Emergence and Growth of Beggarticks (*Bidens pilosa* var. *radiata*) in Different Plant Communities under Experimental Field Conditions

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Abstract: *Bidens pilosa* var. *radiata* (beggarticks) is an invasive weed that is commonly found in tropical and subtropical regions, especially Taiwan. Here, we investigated the emergence and growth of *B. pilosa* in 16 different monocultures and polycultures of various plant species, in order to evaluate its invasion in agricultural fields. Sixteen horticultural and agronomic species were chosen, and an orthogonal matrix of fertilizer and disturbance gradients was designed to evaluate the invasiveness of *Bidens pilosa* var. *radiata* in varied conditions. Results indicated that *B. pilosa* was dominant in C3 and Poaceae monoculture and polyculture groups. Legumes in polycultures and all-legume monocultures were found to be resistant to *B. pilosa* invasion as compared with other plant species in this study. We also found that severe disturbances interfered with the growth of the test plants, thereby facilitating *B. pilosa* emergence and growth.

Key words: *Bidens pilosa* var. *radiata*, ecology, invisibility, community, tropical, weed.

1. Introduction

The invasion of local habitats by exotic species has led to serious environmental problems and huge economic losses worldwide [1-4]. Unfortunately, the global movement of goods and people has accelerated the distribution of alien species into new environments [5]. Various studies have indicated that interactions between invasive and native plants are affected by several factors, including anthropogenic disturbance, site size and species diversity within a given habitat [6, 7], available habitat resources [8], and genetic features of the invasive and native plants [9]. Many hypotheses and models have been proposed in order to explain biological invasion and its mechanism. Some papers have concluded that compared to monocultures,

diverse communities have an increased resistance to invasion, owing to their ability to efficiently utilize resources [10-12]. However, both neutral and negative relationships between diversity and invasion have been reported. The findings, however, remain inconclusive.

Taiwanese flora is widely diverse, with more than 4,000 vascular plant species and a wide spectrum of forest types [13]. Invasive plant species have threatened the local natural ecosystems by decreasing the dissemination and survival rates of the local plants [14]. To implement a worldwide inter-governmental policy on biodiversity, various pilot investigations have been launched to examine relevant issues on biodiversity, plant invasion, and ecological complexity.

Bidens pilosa var. *radiata*, a member of the Compositae family, is used as a traditional medicinal in many of Taiwan's aboriginal communities; many of its pharmacological effects have also been reported [15-17]. It was first introduced into Taiwan 25 years

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ago as a pollen producer in the honey industry. *B. pilosa* var. *radiata* has dominated over *B. pilosa* var. *minor* and *B. pilosa* var. *pilosa*, which have been previously introduced into Taiwan. *B. pilosa* var. *radiata* is now widespread throughout the island at elevations less than 1,500 m above sea level. *B. pilosa* var. *radiata* fruit is a needle-like spine that facilitates its propagation. In addition, *B. pilosa* var. *radiata* has now been listed as an extremely invasive species (Taiwan Invasive Species Network, under Council of Agriculture). This study evaluated the emergence rate and growth of this invasive species in competition with different species. An experimental field plot with 4 fertility gradients and 4 disturbance levels was designed. Sixteen species assigned to 4 functional groups and different species combinations were used to establish experimental plant communities. *B. pilosa* var. *radiata* was then introduced into the previously established plant communities, and its emergence and growth in competition with the 16 species were studied.

It has been reported that the old world plants are less invasive than new world plants [18]; it has also been proposed that rich-species communities are less invaded [19-21]; Holgate [21] concluded that among the island ecosystems, temperate plants are more invasive than tropical plants. Further, Elton [19] reported that island plants are more susceptible to invasion than mainland plants. To investigate the process of growth in established and invader species, factors such as resource availability and physical disturbances, which affect the emergence and growth of *B. pilosa* var. *radiata*, were analyzed. This study considers the effect of species richness, resource availability, and human interference on *B. pilosa* var. *radiata* invasion.

2. Materials and Methods

2.1 Experimental Site

The experiment was carried out from July 12 to September 2 of 2006 at experimental field, National Taiwan University, Taipei, Taiwan. Data were

collected thrice, i.e., on 19 July, 26 July, and 18 August 2006. The following climatic parameters during experimental period recorded: average temperature, 27.8 °C; average relative humidity, 71%; and average sunlight availability, 214.6 hours per month. No weeds belonging to either the *Bidens* or other genera were found within and around 100 m of the experimental plots. These plots were filled with peat moss (Biolan, Finland), perlite, and vermiculite (both from Knownyou Co., Ltd) at a concentration ratio of 3:1:1. At the start of the experiment, the electrical conductivity measured at pH 6.8 was 0.7 mS/cm.

