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Allelopathic Effects of Mungbean (*Vigna radiata*) on Subsequent Crops

Sukumarn Lertmongkol[1]*, Ed Sarobol[1] and Cha-um Premasthira[2]

ABSTRACT

Mungbean contains allelochemicals that can either inhibit or promote the growth and yield of subsequent crops in certain cropping systems. To examine the role of mungbean in a cropping system, the allelopathic effects of mungbean on the seed germination and plant growth of subsequent crops were evaluated in laboratory and pot experiments. In the laboratory experiment, the allelochemicals in mungbean inhibited the germination and root length of lettuce, whereas it had no negative effect on *Echinochloa crus-galli* seed germination. The pot experiment revealed that allelochemicals from decomposed mungbean in soil reduced the seed germination and plant height of subsequent crops especially in soybean (*Glycine max*) and lettuce (*Lactuca sativa*). The seed germination of soybean and lettuce was severely inhibited while the plant height of *Echinochloa crus-galli* was reduced. A high performance liquid chromatogram of the allelochemical compounds from the mungbean root and stem was composed of one major peak that had a retention time identical to that of thioglycerol and four other different peaks with one of these peaks having a retention time similar to that of aglycone.

Keywords: mungbean allelopathy, growth, yield, subsequent crops.

INTRODUCTION

Allelopathy is a phenomenon in which chemicals of plant or microbial origin affect the growth, development and distribution of other plants and microorganisms in natural communities or in an agricultural system (Rizvi *et al*., 1990). Allelopathy encompasses both inhibitory and stimulatory activities which affect crop growth, yield and microorganisms (Rice, 1984). Chemicals, in this regard, released by plant are collectively called allelopathic substances or allelochemicals (Einhellig, 1987). Mungbean [*Vigna radiata* (L.) Wilczek] or green gram is one of the most important, short-season, summer-growing legumes grown widely throughout the tropics and subtropics (Thomas *et al*., 2004). Mungbean is affected by its own toxic exudates or by phytotoxins produced when crop residues decompose in the soil (Einhellig, 1995). Continuous cropping of mungbean can lead to plant growth inhibition. Allelochemicals from mungbean inhibit as much as 10–25% of crop growth when mungbean is planted following a previous crop of mungbean. Mungbean plants are allelopathic and their surrounding soil is often

[1] Department of Agronomy, Faculty of Agriculture, Kasetsart University, Bangkok 10900, Thailand.

[2] Botany and Weed Science Division, Department of Agriculture, Ministry of Agriculture and Cooperative, Bangkok 10900, Thailand.

* Corresponding author, e-mail: agrsml@ku.ac.th

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toxic (Chang *et al.*, 1995). Seed yields of mungbean and sesame when grown under mixed cropping with variable seeding rates were less than their sole crop yields but the combined yields or equivalent yields of mungbean and sesame from mixed cropping were more than the sole crop yield of either mungbean or sesame (Ali *et al.*, 2007). A three-year study at Annamalai University of weed management in wetland transplanted rice, using a rice-mungbean cropping sequence with treatments assigned to the same plots every season, revealed that the population of lowland weeds, like *Cyperus difformis*, was drastically reduced by the introduction of a relay crop of mungbean in the sequence (Kathiresan, 2002). Therefore, this study was conducted to evaluate the allelopathic potential of different mungbean cultivars, and to estimate the allelopathic impact of mungbean on the subsequent crops.

