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Allelopathic effects of *Chromolaena odorata* (L.) King & Robinson and *Mikania micrantha* H.B.K. on three selected weed species

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Abstract

The use of chemical pesticides leads to negative impacts such as pesticide residue problem and weed resistance. Thus, an economical and environmentally safe method such as allelopathy needs to be explored for controlling weeds in agricultural areas. Therefore, a study was conducted to determine the allelopathic effects of the aqueous leaf extract and leaf debris (incorporated into the soil) of *Chromolaena odorata* and *Mikania micrantha* on three bioassay weed species namely *Eleusine indica*, *Cyperus iria* and *Ageratum conyzoides* under laboratory and greenhouse conditions. Three concentrations of each of the aqueous leaf extracts (12.5, 25.0 and 50.0 g/L) and leaf debris (2.5, 5.0 and 10.0 g/500 g soil) of *C. odorata* and *M. micrantha* were used in the experiment. The experimental design used was the complete randomized design (CRD) with three replications. The experiment was conducted twice. Results showed that the leaf extracts of *C. odorata* and *M. micrantha* significantly reduced all seedling growth parameters of the three bioassay species with the exception of the effect of *C. odorata* on the shoot length of *C. iria*. Leaf extracts of both species significantly inhibited growth parameters of *E. indica* and *A. conyzoides* at 50.0 g/L by more than 96 % compared to the control. The speed of germination index (S) was the most sensitive compared to that of the other indices but the Days required for 50% germination of total germinated seeds (T_{50}) and the Days required for 50% germination of the total seeds (T'_{50}) showed the least difference. At 50.0 g/L of *C. odorata* leaf extract, the "speed of germination index" of *E. indica* and *A. conyzoides* was 0, which is the lowest possible result. The leaf debris of *C. odorata* and *M. micrantha* significantly inhibited *A. conyzoides* and *C. iria* at all seedling growth parameters. The shoot length and dry weight of *A. conyzoides* was greatly reduced by *M. micrantha* leaf debris at 50.0 g/L by 87% and 90.4% of the control respectively. Whilst, at the same concentration, the fresh weight of *C. iria* was reduced by 93.5% compared to that of the control. Therefore, *C. odorata* and *M. micrantha* show allelopathic properties when used as cover crop and mulch by controlling the growth of *A. conyzoides*, followed by *C. iria* and *E. indica*. Further studies need to be conducted to investigate the type of inhibition mechanisms involved.

Keywords: Allelopathy, aqueous leaf extract, leaf debris, *Chromolaena odorata*, *Mikania micrantha*.
Abbreviations: S_speed of germination; T_{50} _Days required for 50% germination of total germinated seeds; T'_{50} _Days required for 50% germination of the total seeds; CRD_completely randomised design.

Introduction

The invasive nature of weeds is thought to be due to their ability to displace other species by means of allelopathy. Allelopathy can be defined as the negative or positive effects of chemicals that are released by one plant species on the growth of another plant species (Putnam and Tang, 1986). This property is attributed to allelochemicals which are secondary metabolites like terpenoids and phenolics which have specific functions (Khanh et al., 2007). Allelochemicals are released into the environment through volatilization, leaching and root exudation during growth and decomposition of plants or from root residues. Allelochemicals are present in all plant tissues including leaves, flowers, fruits, stems, roots, rhizomes, seeds and pollen (Putnam and Tang, 1986). Allelochemicals can directly inhibit the growth of other plants and/microorganisms because of the water-soluble nature of these chemicals (Inderjit, 1996) or indirectly affect plants through inhibiting the growth of microorganisms, such as nitrogen-fixing and nitrifying bacteria (Ibrahim et al., 1999). Allelopathy exists naturally and the production of allelochemicals is important in determining diversity, dominance and natural succession of vegetation as well as plant productivity in agro-ecosystems (Young and Bush, 2009). Thus, the use of allelopathic plants in weed management is getting much attention at both national and international levels (Weston, 1996). These chemicals could be used for weed management directly or their chemical compounds could be used to develop new herbicides (Khan et al., 2005). Therefore, the use of the allelopathic properties of *Chromolaena odorata* and *Mikania micrantha* undoubtedly has potential for further development to complement the currently used chemical pesticides. *Chromolaena odorata* (Family: Asteracea), also known as the Siam weed in Malaysia, is a perennial shrub that can grow from 3 m to 7 m high. It has a taproot which is deep and massive and leaves with pungent odor when crushed. This weed is native to Mexico, the West Indies and tropical South America and has become a serious weed of plantation crops and pastures of Southern Asia and Western Africa. It is propagated by seed dispersion and the seeds germinate usually after the rainy season. The seedlings need sunlight with partial shade to survive. This weed is not susceptible to insect attack because of its oil that has insect repellant properties.