2.2 Plot Design

The experiments were conducted in the experimental field of the Department of Horticulture, National Taiwan University, Taipei, Taiwan. The experimental design was similar to those proposed by Burke and Grime [22] and Campbell and Grime [23], with slight modification. Each plot contained 4 physical disturbance levels and 4 soil fertility gradients, which were imposed orthogonally. Thus, 16 subplots were created within each plot. The 50-cm surrounding area of each plot acted as a buffer zone to reduce any possible edge effects (Fig. 1). The distribution of each plant species was shown in Table 1. Briefly, plot nos. 1 to 16 (pools 1 and 2) had monocultures of all test species, plot nos. 17 to 33 (pools 3 and 4) had polycultures of all plant species in different combinations. Each plot was further divided into subplots of size 25 cm × 25 cm by using thin wooden boards (0.5 cm) to allow differential administration of fertility gradients and physical disturbances (Fig. 1).

2.3 Species Used

Different functional traits of seeds were selected for the study as per the trait selections of Xu et al. [24]. Plant species were ecologically and botanically categorized into 4 groups: C3, Poaceae, forbs, and legume. All species used were those that commonly

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Fig. 1 Layout of experimental field with different fertility and disturbance gradients.

Table 1 Seeds sowed in different lane (refer Table 1 for species used).

Pool 1 (monoculture)	Pool 2 (monoculture)	Pool 3 (polyculture)	Pool 4 (polyculture)
1	9	1+5 (C3+F)	9+10+11+12 (All F)
2	10	5+9 (Po+F)	13+14+15+16 (All L)
3	11	9+13 (F+L)	1,2 + 5,6 (2C3+2Po)
4	12	13+1 (L+C3)	5,6 + 9,10 (2Po+2F)
5	13	2+6 (C3+Po)	9,10+13,14 (2F+2L)
6	14	6+10 (Po+F)	13,14+1,2 (2L+2C3)
7	15	1+2+3+4 (All C3)	1,2+5,6+9,10+13,14 (2C3+2Po+2F+2L)
8	16	5+6+7+8 (All Po)	3,4+7,8+11,12+15,16 (2C3+2Po+2F+2L) 1~16 (All)

found growing in various Taiwanese territories, and thus, all species were adapted to the climatic and soil characteristics of our experimental site. None of these test species was naturally present at the site during the experimental period. Sixteen plant species (Table 2) were bought from local supplier (Knownyou Co., Ltd, Taiwan), of which the germination rate was labeled averagely 80% or above. *B. pilosa* var. *radiata* seeds were collected from an uncultivated field. Numbers of sowing seed were referred to seed's provider manual as listed in Table 2. To sow evenly, seeds were mixed with

sand before sown. Water was administered once per two days during the first 14 days. After 14 days, fifty seeds of *B. pilosa* var. *radiata* were sown to each subplot.

2.4 Creation and Administration of Fertilizer-Disturbance Gradients

Fertilizer gradients were maintained by applying the 30:10:10 NPK water-soluble fertilizer (Hyponex #5; TaiHort Ltd, Taiwan) every 7 days after sowing. A 4-step gradient was applied using fertilization rates of 0, 33, 66, and 100 kg/ha. After all 16 species had

Table 2 Different plant species used in this study.

	Species (Family name)	Family	No. seeds/subplot (per 25 cm ²)	Designated as
1	<i>Begonia semper</i> Norms	Begoniaceae	50	C3
2	<i>Impatiens walleriana</i>	Balsaminaceae	50	C3
3	<i>Gypsophila elegans</i>	Caryophyllaceae	50	C3
4	<i>Ipomoea aquatica</i>	Convolvulaceae	50	C3
5	<i>Axonopus affinis</i> Chase	Poaceae	50	Po
6	<i>Cynodon dactylon</i>	Poaceae	50	Po
7	<i>Zea mays</i>	Poaceae	13	Po
8	<i>Paspalum notatum</i> Flugge	Poaceae	50	Po
9	<i>Hyptis suaveolens</i>	Lamiaceae	50	F
10	<i>Zoysia tenuifolia</i>	Poaceae	50	F
11	<i>Axonopus compressus</i>	Poaceae	50	F
12	<i>Solanum photeinocarpum</i>	Solanaceae	50	F
13	<i>Phaseolus radiatus</i>	Leguminosae	13	L
14	<i>Mimosa pudica</i> L.	Leguminosae	25	L
15	<i>Glycine max</i>	Leguminosae	13	L
16	<i>Sesbania cannabina</i>	Leguminosae	50	L

