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Effects of Invasive Plant *Mikania micrantha* on Plant Community and Diversity in Farming Systems

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ABSTRACT

To explore the effects of invasive plant *Mikania micrantha* H.B.K invasion on plant community and diversity in farming systems, the composition, density, importance value, species richness, diversity indices and evenness index were analyzed under five different *M. micrantha* cover classes (0, 1-25, 26-50, 51-75 and 76-100%). The study took place in farm fields in Longchuan County, Northwest of Yunnan, China. A total of 20 plant species from 20 genera and 10 families were identified. Within communities where *M. micrantha* occurred, *M. micrantha* was the most dominant species with the highest population density. Population density and importance values of some dominant species, *Ageratum conyzoides*, *Bidens pilosa*, *Borreria latifolia*, *Digitaria sanguinalis* and *Galinsoga parviflora* clearly declined as *M. micrantha* cover increased and their importance values were significantly negative correlated with *M. micrantha* cover ($p<0.05$). The cover of *M. micrantha* clearly was also negatively correlated with *Eleusine indica*, *Phyllanthus urinaria* and *Siegesbeckia pubescens* ($p<0.05$). By contrast, population density and importance values for *Commelina communis* and *Kyllinga cylindrical*, increased substantially with increased *M. micrantha* and there were significant positive correlations between their importance values and *M. micrantha* cover ($p<0.05$). Maximum values for species richness (17.00), Simpson index (0.86), Shannon-Wiener index (2.10) and Pielou index (0.73) occurred in 1-25% cover of *M. micrantha*; the next highest values occurred with 0% cover of *M. micrantha*. Most species richness, diversity and evenness values within *M. micrantha* cover ranges of 1-25 and 0% were not significantly different but as *M. micrantha* cover increased, species richness, diversity and evenness values significantly declined, going from 26-100% cover of *M. micrantha*. Overall, it was concluded that *M. micrantha* invasion had profound effects on plant community and species diversity in farming systems which must be taken account as we attempt to manage its invasions.

Key words: Invasive alien plant, *Mikania micrantha*, importance values, species diversity index, species evenness index

INTRODUCTION

The rapid spread of invasive alien species has become a major concern among ecologists, naturalists, biologists and land managers worldwide. Invasive alien species are now considered one of the most serious threats to global biodiversity (Mack *et al*., 2001; Ricciardi, 2004; Porte *et al*., 2011). Moreover, much evidence indicates that as international trade and economic industrialization increase, the magnitude of the threat posed by invasive species increases globally (Lodge, 1993; Hulme, 2009). Invasive alien species alter ecosystem processes (Powell *et al*., 2011), decrease native species abundance and richness via competition, predation, hybridization and indirect effects (Gaertner *et al*., 2009; Sugiura and Taki, 2012), change community structure (Hejda *et al*., 2009) and alter genetic diversity (Ellstrand and Schierenbeck, 2000; Roux *et al*., 2013). Thus, the effect of invasive alien species on local plant communities and biodiversity has become a major research focus worldwide.

Mikania micrantha H.B.K. (Asteraceae), a perennial herb or semi-woody vine, is native to Central and South America (Zhang *et al*., 2004). The vine has been listed among the top 100 worst invasive species and as one of the top 10 worst weeds in the world (Lowe *et al*., 2001; Zhang *et al*., 2004). *Mikania micrantha* is present in tropical Asia, parts of Papua New Guinea, Indian Ocean islands, Pacific Ocean islands and Florida in the U.S. (Zhang *et al*., 2004; Manrique *et al*., 2011). It has colonized a broad range of farming systems and forest lands, banks of streams and rivers, roadsides and railway tracks, pastures and open disturbed areas (Zhang *et al*., 2004). In invaded habitats, due to rapid growth, vegetation smothering habit and action of allelopathic chemicals, *M. micrantha* has caused serious economic loss, biodiversity loss and negative environmental impacts (Zan *et al*., 2000; Zhang *et al*., 2004; Shen *et al*., 2013a).

