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Harmful effects and chemical control study of *Mikania micrantha* H.B.K in Yunnan, Southwest China

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Invasive alien species *Mikania micrantha*, which originated from Central and South America, has spread quickly and become one of the most seriously invasive weedy species in Yunnan Province, Southwest of China. The harmful effects of this plant on major cash crops and local plant communities have been surveyed in 50 townships of 6 counties of Yunnan Province 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, such as Lincang District, Baoshan District and Dehong Prefecture. The species has resulted in a series of negative impacts on farming cash crops and local plant communities. Compared with the control effects of 20 soil and foliar-applied herbicides, soil-applied herbicides Atrazine, Bensulfuron methyl and Prometryne have higher bioactivity and selectivity to *M. micrantha* germination and seedling. Foliar-applied herbicides Sulfometuron methyl, Starane and Glyphosate have better control efficiency on *M. micrantha* growth, but the security is low. As a result, it recommends that Atrazine should be used for sugarcane, orchard and rubber land, Glyphosate for non farming land and rubber land, Sulfometuron methyl for forest land, and 2, 4-D for maize land, respectively.

Key words: *Mikania micrantha*, crop yield loss, plant community, chemical control, Yunnan Province.

INTRODUCTION

Mikania micrantha is a perennial herb or semi-woody vine of Compositae, which is native to Central and South America. It has been considered one of the worst noxious weeds around the world and nominated among 100 of the “World’s Worst” invaders (Holm et al., 1977; Lowe et al., 2001). *M. micrantha* has caused severe economic losses and created serious ecological problems in many countries and regions (Barreto and Evans, 1995). It resulted in serious consequences on farming crops, native plant communities and natural environments (Holm et al., 1977; Cronk and Fuller, 1995). Once established the weed damages or kills other plants by cutting out the light, twinning and smothering (Huang et al., 2000). Moreover, it competes for water and soil nutrient and releases substances that inhibit the growth of other plants (Holm et al., 1977; Muniappan and Viraktamath, 1993; Cronk and Fuller, 1995; Huang et al., 2000; Li and Jin, 2010). *M. micrantha* has become one of the most widespread and threatened invasive weeds in subtropics and tropics globally.

The serious impacts of *M. micrantha* on agricultural and forest production and ecological environments have been captured attention by international and national governments and researchers inrecent years.

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M. micrantha has widely invaded and distributed to Southeast Asia, Pacific Islands and South China (Muniappan and Viraktamath, 1993; Kong et al., 2000; Zhang et al., 2004). In China, *M. micrantha*, known as “the plant killer”, was first reported in 1910 in Hong Kong and has started to spread and invade widely since the 1980s (Guang et al., 2003; Zhang et al., 2004; Guo et al., 2005). Yunnan Province of China is located in the eastern Hindu-Kush Himalaya region, northern zone of the Southeast Asia sub-continent (21°8'32''-29°15'8''N, 97°31'39''-106°11'47E). It belongs to southwest edge of the country and shares a 4061 km border with Laos, Myanmar, and Vietnam. Due to local particular geological and ecological conditions, Yunnan has been one of the most seriously afflicted areas of invasive alien species and its risk is still increasing (Shen et al., 2012). *M. micrantha* was reported that invaded Yunnan from Myanmar border since 1950s (Du et al., 2006). In 2008, the total afflicted areas of *M. micrantha* was over 27, 000 ha in Yunnan, mostly distributed in Dehong Prefecture, Baoshan District and Lincang District. In these areas, the infestation of *M. micrantha* makes cultivation and harvesting of agricultural crops and forest products become difficult. It was estimated that economic loss caused by *M. micrantha* was over several millions USA dollars per year, including crop yield decline, labour to replant seedling and herbicide costs. Moreover, *M. micrantha* destroyed a great variety of trees, shrubs and grasses in wild plant communities and resulted in biodiversity loss and prevention of forest regeneration through invading, twinning and smoothing. According to biological and ecological characteristics of *M. micrantha*, most tropics and subtropics of Yunnan Province are constantly at high risk from it (Kong et al., 2000; Du et al., 2006).

Since 2006, with financial support of Yunnan Provincial Government, Yunnan Provincial Agricultural Bureau and Yunnan Provincial Financial Bureau, Yunnan Academy of Agricultural Sciences has been responsible for investigation, monitoring and control studies of *M. micrantha* in Yunnan Province. This article reports that the harmful effects of *M. micrantha* on local major cash crops in fields and its herbicide controls done by Yunnan Academy of Agricultural Sciences in laboratory and greenhouse since 2006. The findings of *M. micrantha* research are important to future risk assessment, forecasting and control of *M. micrantha* in Yunnan and other regions.