MATERIALS AND METHODS

This study was conducted at the Botany and Weed Science Division, Department of Agriculture, Ministry of Agriculture and Cooperatives and the Department of Agronomy, Faculty of Agriculture, Kasetsart University during 2007–2009. It was designed to test the allelopathic effect of mungbean on the germination and growth of lettuce (*Lactuca sativa* L.) and *Echinochloa crus-galli*. Four mungbean cultivars—namely, CN36, CN72, KPS1 and KPS2—were selected to test their allelopathic effects. Lettuce and *Echinochloa crus-galli* were seeded in Petri dishes containing agar medium. They were each seeded alone and also with each of the four mungbean cultivars CN36, CN72, KPS1 or KPS2. For control treatments, 20 mungbean seeds per cultivar were planted in the middle of a Petri dish with 10 seeds per row. The same procedure was used for lettuce and *Echinochloa crus-galli* where they were also each seeded alone as control treatments. For allelopathic treatments, lettuce and *Echinochloa crus-galli* were each seeded, in different Petri dishes, alongside each of the four mungbean cultivars. Thus, for each tested plant, there were five total treatments and they were replicated four times in a completely randomized design (CRD). The Petri dishes were placed under a 24-hour light intensity of 2,000 lux at 24 °C room temperature for 7 d. The germination percentage, root and shoot length (cm) and root and shoot dry matter (g/10 seedlings) were recorded. To identify chemicals released from mungbean, a laboratory assay was carried out using high performance liquid chromatography (HPLC; Perkin Elmer Model 250). Fractionation was achieved by rinsing the samples with a mixture of methanol, as substance A, and acetic acid + water (5:95) as substance B. Rinsing with substance A was in the following order: 0^{th}–5^{th}, 5^{th}–10^{th}, 10^{th}–15^{th}, 15^{th}–20^{th}, 20^{th}–25^{th}, 25^{th}–30^{th} and 30^{th}–35^{th} minute with 15, 20, 30, 40, 50, 60 and 99% of substance A, respectively. The extraction method followed Weston *et al.* (1987).

The pot experiment was conducted using eight tested crops, that is, rice (cv. Pathumthani 1), soybean (cv. CM60), lettuce (cv. Grand Rapids), *Echinochloa crus-galli,* sesame (cv. KU18), corn (cv. KSX4901), sorghum (cv. DA5), and sunflower (cv. PAC77). Each tested crop was planted in pots 26.7 cm in diameter which contained 5 kg of soil. The soil was collected from the field, after the mungbean crop had been harvested and was allowed 1 mth for its residue to decompose. Each tested crop was separately planted with 5 seeds/pot and after emergence, 3 plants/pot were maintained. The pots received 1,000 mL of water every day in the morning for 30 d. Data on the germination percentage and plant height (cm) were recorded. A randomized complete block (RCB) design with three replications was used. The experiment was carried out during July–August 2007. Soil in the control pots of each crop was obtained from the field adjacent to the plot where the mungbean was grown.

RESULTS AND DISCUSSION

The results revealed that all four mungbean cultivars inhibited germination of lettuce but not *Echinochloa* (Table 1). Lettuce seeded alongside the mungbeans had a germination percentage between of 58.75 and 66.25 whereas lettuce alone had 91.25% germination. In contrast, *Echinochloa* seeded alongside the mungbeans had 91.25–98.75% germination as compared with 91.25% when the *Echinochloa* was seeded alone. Potentially, there may have been allelochemicals released from the mungbeans that inhibited the germination of the lettuce but did not reduce the germination of *Echinochloa crus-galli*. On the other hand, three out of four of the cultivars (CN36, KPS1 and KPS2) produced increased seed germination of *Echinochloa crus-galli*.

It was clear that mungbean grown alongside lettuce caused reductions in the root length, shoot length and dry matter of lettuce (Table 1). However, *Echinochloa crus-galli* seeded alongside the mungbeans had significantly shorter roots compared to the *Echinochloa* seeded alone. The shoot length and dry matter of *Echinochloa,*

Table 1 Allelopathic potential of four mungbean cultivars on seed germination, root length, shoot length and dry matter of lettuce and *Echinochloa crus-galli* grown in agar medium in Petri dishes.