This weed has also been found to depress the growth of rubber trees when used as ground cover (Holm et al., 1977). Ambika and Jayachandra (1980) reported that the laboratory and field studies of its leachates and extracts inhibited crop growth whilst the aerial parts of the weed released volatile inhibitors (Ambika and Jayachandra, 1992). The residues of the decomposed weed in the soil remained toxic for up to six months, and after six months crop growth was promoted (Ambika and Jayachandra, 1984). Studies showed that phenolics, alkaloids and amino acids were the main allelochemicals in *C. odorata* (Ambika and Jayachandra, 1984). *Mikania micrantha* (Family: Asteraceae) also known as 'selaput tunggul'or'ulam tikus' in Malaysia, is a multi branched, scrambling perennial vine. It has cushion-like growth, with twining stems of up to 30 cm thick, which can form a dense cover over the tree canopy (Zhang et al., 2004). It is native to Central and South America and has invaded the tropical regions of the Pacific, South-East Asia, China, India and other countries of the world (Holm et al., 1977).It had been listed as one of the ten worst exotic weed species in South-east and South Asia (Zhang et al., 2004) and reproduces easily through seed dispersal by the wind and by rooting at stem nodes (Ismail and Mah, 1993). It is a problematic weed in cacao, rubber and oil palm plantations because it has a very rapid growth habit and can suppresses the growth of other plants by reducing the light availability by quickly forming a dense canopy over the host plant, and by the secretion of allelochemicals in the surrounding area (Tripathi et al., 2012). *Mikania* was tested as a cover crop in rubber plantations in Malaysia and Indonesia but was found to have a negative effect on the growth and yield of the rubber trees (Wong, 1964). Ismail and Chong (2002) identified caffiec acid, P-hydroxybenzaldehyde, resorcinol and vanillic acid as the allelochemicals present in the leaf extracts of *M. micrantha*. Shao et al. (2005) isolated sesquiterpenoids and these compounds inhibited seed germination and seedling growth of the test species.

Since *C. odorata* and *M. micrantha* are prominent and dominant weed species in the rubber and oil palm plantations of Malaysia, their allelopathic effects showed potential for further exploitation as bio- herbicides. Thus, the present study was conducted to determine whether *C. odorata* and *M. micrantha* showed allelopathic effects on the growth of the three bioassay weeds species, namely *Eleusine indica*, *Cyperus iria* and *Ageratum conyzoides* which are common weeds in oil palm and rubber plantations of Malaysia. Thus, the objectives of the study were (1) to determine the effects of the aqueous leaf extract of *C. odorata* and *M. micrantha* on the seed germination indices and seedling growth and (2) to determine the effects of the leaf debris of the two species incorporated into the soil, on the germination and seedling growth of the three selected weed species.

Results and Discussion

Effect of the aqueous leaf extracts of C. odorata and M. micrantha on the three bioassay weed species