MATERIALS AND METHODS

Impact assessment of *M. micrantha* on crop yields

The occurring situation of *M. micrantha* has been investigated from 50 townships in Luxi, Lianghe, Yingjiang, Longchuan, Ruili, and Wanding Counties or Cities in Dehong Prefecture of Yunnan Province since 2006. Twenty areas of farming land were randomly selected in each township and they are grouped into 7 by crop types. Twenty-five quadrates (one meter square) were surveyed along the diagonal of each farming land. The occurring frequency (%) was calculated for each species in a farmland as a percentage of quadrates in which the species is present. If species X is present in only a quadrate, the occurring frequency will be 1/25x100=4%. According to occurring frequency of *M. micrantha*, four different occurring levels were identified: I level, distributed widely, found commonly, and the frequency is over 51%; II level, distributed less widely, found less commonly, and the frequency is 31 to 50%; III level, distributed few, found partly, and the frequency is 11 to 30%; IV level, distributed sporadically, found occasionally, and the frequency is low 10%. According to different occurring frequency of *M. micrantha*, crop yields were measured and analyzed compared to unoccured quadrates of *M. micrantha* at the same areas.

Impact evaluation of *M. micrantha* on plant species and communities

As one of the most severe areas afflicted of *M. micrantha*, the plant species and communities were surveyed in Dehong Prefecture, Yunnan Province. According to cover degree of *M. micrantha* based on visual assessment (Shang and Cai, 1992), *M. micrantha* communities were divided into five groups: I group, *M. micrantha* cover degree is low 20%; II group, *M. micrantha* cover degree is 21 to 40%; III group, *M. micrantha* cover degree is 41 to 60%; IV group, *M. micrantha* cover degree is 61 to 80% and; V group, *M. micrantha* cover degree is over 81%. There were 10 line transects and 200 quadrats for each kinds of *M. micrantha* groups. Spaced approximately 200 m apart of transects was determined by hand Global Position System (GPS) devices. One meter square quadrates were surveyed along every 10 m of the transect lines. For each quadrat, four parameters were recorded: plant height, 20 plants for each species were measured randomly; density, the number of each plant species was counted; biomass, fresh weight of all plants was measured with harvesting methods and; plant cover frequency, the number of each species quadrats accounts for the total number of all quadrats surveyed was recorded.

Soil herbicide bioassay for *M. micrantha* and crops

During *M. micrantha* soil-applied bioassay experiments, 10 types of herbicides were selected, such as 10% Bensulfuron methyl (WP), 50% Prometryn (WP), 10% Metsulfuron-methyl (WP), 80% Flumetsulam (WP), 38% Atrazine (SC), 90% Acetochlor (EC), 33% Pendimethalin (EC), 25% Oxadiazon (EC), 80% Ametrex (WP), 72% Metolachlor (EC). The information of trade name, make, ai content (v/v) of each herbicide as shown in Table 1. *M. micrantha*, maize, wheat, broad bean, buckwheat, rape, potato, and soybean were tested with pre-emergence herbicide in the greenhouse. There were 5 level herbicide settings with 10 replicates for each tested plant according to the herbicide dosage. After 20 days herbicide spraying, the seedling number of all plants was recorded and prevention efficiency on *M. micrantha* and toxicity rate on other plants was calculated and assessed.

Foliar herbicide bioassay for *M. micrantha* and crops

During *M. micrantha* foliar-applied bioassay experiments, 10 another types of herbicides were selected, such as 41% Glyphosate (AS), 75% Tribenuron-methyl (SC), 20% Paraquat (SL), 80% Clopyralid (WP), 75% Sulfometuron-Methyl (SC), 15% Sulcotrione (AS), 72% 2, 4-D (EC), 57% Metostrey (WP), 40% Carfentrazone-ethyl (SC), 20% Starane (EC). The information of trade name, make, ai content (v/v) of each herbicide as shown in Table 1. *M. micrantha*, maize, sugarcane, banana, lemon, soybean,

Table 1. The soil and foliar-applied herbicides and their dosages to *M. micrantha* and crops.

