A comparison of seed germination ability between exotic and indigenous weeds in Taiwan

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Abstract

The influence of environmental factors on seed germination ability between five exotic weeds, i.e., floss flower (*Ageratum houstonianum* Mill.), celosia (*Celosia argentea* L.), mile-a-minute (*Mikania micrantha* Kunth), beggarticks (*Bidens pilosa* L.) and passionflower (corkystemmed)(*Passiflora suberose* L.), and an indigenous weed flatsedge (*Cyperus iria* L.) in Taiwan was evaluated. While seeds of all six species germinated at temperatures between 20 and 36 C with the optimum for passionflower falling between 24 and 32 C, seeds of the two Compositae spp., floss flower and beggarticks, preferred lower temperature, with declining germination rate at increasing temperature. The germination of five weeds was inhibited with osmotic potentials increasing from -0.4 to -1.0 MPa, but that of passionflower was not affected by osmotic potential up to -1.0 MPa. Seed germination of all five exotic weeds was not altered much when pH of the moisture supply varied between 4.0 and 9.0, in contrast, that of the indigenous flatsedge was significantly reduced to 30% with pH increasing from 8.0 to 9.0. Although the seed germination of floss flower, mile-a-minute, beggarticks and flatsedge was light-dependent, that of celosia and passionflower was only slightly inhibited in dark. Under the climate conditions and soil environments in Taiwan, the five exotic weeds tested, especially passionflower, are expected to display higher seed germination ability than the indigenous weeds. Therefore, the invasion risk of exotic weeds should be closely monitored in both the field and non-farming lands.

Key words: seed germination, environment, exotic, indigenous, weeds.

台灣外來與本土雜草種子發芽能力之比較

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摘 要

本研究針對台灣五種外來雜草在不同環境下之發芽能力進行比較分析，包括紫花霍香薊(*Ageratum houstonianum* Mill.)、青葙(*Celosia argentea* L.)、小花蔓澤蘭(*Mikania micrantha* Kunth)、大白花咸豐草(*Bidens pilosa* L.)及三角葉西番蓮(*Passiflora suberose* L.)，並以本土雜草碎米莎草(*Cyperus iria* L.)爲對照比較其發芽潛力差異。在各種溫度處理下發現在 20 至 36 C 範圍內六種雜草均可發芽，尤其三角葉西番連在 24 至 32 C 溫度下有最適當之發芽率。然而菊科植物紫花霍香薊與大白花咸豐草則適合在較低溫度下發芽。研究發現所有雜草種子在滲透潛勢-0.4 至-1.0 MPa 範圍內，其發芽抑制程度均隨之增加，唯獨三角葉西番蓮不受影響。此外，當發芽環境 pH 值改變時，

在 pH 4.0 至 9.0 範圍內所有雜草之發芽均不受影響，但在 pH 9.0 時本土雜草碎米莎草之發芽則受抑制程度達 70%。雖然有四種雜草，包括紫花霍香薊、小花蔓澤蘭、大白花咸豐草、及碎米莎草之發芽必需光照，但也發現青葙及三角葉西番蓮在黑暗下其發芽僅受輕微抑制。於台灣氣候土壤環境下，顯然測試之五種外來雜草，尤其是三角葉西番蓮，其種子發芽競爭力高於本土雜草碎米莎草。

關鍵字：種子發芽、環境、外來、本土、雜草。

Introduction

Floss flower (*Ageratum houstonianum* Mill.), an annual weed native to tropical America, appears widely in arable lands, wastelands and on roadsides. In favorable conditions, this plant completes its life cycle in less than 2 months, with a plant height up to 90 cm and hundreds of flower heads; yet, it could also grow into a tiny plant with a single flower under extremely wet or dry conditions (Baker 1965).

Celosia *(Celosia argentea* L.) is an annual herb presumably originating from tropical Africa; and many cultivars with a plant height of 0.4 to 2 m (Dassanayake, 1981) are widely distributed at low altitudes (Henty and Pritchard, 1975) in tropical and subtropical areas (Smith, 1981).

Mile-a-minute (*Mikania micrantha* Kunth) is native to tropical America, yet, some researchers postulated it to originate from Asia and the Pacific Islands. This rapid-growing species, which can smother young plants with its rampant vine, is a troublesome weed in plantations, such as tea, rubber, coffee, coconut, cacao, and oil palm.