As seen from the results shown in Table 1, the aqueous leaf extracts of both species showed significant effects on the seedling growth of the three bioassay species, with the exception of the effect of the leaf extract of *C. odorata* on the shoot length of *C. iria*. There was significant reduction of the shoot length of *E. indica* and *C. iria* by 47.5% and 82.3%, respectively at 25.0 g/L and by 100% for the two bioassay species at 50.0 g/L of the *C. odorata* extract (compared to the control). Meanwhile, the *M. micrantha* extract inhibited significantly the shoot length of *E. indica*, *C. iria* and *A. conyzoides* by 96.3%, 63.9% and 98.23% respectively at 50.0 g/L compared to control. Both extracts inhibited significantly the radicle length and fresh weight of the bioassay species at 50.0 g/L. However, at 12.5 g/L, the 85.3% inhibition of the radicle length of *A. conyzoides* by the *C. odorata* extract was significantly higher than the 77.9% inhibition by *M. micrantha.* Conversely *M. micrantha* inhibited significantly the fresh weight of *A. conyzoides* by 66.6% which was higher than the 55.4% inhibition (compared to the control) by *C. odorata*. This showed that the aqueous extracts of both species exerted different degrees of inhibition on the seedling growth of the three weed bioassay species. Varied responses occur because of the selectivity of the allelochemicals on the target varieties (Inderjit and Duke, 2003). The results obtained are similar to those of Gao et al. (2009) where it was shown that different crops behaved differently in their response to the aqueous extract of *Hemistepta lyrata*, demonstrating that allelopathy is a selective mechanism. Results also showed that the extracts were concentration dependent because there were increments in inhibition percentage in *A. conyzoides* with increasing concentration of the extract. This result is in accordance to a previous report by Fariba et al. (2007), where allelochemicals were found to stimulate or inhibit plant growth depending on their concentration. In addition, both extracts showed more severe inhibitory effects on the radicle than on the shoot length of the bioassay species. This is because the root is the first organ that absorbs the allelochemicals from the environment. Besides, root tissue has greater permeability compared to shoot tissue (Nishida et al., 2005). Table 2 shows that the inhibitory effects of the aqueous extracts of both species on G_T (total germination), S (speed of germination) and AS (speed of accumulated germination) are dependent on the extract concentration and plant species. The G_T, S and AS of *C. iria* and *A. conyzoides* were completely inhibited by the *M. micrantha* leaf extract at all concentrations. In the present study, multiple indices were used in order to validate the findings of the study by Bewley and Black (1985), where more than one index was used in order to reflect the germination more accurately. In the present study, the G_T of *A. conyzoides* at the 12.5 g/L concentration of the C. odorata extract was not significant but the S and AS indices of *A. conyzoides* were significant at the same concentration. This showed that the G_T was not sensitive enough at the lowest concentration of *C. odorata*, to express allelopathic activity. This is because G_T gave germination interpretation as being used currently (Chiapusio et al., 1997). In the study, T_{50} (Days required for 50% germination of total germinated seeds) and T'_{50} (Days required for 50% germination of the total seeds) were found to be ineffective in reflecting allelopathic activity of both the extracts. This is in line with the report by Anjum and Bakwa (2005), where T_{50} was found to be ineffective compared to the control when different treatments of both *Helianthus annuus* and *Triticum aestivum* extracts were used on three weed species.

Effect of C. odorata and M. micrantha leaf debris on the bioassay weeds species

The germination rate of *C. iria* and *A. conyzoides* were significantly reduced with the incorporation of increasing amounts of *M. micrantha* leaf debris into the soil (Table 3). However, the *C. odorata* leaf debris did not significantly affect the germination rate of the bioassay species. *Chromolaena odorata* leaf debris inhibited significantly the

Table 1. Effects of the aqueous leaf extracts of *C. odorata* and *M. micrantha* on seedling growth (% of the control) of *E. indica*, *C. iria* and *A. conyzoides.*

Leaf extract conc. (g/L)	Shoot length		Radicle length		Fresh weight	
	C	M	C	M	C	M
E. indica						
0 (control)	100.0^{a}	100.0^{a}	100.0^{a}	100.0^{b}	100.0^{a}	100.0^{b}
12.5	93.3^{a}	113.4^{a}	88.2^{a}	125.6^{a}	88.3^{a}	148.6^{a}
25.0	52.5^{b}	100.8^{a}	45.5^{b}	64.2^{c}	36.6^{b}	92.2^{b}
50.0	0.0^{c}	3.7^{b}	0.0^{c}	2.4^{d}	0.0^{c}	3.6^{c}
C. iria						
0 (control)	100.0^{a}	100.0^{a}	100.0^{a}	100.0^{a}	100.0^{a}	100.0^{a}
12.5	113.9^{a}	103.9^{a}	68.9^{ab}	68.9^{a}	128.8^{a}	128.8^{a}
25.0	99.5^{a}	101.4^{a}	40.8^{b}	29.4^{b}	5.5^{b}	29.2^{b}
50.0	110.0^{a}	36.1^{b}	30.8^{c}	12.4^{b}	6.0^{b}	16.3^{b}
A. conyzoides						
0 (control)	100.0^{a}	100.0^{a}	100.0^{a}	100.0^{a}	100.0^{a}	100.0^{a}
12.5	113.8^{a}	77.2^{b}	14.7^{b}	22.1^{b}	44.6^{b}	33.4^{b}
25.0	17.7^{b}	25.8^{c}	2.1^{c}	4.5^{c}	15.7^{c}	30.9^{b}
50.0	0.0^{c}	1.77^{d}	0.0^{c}	0.3^{c}	0.0^{d}	0.0^{c}