Name	Treatment and dosage (ai g/hm^2)					Manufacturer
	I	II	III	IV	V	
10%Bensulfuron methyl (WP)	15	30	45	60	75	Monsanto Company of USA
50%Prometryn (WP)	450	600	750	900	1050	Kunming Pesticide Station
10%Metsulfuron-methy (WP)	5	10	15	20	25	Zhejiang L&G Industrial CO., LTD
80%Flumetsulam (WP)	5	10	15	20	25	The Dow Chemical Company of USA
38%Atrazine (SC)	40	60	80	100	120	Jihua Group I CO., LTD
90%Acetochlor (EC)	100	200	300	400	500	Monsanto Company of USA
25%Oxadiazon (EC)	30	50	70	100	130	Rhone-Poulenc of France
80%Ametrex (WP)	40	60	80	100	120	Agan Chemical Company of Israel
72%Metolachlor (EC)	40	55	70	90	105	Novartis Diagnostics
33%Pendimethalin (EC)	600	800	1000	1200	1400	American Cyanamid Company
41%Glyphosate (AS)	800	1000	1200	1500	1800	Monsanto Company of USA
75%Tribenuron-methyl (SC)	10	15	20	25	30	DuPont Company of USA
20% Paraquat (SL)	500	600	700	800	900	Syngenta (China) Investment CO., LTD
80%Clopyralid (WP)	5	10	15	20	25	The Dow Chemical Company of USA
15%Sulcotrione (AS)	300	600	900	1200	1500	Shenyang Research Institute of Chemical Industry
57%Metostrey (WP)	400	600	800	1000	1200	Xi'an Modern Chemistry Research Institute
40%Carfentrazone-ethy (SC)	20	30	40	50	60	American FMC Company
20%Starane(EC)	100	200	300	400	500	The Dow Chemical Company of USA
72% 2,4-D (EC)	50	100	150	200	250	Changzhou Wintafone Chemical Co., Ltd
75%Sulfometuron-Methyl (SC)	30	50	70	90	110	Jinlong Chemical CO., LTD. Of Jinhua City of Zhejiang Province

orange, and potato were tested with postemergence herbicide in the greenhouse. After 50 days of plants growth and 1m higher of *M. micrantha* stems, 5 level herbicide settings with 10 replicates were designed for each tested plant according to the herbicide dosage. After 30 days of treatments, plants were harvested and their fresh weight was measured, and then calculated and assessed prevention efficiency on *M. micrantha* and toxicity rate on other crops.

Data analysis

The important value (SDR), Simpson ecological dominance index (C), Shannon-Wiener species diversity index (H), and Pielou evenness index (J) (Shang and Cai, 1992) of *M. micrantha* invaded communities were calculated with the following formula:

$SDR = (A+B+C) / 4$;
$C = \sum (P_i)^2$;
$H = - / \sum P_i \ln Pi$;
$J = H / \ln S$

A-relative cover, B-relative density, C-relative frequency, Pi-individual plant/total number of all plants, S-plant species richness. Prevention efficiency on *M. micrantha* and toxicity rate on other plants were calculated and assessed. From regression equation with herbicide dosage (X) and strain prevention efficiency (%), LD_{90} and selectivity index were measured. LD_{90} is the herbicide doge when prevention efficiency of *M. micrantha* is over 90%, and Selectivity Index (RI) = *M. micrantha* LD_{90} / crop LD_{10}. The suppression equation: prevention efficiency (%) = [CK (density or fresh weight) – treatment (density or fresh weight)] ×100/ CK (density or fresh weight). Lower RI means stronger selectivity and higher safety to other no-target plants. Data were subjected to Analysis of variance (ANOVA) by Duncan's Multiple Range Test (DMRT) methodology.

RESULTS

Impacts of *M. micrantha* on crops

Table 2 showed that the occurring distribution of *M. micrantha* in different farming land was various. The maximum average percentage of *M. micrantha* occurrence in farming land was 23.24 in sugarcane, the next were bamboo (16.34), lemon (15.65), banana (12.15), and orange (9.51), and the lowest were tea (3.55) and shaddock (1.42), and most of them were significant (Table 2). According to occurring levels of *M. micrantha*, the yield loss percentage of seven main crops was analyzed compared to *M. micrantha* unoccurred quadrats (Table 3). As increasing in *M. micrantha* spread and population quantity, crops were declining quickly, especially some cash crops such as sugarcane, lemon, banana, and orange. Within *M. micrantha* occurring III level, the reduction of sugarcane, lemon, orange, tea, and banana yields was by 15 to 20%. For occurring II level of *M. micrantha*, the declining range of sugarcane, lemon, orange, tea, and banana outputs was 30 to 40%, and the yield loss of sugarcane, lemon, orange, and

Table 2. The occurring distribution of M. micrantha in different farming land.