Some reports have shown that *M. micrantha* threatens crops production, native species and biodiversity of invaded ecosystems (Zhang *et al*., 2004; Manrique *et al*., 2011; Day *et al*., 2012). In natural ecosystems, it grows quickly and overtops vegetation, blocking sunlight to these species, as well as forming dense monospecific stands on the ground, smothering or suppressing growth of grasses and herbaceous species (Zhang *et al*., 2004; Day *et al*., 2012). Species richness, native seedlings, adult plants and native species diversity have decreased due to the presence of *M. micrantha* (Kaur and Malhotra, 2012). This weed can also affect species composition through its ability to alter the soil chemistry and mineral recycling which in turn affects soil microbial communities (Wong, 1964; Li *et al*., 2007; Shen *et al*., 2015). In farming systems, *M. micrantha* may completely smother crops or trees, blocking sunlight, thus reducing growth, flowering and yield or even killing the plant (Wong, 1964; Wang *et al*., 2008; Day *et al*., 2012; Shen *et al*., 2013a). However, there is scant literature available on the effects of *M. micrantha* on plant community diversity in invaded farming systems.

The present study examined the effects of the invasive plant *M. micrantha* on plant community diversity in farming systems in Longchuan County, Northwest Yunnan, China. These findings are valuable for increasing our understanding of the relationship between *M. micrantha* and associated native plants/plant communities in infested habitats and providing useful suggestions for *M. micrantha* management in agricultural systems.

MATERIALS AND METHODS

Study site: The study site was located in Longchuan County (24°08-24°39'N, 97°17-97°39'E), Northwest Yunnan, China. This area is characterized by a typical tropical climate, having a rainy season featuring heavy rainfall with 90% humidity alternating with a dry season (Shen *et al*., 2014). Rainfall averages 1595 mm year^{-1} and the annual mean temperature is 18.9°C. Recently, the range of *M. micrantha* has been expanding rapidly within Longchuan County, invading agricultural areas and forest margins. It has infested sugarcane, orange, banana, coffee, bamboo, sweet potato, maize crop, as well as artificial pasture and secondary forest in Longchuan County (Shen *et al*., 2013a).

Methods: In October 2013, the field investigations were conducted in Zhangfang Township in Longchuan County. According to cover values of *M. micrantha* based on visual assessment (Shang and Cai, 1992), the surveyed communities were divided into five groups based on cover class: Group I, *M. micrantha* cover of 0%; group II, *M. micrantha* cover of 1-25%; group III, *M. micrantha* cover of 26-50%; group IV, *M. micrantha* cover of 51-75% and group V, *M. micrantha* cover of 76-100%.

For each *M. micrantha* cover class, there were four 30×30 m plots (replicates) established in farming systems, with an attempt to encompass all types of farming crops, such as sugarcane, maize crop, banana, vegetables and others. All plots were located in the same local area, with similar climate and altitude. Then, fifteen 1×1 m quadrats were randomly selected in each plot for statistical analysis. Thus, a total of 300 quadrats were surveyed. For each quadrat, plant species, plant cover, plant number, frequency and plant height were surveyed and the locations of all quadrats were recorded with GPS.

Data analyses: Species density of each plant was determined by dividing the number of individuals or tussocks by the plot. Species cover was determined as the proportion of the quadrat area covered by the canopy of a given species and the species frequency was summarized as the number of quadrats with at least one individual divided by the total number of the sampled quadrats in a plot. The importance value for a given species was calculated by computing the sum of its relative density, relative cover and relative frequency. Relative values were obtained via dividing species specific values by the sums of the densities, cover proportions and frequencies of all species in a plot, respectively.

Species richness, diversity and evenness were estimated as follows: (1) Simpson diversity index (D) was calculated as:

$$D = 1-\sum[N_i(N_i-1)/N(N-1)]$$

where, N_i is the total number of individuals from species i in a plot and N is the total number of individuals from all species in a plot. D ranges from 0-1, with 1 being the maximal diversity, (2) Shannon-Wiener diversity index H (Ma and Liu, 1994) was measured as:

$$H = -\sum p_i \ln p_i$$

where, p_i is the proportion relative to the total number of species per plot and (3) Pielou evenness index (J) (Ma and Liu, 1994) were calculated as:

$$J = H/\ln S$$

where, S is the species richness of each plot.

