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The allelopathic potential of several rice varieties on barnyard grass (*Echinochloa crus-galli* L. Beauv.)

[Potensi alelopati daripada beberapa varieti padi terhadap rumput sambau (*Echinochloa crus-galli* L. Beauv.)]

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Key words: allelopathy, rice variety, effect factor, relay seeding technique, *Echinochloa crus-galli*

Abstract

A total of 148 rice varieties were tested for their allelopathic potential on *Echinochloa crus-galli* using the 'relay seeding technique'. Seven days after the rice seed germinated, non-dormant seeds of *E. crus-galli* were placed close to the rice seedlings. The 'effect factor' (EF) of the rice varieties was calculated as (relative root length + relative shoot length + relative seedling dry weight)/3 and used as the indicator of the allelopathic potential of the rice varieties. Reduction of weed growth was calculated as (1 – EF) x 100, whereby 1 is the 'control factor' in which no reduction occurs.

Significant differences among the rice varieties with regard to their effects on root length, shoot length and dry weight were observed and these ultimately produced the significant differences in the 'effect factor'. The results showed that there were 12 varieties with highly inhibitory effects on the weed growth. The percentages of growth reduction were Makmur (44%), MR 14 (40%), Acheh Puteh (37%), Manik (37%), MR 59 (37%), Seberang (36%), Sekencang (35%), MR 15 (34%), Anak China (33%), Anak Ikan China (33%), Anak Ikan China (33%) and Y1021 (33%). The weakly allelopathic rice varieties identified were Lembut Ketam (1%), MR 212 (3%), Chempaka 173 (4%), MR 109 (5%), MR 219 (5%) and MR 58 (7%). The following three varieties namely Janda Berhias, Muda 2 and Mayang Seroi 70 caused 8% growth reduction in the *E. crus-galli* seedlings.

Introduction

Yield loss in rice due to weed competition is a great problem throughout the world (Ampong-Nyarko and De Datta 1991; Pandy and Pingali 1996). On an average, 10% loss in agricultural yield occurs due to weed infestation, despite methods of intensive control. Every year approximately 3 million tonnes of herbicides are used to control weeds (Stephenson 2000), and this directly affects our environment. Therefore, a sustainable weed management programme for rice namely; utilising low-inputs and conserving resources, is an important aspect of rice farming.

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Due to heavy doses of agro-chemical applied for agriculture and the development of herbicide-resistant weed species, concerned agricultural scientists are very keen to develop allelopathic crop varieties. Allelopathy, namely the direct influence of a chemical released from one plant on the development and growth of another, may provide an alternative to current weed control methods. Cultivars of rice that posses high allelopathic activity to major weed species could reduce the loss in crop yields due to weeds and hence reduce herbicide application and costs, ultimately helping to safeguard our environment (Fujii 1992, 1993; Kim et al. 1999).

In many parts of the world, allelopathy has been studied for use in weed control, low-input agriculture (Gliessman 1982), intercropping systems, and nutrient recycling (Rizvi and Rizvi 1992). Identification of allelopathic crop accessions/varieties have been done in cucumber (Putnam and Duke 1974), oat (Fay and Duke 1977), and rice (Dilday et al. 1991; Azmi et al. 2000).

Barnyard grass *(Echinochloa crus-galli)* locally known as rumput sambau, is a noxious weed of rice fields and can cause almost total loss of the paddy crop. It is also the most frequently reported weed in rice fields in many countries including Malaysia (Azmi and Mortimer 2000). This species infested 4,097 ha, equivalent to 59.8% of the total weed infested area in MADA. Approximately 82.6% of the areas encountered grass weed problems were caused by *Echinochloa* species (Ho et al. 1990). Studies on the allelopathic potential of rice varieties received special attention from the weed scientists of Japan and Korea, but there has been very limited reports of work done in Malaysia (Azmi et al. 2000). The objective of this study was to screen out the allelopathic rice varieties available in Malaysia.

Materials and methods

Seed sources

A total of 148 rice varieties/lines were obtained from the MARDI Rice Genebank, Seberang Perai, Malaysia. The seeds were stored in air tight bottles at –4 °C until used. The non-dormant seeds of *E. crus-galli* were purchased from the HERBISEED company, UK.