Farming crop	Occurring percentage				Average (%)
	I	II	III	IV	
Sugarcane	6.40±0.35[b]	18.90±1.14[a]	25.30±1.52[ab]	37.40±2.36[d]	23.24±1.36[a]
Lemon	4.15±0.14[c]	12.25±0.82[c]	13.65±0.91[c]	42.96±2.81[c]	15.65±0.94[b]
Orange	1.72±0.05[e]	6.31±0.36[d]	22.14±1.45[b]	52.61±3.05[b]	9.51±0.51[d]
Banana	2.54±0.08[d]	4.75±0.20[e]	13.54±0.94[c]	47.42±2.94[bc]	12.15±0.64[c]
Shaddock	0.91±0.02[f]	2.21±0.08[f]	1.81±0.07[e]	65.20±3.46[a]	1.42±0.05[f]
Tea	0.25±0.01[g]	1.24±0.04[g]	6.35±0.38[d]	72.43±4.07[a]	3.55±0.12[e]
Bamboo	8.81±0.55[a]	15.31±1.01[b]	28.93±1.57[a]	33.37±2.53[d]	16.34±1.05[b]

Data are expressed as mean ± standard deviation. The different letters within same column mean significant differences at P <0.05. I, II, III and IV mean the occurring frequency of *M. micrantha* were over 51%, 31 to 50%, 11 to 30%, low 10%, respectively. The same as in Table 3.

Table 3. The effects of *M. micrantha* on crop yield.

Farming crop	Yield loss percentage			
	I	II	III	IV
Sugarcane	66.71±3.65[ab]	33.14±2.16[b]	15.20±0.85[b]	5.45±0.26[d]
Lemon	70.25±5.11[a]	35.25±2.31[ab]	19.94±1.06[a]	8.90±0.43[b]
Orange	73.15±5.60[a]	39.60±2.40[a]	19.21±1.02[a]	7.24±0.36[c]
Banana	62.65±3.25[b]	36.44±2.36[ab]	18.73±0.95[a]	10.35±0.52[a]
Shaddock	27.86±1.73[cd]	13.75±1.02[d]	4.87±0.24[d]	2.58±0.04[f]
Tea	33.90±2.05[c]	30.21±1.94[b]	16.43±0.77[b]	7.25±0.28[c]
Bamboo	23.42±1.65[d]	19.55±1.20[c]	6.14±0.31[c]	3.32±0.06[e]

banana was over 60% within occurring I level. Most yield loss of seven crops for occurring IV level of *M. micrantha* was less 10% (Table 3).

Impacts of *M. micrantha* on plant communities

In *M. micrantha* communities, the density, biomass and cover of all plants were analyzed. Figure 1 showed that the density, biomass and cover of invasive plants were significantly higher than native plants in all *M. micrantha* communities. As in increasing in *M. micrantha* cover, from 0 to 20% to 81 to 100% the density, biomass and cover of native plants were declining, which from 208 to 101 plant/m^2, 74 to 37 g/m^2, 46 to 23%, respectively. The density of invasive plants (301 to 215 plant/m^2) was decreased with *M. micrantha* cover increased, but oppositely their biomass (100 to 198 g/m^2) and cover (78 to 91%) were increasing (Figure 1). The total density and total cover of all plants were decreased with increasing of *M. micrantha* cover. From 0 to 20% to 81 to 100% of *M. micrantha* cover, the total biomass was increased from 175 to 236 g/m^2, and the total density and total cover were declined by 37.98 and 7.99%, respectively.

Moreover, the diversity index, evenness index and dominance index were various with in different *M. micrantha* communities (Figure 2). With increasing of *M. micrantha* cover, the Shannon-Wiener diversity index (H) and Pielou evenness index (J) were increased firstly and then declined. There were the highest diversity index (1.77) and evenness index (0.78) when *M. micrantha* cover being 41 to 60%. From 41 to 100% of *M. micrantha* cover, the diversity index and evenness index were obviously declined in all treatments. The dominance index (C) was reduced firstly and then increased with *M. micrantha* cover increasing. The 0 to 20% and 41 to 60% of *M. micrantha* cover had the highest dominance index (0.28) and lowest dominance index (0.21), respectively (Figure 2).

