Plant Knowledge Journal
ISSN: 2200-5390
EISSN: 2200-5404
1(2): 37-40 (2012)

Southern Cross Publishing Group
AUSTRALIA

Allelopathic potential of leaf, stem and root extracts of some Iranian rice (*Oryza sativa* L.) cultivars on barnyardgrass (*Echinochloa crus-galli*) growth

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Abstract

Selection of rice cultivars with greater allelopathic potential can be used as a tool in sustainable weed management. Two laboratory and greenhouse experiments were conducted to identify the potential allelopathic effects of leaf, stem and root extracts of ten Iranian rice (*Oryza sativa* L.) cultivars (Mosa Tarom, Hasani, Champa, Anbarbo, Fajr, Neda, Khazar, Mehr, Salari and Kamfiruzi) on barnyardgrass (*Echinochlea crus-galli*) growth. Results showed that allelopathic potential of leaf extract was more effective than root and stem extracts of rice cultivars. Among the rice cultivars, Kamfiruzi and Salari allelopathic effects caused a significant decrease ($p \leq 0.01$) in seed germination (46 and 45%), radical length (93 and 92%), shoot length (65 and 57%) and fresh weight (68 and 68%) of barnyardgrass in laboratory assay as well as weed biomass (67 and 62%) and height (57 and 56%) in greenhouse experiment. There were significant direct effect, path coefficient, between weed radical length, radical fresh weight ($p=0.29$, $p \leq 0.05$) and shoot fresh weight ($p=0.45$, $p \leq 0.01$). In general, the leaf and root extracts of Kamfiruzi and Salari which were native cultivars showed a prominent allelopathic effect on the growth of barnyardgrass. Our results suggest that there is a possibility of developing a new ecological weed management strategy using rice cultivars with higher allelopathic potential. This means breeding of rice cultivars for higher allelopathic potential might provide natural herbicides for growers.

Keywords: Seed germination, rice cultivars, allelopathy.

Introduction

Rice (*Oryza sativa* L.) is the most important annual summer food crops in Iran. Weeds such as barnyardgarss (Echinochloa crus-galli) are the most sever and widespread biological constrains in the rice production (Zimdhal, 2004). In Iran, barnyardgrass is one of the most successful yield-limiting weeds in the rice fields which its control mostly relies on herbicides. Increasing use of herbicides might lead to enhance environmental pollution and human exposure to toxic materials (Zimdhal, 2004). In recent years, much concerns has been raised about the positive aspects of allelopathy as an important strategy of ecological weed management via selecting high allelopathic potential of rice cultivars as it can reduce environmental damage associated with agricultural production such as herbicides (Chou et al., 1999; Fujii 1992; Garrity et al., 1992; Lin et al., 1992; Dilday et al., 1994; Hassan et al., 1994; Olofsdotter et al., 1995; Chung et al., 2001, 2003; Ahn and Chung, 2000). Much interest has been generated for allelopathic potential of rice since Dilday et al. (1994) identified the allelopathic effects of about 10,000 cultivars on ducksalad (*Heteranthera limosa*) in a field study. It has also been reported that about 4% of the rice cultivars have shown allelopathic potential against some troublesome weed species in paddy fields such as barnyardgrass, redstem (Ammannia spp.), sedge (*Cyperus* spp.) and ducksalad (Asghari et al., 2006). Several compounds like phenolic acid, fatty acids, indoles and terpenes have been identified in rice root exudates as allelochemicals which can inhibit growth of neighboring plant species (Kato-Noguchi, 2008). The allelopathic potential of rice were evaluated in a set of laboratory, greenhouse, and field experiment by using extracts and residues, and the results showed that there was genetic variation in allelopathic activity among cultivars (Chung et al., 2001). Olofsdotter et al. (1999) reported that there were significant differences among rice cultivars to suppress barnyardgrass growth. Two laboratory and greenhouse experiments were conducted to identify the potential allelopathic effects of leaf, stem and root extracts of ten Iranian rice cultivars on barnyardgrass growth.

Results

Laboratory experiment

The extract of different parts of rice plant had a significant effect ($p \leq 0.05$) on barnyardgrass germination and initial growth (Table 1 and Fig. 1). However, leaf extract was more effective than root and stem extract. Rice cultivars also significantly affect barnyardgrass growth. All the cultivars decreased radicle fresh weight, shoot length, radicle length, and germination percentage of the weed. Among the rice cultivars, Kamfiruzi and Salari had a greater allelopathic effect so that these cultivars caused a significant decrease ($p \leq 0.01$) in seed germination (46 and 45 %), radical length (93 and 92 %), shoot length (65 and 57 %) and fresh weight (68 and 68 %) of barnyardgrass in laboratory assay.