The 'Relay Seeding Technique'

The 'Relay Seeding Technique' method (Navarez and Olofsdotter 1996) was used to observe the effects of the root exudates of rice varieties/lines on the growth of *E. crus-galli*. A total of 20 clean seeds of each variety were placed in petri dishes, each lined with 9-cm diameter filter paper, and moistened with 5 ml of distilled water. The petri dishes were covered and kept in the laboratory under alternating light/dark conditions for 12 h. Ten tube lights (TLD 36 Watt/54, Philips) were fixed 1.22 m above the petri dishes to provide sufficient light to the germinating seeds. The average temperature recorded was 25 °C. Four replications were made for each variety.

After 7 days, the rice seedlings were thinned to 10 seedlings per petri dish, and the lids of the petri dishes were removed. A total of 20 non-dormant weed seeds of *E. crus-galli* were put into each petri dish by placing them close to the rice seedlings. For control, 20 weed seeds were placed into petri dishes without rice seeds. All petri dishes were further incubated for an additional 10 days after placing the weed seeds. Five milliliters of distilled water was added every day to each petri dish to maintain adequate water supply. Thus the relay seeding technique ensured that there was no competition for water, nutrient or light. Seventeen days after initiation of the experiment, the root length and shoot length of ten randomly selected weed seedlings per petri dish were measured. The ten weed seedlings were oven-dried at 70 ºC for 4 days before determination of the dry weight.

The experiment was set in a completely randomized design. The 'effect factor' (EF) was calculated as (relative root length + relative shoot length + relative seedling dry weight)/3 and used as the indicator of the allelopathic potential of the rice varieties. The lower the value of EF, the higher the allelopathic potential of the rice variety. Reduction of weed growth was calculated as (1 – EF) x 100, where '1' is the "control factor" (i.e. the effect factor under no reduction).

Statistical analysis

The data on root length, shoot length and dry matter were subjected to one-way analysis of variance (ANOVA). Data of the four replicates were pooled and mean values were separated on the basis of LSD at the 0.05 probability level. The MINITAB statistical program was used to do all the analyses.

Results and discussion

Table 1 shows the mean root length, shoot length and seedling dry weights of *E. crus-galli,* as well as the 'effect factor' of each of the rice varieties. The root length and shoot length of *E. crus-galli* were significantly affected by the exudate of some rice varieties, resulting in stunted roots with pruned root tips. In some cases the root tip of the weed became discoloured. The effects of the rice seedling exudates on the root and shoot lengths of *E. crus-galli* may consequently affect the dry weight of *E. crus-galli*.

The inhibition rate of the root length, shoot length and dry weight of *E. crus-galli* ranged from 10.68–80.30%, 0.10–35.20% and 2.70–27.0%, respectively *(Table 1)*. The highest root length reduction of the weed was caused by the variety Manik (80.30%) followed by Makmur (77.39%) and the lowest root length reduction of the weed was caused by the variety Lembut Ketam (10.68%). With regard to the shoot length, the MR 14 and Makmur varieties caused the highest reduction (35.20%) whereas Anak Singgora produced the lowest reduction (0.01%). These results are in agreement with those reported by Kim et al. (1999) and Chung et al. (2000), whereby it was shown that some cultivars of rice exhibited strong inhibitory effects on the growth of *E. crus-galli.*

Some varieties showed the reverse effect by stimulating the growth of the weed. A number of varieties (36) including MR 105 (11.5%) and Burok Bakul (11.5%) were found to stimulate the shoot growth of the weed. Two varieties, namely Anak Limbat and Jarum Emas had very little stimulating effect on the weed species. Rice (1984) reported that stimulatory effects could occur at lower concentrations of the allelopathic substances. While at higher concentrations, they might cause inhibitory effects. Probably, variation occurred in the amount and type of allelochemicals produced by the different rice varieties. Further research needs to be carried out to clarify these observations. In terms of the dry weights of *E. crus-galli,* the variety MR 59 caused the highest growth inhibition (27.03%) followed by Makmur (18.92% inhibition), whereas MR 81, Anak Gajah, Anak Ulat, Batas-2, Chatek, Che Ali Puteh etc. affected the lowest inhibition (2.70%). The stimulatory effects on the shoot length of *E. crus-galli* may contribute to an increase in weed dry weight. Fourteen varieties including MR 109 and MR 119 did not cause reduction in dry weight of the weed.