Note: Means within rows followed by same alphabet are not significantly different (p<0.05) according to Duncan Multiple range test .C= *C. odorata*, M= *M. micrantha*

Table 2. Effects of the aqueous leaf extract of *C. odorata* on seedling germination indices (% of the control) of *E. indica*, *C. iria* and *A. conyzoides.*

Leaf extract conc. (g/L)	G_T		T_{50}		T'_{50}		S		AS	
	C	M	C	M	C	M	C	M	C	M
E. indica										
0 (control)	93.3^{a}	93.3^{a}	2^{b}	2^{b}	2^{b}	2^{ab}	3.10^{a}	3.10^{a}	9.02^{a}	9.02^{ab}
12.5	81.7^{a}	100.0^{a}	3^{ab}	3^{ab}	3^{ab}	3^{ab}	2.71^{a}	3.25^{a}	8.22^{a}	10.54^{a}
25.0	45.0^{b}	90.0^{a}	4^{a}	3^{a}	5^{a}	3^{a}	0.90^{b}	2.44^{b}	2.16^{b}	7.18^{b}
50.0	0.0^{c}	3.33^{b}	0^{c}	1^{c}	0^{c}	1^{b}	0.00^{b}	0.10^{c}	0.00^{b}	0.31^{c}
C. iria										
0 (control)	83.3^{a}	83.3^{a}	3^{a}	3^{a}	3^{b}	3^{b}	2.33^{a}	2.33^{a}	7.03^{a}	7.03^{a}
12.5	56.7^{ab}	38.3^{b}	5^{a}	5^{a}	5^{a}	6^{a}	1.15^{b}	0.82^{b}	2.83^{b}	2.06^{b}
25.0	48.3^{b}	36.7^{b}	5^{a}	5^{a}	6^{a}	5^{ab}	1.04^{b}	0.71^{b}	2.65^{b}	1.66^{b}
50.0	45.0^{b}	20.0^{b}	4^{a}	2^{a}	5^{a}	3^{b}	0.84^{b}	0.37^{b}	1.87^{b}	0.84^{b}
A. conyzoides										
0 (control)	98.3^{a}	98.3^{a}	2^{a}	2^{bc}	2^{a}	2^{b}	3.37^{a}	3.37^{a}	10.69^{a}	10.69^{a}
12.5	80.0^{a}	73.3^{b}	3^{a}	4^{ab}	4^{a}	5^{a}	2.11^{b}	1.55^{b}	6.38^{b}	4.05^{b}
25.0	23.3^{b}	31.7^{c}	3^{a}	5^{a}	3^{a}	6^{a}	0.40^{c}	0.53^{c}	0.80^{c}	0.95^{c}
50.0	0.0^{b}	1.7^{d}	0^{b}	1^{c}	0^{c}	1^{b}	0.00^{c}	0.02^{d}	0.00^{c}	0.02^{c}

Note: [a] Means within rows followed by same alphabet are not significantly different (p<0.05) according to Duncan Multiple range test C= *C. odorata*, M= *M. micrantha*

shoot length of *E. indica* at 5.0 g and 10.0 g by 63.8% and 58.5% respectively (compared to the control). The *M. micrantha* leaf debris at 2.5, 5.0 and 10.0 g caused significantly higher reduction in shoot length of *A. conyzoides* by 68.3%, 70% and 87% over the control, compared to that of *C. odorata* leaf debris. In addition, the fresh and dry weight of *C. iria* and *A. conyzoides* were significantly inhibited by the *M. micrantha* leaf debris, higher than that exhibited by the *C. odorata* leaf debris. This may be due to the higher amount of allelochemical-induced inhibition of nutrient uptake occurring in the presence of *M. micrantha* (Ismail and Chong, 2002).This also indicates that *M. micrantha* may contain higher amounts of phytotoxins compared to *C. odorata* as different types of leaf debris release different concentrations of allelochemicals into the soil. The concentration of allelochemicals in the soil is the dominant factor that determines phytotoxicity in the soil. This concentration in the soil is also affected by soil factors such as adsorption, desorption and degradation (Kobayashi 2004).