emerged for 21 and 35 days, 4 disturbance gradients—zero, low, mild, and strong—were created within each subplot, using a special cutting tool reported by Burke and Grime [22]: circular iron rings of diameters 5 cm (small) and 10 cm (large) were used to create 2-cm-deep gaps below the soil surface. The zero, slight, intermediate, and harsh disturbance gradients were created by using no, 5 small, 5 large, and 5 small and 5 large rings, respectively.

2.5 Data Collection

Five seedlings from each subplot ($n = 5$) were chosen for data collection. Emergence was defined as the appearance of a seedling above the soil surface. Emergence percentages were calculated at 7, 14, and 28 days after sowing, from the total *B. pilosa* seeds sown and germinated in each subplot. In addition, plant heights (measured from the soil surface to the shoot apical meristem) were measured at 7, 14, and 28 days after sowing.

2.6 Statistical Analysis

The experiment was analyzed as a randomized block. The rationale of the experimental design was based on a study by Burke and Grime [22], which discussed the

“more successful” invaders, and aimed to describe exotic species that occur at low frequencies and are difficult to observe/analyze experimentally. Simple linear regression was used (SigmaPlot ver 10.0) to examine a potential relationship between the fertilizer gradient and emergence rates and between disturbance gradients and *B. pilosa* var. *radiata* height.

3. Results

3.1 Emergence of Seedlings

Sesbania cannabina germinated at the fastest rate of all tested plants (within 2 days). All plant species achieved an average emergence rate of 70% and height of 22–25 cm after 14 days. In the 4-species plots (nos. 17–30), *Ipomoea aquatica* and *Zea mays* germinated at the fastest rates. Notably, only *Z. mays* survived in the all-Poaceae group (plot 24), thus suggesting that *Z. mays* interrupts the growth of other species. In the 6 different 2-species combinations, Poaceae and legumes germinated faster and grew higher than C3 and forbs. The legume *P. radiatus* grew up to 20 cm in height within 2 weeks and competed for sunlight and soil resources with other plants. In addition, it was particularly dominant when grown in 2 different 2-species combinations (plot nos.

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29 and 30). The heights of C3 and Poaceae were less than 5 cm. In 16-species combinations, most C3 and Poaceae plants had an emergence rate of over 70% and performed better than in the 2-species and 4-species combinations (data not shown).

3.2 *B. pilosa* var. *radiata* in 14-Day Monoculture Communities

Seeds of *B. pilosa* var. *radiata* were sown after monocultures had grown for 14 days. The overall

emergence rate of *B. pilosa* in the 14-day monoculture communities was found to be 10-15%. Additionally, *B. pilosa* var. *radiata* grew higher in C3 and Poaceae communities than in forb or legume communities (Fig. 2). This was particularly noteworthy in the C3 and Poaceae communities that underwent severe physical disturbances. In these communities, *B. pilosa* var. *radiata* grew up to 4-8 cm in height, whereas *B. pilosa* var. *radiata* in undisturbed communities achieved heights of merely 1-2 cm (Fig. 3).

Fig. 2 Emergence rates of 14 days *B. pilosa* var. *radiata* in monoculture with different fertilizer gradient applied. Reported values are the mean $\pm$ standard deviation ($n = 5$). Data bearing different capital letters in a same treatment group are significantly different ($P < 0.05$).

Fig. 3 Emergence rates of 14 days *B. pilosa* var. *radiata* in polyculture with different fertilizer and disturbance gradient applied. Reported values are the mean $\pm$ standard deviation ($n = 5$). Data bearing different superscript letters in the same column (uppercase) and in the same row (lowercase) are significantly different ($P < 0.05$).