There were 72 varieties that caused a stimulatory effect on the weed dry weight, and these included Malinja and Kutu Chempaka each of which caused 16.2% increase in the dry weight. It was found that the stimulation in dry weight of the weed ranged from 2.70% (Burok Bakul, Chatek Kuning and Byatgele) to 16.22% (Malinja and Kutu Chempaka, Pasir, MR 67, Jintan Kuning, Jintan Puteh etc.). Therefore, it is apparent that in spite of root length reduction of the weed caused by some rice varieties, many varieties such as Jarom Emas, Koncho Kecil 58, Mayang Seroi 70,

Table 1. Root length, shoot length, seedling dry weight of *Echinochloa crus-galli,* 'effect factor' and weed growth reduction as effected by allelopathic rice varieties

Rice variety	Acc. No	RL (mm)	RLR (%)	SL (mm)	SLR (%)	DW (mm)	DWR (%)	EF	GR (%)
Acheh Puteh	00008	11.70	67.55	41.40	23.90	7.50	18.92	0.63	37
Acheh Puteh (unsel)	00011	14.20	60.61	47.90	11.95	8.25	10.81	0.72	28
Amur	00026	15.10	58.11	47.03	13.55	8.25	10.81	0.72	28
Anak China	00032	10.25	71.57	45.25	16.82	8.50	8.11	0.67	33
Anak Didek–1	00036	13.45	62.69	44.95	17.37	8.25	10.81	0.69	31
Anak Didek–3	00038	14.60	59.5	47.65	12.41	8.25	10.81	0.72	28
Anak Gajah	00047	14.90	58.67	52.75	3.03	9.00	2.70	0.78	22
Anak Ikan China	00053	12.93	64.13	45.90	15.62	7.75	16.22	0.67	33
Anak Ikan China	00056	13.75	61.86	44.95	17.37	7.50	18.92	0.67	33
Anak Ikan China	00057	15.95	55.76	52.35	3.77	8.75	5.40	0.78	22
Anak Ikan Kelubi	00066	19.95	44.66	51.50	5.33	9.25	0.0	0.81	19
Anak Ikan Sombong	00073	19.25	46.6	53.55	1.56	9.00	2.70	0.82	18
Anak Ikan Tinggi	00082	17.95	50.21	53.25	2.11	9.00	2.70	0.81	19
Anak Ikan Tinggi	00088	16.90	53.12	57.50	–5.70	8.50	8.11	0.81	19
Anak Ikan Tinggi	00089	17.85	50.49	52.95	2.66	8.25	10.81	0.78	22
Anak Limbat	00100	19.50	45.91	53.75	1.19	9.00	2.70	0.83	17
Anak Limbat	00101	19.20	46.74	54.50	–0.18	8.75	5.40	0.82	18
Anak Naga	00113	16.05	55.48	50.50	7.17	9.00	2.70	0.78	22
Anak Naga	00114	20.50	43.13	55.40	–1.84	8.25	10.81	0.82	18
Anak Nalong	00120	20.85	42.16	58.40	–7.35	8.25	10.81	0.84	16
Anak Puteh	00125	13.65	62.14	56.10	–3.12	8.25	10.81	0.76	24
Anak Siam	00129	21.85	39.39	54.50	–0.18	8.25	10.81	0.83	17
Anak Singgora	00131	16.75	53.54	54.35	0.09	8.00	13.51	0.77	23
Anak Ulat	00134	14.15	60.75	56.10	–3.12	9.00	2.70	0.79	21
Arohan C	00148	16.75	53.54	56.50	–3.86	8.25	10.81	0.79	21
Ayam	00161	16.50	54.23	61.10	–12.32	8.75	5.40	0.84	16
Badshabhog	00166	18.00	50.07	59.60	–9.56	9.25	0.0	0.86	14
Bahagia	00167	12.15	66.30	53.40	1.84	8.50	8.11	0.74	26
Batas	00184	23.65	34.40	56.80	–4.41	9.00	2.70	0.88	12
Batas	00185	15.80	56.17	57.05	–4.87	8.75	5.40	0.80	20
Batikan	00187	13.65	62.14	56.13	–3.18	8.75	5.40	0.78	22
Bisbang A	00213	15.75	56.31	54.25	0.27	10.50	–13.50	0.85	15
Bodong	00223	16.60	53.95	61.55	–13.14	10.25	–10.80	0.89	11
Bok Soi 40	00227	18.50	48.68	53.15	2.30	9.75	–5.41	0.84	16
Bunga Melor	00248	20.95	41.89	58.25	–7.08	9.25	0.0	0.88	12
Burok Bakul	00271	19.60	45.63	60.65	–11.49	9.50	–2.70	0.89	11
Byatgele	00273	18.85	47.71	55.85	–2.66	9.50	–2.70	0.85	15
Chatek	00304	21.65	39.94	58.00	–6.62	9.00	2.70	0.87	13
Chatek Kuning	00320	17.20	52.29	53.80	1.10	9.50	–2.70	0.83	17
Che Ali Puteh	00323	13.35	62.97	50.45	7.26	9.00	2.70	0.75	25
Che Lawi 16	00325	24.00	33.43	49.85	8.36	8.50	8.11	0.83	17
Che Mek Molek	00327	12.75	64.63	54.75	–0.64	9.25	0.0	0.78	22
Chempaka 173	00334	29.20	19.00	53.85	1.01	10.25	–10.80	0.96	4
Compena	00363	16.70	53.67	52.80	2.94	10.00	–8.11	0.83	17
Dulitik	00412	15.25	57.70	52.30	3.86	8.25	10.81	0.75	25
Gading	00449	15.10	58.11	56.30	–3.49	9.75	–5.41	0.83	17
Haji Haroun	00498	22.65	37.17	53.80	1.10	8.50	8.11	0.84	16