Materials and Methods

Plant materials

Chromolaena odorata and *Mikania micrantha* plants were collected from Bangi, Selangor, Malaysia (located at N 050 32.778', E 1020 51.025'). The leaves were collected from March until December 2011. The leaves were washed and oven dried at 30 ºC for 72 hours, ground by a commercial blender and stored in the laboratory at room temperature. Weed seeds of *Eleusine indica* (goose grass) and *Cyperus iria* (rice flat sedge) were purchased from Herbiseed and *Ageratum conyzoide*s (goat weed) seeds were collected from the area around the greenhouse of Universiti Kebangsaan Malaysia, Bangi, Selangor, Malaysia.

Water extraction using dried leaf samples of C. odorata and M. micrantha

Approximately 10 g each of the dried *Chromolaena odorata*

Table 3. Effects of the leaf debris of *C. odorata* and *M. micrantha* incorporated into soil on the germination and seedling growth (% of the control) of *E. indica*, *C. iria* and *A. conyzoides.*

Leaf debris conc. (g/500 g soil)	Germination (%)		Shoot length		Fresh weight		Dry weight	
	C	M	C	M	C	M	C	M
E. indica								
0 (control)	96.7^{a}	96.7^{a}	100.0^{a}	100.0^{a}	100.0^{b}	100.0^{a}	100.0^{b}	100.0^{a}
2.5	100.0^{a}	98.3^{a}	99.0^{a}	111.7^{a}	196.1^{a}	63.0^{b}	185.3^{a}	105.5^{a}
5.0	90.0^{a}	100.0^{a}	36.2^{b}	104.2^{a}	20.8^{b}	67.8^{b}	32.9^{b}	91.7^{a}
10.0	90.0^{a}	98.3^{a}	41.5^{b}	117.6^{a}	32.8^{b}	120.7^{a}	31.5^{b}	128.6^{a}
C. iria								
0 (control)	100.0^{a}	100.0^{a}	100.0^{a}	100.0^{a}	100.0^{a}	100.0^{a}	100.0^{a}	100.0^{a}
2.5	83.3^{ab}	70.0^{ab}	92.7^{ab}	49.7^{b}	73.1^{b}	20.2^{b}	82.9^{ab}	31.1^{b}
5.0	90.0^{ab}	66.7^{b}	23.1^{b}	37.6^{bc}	45.2^{c}	18.4^{b}	71.3^{b}	30.9^{b}
10.0	71.7^{b}	53.3^{b}	36.8^{c}	21.4^{c}	17.3^{d}	6.5^{b}	38.5^{c}	13.4^{b}
A. conyzoides								
0 (control)	100.0^{a}	100.0^{a}	100.0^{a}	100.0^{a}	100.0^{a}	100.0^{a}	100.0^{a}	100.0^{a}
2.5	100.0^{a}	41.7^{b}	71.2^{b}	31.7^{b}	69.2^{b}	31.8^{b}	52.9^{b}	26.3^{b}
5.0	86.7^{a}	33.3^{b}	59.1^{c}	30.0^{b}	90.9^{a}	36.7^{b}	62.7^{b}	21.9^{b}
10.0	83.3^{a}	15.0^{c}	60.2^{c}	13.0^{c}	71.0^{b}	25.5^{b}	52.8^{b}	9.6^{c}

Note: Means within rows followed by same alphabet are not significantly different (p<0.05) according to Duncan Multiple range test C= *C. odorata*, M= *M. micrantha*

Table 4. Formulae for calculating germination indices.

Germination index	Formulae		References
Total germination (Final germination percentage) (G_T)	$G_T = \frac{N_T \times 100}{N}$	N_T: proportion of germinated seeds in each treatment for the final measurement N: Number of seeds used in bioassay	Widely used
T_{50}	Days required for 50% germination of total germinated seeds		Josep and Maria, 2002
T'_{50}	Days required for 50% germination of the total seeds		Josep and Maria, 2002
Speed of germination (S)	$S= (N_1\times 1) +(N_2-N_1)\times 1/2+(N_3-N_2)\times 1/3+.....-N_{n-1})\times 1/n$	(N_n N_1, N_2, N_3, N_{n-1}, N_n: Proportion of germinated seeds observed at first, second, third.....(n-1), (n) days or hours	Bradbeer, 1988
Speed of accumulated germination (AS)	$AS= [N_1/1+N_2/2+ N_3/3...+N_n/n$	N_1, N_2, N_3, N_n: cumulative number of seeds which germinate on time 1,2,3.....,N	Bradbeer, 1988

