Research reports

Factors affecting germination of Siam weed (*Chromolaena odorata* (L.) King & Robinson) seeds

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Summary

Effects of several environmental factors on germination and emergence of Siam weed (*Chromolaena odorata* (L.) King & Robinson) were examined in laboratory and greenhouse. Total germination was reduced in dark conditions (25%) compared to that in alternating light/dark conditions (90%). The highest level of germination was observed when seeds were exposed to alternating light/dark together with the application of gibberellic acid (GA_3). The optimum alternating temperature 20/30°C resulted in 84% germination at day 10. Germination was reduced under simulated moisture stress, and no germination was observed at -1.19 MPa. Maximum germination (87%) occurred at pH 7. Increasing NaCl concentration reduced the germination percentage (12% recorded at 170 mM) and growth of Siam weed. Greater emergence was obtained when seeds were sown on the soil surface (73% in Serdang Series and 88% in Sungai Buluh Series), but no seedlings emerged when seeds were planted 2 cm deep. Shade levels of 50 and 70% reduced plant dry matter by 50 and 63% respectively relative to growth in full sunlight. The number of leaves and leaf area also decreased significantly in plants grown under 50% shade as compared to those receiving full sunlight.

Introduction

Chromolaena odorata (L.) King & Robinson, also known as triffid weed (Kluge 1991) or Siam weed, is a perennial, scrambling shrub of the family Asteraceae which has a wide distribution in the Old World tropics from west and south Africa to Asia and the Pacific. The species poses a serious weed problem in many regions of the world (Holm *et al.* 1977). It is ranked among the three most serious weeds in plantations of coconut in Sri Lanka and of rubber and oil palm in Indonesia and Malaysia (Holm *et al.* 1977). In South Africa, Siam weed is primarily a problem in conservation areas (Kluge 1991). The plant also grows profusely on the wastelands and roadsides of northeastern India and elsewhere at lower altitudes (Yadav and Tripathi 1981). Siam weed will grow on most soil types but prefers well-drained sites (Pancho and Plucknett 1971) and will not grow in water-logged or saline soils (Cruttwell McFadyen 1989).

Siam weed plants do not spread vegetatively, though old stems may die and be replaced by new shoots from ground level. Seed production is prolific: up to 87 000 seeds per mature plant or 400 000 per m^2 in 3-year-old fallow land (Kushwaha *et al.* 1981). The achenes bear a small stiff pappus and are efficiently wind-dispersed. Wind-carried mature seeds drop on open areas where they eventually germinate and establish themselves.

Several environmental factors are known to promote or inhibit weed seed germination (Taylorson 1987). Temperature, moisture, light, and pH requirements for germination vary considerably from species to species (Jain and Singh 1989). Some weed species can emerge from a wide range of planting depths (Singh and Achhireddy 1984), while others must be close to the soil surface (Biswas *et al.* 1975). Preliminary studies on the effects of environmental factors on Siam weed have been reported (Eramus and van Staden 1986, 1987). An understanding of germination biology can help to predict the potential for its spread into new areas and be useful in developing effective control measures. The purpose of this research was to examine the effects of some environmental factors on germination and growth of Siam weed.

Material and methods

Hand-harvested Siam weed mature fruits were obtained from an orchard near Lenggeng, Negeri Sembilan, Malaysia. The pappus was removed using forceps and the seeds stored for two weeks at room temperature until use in experiments. In all experiments, 20 seeds were placed in a 9 cm petri dish lined with two sheets of Whatman No. 2 filter paper, which was then moistened with 6 mL of distilled water or the appropriate solution described later for the pH, salinity and moisture stress experiments. Unless otherwise noted, germination tests were conducted at 20/30°C in a 12 h dark/12 h light regime (175 µmol m^{-2} s^{-1}). Seeds were considered germinated when the radicle attained a length of 1 mm. Germination counts were taken at 2 day intervals over a 10 day incubation period. Germination data were expressed as percentages and analysed following arcsin transformation. Fresh weight and radicle length of seedlings were determined at day 10.

