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学位論文全文に代わる要約
Extended Summary in Lieu of Dissertation

氏名：
Name　Shicai Shen

学位論文題目：
Title of Dissertation　Distribution, impact and control of invasive alien species *Mikania micrantha* H.B.K. in Yunnan Province of China
(外来植物*Mikania micrantha* H.B.K.の中国雲南省における分布, 影響および管理)

学位論文要約：
Dissertation Summary

Mikania micrantha is one of the most noxious invasive alien species in the world. The weed is native to Central and South America and has invaded and caused great negative impacts in Yunnan Province, Southwest China. In order to understand its biological and ecological characteristics and explore comprehensive control methods, a series of studies on distribution, impacts and control methods of *M. micrantha* have been undertaken in Yunnan. The main contents and results were as follows:

1. The harmful effects of this plant on major cash crops and local plant communities have been surveyed in 50 townships of 6 counties or cities of Yunnan since 2006. Moreover, bioactivity and selectivity of 20 types of herbicides on *M. micrantha* and farming crops have been tested and analyzed since 2007. The results showed that *M. micrantha* is mostly distributed in subtropical and tropical areas of Yunnan. The occurring distribution of *M. micrantha* in different farming land was varied. The maximum average percent occurrence for *M. micrantha* in farming land was 23.24 in sugarcane, the next highest percentages were for bamboo (16.34), lemon (15.65), banana (12.15), and orange (9.51), and the lowest percentages were tea (3.55) and shaddock (1.42), and most of the differences were significant. As *M. micrantha* occurrence and population density increased, crop yield declined rapidly, especially for certain cash crops such as sugarcane, lemon, banana, and orange. The density, biomass and cover of invasive plants were significantly higher ($P<0.05$) than native plants in all *M. micrantha* communities. As *M. micrantha* cover increased, from 0-20% to 81-100%, the density, biomass and cover of native plants declined from 208 plant/m^2 to 101 plant/m^2, 74 g/m^2 to 37 g/m^2, 46% to 23%, respectively. The density of invasive plants decreased with increased *M. micrantha* cover (301 plant/m^2 to 215 plant/m^2), but conversely their biomass (100 g/m^2 to 198 g/m^2) and cover (78 to 91%) increased with increased *M. micrantha* cover. The total density and total cover of all plants were decreased with increasing of *M. micrantha* cover. The seed germination rate of *M. micrantha* was significantly reduced after preemergence herbicide application for 10 types of soil-applied herbicides. Bensulfuron methyl, metsulfuron-methyl and flumetsulam had the highest bioactivity on *M. micrantha*. Atrazine, bensulfuron methyl and prometryne had higher bioactivity and selectivity to *M. micrantha* germination and seedling growth. For postemergence herbicides, tribenuron-methyl, clopyralid, carfentrazone-ethyl, sulfometuron-methyl and starane had higher bioactivity on *M. micrantha* (according to LD_{90}) and also had higher costs. Glyphosate and 2, 4-D had higher efficacy and lower costs by comparison, but

required higher herbicide dosages. As a result, it is recommended that atrazine should be used in sugarcane, orchard and rubber land, glyphosate for non-farm land and rubber land, sulfometuron methyl for forest land, and 2, 4-D for maize land, respectively.

2. To explore the effects of invasive plant *M. micrantha* 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%) in Longchuan County of Yunnan. A total of 20 plant species from 20 genera and 10 families were identified. All plants were herbaceous, among which there were 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. Within communities where *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, 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 *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 ($P<0.05$), but total density of native plants declined substantially. 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*, *Eleusine indica*, *Galinsoga parviflora*, *Phyllanthus urinaria*, *Siegesbeckia pubescens* ($P<0.05$). For other species a general trend was not discernable because their frequency varied across the *M. micrantha* categories. 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 ($P<0.05$), going from 26-100% cover of *M. micrantha* (Table 1). 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.

Table 1: Biodiversity indices of plant communities under different *Mikania micrantha* cover

Cover of *M. micrantha*	Diversity indices			
	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.

3. To elucidate the competitive mechanisms between a sweet potato crop and an invasive plant, *M. micrantha*, field experiments were carried out utilizing a de Wit replacement series in Longchuan County of Yunnan. In monoculture, the total biomass, biomass of adventitious root, leafstalk length, and leaf area of sweet potato were all higher than those of *M. micrantha,* and in mixed culture the plant height, branch, leaf, stem node, adventitious root, flowering and biomass of *M. micrantha* were suppressed significantly ($P<0.05$). The relative yield (RY) of *M. micrantha* and sweet potato was significantly less ($P<0.05$) than 1.0 in mixed culture, and only for a ratio of sweet potato to *M. micrantha* of 1:3 was the RY of *M. micrantha* greater than that of sweet potato, showing that the intraspecific competition between two plants was less than their interspecific competition (Table 2). The relative yield total (RYT) of *M. micrantha* and sweet potato was less than 1.0 in mixed culture (ranging from 0.45 to 0.54) indicating that there was competition between the two plants. The competitive balance index (CB) of sweet potato of -0.39 was significantly less than zero ($P<0.05$) when grown with *M. micrantha* in mixed culture at 1:3 (sweet potato: *M. micrantha*), whereas for the other ratios the CB index was greater than zero and the maximum CB index was 1.87 (Table 2). The pH of initial soil (CK) was obviously lower than those of seven treatments, but other soil nutrient contents of initial soil were significantly higher ($P<0.05$). In monoculture, the organic matter content, pH, total N content, total K content, available N content, available P content, and available K content of *M. micrantha* soil were significantly higher ($P<0.05$) than those of sweet potato, and significantly decreased as proportions of sweet potato increased in mixed culture. The total P content of soil from the *M. micrantha* monoculture was significantly less than in sweet potato soil ($P<0.05$), and increased as the proportion of sweet potato increased in mixed culture. Both exchangeable Ca content and Mg content of the soil in *M. micrantha* monoculture were significantly greater ($P<0.05$) than those of sweet potato in monoculture, and significantly decreased ($P<0.05$) as the proportion of sweet potato increased in mixed culture. For the soil micronutrients in monoculture, available Cu, available Zn and available Fe associated with soil where *M. micrantha* was grown were all significantly less ($P<0.05$) than those of sweet potato, and increased as the proportion of sweet potato increased in mixed culture. However, available Mn content and B content of *M. micrantha* were significantly greater ($P<0.05$) than that of sweet potato in monoculture, and gradually decreased