and *Mikania micrantha* leaves were soaked separately in 200 mL distilled water and agitated for 48 hours by an orbital shaker (120 rpm; Firstek Scientific Model S102, Hsin Chuang, Taiwan) at room temperature ((28±3ºC)). The extracts were filtered through a layer of plastic filter and further centrifuged, (Jouan MR 14.11) at 6000 rpm for 15 min. The supernatant of each species was collected and filtered through one layer of 0.2 µm cellulose membrane filter (Whatman International Ltd., Maidstone, England) using a filter pump. The extracts were stored in a refrigerator at 4ºC until time of use. Three concentrations of each of the aqueous extracts were used in the experiment, namely 12.5 g/L, 25.0 g/L and 50.0 g/L.

Laboratory bioassay

Exactly 5 mL of each aqueous extract/ distilled water (for control) were used to wet the filter paper in the petri dishes with three replicates per concentration. The petri dishes were incubated at 28ºC (12 hour photoperiod) and checked daily (Ismail and Siddique, 2011).The seed germination indices i.e G_T (total germination), S (speed of germination), AS (speed of accumulated germination), T_{50} (number of days required for 50% of the total number of seeds to have germinated) and T'_{50}(number of days for 50% of the total number of germinated seeds) as well as seedling growth, i.e shoot length, radicle length and fresh weight were observed and recorded after seven days. These indices were calculated as described in Table 4. Seeds were considered germinated when the radicle length was more than 2 mm. Shoot length, radicle length and fresh weight of seedlings were expressed as percentage of the control (Ismail and Siddique, 2011).

Pot experiments

The dried leaves of *Chromolaena odorata* and *Mikania micrantha* were ground separately using a commercial blender and stored at 4ºC until time of use. Three concentrations of the leaf debris of both species used in the experiment, namely 2.5 g, 5.0 g, and 10.0 g per 500 g soil were incorporated separately into the soil (83% sand, 10% clay, 7% silt; 1.3% organic matters, pH 5.68) and placed in

black polybags (height 12 cm x diameter 8 cm). Similar polybags were filled with soil without any debris for the control. Twenty seeds of each of the three weed species were sown into each bag and watered regularly. The polybags were kept in the greenhouse (temperature: 25-38ºC, light density: 780±250 $\mu Em^{-2}s^{-2}$ and relative humidity: 55%). After 14 days, the seedlings were thinned to 10 per polybag. Germination and seedling growth (shoot length, fresh and dry weights) were recorded after four weeks (Ismail and Siddique, 2011).

Statistical analysis

All experiments were conducted using the Completely Randomised Design (CRD) with three replications and were conducted twice. The experimental data was subjected to the analysis of variance (one-way ANOVA) and means were compared using the Duncan Multiple range test at the 5% level of significance. The statistical analysis was done using the SPSS version 17.0 software (SPSS Inc., Chicago, USA).

Conclusion

It can be concluded that the aqueous leaf extracts of *Chromolaena odorata* and *Mikania micrantha* significantly inhibited the root length, fresh weight, G_T, S and AS of *C. iria* and *A. conyzoides* at 50.0g/L. However, all seedling growth parameters of *E. indica* were significantly inhibited at 25.0g/L of *C. odorata* and 50.0g/L of *M. micrantha* leaf extracts. The leaf debris of both *C. odorata* and *M. micrantha* significantly inhibited all the parameters for seedling growth of *C. iria* and *A. conyzoides* at 10.0g. The leaf debris of *C. odorata* significantly inhibited the shoot length of *E. indica* at 5.0 and 10.0g, whilst leaf debris of *M. micrantha* stimulated the shoot length of *E. indica* at the same concentrations. Therefore, the inhibitory effects of *C. odorata* and *M. micrantha* on the weed growth parameters of the weed *A. conyzoides* were found to be concentration and species-dependant. The difference in the sensitivity of *C. odorata* and *M. micrantha* on weed inhibition may be useful in the development of new weed management methods for crop production.

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