

SHORT REPORT

Allelopathic potential of cucumber (*Cucumis sativus*) on barnyardgrass (*Echinochloa crus-galli*)

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Keywords: allelopathy, *Cucumis sativus*, *Echinochloa crus-galli*, weed management.

INTRODUCTION

Rice is the most important crop in Vietnam, while barnyardgrass (*Echinochloa crus-galli* L. Beauv.) is the most significant biological constraint to rice production. In spite of the wide use of commercial herbicides to control barnyardgrass, the rice crop yield loss from this weed remains high. The negative impacts of commercial herbicide use in relation to environmental contamination make it necessary to diversify the weed management options (Putnam 1988; Weston 1996; Einhellig 1999). Controlling weeds through allelopathy is one of the strategies to reduce commercial herbicide dependency (Rice 1984; Putnam 1988; Duke *et al.* 2000). It has been observed that many plant species can provide excellent weed suppression after the incorporation of their residues into the soil (Semidey 1999; Caamal-Maldonado *et al.* 2001). However, in Vietnam there has been, so far, no attempt to exploit the allelopathy of plants for possible weed control purposes in the agricultural field setting.

Cucumber (*Cucumis sativus* L.) is also one of the major crops in Vietnam. After harvesting, the plant parts of cucumber (stems, leaves, and roots) are mostly discarded. Cucumber plants have been reported to possess allelopathic potential by exuding allelochemicals from their roots (Putnam & Duke 1974; Yu & Matsui 1994; Yu *et al.* 2003). Therefore, it is of interest to assess the allelopathic potential of cucumber plants for possible weed control purposes. The present research was carried out at the

Cuu Long Delta Rice Research Institute (CLRRI), Vietnam, to determine the allelopathic potential of a local cucumber variety on the germination and growth of barnyardgrass under laboratory and greenhouse conditions.

MATERIALS AND METHODS

Plant materials

Cucumber (*C. sativus* L. cv. Phung Tuong) plants (including the stems, leaves, and roots, but excluding the flowers and fruit) were obtained from the field after the final crop harvest and dried at 50°C for 3 days.

Seeds of barnyardgrass (*E. crus-galli* L. Beauv.) were collected in the rice field and the large seeds were selected and dried under full sunlight. Then, these seeds were incubated at 50°C for 24 h to break their dormancy and were used for the experiments. Their germination rates were ~76–85%.

Laboratory bioassay

Dried cucumber plants were soaked in distilled water in the ratio of 4.0 g of dry cucumber to 1 L of distilled water for 0, 3, 5, 7, 9, 11, 13, 15, and 17 days. The dried cucumber plants were also soaked in distilled water in the ratio of 0, 2.67, 4.00, and 5.33 g of dry cucumber to 1 L of distilled water for 9 days. After soaking, the suspension (10 mL) of these water extracts was added onto filter paper (No. 1; Whatman International, Maidstone, UK) in a 10 cm Petri dish and 100 seeds of barnyardgrass were sown on the filter paper. After 15 days of incubation at room temperature (~28°C), the germination percentage, plant height, root length, and fresh weight of barnyardgrass were determined. The experiments were repeated four times in a completely randomized block

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Received 7 February 2007; accepted 16 November 2007

doi:10.1111/j.1445-6664.2008.00285.x

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Table 1. Effect of the soaking periods of cucumber on the germination and growth of barnyardgrass

Soaking period (days)	Germination (%)	Shoot length (mm)	Root length (mm)	Flesh weight (mg per Petri dish)
0	75.3a	49.6a	45.5a	762a
3	52.6b	29.1c	10.5b	252d
5	44.4c	26.6e	8.9bc	297c
7	33.9e	22.2f	6.5de	217de
9	29.4f	20.5g	6.3e	199e
11	36.5de	23.0f	7.1cde	246d
13	39.2d	27.9d	7.9cde	289c
15	39.5d	32.3b	7.6cde	297c
17	49.2b	33.3b	8.6cde	346b

Dry cucumber plants (4.0 g) were soaked in water (1 L) and the biological activity of the soaking solution was determined. The means followed by the same letters in each column are not significantly different at the 5% level of probability.

design. The differences among the treatments were subjected to Duncan's Multiple Range tests.

Greenhouse bioassay

Field soil was dried, crushed, mixed, and placed into pots (30 cm internal diameter \times 20 cm, 8 kg of soil per pot). The dried cucumber plants were powdered and spread over the soil surface of these pots at 4.81, 9.82, 14.73, 19.64, and 24.55 g of cucumber powder per pot. After watering, these pots were kept in a greenhouse for 9 days. Then, 20 seeds of barnyardgrass were sown in the pots. An adequate water supply was ensured. The germination rate of barnyardgrass was determined at day 8 after sowing, the tillers of barnyardgrass were counted at days 14 and 42 after sowing. The experiments were repeated four times in a completely randomized block design. The differences among the treatments were subjected to Duncan's Multiple Range tests.

Determination of phenolic acids in cucumber

The dried cucumber plants were extracted with 70% (v/v) aqueous methanol and extracted again with methanol, and the two extracts were combined. Phenolic acids in these extracts were analyzed using high performance liquid chromatography (HPLC) according to the methods of Xuan *et al.* (2003).