as the sweet potato proportion increased in mixed culture. Evidently sweet potato has a competitive advantage in terms of plant growth characteristics and greater absorption of soil nutrients.

Table 2: Relative yield, relative yield total and competitive balance index of sweet potato and *Mikania micrantha* in mixed culture

Ratios (sweet potato : *M. micrantha*)	Sweet potato relative yield (RYa)	*M. micrantha* relative yield (RYb)	Relative yield total (RYT)	Competitive balance index (CB) for sweet potato
3:1	0.87±0.004a **	0.13±0.001d**	0.50±0.001b**	1.87±0.014a**
2:1	0.80±0.008b**	0.21±0.003c**	0.51±0.005b**	1.35±0.008b**
1:1	0.64±0.007c**	0.25±0.001c**	0.45±0.003d**	0.93±0.013c**
1:2	0.60±0.004d**	0.33±0.005b**	0.46±0.002c**	0.60±0.019d**
1:3	0.43±0.004e**	0.64±0.017a**	0.54±0.009a**	-0.39±0.028e**

Data are expressed as mean ± standard deviation. The different letters within same column mean significant differences at $P < 0.05$. The t-test was used to compare each value with 1.0 and 0, ** indicate significant differences at 0.01 level.

4. To examine the combined effect of competition and chemical herbicide on invasive species *M. micrantha*, a set of field experiments of sweet potato and bentazon were conducted in Longchuan County of Yunnan. The results showed that after 30 days planting, the inhibition rates were 21.13-49.62% and significantly increased ($P<0.05$) with declining proportions of *M. micrantha*. The suppressed rates were significantly increased ($P<0.05$) with declining proportions of *M. micrantha* for ratios of sweet potato to *M. micrantha* of 1:1, 1.5:1, 2:1, and 2.5:1 after 60, 90 and 120 days planting. However, for ratios of sweet potato to *M. micrantha* of 2.5:1 and 3:1, the inhibited rates were gradually increased as proportions of sweet potato increased in mixed culture but there were not significant from 60 to 120 days growth. The preferred plant ratio of sweet potato to *M. micrantha* for effective control of *M. micrantha* was 2.5:1. From the herbicide dosage (X) and strain prevention efficiency (%) of *M. micrantha*, the toxicity regression equation for *M. micrantha* was derived as $Y = 0.95x+19.712$ (R^2=0.832) and the LD90 was 1109.85 g ai/hm^2. According to the regression equation with herbicide dosage (X) and strain prevention efficiency (%) of sweet potato, the toxicity regression equation for sweet potato was $Y = 0.3902x-30.17$ (R^2=0.9417) and LD_{10} was 1544.25 g ai/hm^2. Selectivity index = sweet potato LD10 / *M. micrantha* LD90 was 1.39 indicating that bentazon has excellent selectivity for sweet potato under effective control of *M. micrantha*. The control rates ranged from 77.35 to 90.59% when bentazon was applied at 720-1080 g ai/hm^2 and which were safe rates for sweet potato. Treatments 3 and 6 tested control of *M. micrantha* via sweet potato competition alone. The suppression rates utilizing sweet potato competition against *M. micrantha* were

significantly increased ($P<0.05$) with increasing growing period. Treatments 7-8 tested control of *M. micrantha* via bentazon control alone. Inhibition rates of *M. micrantha* via bentazon alone greatly declined with increasing growing period. Except for the ratio of sweet potato to *M. micrantha* of 2.5:1 after 120 days, the inhibited rates of single replacement control were much lower than a single bentazon application between 30 and 90 days. Treatments 1, 2, 4, and 5 tested the combined effects of sweet potato competition and bentazon on *M. micrantha*. *M. micrantha* inhibition rates were 82.44-95.34% after 30 days, 80.16-93.74% after 60 days, 75.62-92.57% after 90 days, and 70.38-90.88% after 120 days, respectively. Compared to single treatments involving sweet potato or bentazon, suppression of *M. micrantha* by sweet potato and bentazon combined were obviously higher. The suppression rates on *M. micrantha* for the two methods combined were higher than 90% for a ratio of sweet potato to *M. micrantha* of 2.5:1 with bentazon applied at 1080 g ai/hm^2 from 30 to 120 days. Compared to the application of bentazon alone at 1080 g ai/hm^2, inhibition rates for sweet potato and bentazon combined were higher, for a ratio of sweet potato to *M. micrantha* of 2.5:1 with bentazon applied at 720 g ai/hm^2, beyond 30 days after the herbicide treatment. All results suggested that sweet potato competition and bentazon combined could achieve more secure, sustainable and long term control of *M. micrantha*.