3.3 *B. pilosa* var. *radiata* in 14-Day Polyculture Communities

B. pilosa var. *radiata* had low emergence rates ($< 10\%$) in the subplots that contained 2-species combinations including a legume. C3 and Poaceae plant combination exhibited low resistance to *B. pilosa* var. *radiata* growth, with an emergence rate of only 10%. Similar to the results of monoculture plots, invader plants grew higher in more severely disturbed subplots: the invader plants attained a height of 4-5 cm in severely disturbed subplots containing the C3 and Poaceae and the Poaceae and forb plant combinations, as compared to only a height of 2 cm in the undisturbed subplots. In the 4-species combinations, C3 exhibited low resistance, while the legume communities exhibited high resistance to *B. pilosa* var. *radiata* invasion (Fig. 4). Despite the increased competitive complexity, emergence rates and heights of *B. pilosa* var. *radiata* were similar in monocultures and 2-species polycultures. Interestingly, *B. pilosa* var. *radiata* exhibited higher growth rates in more complex communities, such as the

2-2-2-2-species combinations, than in the less complex communities (Fig. 4).

3.4 *B. pilosa* var. *radiata* in 28-Day Monoculture Communities

B. pilosa var. *radiata* growth in 28-day monocultures generally followed the trend set by the 14-day monocultures discussed above. *B. pilosa* var. *radiata* grew higher in C3 and Poaceae than in legume or forb communities. *B. pilosa* var. *radiata* reached maximum heights of 15 cm and 12 cm in *B. simper* Norms (Poaceae) and *P. notatum* Flugge (Poaceae), respectively (data not shown).

3.5 *B. pilosa* var. *radiata* in 28-Day Polyculture Communities

In 28-day polycultures, all-C3 plots were the least resistant to *B. pilosa* var. *radiata* invasion. The *B. pilosa* var. *radiata* emergence rate in these plots remained 40%. *B. pilosa* var. *radiata* height was less than 2cm across the disturbance gradients (Fig. 5) in 28-day polycultures. In complex communities, *B.*

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Fig. 4 Emergence rates of 14 days *B. pilosa* var. *radiata* in polyculture with different fertilizer and disturbance gradient applied. Reported values are the mean $\pm$ standard deviation ($n = 5$). Data bearing different capital letters in a same treatment group are significantly different ($P < 0.05$).

Fig. 5 Emergence rates of 28 days *B. pilosa* var. *radiata* in polyculture with different fertilizer and disturbance gradient applied. Reported values are the mean $\pm$ standard deviation ($n = 5$). Data bearing different capital letters in a same treatment group are significantly different ($P < 0.05$).

pilosa var. *radiata* survived in only a few treatment groups, suggesting that the competition for resources by early-established plant communities led to impaired invasion/growth of *B. pilosa* var. *radiata* (Fig. 6).

4. Discussion

4.1 Experimental Technique

Crossed and continuous gradient plots were used in

vegetative invasibility studies in past [22-24], which have successfully in described plant invasibility strategies and effects of competition on vegetative growth. This study, to our knowledge, is the first large-scale investigation of *B. pilosa* invasibility in local Taiwanese horticultural and agronomical plant communities. This study specifically addresses the effects of biodiversity (monoculture or polyculture),

Fig. 6 Emergence rates of 28 days *B. pilosa* var. *radiata* in polyculture with different fertilizer and disturbance gradient applied. Reported values are the mean $\pm$ standard deviation ($n = 5$). Data bearing different capital letters in a same treatment group are significantly different ($P < 0.05$).

soil fertility, and physical disturbances on *B. pilosa* invasibility.

4.2 Invasibility Assessment

The 50% emergence rate of *Bidens pilosa* var. *radiata* was 5-6 days under growing temperature 20 °C, as reported by Hsu and Lin [25]. This reported emergence rate differs from than 10-15% emergence rate observed in our study. Hsu and Lin [25] also reported an 86% germination rate for *Bidens pilosa* var. *radiata*. Past reports have suggested that the availability of environmental resources as well as the amount of interference by exotic species is the key determinants of invasion success in biodiversified communities. Therefore, in this study, we evaluated *Bidens pilosa* invasion in various horticultural and agronomic plant communities.