Statistical analysis: Data was analyzed by analysis of variance (one-way ANOVA). If significant differences were detected with the ANOVA, Duncan's multiple range tests were used to detect differences among treatments at a 5% level of significance. The relationship and significance of *M. micrantha* cover values and plant importance values were determined by Pearson's coefficient (R) using SPSS.

RESULTS

Plant species and densities: A total of 20 plant species belonging to 20 genera and 10 families were recorded within the study plots (Table 1). All plants were herbaceous, among which 13 annual plants accounted for 65%, 1 annual/perennial plant accounted for 5% and 6 perennial plants occupied 30% of all species, respectively. In our study plots, 10 plants were invasive alien species and the other 10 species were native (Table 1).

There were 13 main species found in the study plots of which ten plants appeared in all five *M. micrantha* communities (Table 1). Within communities *M. micrantha* occurred, population densities of *M. micrantha* were 61.29, 160.84, 297.28 and 568.15 corresponded to *M. micrantha* cover ranges of 1-25, 26-50, 51-75 and 76-100%, respectively. There were five species, four species, two species, two species and three species absent from the 76-100, 51-75, 26-50, 1-25 and 0% *M. micrantha* cover communities, respectively. Eight plants, *Ageratum conyzoides*, *Bidens pilosa*, *Borreria latifolia*, *Commelina communis*, *Digitaria sanguinalis*, *Echinochloa hispidula*, *Galinsoga parviflora* and *Kyllinga cylindrica* occurred in all five *M. micrantha* communities, exhibited high population density and dominance. Of these, population densities of *Ageratum conyzoides*, *Bidens pilosa*, *Borreria latifolia*, *Digitaria sanguinalis* and *Galinsoga parviflora* clearly declined as *M. micrantha* cover increased, however population density of

Table 1: Plant species and densities under different *Mikania micrantha* cover (individual/m^2)

		Plant density (%)				
Plant name	Life form	0	1-25	26-50	51-75	76-100
Ageratum conyzoides[I]	AH	46.15±1.46[a]	43.75±1.22[b]	40.26±1.53[c]	19.30±0.68[d]	10.68±0.44[e]
Amaranthus lividus[I]	AH	3.74±0.20[b]	1.32±0.24[d]	5.13±0.18[a]	2.93±0.20[c]	1.33±0.22[d]
Bidens pilosa[I]	AH	19.65±0.96[a]	17.86±0.75[b]	15.31±0.79[c]	8.81±0.30[d]	8.77±0.43[d]
Borreria latifolia[I]	PH	42.98±1.42[a]	38.97±0.98[b]	34.94±0.67[c]	30.38±0.97[d]	13.16±0.34[e]
Commelina communis[N]	AH	0.53±0.03[e]	1.61±0.19[d]	2.66±0.26[c]	9.25±0.55[b]	15.45±0.49[a]
Conyza canadensis[I]	AH	3.14±0.21[b]	1.33±0.25[d]	4.28±0.27[a]	1.89±0.21[c]	-
Crassocephalum crepidioides[I]	AH/PH	-	-	2.16±0.17[b]	-	8.17±0.62[a]
Cyperus difformis[N]	PH	4.81±0.14[a]	3.26±0.25[b]	1.62±0.27[c]	1.85±0.25[c]	3.24±0.47[b]
Digitaria sanguinalis[N]	AH	59.87±0.92[a]	38.94±0.56[b]	37.34±0.51[c]	34.20±0.82[d]	24.85±0.23[e]
Echinochloa hispidula[N]	AH	4.28±0.25[d]	8.29±0.27[c]	4.32±0.18[d]	9.53±0.37[b]	10.25±0.5[a]
Eleusine indica[I]	AH	9.65±0.45[a]	6.69±0.42[b]	5.63±0.41[c]	-	-
Galinsoga parviflora[I]	AH	14.35±0.62[a]	12.26±0.22[b]	11.49±0.47[c]	7.21±0.29[d]	3.21±0.17[e]
Kyllinga cylindrica[N]	PH	1.63±0.25[e]	2.93±0.19[d]	2.94±0.20[c]	6.16±0.26[b]	7.23±0.29[a]
Laggera pterodonta[N]	PH	1.33±0.08[b]	1.87±0.05[a]	1.87±0.05[a]	-	-
Mikania micrantha[I]	PH	-	61.29±5.77[d]	160.84±15.86[c]	297.28±23.59[b]	568.15±36.19[a]
Oxalis corniculata[N]	PH	7.48±0.33[a]	3.48±0.48[c]	-	4.53±0.37[b]	1.33±0.19[d]
Pharbitis purpurea[I]	AH	-	0.83±0.15[c]	-	1.08±0.19[b]	4.04±0.21[a]
Phyllanthus urinaria[N]	AH	11.72±0.54[a]	3.46±0.36[b]	2.88±0.43[c]	1.61±0.11[d]	-
Siegesbeckia pubescens[N]	AH	9.10±0.76[a]	5.86±0.36[b]	3.74±0.24[c]	-	-
Solanum nigrum[N]	AH	2.97±0.24[b]	-	2.15±0.15[c]	3.49±0.35[a]	-