Beggarticks *(Bidens pilosa* L.), an annual weed originating in tropical America, which has spread throughout the warm regions of the world, is hard to control in arable lands. Within a week of harvest 35 to 60% of the 3000 to 6000 seeds produced by individual plants could germinate; and there could be three to four generations per year in some areas. Seeds of 3 to 5-year old could still retain

80% germination rate (Rochecouste and Vaughan, 1959),

Passionflower (corkystemmed)(*Passiflora suberose* L.), a perennial tendrilous vine originating in tropical America, spreads in the sub-canopy layer where it smothers shrubs, small trees and ground plants (Smith, 1985). In Hawaii, it is naturalized in grassland, shrubland, open dry forest, diverse mesic forest, and exposed ridges (Wagner *et al.,* 1999). In the Galápagos Islands, passionflower distributes among shrubs and rocks, mostly in shady areas, at an altitude from near sea level to about 615 m (Wiggins and Porter, 1971).

Flatsedge (*Cyperus iria* L.), an annual sedge and a major weed of wetlands in Japan, Pacific islands, Australia and India, is an indigenous weed hard to control in the rice field in Taiwan. An individual plant may produce more than 5,000 seeds. It is also a common weed of dry-land field, such as in pineapples, sugarcane, cassava, tea, and corn, in Taiwan.

The invasion risk of the five exotic weeds mentioned above may be low when they appear in agricultural lands or places where human activity occurs frequently. However, this risk may be increased when they find their way into places without agricultural practices. In natural environment, temperature, light, osmotic potential and pH of soils affect seed germination (Chachalis and Reddy, 2000; Koger et al., 2004b; Taylorson, 1987). In Taiwan, little research has been carried out to determine and compare the germination ability of exotic and indigenous weeds under local environmental conditions. The objective of this study was to investigate the effects of temperature, light, osmotic potential and pH on seed germination of several exotic and an indigenous weeds as an initial effort to assess the risks of foreign plants imported into this island.

Materials and Methods

Seed Sources and General Experimental Procedures

Seeds of five exotic weeds, i.e., floss flower (*Ageratum houstonianum* Mill.), celosia *(Celosia argentea* L.), mile-a-minute (*Mikania micrantha* Kunth), beggarticks *(Bidens pilosa* L.) and passionflower (corkystemmed)(*Passiflora suberose* L.), and an indigenous flatsedge (*Cyperus iria* L.) were collected in

Taichung, Taiwan during the summer of 2005. Germination studies were conducted in incubators by using Petri dishes (diameter 9 cm) lined with filter paper pre-moistened with 5 ml of either distilled water or treatment solution. Fifty seeds of each species were placed in Petri dish with cover to prevent loss of moisture. Germination of seeds was based on the extrusion of bud through seed coat. Temperature experiment was performed in order to determine the optimum temperature for seed germination of each species. Thereafter, responses of seed germination to osmotic potential, pH and light were conducted at the optimum temperature for each species.

Effect of Temperature on Seed Germination

Seeds were incubated at 8, 12, 16, 20, 24, 28, 32, and 36 C in dark, and the experiment was started by adding 5 ml of distilled water to the Petri dish. A supplement of 2 ml distilled water/Petri dish was provided every day throughout the experiment; and the germination was measured 14 days after treatment.

Effect of Osmotic Stress on Seed Germination

Aqueous solutions with osmotic potentials of -0.2, -0.4, -0.6, -0.8 and -1 MPa were prepared by dissolving 154, 191, 230, 261 and 297 g, respectively, of polyethylene glycol (PEG) 8000 in 1 L of deionized water (Michel, 1983; Steuter et al., 1981). PEG-free water was used as control. Seeds were incubated at 36 C, and each Petri dish received 5 ml of PEG solution at the beginning of the experiment; thereafter, fresh PEG solution was provided every other day throughout the 21-day period..

Effect of pH on Seed Germination

The effect of pH ranging from 4.0 to 9.0 on germination was determined at 36 C. Buffer solution of 2 mM potassium hydrogen phthalate was adjusted to pH 4.0 with 1N HCl, and solution of 2 mM MES (2-[N-morpholino] ethanesulphonic acid) was adjusted to pH 5.0 and 6.0, respectively, with 1N HCl (Nandula et al., 2006). Buffer solutions at pH 7.0 and 8.0 were prepared with 2 mM HEPES [N-(2-hydroxymethyl)piperazine-N’-(2-ethanesulfonic acid)] solution and adjusted with 1 N NaOH (Nobel and Berry, 1985; Rys and Phung, 1985). Finally, a 2 mM tricine [N-Tris(hydroxymethyl) methylglycine] buffer solution was adjusted to pH 9.0 with 1 N NaOH (Nobel and Berry, 1985). At the beginning of the experiment each Petri dish received 5 ml of an appropriate pH solution, which was replaced with fresh solution every other day for 21 days.