B. pilosa var. *radiata* commonly thrives in non-fertilized soil, which may explain why non-fertilized plants, encountering poor growth, are susceptible to invasion of *B. pilosa* var. *radiata*. Accordingly, results from our disturbance gradient experiments clearly indicate that severe disturbances, which impeded the growth of the established species, facilitated *B. pilosa* var. *radiata* emergence and

growth. When fertilizer was applied, established plant species grew better and were more capable of resisting or competing with *B. pilosa* var. *radiata*. Thus, fertilizer application eventually affected *B. pilosa* var. *radiata* invasion, as indicated by the negative correlation between the fertilizer amount and *B. pilosa* var. *radiata* emergence rate as noted at 14 and 28 days both (Fig. 7a, b). In contrast, disturbance impeded the growth of established plants and possibly facilitated the invasion/growth of *B. pilosa* var. *radiata*. Thus, positive correlation found between severity of disturbance and height of *B. pilosa* var. *radiata* was noted at 14 and 28 days both (Fig. 7c and d)

4.3 Hypothesis Explanation

Certain bioactive constituents in *B. pilosa* var. *radiata* have been characterized recently [15, 26, 27]. However, few studies have concentrated on its expansion in natural system and ecology. Leroux *et al.* [28] reported that *B. pilosa* var. *radiata* lowers carrot yield, but the interaction of *B. pilosa* var. *radiata* with different plants in natural systems has not yet been conclusively explained. Continuous gradients are widely adopted to assess the relationship between native and foreign species [22-24]. Studies have

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Fig. 7 Regression relation between emergence rate and fertilizer gradient (%) of 14 d and 28 d (a, b); disturbance gradient and invasive plant height (cm) of 14 d and 28 d (c, d).

demonstrated that highly diverse plant communities tend to resist exotic species invasion, because these communities could utilize natural resources most efficiently [9, 28, 29]. However, other workers reported species diversity is significantly higher in polycultures than in the monocultures, supporting the diversity-begets-diversity hypothesis [30]. The 14-day and 28-day growth of *B. pilosa* var. *radiata* was dominant in C3 and Poaceae monoculture and polyculture groups. Legume communities appear to retard *B. pilosa* var. *radiata* growth. However, though *S. cannabina* performed fastest in growth among all communities, it failed to resist the bioinvasion of *B. pilosa* var. *radiata* as observed in *P. radiatus*. Results

also suggest that legume polyculture combination, and the all-legume community shown to reduce *B. pilosa* var. *radiata* invasion (Fig. 4). In this study, we found that growth of *B. pilosa* var. *radiata* supports the high-diversity-resists-invasion theory in the early stage (14-day), while adaptation and dominance of *B. pilosa* var. *radiata* over the established environment led to its invasion success at the late stage (28-day). A low and slow emergence rate for C3, Poaceae and forbs species is another reason for the success of invasion. The high and rapid emergence rate of *B. pilosa* var. *radiata* has a competitive effect in adopting environmental resources such as sunlight, water and nutrition.

4.4 Indications of Invasibility Study

Various parameters have been applied to the measurement and evaluation of invasibility and growth, such as plant canopy area [14], total area covered [30, 31], and biomass [11, 24]. We chose to measure plant height, due to the rapid growth rate of *B. pilosa*, which is the key factor of competition for sunlight and thus viability. As indicated by Hsu [32], *B. pilosa* var. *radiata* has allelopathic properties that inhibit the emergence and growth of other species; this may explain the reason for the ability of *B. pilosa* var. *radiata* to outcompete other species in both wild and experimental habitats.

Although *I. aquatica* (C3) was dominant in the C3 community, in monoculture communities, it had no affect on *B. pilosa* var. *radiata* growth (Fig. 2). Disturbance and fertility gradients successfully influenced the growth of sown species in monocultures (Fig. 2 and 3). Invading species are typically abundant in established communities that have been severely disturbed, indicating a possible

correlation between the severity of disturbance and invasion.

4.5 Statistical Correlation on Fertility and Physical Disturbance

Variations in the community structure and biological characteristics of plants determine resource availability. Therefore, plant dominance in an established community is related to dynamic changes within the established species, such as disturbances and changing environmental conditions, as indicated by Davis et al. [33] and Symstad [34]. In our study, regression analysis confirmed that *B. pilosa* emergence rate and fertilizer quantity were negatively correlated (Table 3a, Fig. 7). This suggests that the original plants, supplied with higher amounts of fertilizer, may be able to grow faster and resist the invasion of *B. pilosa* better, which explains the low emergence rates of *B. pilosa* under these conditions. In the disturbance experiments, disruption of the growth of the tested plants may have facilitated the growth (height) of invasive *B. pilosa* (Table 3b). Lodge [35]

Table 3 Simple linear regression coefficients on the relationships between (a) fertilizer gradient and *B. pilosa* emergence rate; (b) disturbance gradient and *B. pilosa* height.