Bioactivity and selectivity of soil-applied herbicide

Germinated seed rate of *M. micrantha* was significantly reduced after preemergence herbicide for 10 types of soil-applied herbicides. Prevention efficiency over 90% of the herbicide dosage (LD_{90}) found that lower LD_{90} means higher bioactivity for *M. micrantha* (Table 4). Bensulfuron methyl, Metsulfuron-methyl and Flumetsulam had the highest bioactivity on *M. micrantha*. Moreover, LD_{90} have significant difference on crop safety, which higher selectivity indicates crops are higher sensitive to

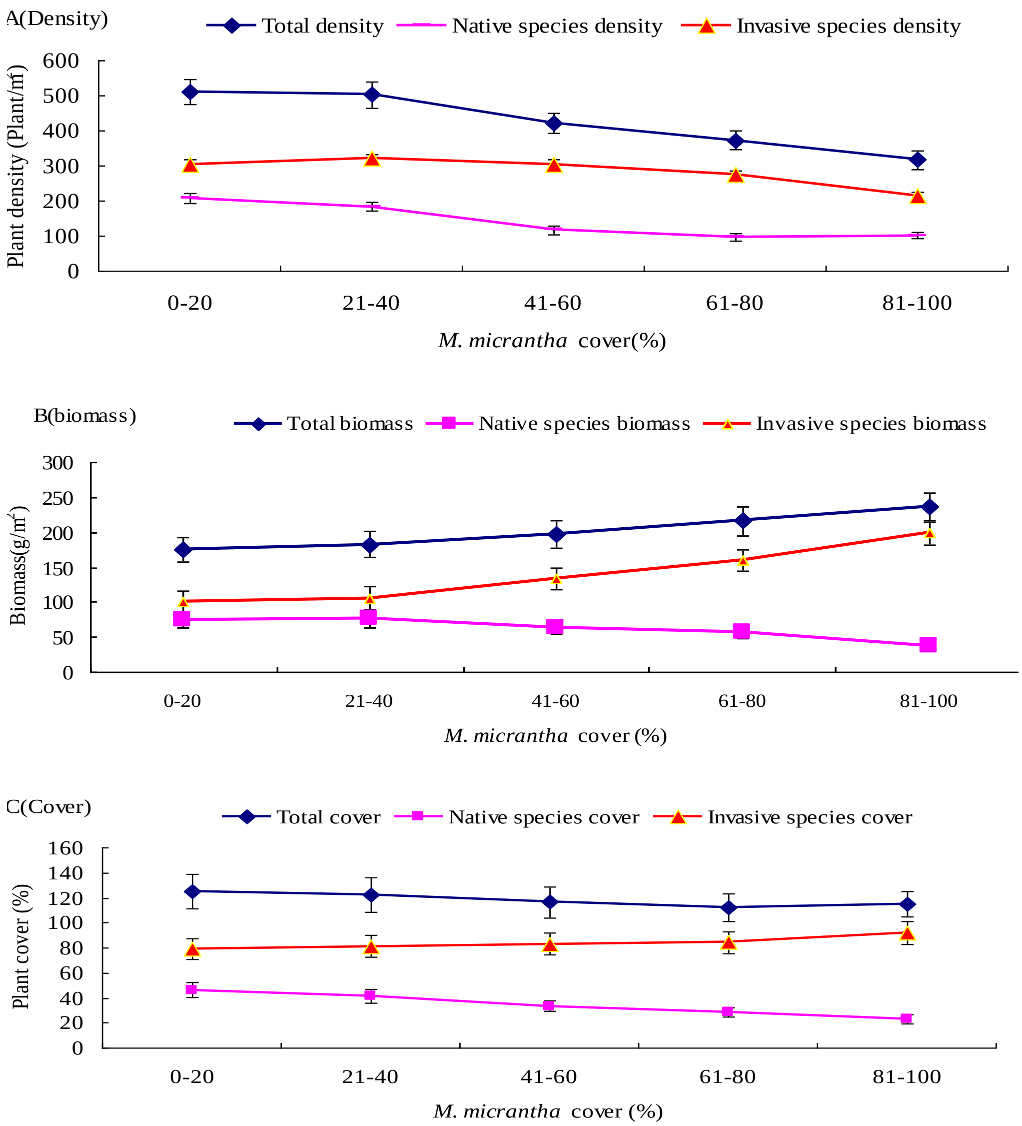

Figure 1. Plant density, biomass and cover of plants in different *M. micrantha* communities.

herbicide.Atrazine, Bensulfuron methyl and Prometryne had higher bioactivity and selectivity to *M. micrantha* germination and seedling.