(cont.)

Table 1. *(cont.)*

Rice variety	Acc. No	RL (mm)	RLR (%)	SL (mm)	SLR (%)	DW (mm)	DWR (%)	EF	GR (%)
Haji Harun 10	00502	15.20	57.83	49.75	8.55	10.25	–10.80	0.81	19
Intan Merah	00541	17.50	51.45	50.15	7.81	8.75	5.40	0.78	22
Jambok	06212	13.20	63.38	49.95	8.18	8.25	10.81	0.72	28
Janda	00565	18.30	49.24	52.05	4.32	8.25	10.81	0.78	22
Janda Berhias	00566	27.75	23.02	52.55	3.40	9.75	–5.41	0.92	08
Jarum Emas	00569	12.60	65.05	54.65	–0.46	9.25	0.0	0.78	22
Jenalek	00587	21.15	41.33	53.30	2.02	9.00	2.70	0.84	16
Jintan Kuning	00600	20.90	42.02	59.95	–10.20	9.50	–2.70	0.90	10
Jintan Puteh	00620	15.90	55.89	52.55	3.40	9.50	–2.70	0.81	19
Kadaria (MR 27)	04554	11.90	66.99	45.65	16.08	8.75	5.40	0.75	25
Kalimonch	04281	9.95	72.34	47.70	12.31	9.00	2.70	0.70	30
Kedah	00672	12.25	66.02	49.90	8.27	8.75	5.40	0.73	27
Kedinga B (dry)	00677	11.60	67.82	50.90	6.43	9.00	2.70	0.74	26
Ketitir	00694	16.10	55.34	53.95	0.83	8.75	5.40	0.79	21
Ketumbar	07899	18.50	48.68	57.15	–5.05	10.25	–10.80	0.88	12
Koncho Kecil 58	00712	11.80	67.27	57.50	–5.70	9.25	0.0	0.79	21
Kutu Chempaka	00737	20.70	42.58	50.75	6.71	10.75	–16.20	0.88	12
Landak	00749	15.30	57.56	51.80	4.78	8.75	5.40	0.77	23
Lantit	00755	28.50	20.94	52.85	2.85	8.75	5.40	0.90	10
Lembu Basah	00777	18.75	47.99	48.20	11.40	9.00	2.70	0.79	21
Lembut Ketam	08076	32.20	10.68	57.15	–5.05	9.75	–5.41	0.99	1
Lembut Pandan 36	00789	22.25	38.28	46.90	13.79	9.50	–2.71	0.83	17
Mahsuri	00826	19.90	44.80	48.20	11.40	10.50	–13.5	0.85	15
Makmur	04558	08.15	77.39	35.25	35.20	7.50	18.92	0.56	44
Malinja	00839	24.90	30.93	42.60	21.69	10.75	–16.2	0.87	13
Manik (MR 52)	04556	07.10	80.30	37.50	31.07	9.50	–2.70	0.63	37
Mayang Ebos 80	00877	18.05	49.93	45.90	15.62	8.75	5.40	0.76	24
Mayang Gerbi 101	00888	16.80	53.40	46.25	14.98	9.75	–5.41	0.78	22
Mayang Mandin	00904	20.45	43.27	53.25	2.11	8.00	13.51	0.80	20
Mayang Pasir	00909	21.15	41.33	56.03	–2.99	8.25	10.81	0.83	17
Mayang Sagumpal	00956	13.20	63.38	59.85	–10.02	9.50	–2.70	0.83	17
Mayang Seroi 70	00974	24.50	32.04	59.70	–9.74	9.25	0.0	0.92	08
Mek Bujang Kelsom	00988	13.75	61.86	59.85	–10.02	9.25	0.0	0.82	18
Melor	01001	20.60	42.86	58.85	–8.18	9.25	0.0	0.88	12
Merah	01007	15.75	56.31	58.45	–7.44	8.25	10.81	0.79	21
Morak Sepilai Kechil	01015	17.75	50.76	56.80	–4.41	8.75	5.40	0.82	18
MR 100	07733	14.85	58.81	54.75	–0.64	9.75	–5.41	0.82	18
MR 103	07486	18.65	48.27	45.35	16.64	8.50	8.11	0.75	25
MR 105	07737	20.83	42.22	60.68	–11.54	9.50	–2.70	0.90	10
MR 106	07487	11.15	69.07	45.10	17.09	8.50	8.11	0.68	32
MR 109	07740	27.30	24.27	59.90	–10.11	9.25	0.0	0.95	05
MR 119	07832	24.30	32.59	52.90	2.76	9.25	0.0	0.88	12
MR 123	07488	18.95	47.43	48.10	11.58	8.00	13.51	0.75	25
MR 127	07489	19.15	46.88	41.75	23.25	8.75	5.40	0.74	26
MR 14	04569	9.98	72.31	35.25	35.20	8.25	10.81	0.60	40
MR 15	04570	10.38	71.21	40.73	25.13	8.15	11.89	0.66	34
MR 167	08646	25.30	29.82	53.05	2.48	9.50	–2.70	0.90	10
MR 185	08455	17.00	52.84	58.25	–7.08	10.00	–8.11	0.86	14