Temperature

Germination experiments were conducted in a growth incubator at alternating temperatures of 15/30, 20/30, 30/35 and 30/40°C. Alternating temperature chambers provided 12 hours each of dark and light, at the respective low and high temperatures.

Light and GA_3

Light requirements were determined by comparing germination in petri dishes wrapped in aluminium foil with those exposed to 175 µmol m^{-2} s^{-1} of unfiltered cool white fluorescent light at seed level. The germinator provided 12 hours of exposure to light and 12 hours to darkness. The effect of 8.6×10^{-5}M gibberellic acid (GA_3) was determined by adding GA_3 to the germination medium and then wrapping petri dishes in foil.

Simulated moisture stress

Moisture stress was simulated with solutions of mannitol (d-mannite) that would provide osmotic potentials of -0.01 up to -1.19 MPa (Ismail and Shukor 1990).

pH

Buffered pH solutions were prepared using 0.1M potassium hydrogen phthalate in combination with either 0.1M HCl or 0.1M NaOH to obtain solution pH levels of 4, 5 and 6. A 0.025M sodium tetraborate solution was added in combination with 0.1M HCl to prepare solutions with pH levels of 7, 8, 9 and 10 (Shaw *et al.* 1991).

Salinity

To study the effects of salinity on germination, reagent grade NaCl was used to prepare saline solutions of 0 (control), 4.2, 8.4, 20, 80, 170 and 340 mM as described by Reddy and Singh (1992). Five mL of the appropriate solution was used as the germination medium.

Depth of planting

Seeds were planted in plastic trays in 1 cm increments at depths up to 10 cm in soil

(Serdang Series, sandy loam soil and Sungai Buluh Series, loamy sand) collected from an experimental plot at Universiti Pertanian Malaysia, Serdang, and the rubber estate at the Rubber Research Institute, Sungai Buluh, Selangor, respectively. The trays were kept at 30 ± 5°C on greenhouse benches. Trays were watered as needed to maintain adequate moisture. Twenty seeds were planted in each of five replicates per depth of burial. Seedlings were considered emerged if shoots appeared at the soil surface. Emergence was recorded after 21 days of planting.

Shading

Ten seeds of Siam weed were sown in each pot (13 cm diameter) containing 3.5 kg of either Serdang Series or Sungai Buluh Series soil. The pots were placed on benches in the greenhouse at 30 ± 5°C for about four weeks before being transferred under four shading levels, namely 0% (control in full sunlight), 35, 55, and 70%. The shade structures measured 1.5 × 1.5 × 1.5 m with netting on the top and sides of the structures. There were 10 pots for each of the shade levels with five replications. The number of leaves, leaf area and plant dry weight were determined six weeks after the seedlings were transferred under shade. The plants in each pot were removed at the soil surface for dry weight determination.

Statistical analysis

The experimental design of all experiments was a randomized complete block with five replications and was conducted twice. The data were pooled and subjected to analysis of variance, and means were compared with an LSD test at the 5% level of significance.

Results and discussion

Temperature

The optimum temperature regimes for Siam weed germination were alternating temperatures of 20/30 and 25/30°C, with 84 and 70% germination, respectively, recorded at day 10 (Table 1). Germination decreased at temperatures below this range with only 52% germination at 15/30°C after day 10. Seeds did not germinate at 30/40°C. The results indicate that Siam weed has the capacity to germinate under a range of temperatures, which may account at least in part for the continuous emergence of this weed throughout the year. Our results have shown that the optimum temperatures for Siam weed seed germination are similar to temperatures under local conditions, which are favourable for the establishment of this weed.

Temperature is considered an important factor in weed seed germination. Some seeds germinate over a wide range of temperatures (Fernandez-Quinantilla *et al.* 1990) while others require critical levels of relatively high temperature (Toole 1973). Our results have shown that Siam weed germinated better at alternating moderate temperature. Other species, such as sorghum-almum (*Sorghum almum* Parod) and hairy beggarticks (*Bidens pilosa* L.), have also been reported to germinate better at alternating temperatures (Reddy and Singh 1992). In contrast, some species, such as dogfennel (*Eupatorium capillifolium* [Lam.] Small) and yankeeweed (*Eupatorium compositofolium* Walt.), germinated better at constant temperature (MacDonald *et al.* 1992).