Treatment	Germination (%)	Root length (cm)	Shoot length (cm)	Dry matter (mg/10 seedlings)
	Lettuce			
Lettuce alone	91.25^{a*}	2.43^{a}	0.39^{b}	15.5^{a}
Lettuce with mungbean cv. CN36	58.75^{b}	1.82^{b}	0.46^{a}	10.7^{b}
Lettuce with mungbean cv. CN72	61.25^{b}	1.77^{b}	0.39^{b}	9.1^{b}
Lettuce with mungbean cv. KPS1	58.75^{b}	0.33^{c}	0.33^{b}	8.3^{c}
Lettuce with mungbean cv. KPS2	66.25^{b}	0.38^{c}	0.38^{b}	10.2^{b}
	Echinochloa crus-galli			
Echinochloa crus-galli alone	91.25^{b}	6.33^{a}	1.86^{b}	46.1^{a}
Echinochloa crus-galli with mungbean cv. CN36	96.25^{a}	5.06^{a}	2.88^{a}	51.3^{a}
Echinochloa crus-galli with mungbean cv. CN72	91.25^{b}	4.47^{b}	2.52^{a}	42.9^{b}
Echinochloa crus-galli with mungbean cv. KPS1	98.75^{a}	4.19^{b}	2.82^{a}	52.1^{a}
Echinochloa crus-galli with mungbean cv. KPS2	96.25^{a}	3.61^{c}	2.38^{a}	45.7^{a}
CV (%)	8.0	8.2	11.2	9.6

* Mean values in each column of each plant followed by the same superscript letter are not significantly different at 0.05 probability level by LSD.

however were not negatively affected by the allelochemicals of mungbeans except for cultivar CN72. Xiaofang *et al*. (2008) reported that an aqueous alcohol extract of mungbean exhibited the strongest inhibitory activity against the formation of fluorescent advanced glycation endproducts (AGEs) in a bovine serum albumin (BSA)-glucose model. Siriporn *et al*. (1999) applied crude extracts from 30-day old mungbeans to lettuce (*Lactuca sativa* L.), rice (*Oryza sativa* L. cv. RD 23), barnyard grass (*Echinochloa crus-galli* Beauv.) and horse purslane (*Tranthema portulacastrum* L.) seeds at the rate of 1.0, 2.5, 5.0 and 10 g of fresh weight and found that the root length of lettuce, rice, barnyard grass and horse purslane were inhibited by 95, 77, 75 and 69%, respectively, compared with those of the control. The growth of lettuce was completely inhibited when treated with 2.5 g of extracts, whereas growth was completely inhibited with 5.0 g of extracts for rice, and 10.0 g for both barnyard grass and horse purslane. Mungbean root exudation also affected the growth of crops and weeds. The root length of lettuce and rice seedlings were inhibited by 21 and 23%, respectively, when planted at the same time with mungbean, whereas the root length of barnyard grass increased by 7%. The dry weights of lettuce, rice and barnyard grass were inhibited by 94, 42 and 49%, respectively. These results indicated that mungbean contains allelopathic substances that may inhibit or stimulate plant growth and the substances can be released to the soil through root exudation.

HPLC analysis in the present study revealed that the root extracts produced chromatogram images consisting of two big peaks having retention times of 18.10 and 21.72 min, respectively, and three small peaks having retention times of 10.14, 26.53 and 27.81 min, respectively (Table 2). These results indicated that there were five compounds involved in the allelopathic action of mungbean root extracts in which the second of the big peaks had a retention time of 18.10 min that was identical to the standard saponin compound called thioglycerol (Table 2). Extracts from the mungbean stem yielded chromatogram images consisting of two big peaks having retention times of 15.34 and 24.42 min and three small peaks having retention times of 11.91, 16.48 and 18.57 min in which the second of the big peaks had a retention time of 15.34 min that was identical to the standard saponin compound

Table 2 Retention time of compounds in extracts from the root of mungbeans and the standard saponin compound.