Effect of Light on Seed Germination

The effect of light on seed germinations of six weed species, i.e., floss flower, celosia, mile-a-minute, beggarticks, passionflower, and flatsedge, was determined in a growth chamber with constant temperature at 16, 32, 24, 24, 24 and 28 C, respectively. Fluorescent and incandescent lamps were used to produce a photosynthetically active photonflux density of 300 μmol m^{-2} s^{-1}. Germination in dark was determined by wrapping Petri dishes in a layer of aluminum foil. Germination rate was determined 21 days after treatment.

Data are presented mean ± standard error of the sample mean of three independent experiments. Experiments were arranged in a completely randomized design.

Results and Discussion

Effect of Temperature on Seed Germination

Seeds of all six weeds were able to germinate from 20 to 36 C (Figure 1), which coincide with the averaged temperatures from April to November in Taiwan (Figure 2). The optimal temperature range for the germination of passion flower was between 24 and 32 C. The two Compositae spp., floss flower and beggarticks, were found to prefer lower temperature, and their germination declined with an increasing temperature. Current data on seed germination 14 days after treatment indicate that most exotic weeds with a higher germination rate than the indigenous flatsedge are fully capable of germinating from early spring to late autumn in Taiwan.

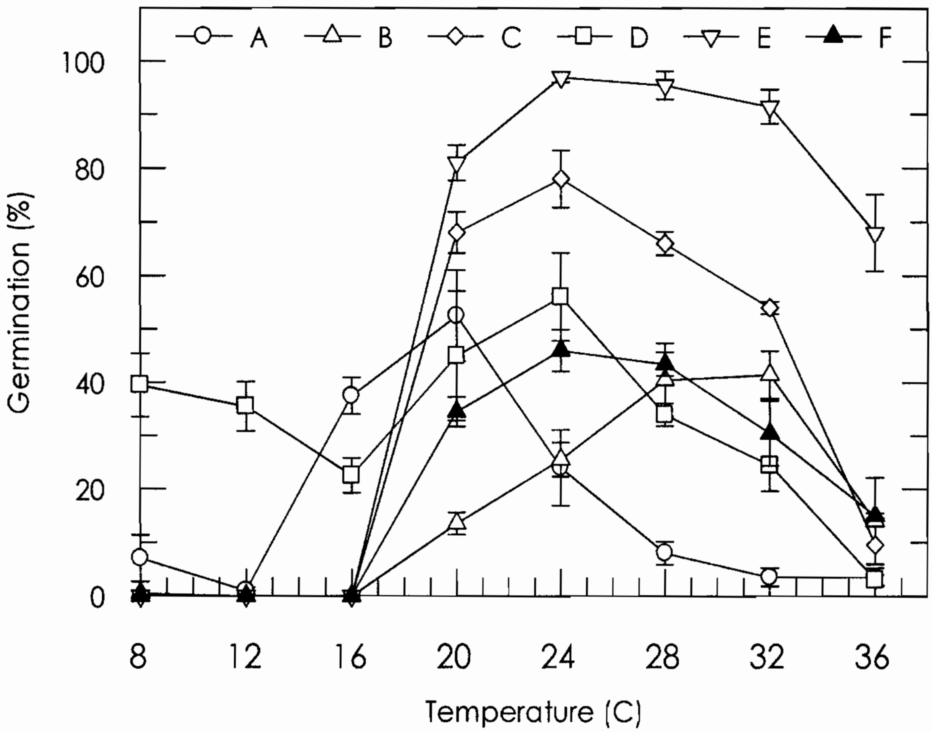

Figure 1. Seed germination of five exotic weeds, i.e., (A) *Ageratum houstonianum* Mill., (B) *Celosia argentea* L., (C) *Mikania micrantha* Kunth, (D) *Bidens pilosa* L., and (E) *Passiflora suberose* L., and an indigenous weed (F) *Cyperus iria* L. under various temperature. Mean of three replicates and standard error of the sample mean are presented.