Group	(a)					
	fertilizer 14 d $y = b[1]x + b[0]$			fertilizer 28 d $y = b[1]x + b[0]$		
	r^2	b[0]	b[1]	r^2	b[0]	b[1]
1+5	0.11	7.13	0.25	0.25	5.25	0.40
5+9	0.22	8.50	-0.98	0.56	11.88	-1.98
9+13	0.08	1.75	-0.20	0.83	2.00	-0.55
13+1	0.01	1.88	-0.05	0.11	1.63	-0.23
2+6	0.85	16.13	-2.95	0.81	15.00	-2.68
6+10	0.87	27.25	-5.85	0.50	23.25	-4.35
1+2+3+4	0.72	54.13	-13.68	0.68	56.50	-13.98
5+6+7+8	0.93	14.88	-3.38	0.92	10.38	-2.15
9+10+11+12	0.24	4.50	-0.95	0.02	1.88	0.20
13+14+15+16	0.14	1.13	-0.13	0.00	0.00	0.00
1,2+5,6	0.01	1.75	0.03	0.01	0.25	-0.05
5,6+9,10	0.85	6.87	-1.40	0.00	0.00	0.00
9,10+13,14	0.00	4.38	-0.05	0.00	0.00	0.00
13,14+1,2	0.99	1.13	1.30	0.00	0.00	0.00
1,2+5,6+9,10+13,14	0.49	15.25	-2.28	0.00	0.00	0.00
3,4+7,8+11,12+15,16	0.45	0.25	1.13	0.34	0.13	0.30
1 to 16	0.50	6.13	-1.35	0.80	0.38	-0.10

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(b)

Group	Disturbance 14 d $Y = b[1]x + b[0]$			disturbance 28 d $y = b[1]x + b[0]$		
	r^2	b[0]	b[1]	r^2	b[0]	b[1]
1+5	0.87	1.79	0.87	0.85	2.31	1.51
5+9	0.66	2.11	0.72	0.14	4.31	0.03
9+13	0.50	2.28	-0.51	0.93	1.83	-0.48
13+1	0.50	2.35	-0.38	0.03	1.40	-0.13
2+6	0.99	3.36	0.21	0.82	2.64	0.71
6+10	0.87	3.60	0.26	0.54	3.41	0.22
1+2+3+4	0.85	5.30	-0.68	0.02	2.75	0.07
5+6+7+8	0.75	4.11	-0.28	0.03	2.03	-0.10
9+10+11+12	0.07	2.14	-0.18	0.74	12.68	3.26
13+14+15+16	0.07	0.58	0.11	0.00	0.00	0.00
1,2+5,6	0.03	2.28	-0.16	0.07	0.25	-0.05
5,6+9,10	0.92	2.16	-0.21	0.00	0.00	0.00
9,10+13,14	0.86	1.84	0.31	0.00	0.00	0.00
13,14+1,2	0.20	2.25	-0.07	0.00	0.00	0.00
1,2+5,6+9,10+13,14	0.70	27.30	-6.40	0.00	0.00	0.00
3,4+7,8+11,12+15,16	0.18	5.00	-0.79	0.41	1.25	2.65
1 to 16	0.83	1.79	-0.43	0.86	4.25	-1.15

Fig. 8 Relationship between fertilizer gradient and disturbance gradient in 28 d field test. Line shown is linear regression line.

proposed that highly diverse communities are less susceptible to invasion by exotic species, because fewer resources are available to the invaders. There was a highly significant, positive correlation between fertilizer quantity and disturbance gradient in the

28-day field test (Fig. 8, $r^2 = 0.38$; $b[0] = -0.11$; $b[1] = 0.090$; confidence interval: 95%). Based on these results, this work demonstrates that a neutral relationship exists between *B. pilosa* var. *radiata* and the selected 16 plants at both the early (14 days) and

later (28 days) stages. Factors including biological traits, emergence rates, and established species characteristics affect *B. pilosa* var. *radiata* dominance/success. Bazzaz [36] reported similar observations, concluding that the interactions between native and exotic species determine invasion success. The introduction of a foreign plant into an established community is a complex process and cannot be fully understood until all factors such as site-site variation, species characteristics, physical-biological interactions, and plant-soil interactions are fully considered. In this study, factors such as biological traits, emergence rate, and characteristics of previously established species were found to determine the success of *B. pilosa* var. *radiata* dominance in established communities.

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