surface or at a depth of 0.5 cm, and no seedlings emerged from seeds placed at a depth of 3.5 cm (Fig. 2B). This reduction in germination at even shallow soil depths could, in part, be attributed to a reduction in light or to inability of germinated Siam weed seedlings to survive before they emerged. Because of the small size of Siam weed seeds[22], resources may have been limited, preventing sustained seedling growth. Light promoted or benefited seed germination of *Euphorbia supina*[23] and *Verbascum thapsus*[24]. Similarly, seedling emergence of these species was greatest from the soil surface down to 0.5 cm. Decreased emergence due to increased planting depth has been reported in *Morrenia odorata*[25], *Bidens pilosa*[14], *Brunichiaovata* [26], and *Campsis radicans* [18].

In a preliminary field study, most of Siam weed seeds were found to be present in the top 2 cm of the soil. A large proportion of seeds of Siam weed remained under enforced dormancy during their burial in soil, and after two years approximately 54% of Siam weed seeds were recovered[8]. So the deeply buried seeds have the potential for germination when they are relocated to near the soil surface by disturbance. This can increase the time and effort needed to control Siam weed, so we suggest that a long-term management system be established to control this invasive weed.

**Acknowledgments**

This work was supported by Science Technology Foundation of Heilongjiang Education Office (11541034), National Natural Science Foundation of China (30900218) and China Postdoctoral Special Science Foundation(200902368), Northeast Agricultural University Science Research Foundation, China Postdoctoral Science Foundation(20080430874), Heilongjiang Postdoctoral Science Foundation(LBH-Z07241).

**References**