Values are given in Mean±SD, Different letters in the same row are significantly different at the 0.5 level, AH: Annual herb, PH: Perennial herb, I: Invasive species and N: Native species

Commelina communis and *Kyllinga cylindrica*, increased substantially with increasing *M. micrantha* cover. With cover increases in *M. micrantha*, total density of both all plants collectively and invasive alien plants were significantly increased but total density of native plants declined substantially (Fig. 1).

Effects of *Mikania micrantha* on plant importance values: Individual species responded differently to increased cover of *M. micrantha*. Importance values of *Ageratum conyzoides*, *Bidens pilosa*, *Borreria latifolia*, *Commelina communis*, *Digitaria sanguinalis*, *Galinsoga parviflora* and *Kyllinga cylindrica* were higher within *M. micrantha* communities. The cover of *M. micrantha* was positively correlated with *Commelina communis* and *Kyllinga cylindrica* ($p<0.05$), whereas, it was negative correlated with *Ageratum conyzoides*, *Bidens pilosa*, *Borreria latifolia*, *Digitaria sanguinalis* and *Eleusine indica*, *Galinsoga parviflora*, *Phyllanthus urinaria* and *Siegesbeckia pubescens* ($p<0.05$). For other species, a general trend was not discernable because their frequency varied across the *M. micrantha* categories (Table 2).

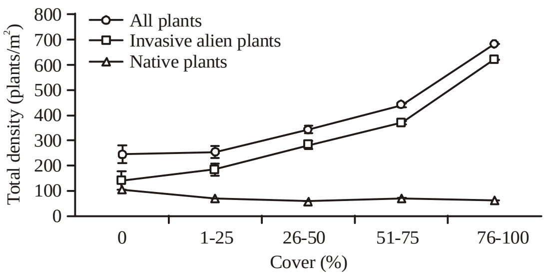

Fig. 1: Total density for all plants, invasive plants and native plants under different levels of *Mikania micrantha* cover

Effects of *Mikania micrantha* on species diversity: This data showed that the 1-25% cover class for *M. micrantha* had the highest species richness (17.00), Simpson index (0.86), Shannon-Wiener index (2.10) and Pielou index (0.73), followed by the 0% cover of *M. Micrantha* class (Table 3). Overall, most species richness, diversity and evenness values within *M. micrantha* cover ranges of 1-25 and 0% were not significantly different from each other. Going from 26-100% cover of *M. micrantha*, as *M. micrantha* cover increased, species richness, diversity and evenness values significantly declined. This evidence indicates that invasion of *M. micrantha* has decreased the species richness, diversity indices and evenness index of local communities substantially.