(cont.)

Table 1. *(cont.)*

Rice variety	Acc. No	RL (mm)	RLR (%)	SL (mm)	SLR (%)	DW (mm)	DWR (%)	EF	GR (%)
MR 20	04575	16.83	53.31	43.38	20.26	10.00	–8.11	0.78	22
MR 206	–	26.70	25.94	47.10	13.42	9.75	–5.41	0.88	12
MR 209	–	19.70	45.35	51.80	4.78	10.00	–8.11	0.85	15
MR 212	–	31.25	13.31	53.50	1.65	10.00	–8.11	0.97	3
MR 214	–	16.50	54.23	47.25	13.14	10.25	–10.8	0.81	19
MR 217	–	23.80	33.98	48.45	10.94	9.00	2.70	0.84	16
MR 219	–	29.00	19.56	55.40	–1.84	9.75	–5.41	0.95	05
MR 220	–	24.60	31.76	47.65	12.41	9.75	–5.41	0.87	13
MR 40	04594	16.25	54.92	46.40	14.71	10.25	–10.8	0.80	20
MR 43	04597	17.75	50.76	47.90	11.95	9.25	0.0	0.79	21
MR 45	04599	19.33	46.38	45.93	15.57	9.00	2.70	0.78	22
MR 49	04602	20.35	43.55	53.85	1.01	9.00	2.70	0.84	16
MR 5	04563	15.65	56.59	44.95	17.37	9.75	–5.41	0.77	23
MR 55	04607	21.25	41.05	56.30	–3.49	8.50	8.11	0.84	16
MR 58	04610	29.90	17.06	55.50	–2.02	9.00	2.70	0.93	07
MR 59	04611	12.50	65.33	45.15	17.00	6.75	27.0	0.63	37
MR 62	04614	16.05	55.48	52.15	4.14	9.00	2.70	0.79	21
MR 65	04617	14.10	60.89	49.15	9.65	8.75	5.40	0.79	21
MR 66	04618	14.10	60.89	49.15	9.65	8.75	5.40	0.74	26
MR 67	04619	19.55	45.77	50.75	6.71	9.50	–2.70	0.83	17
MR 76	04626	19.75	45.21	51.30	5.70	8.50	8.11	0.80	20
MR 81	–	23.80	33.98	47.70	12.32	9.00	2.70	0.83	17
MR 82	04631	22.20	38.42	50.85	6.52	7.75	16.22	0.79	21
MR 84	04633	15.75	56.31	49.35	9.28	8.50	8.11	0.75	25
MR 85	04634	23.55	34.67	49.50	9.00	9.00	2.70	0.84	16
MR 86	04635	12.10	66.44	47.45	12.77	8.50	8.11	0.70	30
MR 95	07728	18.45	48.82	54.05	0.64	9.00	2.70	0.82	18
Muar Kuning 1818	01023	21.05	41.61	59.30	–9.00	8.75	5.40	0.87	13
Muda (MR 71)	04557	10.55	70.73	45.70	15.99	9.00	2.70	0.70	30