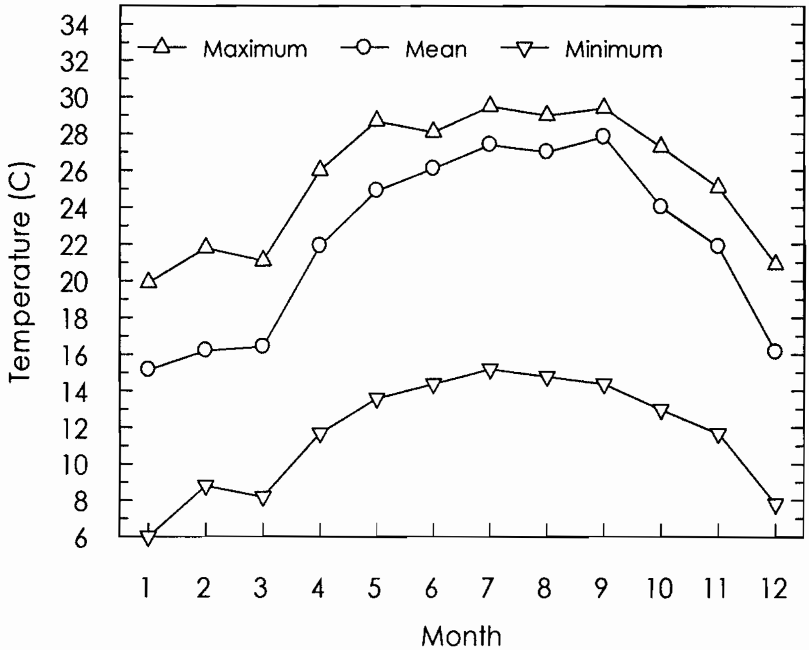

Figure 2. Monthly air temperature during 2005 in Taiwan.

Effect of Osmotic Stress on Seed Germination

Seed germination of all weeds, except passionflower, decreased significantly with increasing osmotic potential, and that of four of these weeds was completely inhibited when osmotic potential reached -1.0 MPa, the highest level used in the experiment (Figure 3). It is noteworthy that the germination of passionflower remained practically unaffected by osmotic potential up to -1.0 MPa (Figure 3). Obviously the exotic passionflower is capable of germinating at an extremely water-deficient environment. With a rainfall more than 200 mm from April to October recorded in 2005 (Figure 4), all six weed species could readily germinate during this period.

Effect of pH on Seed Germination

Buffer solutions with pH of 4.0 to 8.0 did not alter significantly seed germination of all weeds except flatsedge; seed germination of this indigenous weed was decreased from 85% at pH 6.0 to 30% at pH 9.0 (Figure 5). These

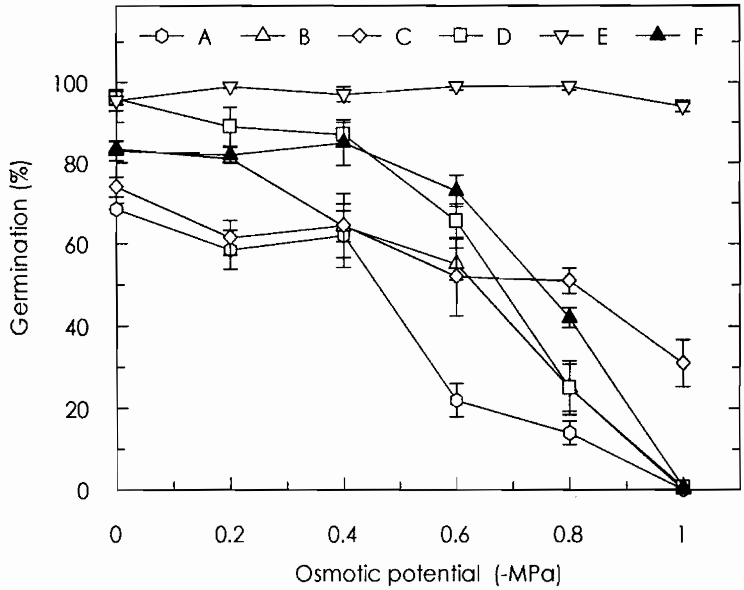

Figure 3. Seed germination of five exotic weeds, i.e., (A) *Ageratum houstonianum* Mill., (B) *Celosia argentea* L., (C) *Mikania micrantha* Kunth, (D) *Bidens pilosa* L. and (E) *Passiflora suberose* L., and an indigenous weed (F) *Cyperus iria* L. under different osmotic stress. Mean of three replicates and standard error of the sample mean are presented.