Bioactivity and selectivity of foliar-applied herbicide

At the period of *M. micrantha* thriving growth, postemergence herbicide has direct effects on it. Prevention efficiency over 90% of the herbicide dosage (LD_{90}) found that Tribenuron-methyl, Clopyralid, Carfentrazone-ethyl, Sulfometuron-Methyl and Starane have higher bioactivity on *M. micrantha* and higher costs. Glyphosate and 2, 4-D had higher prevention efficiency and lower cost on *M. micrantha*, but herbicide dosage amount was so large (Table 5).

DISCUSSION

Invading mechanism of invasive alien species is very complex that it is impossible to explain clearly just from simple biological or ecological characteristics. Mostly, human activities are the major reasons for invasion of invasive alien species (Pearson and Callaway, 2005). According to a long term investigation and monitoring of *M. micrantha* in Yunnan Province, the weed is adapted to a wide range of habitats, including transported roadsides, open disturbed areas, pastures, plantations, cultivated crops, and hamlets. This study found that in farming land *M. micrantha* is usually invaded cash crops in Dehong Prefecture, and mostly distributed in sugarcane, bamboo, lemon, banana and orange (Table 2). In study areas, the crop yield was reduced quickly with *M. micrantha* cover

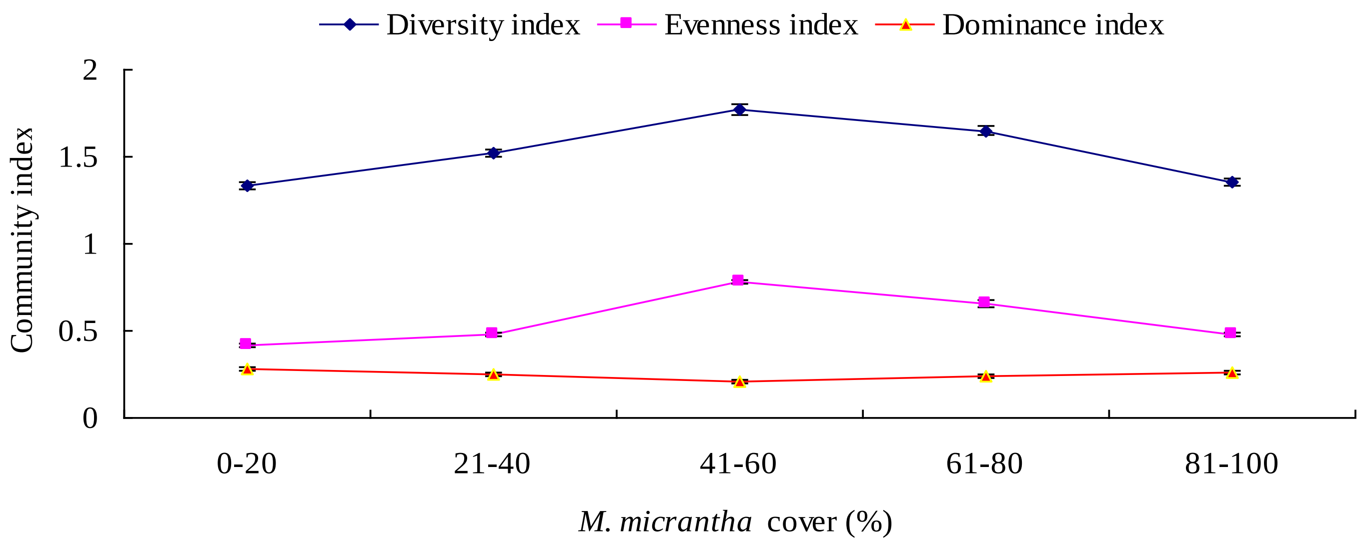

Figure 2. The community indices in different M. micrantha communities.

Table 4. Toxicity and selectivity of soil-applied herbicides to *M. micrantha* and crops.