Light

Germination of Siam weed seeds occurred to a lower level in the dark compared to germination in alternating dark and light conditions (Table 2). Total germination was 90% at alternating light/dark (12h dark/12h light regime), compared to only 25% in the dark. The addition of gibberellic acid to the growth medium seems to have partly overcome the light requirement for germination, as it increased germination in the dark from 25 to 55%. The wet weight and radicle length measurements of the seedlings showed a pattern similar to that of germination. These results show that light does influence germination of this species: germination still occurred in the dark albeit at a lower percentage. However, many reports indicate that other weeds showed that light is essential in increasing of germination (Jain and Singh 1989, MacDonald *et al.* 1992, Reddy and Singh 1992).

Moisture stress

Germination, radicle length and wet weight of Siam weed seedlings decreased as the osmotic stress of the germination medium increased (Table 3). No germination occurred at an osmotic stress of -1.19 MPa. Germination was reduced by 17% at the simulated moisture stress of -0.09 MPa but dropped by 53% of control at a water potential of -0.65 MPa. The decline in germination at -0.83 MPa indicates that the rate of germination slowed as osmotic stress increased. Radicle elongation also decreased with increased osmotic potential. At -0.65 MPa, the radicle length was only 1.5 mm in -0.65 MPa, compared to 19 mm in water. Fresh weight of the seedlings was also reduced with increased osmotic potential. At -0.65 MPa, the fresh weight was 0.3 mg compared to 2.5 mg in water. Germination in other weed species, including *Paspalum conjugatum* Berg. (Ismail 1985), has shown similar sensitivity to osmotic stress. However, Siam weed germination is more sensitive to osmotic stress than *Pennisetum polystachion* (L.) Schultes (Ismail *et al.* 1994). The ability of Siam weed seeds to germinate at -0.65 MPa indicates that germination of Siam weed is not very sensitive to low water potential and the weed may not be restricted to well-drained or moist soils but also be able to establish under low soil moisture conditions.

pH

Siam weed seed germinated 72–65% in buffer solution of pH 6–8 (Table 4). The maximum germination was 90% at pH 7. Germination decreased at pH levels outside this range, with levels of 17 and 8% at pH 5 and 9, respectively. Maximum radicle elongation and fresh weight also occurred at pH 7. Radicle elongation and fresh weight were more sensitive to pH changes from 7 to either 5 or 6 than was germination. This characteristic is com-

Table 1. Effect of various alternating temperature regimes on germination of Siam weed seeds.

	Days (%)				
Temperature °C	2	4	6	8	10
15/30	10	23	40	42	52
20/30	20	55	68	78	84
25/30	10	63	70	70	70
30/40	0	0	0	0	0
LSD (P=0.05)	11	19	14	15	14

Table 2. Effect of light or dark and GA_3 (8.6 × 10^{-3} M) on germination and early growth of Siam weed.

Treatment	Germination (%)	Radicle length (mm)	Fresh weight per seed (mg)
12 hr dark/12 hr light	90	16.3	2.6
12 hr dark/12 hr light + GA_3	95	18.4	3.2
Dark	25	10.0	1.9
Dark + GA_3	55	10.4	2.6
LSD (P=0.05)	26	4.2	0.7

Table 3. Effect of osmotic stress on germination and early growth of Siam weed.

Osmotic stress (MPa)	Germination (%)	Radicle length (mm)	Fresh weight (mg)
0	90	19.0	2.5
-0.01	83	17.7	2.4
-0.09	75	10.9	1.4
-0.47	70	4.8	0.8
-0.65	42	1.5	0.3
-0.83	18	0.7	0.1
-1.01	5	0.1	0.1
-1.19	0	0	0
LSD (P=0.05)	12	2.7	0.4

Table 4. Effect of pH on germination and early growth of Siam weed.

pH	Germination (%)	Radicle length (mm)	Fresh weight (mg)
4	0	0	0
5	17	1.0	0.1
6	72	9.1	1.0
7	90	20.6	2.4
8	65	5.0	0.8
9	8	1.0	0.1
10	0	0	0
LSD (P=0.05)	7	1.8	0.2

Table 5. Effect of salinity on the germination and early growth of Siam weed.