Muda 2	08476	23.35	35.23	58.95	–8.36	9.75	–5.41	0.92	08
Musang A	01044	15.95	55.75	51.10	6.07	8.50	8.11	0.76	24
Nyandal	01126	15.75	56.31	55.88	–2.72	9.00	2.70	0.81	19
Nyandal	01127	10.80	70.04	53.55	1.56	8.75	5.40	0.74	26
Pahit B	01181	16.25	54.92	51.65	5.05	9.00	2.70	0.79	21
Pandasan	01195	20.90	42.02	57.00	–4.78	9.75	–5.41	0.89	11
Panji Kuning	04187	12.30	65.88	53.70	1.29	9.00	2.70	0.76	24
Parjugan C	01201	18.45	48.82	55.45	–1.93	9.75	–5.41	0.86	14
Pasir	01202	17.65	51.04	56.65	–4.13	9.50	–2.70	0.85	15
Pulut Karau	01277	24.25	32.73	50.25	7.63	9.00	2.70	0.85	15
Pulut Siding	04555	14.25	60.47	45.60	16.18	8.50	8.11	0.71	29
Radin	01162	15.30	57.56	53.35	1.93	8.25	10.81	0.76	24
Randin Ebos 36	01352	25.10	30.37	54.95	–1.01	8.50	8.11	0.87	13
Sambug	04161	16.45	54.37	52.00	4.41	9.50	–2.70	0.81	19
Seberang (MR 77)	04559	10.08	72.04	40.73	25.13	8.25	10.81	0.64	36
Sekembang (MR 10)	04553	14.80	58.95	44.15	18.84	9.00	2.70	0.73	27
Sekencang (MR 7)	04552	9.15	74.62	38.05	30.05	9.25	0.0	0.65	35
Siam Pilihan	07102	12.95	64.08	45.55	16.27	8.50	8.11	0.70	30
Tak Tahu	07870	23.10	35.92	57.85	–6.34	9.00	2.70	0.89	11

(cont.)

Table 1. *(cont.)*

Rice variety	Acc. No	RL (mm)	RLR (%)	SL (mm)	SLR (%)	DW (mm)	DWR (%)	EF	GR (%)
Wangi	04151	11.05	69.35	43.45	20.13	9.50	–2.70	0.71	29
Y 1021	07484	9.85	72.68	48.33	11.16	8.00	13.51	0.67	33
No rice	–	36.05	–	55.40	–	9.25	–	–	–
LSD (5%)		5.97		5.72		1.22		–	–

– = Not known/Not applicable; SL = Shoot length; SLR = Shoot length reduction;
RL = Root length; RLR = Root length reduction; DW = Dry weight; DWR = Dry weight reduction
EF = Effect factor; GR = Growth reduction

Mek Bujang, Kelsom, Melor, MR 109 and MR 119 did not cause any reduction in dry weight of the weed.