Herbicides	Toxicity regression equation	LD_{90} g/hm^2	Selectivity index（RI）						
			Maize	wheat	broad bean	buckwheat	rape	potato	soybean
Bensulfuron methyl	Y=1.884x +15.6 R^2=0.9453	39.5	1.38^{a}	1.71^{b}	2.02^{b}	2.76^{b}	3.38^{b}	1.11^{ab}	2.42^{ab}
Prometryn	Y=0.0431x +61.13 R^2=0.8912	669.8	0.71^{b}	0.88^{c}	1.21^{c}	1.77^{c}	4.36^{b}	0.73^{b}	1.39^{b}
Metsulfuron-methyl	Y=2.088x +50.68 R^2=0.8636	18.8	1.23^{a}	2.12^{b}	1.97^{b}	2.91^{b}	3.63^{b}	1.04^{ab}	1.07^{b}
Flumetsulam	Y=1.447x +59.06 R^2=0.9132	21.4	0.59^{bc}	0.63^{c}	0.87^{c}	2.54^{b}	4.39^{b}	1.74^{a}	0.66^{b}
Atrazine	Y=0.242x +54.63 R^2=0.9158	1473.8	0.48^{c}	9.06^{a}	5.99^{a}	13.10^{a}	14.9^{a}	0.83^{b}	7.53^{a}
Acetochlor	Y=0.315x +52.62 R^2=0.9138	1186.3	0.73^{b}	0.95^{c}	0.78^{c}	1.13^{c}	1.22^{c}	0.65^{b}	0.67^{b}
Oxadiazon	Y=0.113x +52.62 R^2=0.9138	329.9	1.29^{a}	1.63^{bc}	2.11^{b}	2.45^{b}	2.72b^{c}	0.88^{b}	0.64^{b}
Ametrex	Y=0.021x +64.57 R^2=0.8727	1205.2	0.48^{c}	9.06^{a}	5.99^{a}	13.10^{a}	14.90^{a}	0.83^{b}	7.31^{a}
Metolachlor	Y=0.383x +40.14 R^2=0.9169	1301.8	0.57^{bc}	2.08^{b}	2.22^{b}	3.07^{b}	4.54^{b}	1.38^{ab}	0.92^{b}
Pendimethalin	Y=0.0297x +60.79 R^2=0.8043	983.5	0.65^{b}	2.04^{b}	1.77^{b}	1.43^{c}	1.39^{c}	0.78^{b}	0.97^{b}

The different letters within same column mean significant differences at 0.05 level. LD_{90} is the herbicide doge when prevention efficiency of *M. micrantha* is over 90%, Selectivity Index (RI) = *M. micrantha* LD_{90} / crop LD_{10}. The same as Table 5.

Table 5. Toxicity and selectivity of foliar-applied herbicides to *M. micrantha* and crops.

Herbicides	Toxicity regression equation	LD_{90} g/hm^2	Selectivity index（RI）						
			Maize	sugarcane	banana	lemon	orange	soybean	potato
Glyphosate	Y=0.0269 x +54.42 R^2=0.8845	1322.7	8.33^{b}	2.02^{b}	12.80^{a}	3.85^{ab}	4.03^{ab}	14.90^{ab}	15.40^{a}
Tribenuron-methyl	Y=2.998 x +4.12 R^2=0.9402	28.7	2.16^{c}	2.58^{b}	5.99c	1.29^{d}	1.22^{c}	3.12^{d}	3.34^{d}
Paraquat	Y=0.0705 x +35.63 R^2=0.9329	771.2	12.30^{a}	1.710^{b}	5.02^{c}	2.04^{c}	2.55^{b}	14.90^{ab}	15.80^{a}
Clopyralid	Y=2.297x +36.06 R^2=0.8406	23.48	7.72^{b}	6.56^{ab}	8.15^{b}	3.48^{ab}	4.33^{ab}	2.69^{d}	2.81^{d}
Sulcotrione	Y=0.0147 x +76.75 R^2=0.9742	901.4	0.27^{d}	0.55^{c}	1.37^{d}	1.32^{d}	1.28^{c}	6.79^{bc}	9.25^{bc}
Metostrey	Y=0.0351 x +60.54 R^2=0.932	839.3	5.59^{bc}	7.22^{a}	4.43^{c}	1.71^{c}	1.79^{bc}	2.81^{d}	3.47^{d}
Carfentrazone-ethyl	Y=0.8377 x +38.55 R^2=0.8062	61.4	1.96^{c}	1.72^{b}	4.65^{c}	5.39^{a}	6.38^{a}	13.90^{ab}	11.60^{b}
Starane	Y=0.056x +67.7 R^2=0.9663	398.2	0.73^{d}	0.79^{c}	1.88^{d}	2.73^{b}	2.37^{b}	4.56^{cd}	6.27^{c}
2, 4 - D	Y=0.0165x +55.44 R^2=0.9741	2094.5	0.59^{d}	0.52^{c}	0.93^{d}	2.01^{c}	2.43^{b}	9.48^{b}	11.30^{b}
Sulfometuron-Methyl	Y=0.117x +71.09 R^2=0.9551	161.6	7.21^{b}	5.18^{ab}	9.91^{ab}	4.53^{ab}	3.08^{b}	16.80^{a}	13.20^{ab}