NaCl (mM)	Germination (%)	Radicle length (mm)	Fresh weight (mg)
0	90	22.3	2.7
4.2	83	21.1	2.4
8.4	77	16.2	1.9
20	75	15.5	1.8
80	52	1.0	0.7
170	12	0.2	0.1
340	0	0	0
LSD (P=0.05)	12	1.9	0.3

Table 6. Effect of depth of seed placement on emergence of Siam weed.

Depth (cm)	Emergence (%)		LSD (P=0.05)
	Serdang Series	Sungai Buluh Series	
0	73	88	2
1	7	10	2
2	0	0	
LSD (P=0.05)	3	3	

Table 7. Effect of shade on leaf number, leaf area and dry weight of Siam weed.

Parameters	Shade levels (%)				
	0	36	52	69	LSD (P=0.05)
No. of leaves	19	19	16	16	1.0
Leaf area (cm^2)	532	505	432	403	58.0
Root dry weight (g)	1.84	1.64	0.82	0.45	0.17
Leaves dry weight (g)	4.40	4.06	2.30	1.84	0.18
Total plant dry weight (g)	6.24	5.70	3.12	2.29	0.56

mon for many weed species. These results are similar to those reported for *Asystasia intrusa* Bl. (Ismail and Shukor 1990) and *P. conjugatum* (Ismail 1985) which germinate under a wide range of pH. A broad pH range for germination indicates that pH should not be a factor limiting Siam weed germination in most soil types.

Salinity

Siam weed seed germination reduced steadily as NaCl concentration increased with 52% germination recorded at 80 mM, 12% at 170 mM NaCl, and no germination at 340 mM NaCl. These results suggest that Siam weed, while sensitive to salinity, was tolerant to higher salt concentrations than *P. conjugatum* (Ismail 1985) and *A. intrusa* (Ismail and Shukor 1990). Similarly, germination of *Solanum elaeagnifolium* Cav. (silverleaf nightshade) was reduced by 90% when exposed to 86 mM NaCl (Boyd and Murray 1982). Increasing NaCl concentration also reduced the radicle length and wet weight of the seedlings. It should be noted that increased osmotic potential is not the only mechanism by which NaCl inhibits seed germination; Na^+ and Cl^- ions exert toxic effects on seed germination beyond the influence of increased osmotic potential (Uhvits 1946).

Depth of planting

Emergence of Siam weed seedlings decreased significantly with increased planting depth (Table 6). No seeds germinated when planted at 2 cm depth. Seedling emergence at the soil surface of Sungai Buluh Series soil was greater than on Serdang Series soil. Soil composition and such characteristics as high organic carbon content may greatly influence germination and consequently seedling emergence (Ismail and Shukor 1990). Maximum emergence from seeds placed on the soil surface suggests that minimum tillage practices enhance germination of viable seed at the soil surface. These results are consistent with observed severe infestations of Siam weed in open undisturbed areas and in wastelands. Lack of light generally limits seedling emergence from the soil. Limited light penetration is the probable reason for the failure of Siam weed to emerge at the greater depths.

Shade

The number of leaves and leaf area decreased under 52% shade (Table 7). Dry weight (roots, leaves and total plant dry weight) decreased significantly with each increase in the level of shade. Reducing available sunlight results in a reduction in photosynthetic activity (Patterson 1982), and reproductive capabilities can decrease with increasing shade levels (Boyd and Murray 1982).

This research has identified a number of specific parameters required for Siam weed germination and establishment. The results indicate that this weed is adapted to a fairly wide environmental niche. Under laboratory conditions, Siam weed seed germination may occur over a wide range of temperatures. Light is one of the factors in determining the amount of seed germination, and maximal seedling germination occurred at the soil surface. Germination occurred under a wide range of acidity and salinity levels, implying that liming or altering soil acidity by various means would have only a limited effect on preventing the establishment of this weed. In addition, Siam weed can germinate under moderate moisture stress. Based on this observation, it seems that this species might easily establish under a wide range of conditions, especially in the Tropics.

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