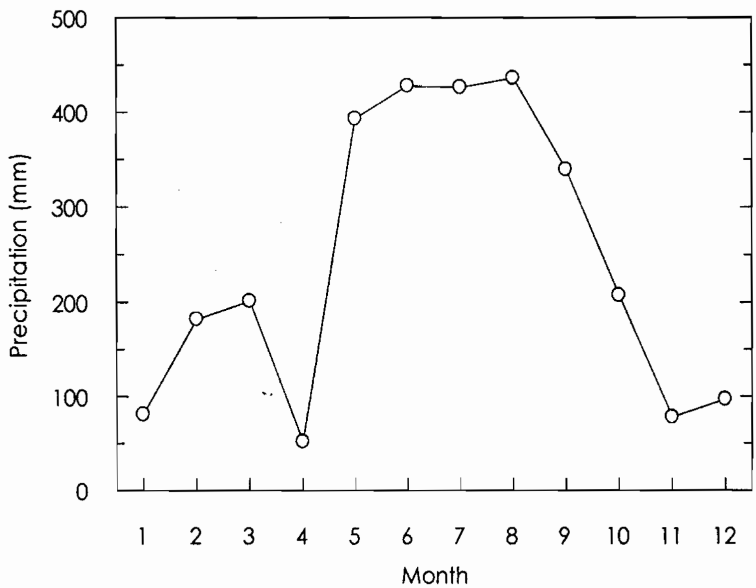

Figure 4. Monthly precipitation during 2005 in Taiwan.

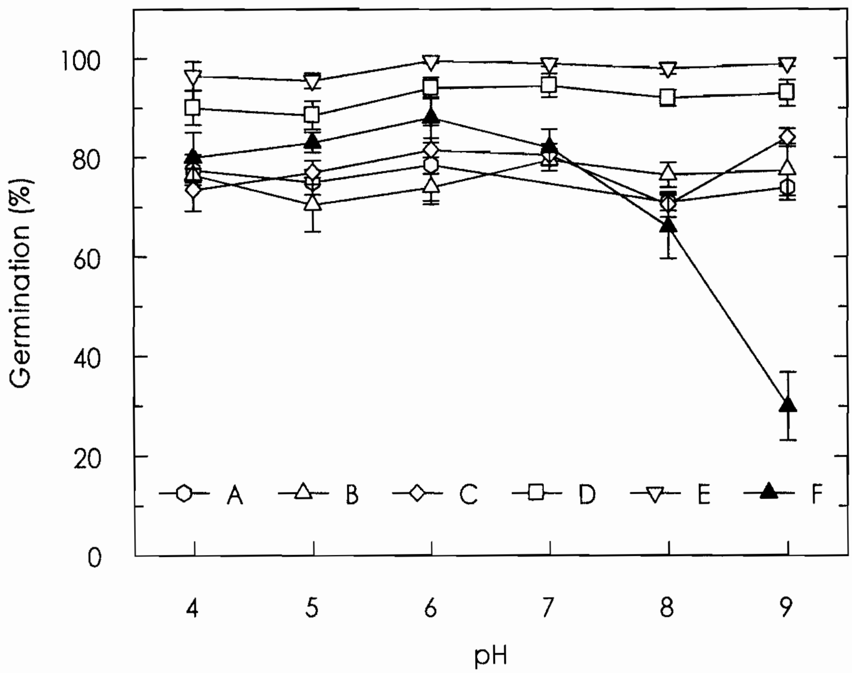

Figure 5. Seed germination of five exotic weeds, i.e., (A) *Ageratum houstonianum* Mill., (B) *Celosia argentea* L., (C) *Mikania micrantha* Kunth, (D) *Bidens pilosa* L. and (E) *Passiflora suberose* L., and an indigenous weed (F) *Cyperus iria* L. Seeds were incubated in Petri dishes to which pH buffer solutions were given. Mean of three replicates and standard error of the sample mean are presented.

results suggest that seed germination of all five exotic weeds is independent of the acidity of the environment, an observation in contrast to previous reports that seeds of most weeds germinate best in a narrow pH range, such as Canada thistle (*Cirsium arvense* L.) (Wilson 1979) and stranglervine (*Morrenia odorata* Lindl.) (Singh and Achhireddy 1984). With the pH of more than 90% of the soils in Taiwan falls between 5.0 and 8.0 (Figure 6), the acidity of environment apparently is not a critical factor to seed germination of all weeds.