increasing, especially for sugarcane, lemon, banana, and orange. When occurring I level of *M. micrantha*, the yield loss of these crops was over 60% (Table 3). For occurring II and I levels of *M. micrantha*, the reduction of most crops yields was by 15 to 20% and less 10%, respectively means that these areas should be the priority to manage for the occurrence and spread of *M. micrantha*. Meanwhile, it was also found that *M. micrantha* has resulted in negative impacts on local communities. As in increasing *M. micrantha* cover, the total density and total cover of all plants were significantly declined, but the total biomass was obviously increased; the density, biomass and cover of native plants were reduced and the biomass and cover of invasive plants were increased; the Shannon-Wiener diversity index (H) and Pielou evenness index (J) were increased firstly and then declined, and the dominance index (C) was reduced firstly and then increased. All these indicated *M. micrantha* could suppress other plants, especially native plants, reduce diversity index and evenness index, and finally change local plant communities and become the single dominant community.

In order to control *M. micrantha*, many extensive exploration and researches on mechanical removal, chemical control, biological control, and ecological control have commonly been practiced over the past two decades (Iporib and Tawan, 1995; Kuo et al., 2002; Fu et al., 2003; Zhang et al., 2004; Moran et al., 2005; Ma and Qiang, 2006). However, because of the strong asexual and sexual reproduction and morphological plasticity, higher compensation capacity, and fast adaptive evolution of *M. micrantha*, the single control method cannot effectively alleviate the damage caused by the weed, and requires to adopt more comprehensive prevention and control measures. Physical control (mowing and slashing) is easily, but it is very labour intensive and uneconomical. Moreover, mechanical control is difficult since the seeds and vine roots of *M. micrantha* disperse easily in contact with moist soil (Huang et al., 2000; Kuo et al., 2002; Zhang et al., 2002). Herbicides are still preferred over other control methods for *M. micrantha* because it is quick, more effective and relatively cheaper (Zhang et al., 2004), but most of them are often low security for crops and control period is short. Moreover, long term application of herbicide could cause negative environmental problems and easily increase the resistance of the target species (Muniappan and Viraktamath, 1993; Hu and Bi, 1994; Mittler, 2006). This study found that some major herbicides Sulfometuron-Methyl, Atrazine, Glyphosate, and 2, 4-D have higher prevention efficiency on *M. micrantha* but lower selectivity and lower safety on crops, thus it should be applied according to different farming crops and adopt some safeguard procedures to protect neighboring crops in fields. Biological control may be a promising alternative to *M. micrantha*, but it is costly to develop and many years are required. Moreover, biological control is impossible to overcome the secondary pollution on environment and has the potential risk to non-target species (Barreto and Evans, 1995; Moran et al., 2005; Sheppard et al., 2005).

CONCLUSION

In Yunnan Province, M. micrantha is mostly invaded in subtropics and tropics, such as Lincang District, Baoshan District and Dehong Prefecture. The weed has caused a series of negative impacts on farming cash crops and local plant communities in these areas. Some major herbicides have higher prevention efficiency on M. micrantha but lower selectivity and lower safety on crops, thus it should be applied according to different farming lands. As distribution and damaging characteristics of *M. micrantha* in Yunnan Province, some comprehensive controlling strategies and further researches for *M. micrantha* should be adopted in the future. Firstly, it is necessary to strengthen the survey and monitoring of *M. micrantha* that the weed could be prevented and managed in the early stage of infestation. Secondly, in these areas afflicted of *M. micrantha*, fundamentally adopted and applied farming and ecological control combined with chemical herbicide. Thirdly, ecological restoration and biodiversity resistance should be practiced in *M. micrantha* occurred areas. Finally, economic gains of *M. micrantha* such as fodder, medicine and manure should be studied more.

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