Type of material	Peak order	Retention time (min)	Area under the peaks (%)
Extracts from root of mungbeans	1	10.14	3.37
	2	18.10	31.46
	3	21.72	28.15
	4	26.53	16.87
	5	27.81	6.79
Standard saponin compound			
Aglycone	1	15.34	49.92
Thioglycerol	2	18.10	38.16
Uronic acid	3	22.64	7.24
Hexose	4	25.71	25.29
Pentose	5	28.83	8.78

called aglycone (Table 3). These results were in agreement with previous reports that mungbean contained rhamnose-galactose-glucuronic acid soyasapogenal B or soyasaponin 1, an allelochemical within the saponin group. Potter and Kimmerer (1989) reported that the saponins occur in the soil rhizosphere around mungbean plants. Shiraiwa *et al*. (1991), Gurfinkel and Rao (2002) and Hubert *et al*. (2005) also reported that the main saponin components in legumes are the group B saponins. Soyasaponin 1 is the dominant structure for the early germination of the seed.

The results of pot experiment showed that the seed germination and plant height of the eight tested crops (rice, soybean, lettuce, *E. crus-galli*, sesame, corn, sorghum and sunflower) were inhibited when grown in soil that incorporated decomposed mungbean from the previous crop (Table 4). Soybean and lettuce did not emerge at all while the germination of *E. crus-galli*, sesame,

Table 3 Retention time of compounds in extracts from the stem of mungbeans and the standard saponin compound.

Type of material	Peak order	Retention time (min)	Area under the peaks (%)
Extracts from stem of mungbeans	1	11. 91	12.34
	2	15.34	38.37
	3	16.48	5.70
	4	18.57	10.88
	5	24.42	30.49
Standard saponin compound			
Aglycone	1	15.34	49.92
Thioglycerol	2	18.10	38.16
Uronic acid	3	22.64	7.24
Hexose	4	25.71	25.29
Pentose	5	28.83	8.78

Table 4 Germination percentage and plant height of eight tested crops grown in control soil and mungbean residual soil.

Plant	Germination (%)		Plant height (cm)	
	Control soil	Mungbean residual soil	Control soil	Mungbean residual soil
Rice (Pathumthani1)	100^{a*}	100^{a}	26.4^{a}	12.8^{b}
Soybean (CM60)	100^{a}	0^{b}	21.6^{a}	0^{b}
Lettuce (Grand Rapids)	100^{a}	0^{b}	7.2^{a}	0^{b}
Echinochloa crus-galli	100^{a}	30^{b}	14.7^{a}	3.5^{b}
Sesame (KU18)	100^{a}	85^{b}	19.0^{a}	9.4^{b}
Corn (KSX4901)	100^{a}	90^{b}	16.1^{a}	11.5^{b}
Sorghum (DA5)	100^{a}	95^{b}	24.2^{a}	13.5^{b}
Sunflower (Pac77)	100^{a}	95^{b}	25.2^{a}	15.7^{b}

* Mean values in each row of each parameter followed by different superscript letters are significantly different at 0.05 probability level by LSD.

corn, sorghum and sunflower was significantly decreased. However, rice seed germination was not affected by the mungbean residue from the soil derived from the mungbean field. The plant height of all crops was also significantly reduced. Roberto (1960) reported the effects from residues of previous mungbean crops and demonstrated that plants grown in soil in which the root-leaf residue mix had been incubated for 1 w prior to seeding were about 50% of the control in total dry weight at any sampling date. The total dry weight was further reduced to about 40% when the incubation time was increased to 3 w. Leaf residues were found to be about 12.3% more toxic than root residues on a proportional residue weight basis. In other crops such as barley, Zoheir *et al*. (2008) reported that the growth of green foxtail, as indicated by plant height and weight, was also significantly reduced when grown in soil previously planted to barley.

CONCLUSION

Mungbean has allelochemicals that inhibited the germination and growth of adjacent and subsequent crops. In the laboratory experiment, mungbean allelochemicals inhibited germination and reduced the root length and dry matter of lettuce, but seemed to stimulate the seed germination and shoot growth of *Echinochloa crus-galli*. Compounds from the mungbean root had a retention time equal to that of thioglycerol while compounds from the mungbean stem had a retention time identical to that of aglycone. The pot experiment indicated that the germination and plant height of the subsequent crops were inhibited. Lettuce and soybean were highly sensitive to allelochemicals in the mungbean residual soil.

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