Table 2: Plant importance values under different *Mikania micrantha* cover

	Importance value (%)						
Plant name	0	1-25	26-50	51-75	76-100	p-value	Relative coefficient®
Ageratum conyzoides	43.16±1.24[a]	40.28±1.12[b]	36.89±0.26[c]	24.31±0.79[d]	19.50±0.49[e]	0.007	-0.966
Amaranthus lividus	7.32±0.21[b]	2.49±0.18[c]	11.94±0.48[a]	7.07±0.09[b]	2.42±0.19[c]	0.736	-0.209
Bidens pilosa	23.44±1.18[a]	20.72±0.74[b]	19.29±0.88[c]	12.24±0.44[d]	11.73±0.33[d]	0.009	-0.962
Borreria latifolia	40.23±1.44[a]	36.82±0.88[b]	28.67±0.99[c]	18.73±0.88[d]	8.48±0.41[e]	0.002	-0.986
Commelina communis	2.46±0.11[e]	4.85±0.20[d]	7.29±0.26[c]	17.27±0.71[b]	26.37±1.30[a]	0.011	0.955
Conyza canadensis	7.11±0.06[a]	4.78±0.12[b]	7.25±0.21[a]	4.72±0.13[b]	-	0.128	-0.770
Crassocephalum crepidioides	-	-	4.80±0.30[b]	-	12.26±0.33[a]	0.168	0.723
Cyperus difformis	9.86±0.21[a]	7.34±0.22[b]	6.96±0.18[c]	4.83±0.12[d]	7.11±0.16[bc]	0.180	-0.709
Digitaria sanguinalis	50.49±1.73[a]	43.75±1.13[b]	42.85±0.76[b]	35.82±0.78[c]	31.58±0.72[d]	0.003	-0.983
Echinochloa hispidula	7.61±0.20[c]	8.22±0.16[b]	7.76±0.23[c]	10.41±0.35[a]	7.87±0.16[c]	0.539	0.371
Eleusine indica	15.37±0.72[a]	10.16±0.25[b]	9.54±0.18[c]	-	-	0.012	-0.952
Galinsoga parviflora	16.56±0.48[a]	15.84±0.32[b]	15.16±0.34[c]	12.26±0.33[d]	4.85±0.11[e]	0.044	-0.888
Kyllinga cylindrica	4.75±0.09[d]	5.09±0.06[d]	7.04±0.15[c]	9.45±0.36[b]	11.63±0.45[a]	0.004	0.977
Laggera pterodonta	4.77±0.10[a]	4.75±0.05[a]	4.68±0.13[a]	-	-	0.054	-0.871
Oxalis corniculata	12.88±0.38[a]	7.27±0.19[c]	-	11.61±0.36[b]	4.62±0.21[d]	0.543	-0.367
Pharbitis purpurea	-	1.22±0.03[b]	-	1.22±0.06[b]	1.75±0.03[a]	0.141	0.754
Phyllanthus urinaria	16.31±0.59[a]	7.22±0.21[b]	7.18±0.20[b]	6.87±0.07[b]	-	0.038	-0.899
Siegesbeckia pubescens	12.53±0.29[a]	7.73±0.26[b]	7.34±0.20[c]	-	-	0.012	-0.953
Solanum nigrum	7.24±0.16[a]	-	7.05±0.13[b]	7.09±0.12[ab]	-	0.624	-0.299

Different letters in the same row are significantly different at the 0.05 level, values are in Mean±SD

Table 3: Biodiversity indices of plant communities under different *Mikania micrantha* cover

	Diversity indices			
Cover of *M. micrantha* (%)	Species richness (S)	Simpson index (D)	Shannon-Wiener index (H)	Pielou index (J)
0	16.25±0.96[a]	0.85±0.04[a]	1.99±0.06[b]	0.70±0.02[a]
1-25	17.00±0.82[a]	0.86±0.04[a]	2.10±0.09[a]	0.73±0.04[a]
26-50	16.50±1.29[a]	0.74±0.04[b]	1.66±0.07[c]	0.57±0.04[b]
51-75	14.50±1.29[b]	0.53±0.05[c]	1.36±0.03[d]	0.49±0.03[c]
76-100	12.50±1.29[c]	0.30±0.03[d]	0.82±0.03[e]	0.31±0.02[d]

Different letters in the same column are significantly different at the 0.05 level, values are Mean±SD

DISCUSSION

Biological invasion is considered one of the greatest threats to species diversity and community structure and recognized as the primary cause of global biodiversity loss (Mack *et al*., 2001; Hulme, 2009; Porte *et al*., 2011). Many studies have shown that invasive alien plants decrease species richness, species diversity indices, evenness index and alter native community structure and function (Ding *et al*., 2007; Ehrenfeld, 2010; Vila *et al*., 2011). This study found that the invasive alien plant *M. micrantha* is no exception.