Cultivar × rice extract interaction was significant for all the measured traits (Table 1). Leaf and root extract of Kamfiruzi as well as leaf extract of Salari were able to reduce barnyardgrass germination percentage. Interestingly, shoot extract of Kamfiruzi, Salari, Neda, Khazar and Mehr could decrease significantly germination percentage of the weed. Additionally, no significant differences were found among these cultivars for germination percentage. There were significant direct effect, path coefficient, between weed radical length, radical fresh weight ($p=0.29$, $p\leq0.05$) and shoot fresh weight ($p=0.45$, $p\leq0.01$).

Greenhouse experiment

The extract of different parts of rice cultivars had a significant effect on weed biomass (Table 2). Among all the extracts, leaf extract was more effective than the others and could reduce barnyardgrass biomass significantly. Rice cultivars had also a significant effect on barnyardgrass biomass. Among the cultivars, Kamfiruzi and Salari had a greater allelopathic effect than the other cultivars so that they were able to reduce barnyardgrass biomass by 67 and 62 %, respectively. The biomass of barnyardgrass was affected by cultivar × rice extract interaction significantly (Table 2). Both leaf and root extract of Kamfiruzi and Salari cultivars as well as leaf extract of Khazar cultivar were able to reduce barnyardgrass biomass more than the other cultivars. The height of barnyardgrass was affected significantly by the extract of different parts of the rice cultivars (Table 2). Like weed biomass, this trait also was decreased drastically by leaf extract. Barnyardgrass biomass was affected by cultivars so that Kamfiruzi and Salari were superior to the others. Cultivar × rice extract interaction was significant for barnyardgrass height. Leaf and root extract of Kamfiruzi and Salari cultivars were able to reduce barnyardgrass height more than the other cultivars.

Discussion

In the present study, the reduction in barnyardgrass initial growth and germination in laboratory experiment and barnyardgrass biomass and height in greenhouse experiment might be indicated allelopathic potential of the rice cultivars (Tables 1 and 2; Fig. 1). Inhibitory effects of different parts of rice cultivars have also been reported by other researchers (Chung et al., 2001; Jung et al., 2004; Asghari et al., 2006). Chung et al. (2001) reported that p-hydroxybenzoic acid may be a key factor in rice allelopathy on barnyard grass. Weir et al., (2004) declared that inhibition of photosynthetic rate, interruption of respiration, ATP synthesis and amino acids metabolism were major physiological and biochemical mechanisms that might be mediated by allelochemicals. Cultivars with greater allelopathic potential might reduce application of herbicides by the farmers since these can lead us to cultivars with a natural source of herbicides.

Although some plants were observed to have allelopathic potential (Kohli, 1998) only some of them e.g. alfalfa (*Medicago sativa* L.) (Xuan et al., 2002), buckwheat (*Eriogonum douglasii*) (Hong et al., 2001), hairy vetch (*Vicia villosa*) and velvet bean (*Mucuna prurients* L.) (Fujii, 2001) showed good weed suppression and thus suggested as natural herbicides in paddy fields or cover crops. Selection of rice cultivars with greater allelopathic potential can be used as a tool in sustainable weed management and might be a way to minimize environmental costs (Asghari et al., 2006).

In our study, the magnitude of potential allelopathic effects differed between the rice cultivars (Tables 1 and 2).

This is in accordance with the results of Ahn et al (2000), Chung et al (2003), Asghari and Musavi (2002), Asghari et al. (2006) and Dilday et al. (1998) who reported that there was a variation in allelopathic activity among rice cultivars. Generally, the leaf and root extracts of Kamfiruzi and Salari which were native cultivars showed a prominent allelopathic effect on the growth of barnyardgrass. These cultivars may include one of the most important gene resources for breeding rice cultivars with higher allelopathic potential. Our results suggest that there is a possibility of developing a new ecological weed management strategy using rice cultivars with higher allelopathic potential. This means breeding of rice cultivars for higher allelopathic potential might provide natural herbicides for growers. Further studies should investigate potential allelopathic cultivars of rice under field conditions.