Effect of Light on Seed Germination

Seed germination of four weeds, i.e., floss flower, mile-a-minute, beggarticks and flatsedge appeared as a light-dependent process (Figure 7), as

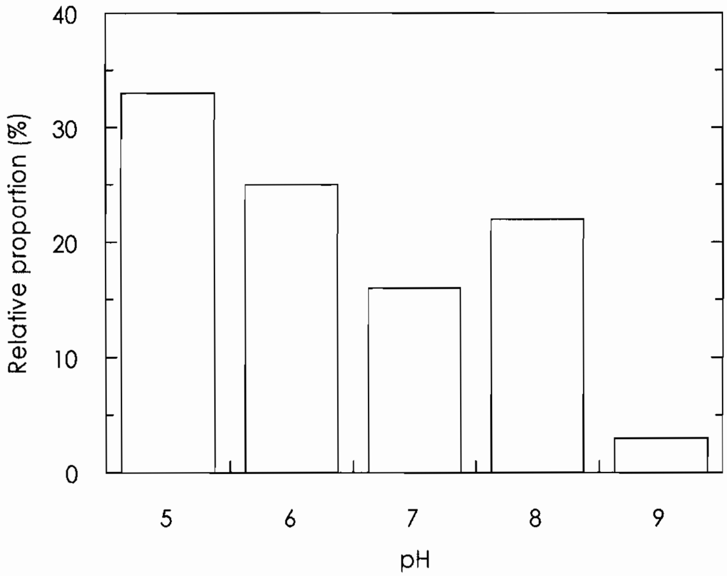

Figure 6. Frequency distribution of soil pH values in Taiwan. Relative proportion is calculated based on soils with pH ranging from 5.0 to 9.0.

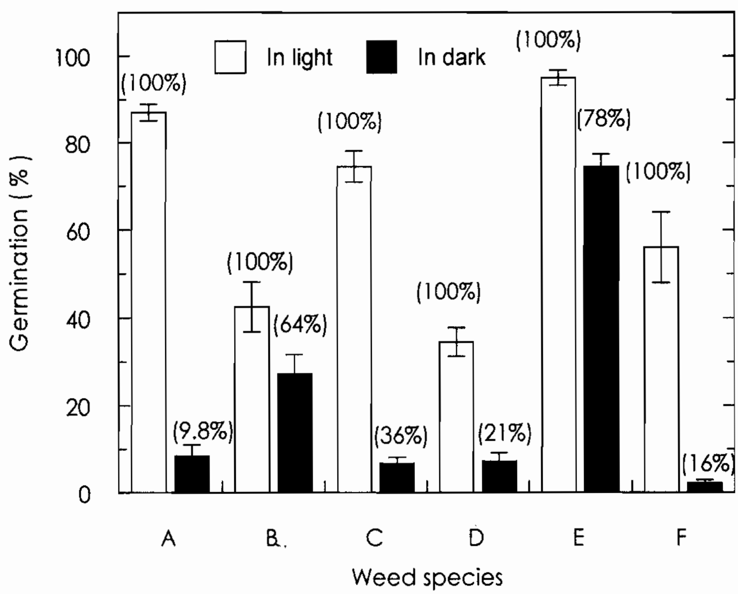

Figure 7. Effect of light on the seed germination of five exotic weeds, i.e., (A) *Ageratum houstonianum* Mill., (B) *Celosia argentea* L., (C) *Mikania micrantha* Kunth, (D) *Bidens pilosa* L. and (E) *Passiflora suberose* L., and an indigenous weed (F) *Cyperus iria* L. Mean of three replicates and standard error of the sample mean are presented.

reported for many weeds, as horseweed (*Conyza cacadensis* L.) (Nandula et al., 2006), goosegrass (*Eleusine indica* L.) (Nishimoto and McCarty, 1997), and purple nutsedge (*Cyperus rotundus* L.) (Miles et al., 1996). Similar to sicklepod (*Senna obtusifolia* L.) (Norsworthy and Oliveira, 2006), celosia and passionflower showed somewhat lower seed germination in dark, suggesting that these two weeds could germinate readily either above or under ground.

In conclusion, this experiment has shown that most exotic weeds have stronger seed germination ability than an indigenous weed we selected under the climate and soil environment in Taiwan. In addition, passionflower appears to be one of the toughest weeds which are able to propagate under extreme environmental conditions. Therefore, the invasion risk of this weed has to be watched closely in the wild.

Acknowledgment

The authors thank Professor C. N. Sun, Dept. of Entomology, National Chung- Hsing University, for her kind encouragement and suggestions on improvements to this manuscript.

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