Mikania micrantha causes serious yield loss of crops and biodiversity loss through both aboveground and underground communities because of its rapid growth, vegetation smothering habit and action of allelopathic chemicals in infested habitats (Zhang *et al*., 2004; Chen *et al*., 2009; Li *et al*., 2012; Shen *et al*., 2014). In farming systems, *M. micrantha* frequently suppresses growth and yield of food crops and cash crops or even kills them (Day *et al*., 2012; Shen *et al*., 2013a). Shen *et al*. (2013a) reported that *M. micrantha* invaded cash crops and was mostly distributed in sugarcane, bamboo, lemon, banana and orange in Longchuan County. The crop yield was reduced quickly with *M. micrantha* cover increasing, especially for sugarcane, lemon, banana and orange. As *M. micrantha* cover increased, the density, biomass and cover of native plants were reduced and the biomass and cover of invasive plants were increased (Shen *et al*., 2013a). The present study indicated that *M. micrantha* had the highest population density and was the most dominant species within communities where *M. micrantha* occurred. Many species are devastated by *M. micrantha* invasion in farming lands. Population density and importance values of some dominant species, *Ageratum conyzoides*, *Bidens pilosa*, *Borreria latifolia*, *Digitaria sanguinalis* and *Galinsoga parviflora* clearly declined, as *M. micrantha* cover increased. Conversely, the population density and importance values of *Commelina communis* and *Kyllinga cylindrical*, actually increased substantially with increasing *M. micrantha* cover, because these two plant species prefer wet habitats and are shade-tolerant.

In natural ecosystems, species richness, native seedlings, adult plants and native species diversity have been shown to decrease in the presence of *M. micrantha* (Kaur and Malhotra, 2012). Our findings showed that most species richness, diversity and evenness values were not significantly different between *M. micrantha* cover ranges of 1-25 and 0%. Within 26-100% cover range for *M. micrantha*, as *M. micrantha* cover increased species richness, diversity and evenness values declined substantially. This evidence demonstrates that the invasion of *M. micrantha* has reduced species richness, diversity and evenness of local communities. The species richness of invasive plants and native plants is equal in study plots but the total density of invasive species is significantly higher than native species. Moreover, with increases in *M. micrantha* cover the total density of invasive species increases substantially but the total density of native species decreases. Thus, *M. micrantha* has higher negative impacts on native species than on invasive alien species and invasive alien species as a whole (including *M. micrantha*) are actively excluding native species in the study area. Thus, some appropriate control measures should be taken immediately.

Compared with other ecosystems, agricultural ecosystems are relatively fragile and lower in diversity. The study county shares a 51 km border with Myanmar, which increases the risk of invasive alien species spread and invasion. Shen *et al*. (2013b) studied the characteristics of seed banks and seedling banks under different habitats invaded by *M. micrantha* and found that seed bank plants accounted for 57.5% of all invasive alien plant species in Longchuan County. Moreover, the study area belongs to subtropical and tropical agricultural ecological system and features farming practices with 2-3 crops in succession per year. The results show that the species richness in farming lands is lower compared to other ecosystems. Firstly, this is because more intensive farming production decreases population density, species richness and diversity indices of communities. Secondly, higher growth and competitive abilities of invasive alien species and numerous disturbances facilitate the establishment of invasive species and suppress native species in farming lands. Our findings are consistent with those of Bellingham *et al*. (2005), who found that invasive alien species often quickly (re)colonize after a disturbance and may dominate during early succession.

CONCLUSION

In conclusion, the results show that *M. micrantha* invasion has reduced population density and importance values of plants substantially and ultimately changed the structure and function of plant communities in farming lands. Moreover, species richness, species diversity and evenness of local communities are also decreased with increasing cover of *M. micrantha*. Due to particular local geological and ecological conditions and intensive farming production besides the invasive plant *M. micrantha*, the study area has been invaded by many other invasive alien species. Thus, determining how to promote the restoration and management of agricultural ecological systems through increasing native species diversity or using some ecological measures to suppress invasive species represents an urgent priority.

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