Materials and methods

Laboratory experiment

The laboratory experiment were conducted in College of Agriculture and Natural Resources of Darab, Shiraz University, Iran to determine the allelopathic potential of leaf, stem and root extracts of ten Iranian rice cultivars (Mosa Tarom, Hasani, Champa, Anbarbo, Fajr, Neda, Khazar, Mehr, Salari and Kamfiruzi) on barnyardgrass growth. The experimental design was completely randomized block with three replications. Barnyardgrass seeds were collected from the research station of College of Agriculture, Darab. Stems, roots and leaves of rice cultivars were sampled at three to four leaf-stage of plants that were grown in greenhouse (Hassan et al., 1994).

Aqueous extract (w/v) of the samples were prepared using 100 g ground samples with 1000 ml distilled water, and stirred for 24 h at 25°C with the method developed by Ahn and Chung (2000). Twenty five seeds of barnyardgrass were placed on two Whatman No. 2 filter papers in Petri dishes treated with 10 ml of each solution concentrations and stored in laboratory (25/20 °C day/night and 10 hours daily light). After seven days incubation, root and shoot lengths and fresh weight of seedling were measured. Roots and shoots were separated, oven dried at 65°C for 4 h before being weighed. Final germination percentage was recorded after 7 days.

Greenhouse experiment

A greenhouse experiment was conducted to evaluate the effect of leaf, stem and root extracts of ten Iranian rice cultivars (Mosa tarom, Hasani, Champa, Anbarbo, Fajr, Neda, Khazar, Mehr, Salari and Kamfiruzi) on barnyardgrass height and biomass. The experimental design was randomized complete block. The greenhouse conditions were maintained 24/16 ºC day/night, controlled light 16/8 h (day/night) and natural humidity. Each pot was filled with 2 kg air-dried soil. Five seeds of barnyardgrass were sown in each pot. At three leaf stage of barnyardgrass, pots were irrigated with 250 ml of the extract or distilled water as control. Ten days after application of the treatments, height of barnyardgrass plants were measured and then harvested plants were oven-dried at 72 °C for 48 h and weighed. Germination percentage was square root transformed to achieve normality. Data were subjected to analysis of

Table 1. Effects of different extract of rice cultivars on radicle and shoot fresh weight and shoot and radicle length of barnyardgrass in laboratory.

Cultivar	Rice Extract											
	Shoot				Root				Leaf			
	Barnyard grass											
	Radicle fresh weight (g)	Shoot fresh weight (g)	Shoot length (mm)	Radicle length (mm)	Radicle fresh weight (g)	Shoot fresh weight (g)	Shoot length (mm)	Radicle length (mm)	Radicle fresh weight(g)	Shoot fresh weight(g)	Shoot length (mm)	Radicle length (mm)
Mosa tarom	0.61±0.05[†]	0.71±0.03	53.1±1.05	21.1±1.19	0.68±0.02	0.63±0.01	49.3±1.11	19.2±1.12	0.71±0.08	0.73±0.02	49.6±2.01	18.2±1.21
Hasani	0.60±0.04	0.72±0.05	66.4±1.28	20.3±1.03	0.58±0.04	0.61±0.09	49.8±1.02	15.1±1.46	0.68±0.09	0.61±0.04	41.3±1.92	16.1±2.01
Champa	0.65±0.09	0.68±0.06	50.3±1.17	18.4±1.07	0.66±0.06	0.66±0.02	50.1±0.98	14.3±1.11	0.61±0.04	0.59±0.05	44.1±1.13	15.2±2.04
Anbarbo	0.43±0.03	0.70±0.09	41.7±1.19	15.1±1.11	0.71±0.08	0.53±0.07	46.6±0.87	11.2±0.99	0.68±0.03	0.58±0.11	49.8±1.19	12.3±0.88
Fajr	0.48±0.02	0.58±0.08	43.1±1.22	11.2±2.14	0.59±0.09	0.56±0.04	38.7±1.12	9.5±0.86	0.55±0.02	0.59±0.09	3.87±1.21	9.5±0.76
Neda	0.51±0.07	0.62±0.03	40.8±1.10	10.3±1.13	0.56±0.03	0.49±0.02	38.9±1.29	9.4±0.91	0.54±0.04	0.62±0.13	33.1±0.96	8.4±0.13
Khazar	0.38±0.05	0.48±0.08	32.1±1.26	8.5±2.21	0.33±0.08	0.44±0.06	34.5±1.33	10.1±1.21	0.43±0.05	0.55±0.01	31.8±0.91	7.1±0.46
Mehr	0.35±0.02	0.49±0.07	31.6±1.16	8.4±1.24	0.43±0.09	0.41±0.01	29.7±1.18	8.2±1.13	0.40±0.1	0.33±0.03	26.4±0.86	7.3±0.31
Salari	0.38±0.04	0.51±0.12	34.4±1.14	7.1±1.31	0.38±0.11	0.23±0.01	31.1±2.31	6.3±1.12	0.41±0.09	0.21±0.02	29.7±0.17	8.4±0.38
Kamphirooz	0.29±0.11	0.43±0.09	21.6±1.13	6.2±1.52	0.21±0.03	0.28±0.04	29.4±2.12	5.1±0.11	0.33±0.06	0.22±0.05	26.3±0.21	7.1±0.21
Control	0.89±0.02	1.02±0.19	78.4±1.29	98.1±2.94	0.87±0.21	0.99±0.10	69.3±2.36	96.2±2.21	0.91±0.87	1.04±0.12	70.3±0.83	95.3±1.13
LSD (0.05)	0.04	0.04	2.7	1.05	0.05	0.03	2	1.8	0.07	0.02	2.8	1