RESULTS AND DISCUSSION

This experiment was designed based on the field observations and field studies over many years on the soil and water conditions in the Mekong Delta, Vietnam. The

amount of capillary water in the cultivated soil layer (0.3 m depth) was ~25% of the soil volume when the soil was saturated with water. Thus, the water volume in 1 ha in the 0.3 m depth soil is 750 m³ (10 000 m² \times 0.3 m \times 0.25). When 2, 3, and 4 t of cucumber plants are applied to 1 ha of field, the concentrations of the cucumber are 2, 3, and 4 t 750 m⁻³, respectively, which correspond to 2.67, 4.00, and 5.33 g L⁻¹, respectively. It was also found that the crop residues decomposed in the cultivated soil layer (0.3 m depth) in the fields of the Mekong Delta.

The water extract of the cucumber plants inhibited the germination, growth of the shoots and roots, and fresh weight of barnyardgrass under Petri dish conditions (Table 1). These inhibitions increased with the increasing soaking periods of the cucumber plants up to 9 days and then decreased thereafter. These results indicate that growth-inhibiting substances might leach and accumulate in the soaking solution, but the degradation of these substances might be faster than their accumulation after 9 days.

These inhibitions, in respect to the germination, growth of the shoots and roots, and fresh weight of barnyardgrass, also increased with the increasing extract concentration of the cucumber plants (Table 2). A significant interaction between the concentration and soaking period was found. Higher extract concentrations gave greater inhibition for each soaking period. The maximum inhibiting effect was found in the extract at the concentration of 5.33 g L⁻¹ with the 9 day soaking.

Table 3 shows that the powder of the cucumber plants significantly inhibited the germination and tiller number

Table 2. Effect of the soaking concentration of cucumber on the germination and growth of barnyardgrass

Concentration (g L ⁻¹)	Germination (%)	Shoot length (mm)	Root length (mm)	Fresh weight (mg per Petri dish)
0.00	78.3a	49.7a	47.4a	771a
2.67	36.4b	22.1b	10.9b	218b
4.00	29.4c	20.5c	6.3c	199c
5.33	20.9d	17.2d	2.5d	132d

Dry cucumber plants were soaked in water (1 L) for 9 days and the biological activity of the soaking solution was determined. The means followed by the same letters in each column are not significantly different at the 5% level of probability.

Table 3. Effect of the dosage of cucumber powder on the germination and growth of barnyardgrass

Powder (g per pot)	Germination (%)	Tiller number per pot	
	Day 8	Day 14	Day 42
0.00	85.0a	20.3a	32.0a
4.91	75.0ab	18.4ab	30.9ab
9.82	67.5bc	18.1ab	29.6ab
14.73	65.0bc	17.6bc	29.1abc
19.64	55.0cd	14.7d	29.0abc
24.55	45.0d	11.7e	24.9c

Dry cucumber powder was applied and the biological activity of the powder was determined. The germination of barnyardgrass was determined at day 8, while the tiller number was determined at days 14 and 42 after the sowing of barnyardgrass. The means followed by the same letters in each column are not significantly different at the 5% level of probability.

of barnyardgrass under greenhouse conditions. These inhibitions increased with the increasing application of powder. This result suggests that growth-inhibiting substances might leach from the cucumber powder into the soil. The concentrations of 4.91, 9.82, 14.73, 19.64, and 24.55 g of cucumber powder per pot corresponded to 2, 3, 4, 5, and 6 t ha⁻¹ of cucumber powder, respectively, as described above.

Nine phenolic acids were found in the cucumber extract and gallic acid was the most prominent (Table 4). Phenolic acids have been found in a wide range of plants and soils and are often mentioned as putative allelochemicals (Inderjit 1996; Inderjit & Nishimura 1999). The growth inhibitory activity of phenolic acids against various plants has been demonstrated at concentrations >1 mol L⁻¹ under controlled conditions. It has been shown that the contribution of phenolic acids to allelopathy might not be due to a single phenolic acid because of the weak inhibitory activity (Inderjit 1996). It has also been demonstrated that mixtures of phenolic acids have additive inhibitory action and/or synergistic inhibitory action (Einhellig 1999). The total amount of

Table 4. Concentrations of phenolic acids in cucumber plants

Phenolic acid	Concentration (mg g ⁻¹ of cucumber)
Gallic acid	10.10
Coumaric acid	4.90
Protocatechuic acid	1.40
<i>p</i> -Hydroxybenzoic acid	4.20
Caffeic acid	2.01
Syringic acid	0.80
Sinapic acid	8.10
<i>trans</i> -Coumaric acid	2.70
<i>trans</i> -Cinnamic acid	4.40

the nine phenolic acids found in the cucumber extract was 38.61 mg g⁻¹ of cucumber (Table 4). Thus, more than one of these phenolic acids might act as allelopathic substances in cucumber plants.

The water extract and powder of cucumber plants inhibited the germination and growth of barnyardgrass under

laboratory and greenhouse conditions. These inhibitions increased with the increasing soaking periods of the cucumber plants in water up to 9 days (Table 1), with the increasing extract concentrations of the cucumber plants (Table 2), and with the increasing applications of the powder of the cucumber plants (Table 3). These results suggest that growth-inhibiting substances might leach from the cucumber plants into the water and soil and act as allelopathic substances. Therefore, cucumber plants might be potentially useful for weed management in the agricultural field setting, which should be investigated further in the field for their practical application.

ACKNOWLEDGMENTS

This study was supported, in part, by a grant-in-aid from the Farming System Division, Cuu Long Delta Rice Research Institute, Vietnam. The authors wish to thank Dr T. D. Xuan, Department of Plant Science, Faculty of Agriculture, Miyazaki University, Japan, for the HPLC analysis.

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