[†] mean ± SE

Table 2. Effects of different extract of rice cultivars on shoot dry weight and height of barnyardgrass in greenhouse.

Cultivar	Rice Extract					
	Shoot		Root		Leaf	
	Barnyard grass					
	Shoot dry weight(g)	Shoot height(mm)	Shoot dry weight(g)	Shoot height(mm)	Shoot dry weight(g)	Shoot height(mm)
Mosa tarom	5.11±0.13[†]	43.3±1.01	5.13±0.09	39.2±1.27	5.03±0.17	40.2±1.14
Hasani	5.33±0.21	48.2±3.02	5.31±0.11	41.2±1.11	4.88±0.21	36.3±1.11
Champa	4.98±0.18	51.1±1.04	4.10±0.13	45.4±2.01	5.91±0.04	41.4±1.09
Anbarbo	6.01±0.19	42.2±2.03	5.31±0.15	38.2±2.26	6.03±0.15	38.1±0.78
Fajr	4.85±0.29	39.3±2.07	4.03±0.12	31.3±1.33	3.89±0.16	36.1±0.81
Neda	4.13±0.08	42.4±1.98	3.36±0.09	37.3±1.08	3.86±0.09	31.4±0.14
Khazar	4.44±0.17	53.4±1.13	3.86±0.07	44.6±2.18	2.98±0.02	42.2±0.27
Mehr	4.02±0.06	39.6±2.21	3.80±0.08	36.2±1.23	3.55±0.06	30.7±2.03
Salari	3.65±0.02	36.1±1.96	3.45±0.11	29.1±0.98	3.66±0.04	28.3±2.12
Kamphirooz	3.21±0.03	31.2±0.98	3. 16±0.06	33.4±0.08	3.05±0.08	26.1±2.14
Control	9.86±0.08	71.8±1.04	10.03±0.97	69.1±0.19	8.81±0.15	68.6±2.03
LSD(0.05)	0.3	2.7	0.4	4	0.2	3

[†] mean±SE

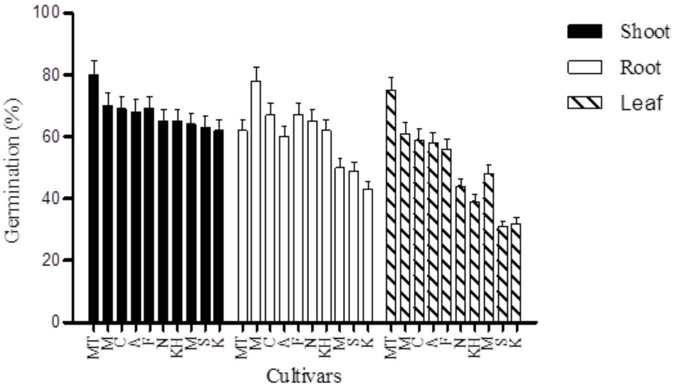

Fig 1. Germination percentage of barnyardgrass as affected by the extract of different parts of the rice cultivars in laboratory experiment. Error bars indicate standard errors (SE). *MT (Mosa tarom), M (Hasani), C (Champa), A (Anbarboo), F (Fajr), N (Neda), KH (Khazar), M (Mehr), S (Salari), K (Kamfiruzi).

variance (ANOVA) and the means were compared (LSD test, $p<0.05$) using SAS (version 9.1, 2002) software.

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