The relationship between the reduction of root length on the shoot length or on the dry matter content of the weed is not clear. It is worthy to note that this non-relationship or very low relationship between root length and shoot length of barnyard grass was also observed by earlier researchers (Navarez and Olofsdotter 1996; Olofsdotter and Navarez 1996). Greater inhibition of root as compared to shoot may be due to the fact that the root was in more intimate contact with the filter paper, which received the allelochemicals directly from the rice roots.

When the effects on root length, shoot length and dry weight of the weed are considered together, it was observed that the variety Makmur caused 77.3, 36.3 and 18.9% reduction of root length, shoot length and dry weight of *E. crus-galli,* respectively. The variety MR 14 caused 72.33% inhibition of root length, 36.3% of the shoot length and 10.81% of the dry weight of the weed. Similarly, the variety Acheh Puteh caused 67.5, 23.9 and 18.92% reduction respectively. Manik meanwhile caused reduction of root length, and shoot length by 80.31% and 31.07%, respectively but no reduction of weed dry weight was observed. The variety Seberang was observed to cause a reduction in root length (72.04%), shoot length (25.13%) and dry weight (10.81%) of the weed.

Many of the earlier reports used only root length reduction to show allelopathic effects of rice on weeds (Olofsdotter and Navarez 1996; Ahn and Chung 2000; Azmi et al. 2000; Chung et al. 2000). However, the above results are based on the ‘effect factor’ and the percentage of growth reduction, in which the effects on root length, shoot length and dry weight of the weed are taken into consideration. This gives a more accurate assessment on the allelopathic effects of one species on another. Azmi et al. (2000) reported that several traditional varieties like Siam ER 54, Jambok, Wangi and the more modern varieties like MR 77 and MR 84 were found to have strong allelopathic effects on lettuce seedlings.

The present study has shown that the rice variety Acheh Puteh has high allelopathic effects on the weed *E. crus-galli* and this result is consistent with that of Azmi et al. (2000). The ‘effect factor’ is positively related to root length ($r^2 = 0.74$), shoot length ($r^2 = 0.51$) and dry weight ($r^2 = 0.36$) of the weed *(Figure 1)*. The results indicated that a significant reduction in the root length, shoot length and dry weight of the weed seedlings occurred due to the allelopathic effect of the rice varieties, and this ultimately affected the 'effect factor' and percentage growth reduction of the weed as shown in *Table 1.* Shoot length was comparatively less affected as compared to root length irrespective of the rice variety used. It should be noted that the higher the value of EF, the less the allelopathic effect of the rice variety.

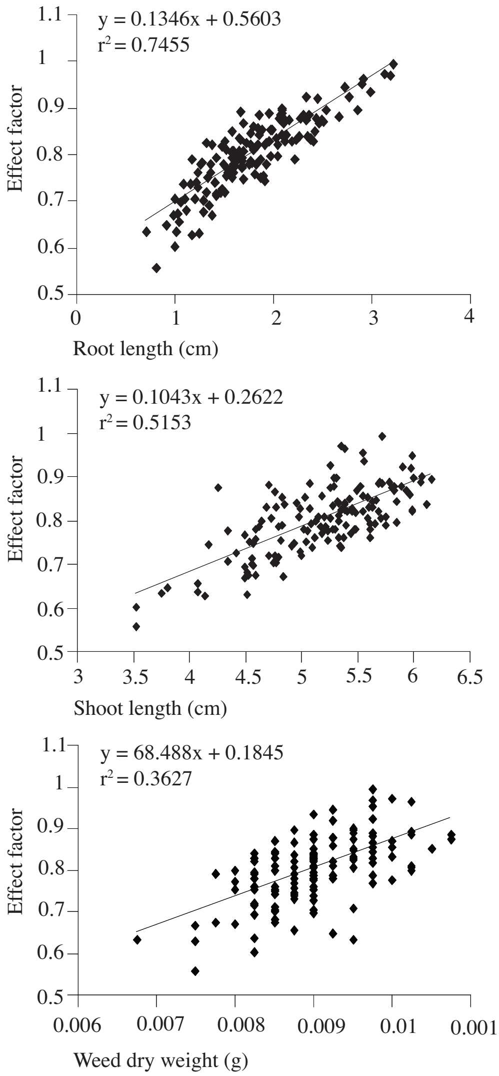

Figure 1. Relationship of 'Effect Factor' with root length, shoot length and dry weight of ***Echinochloa crus-galli***

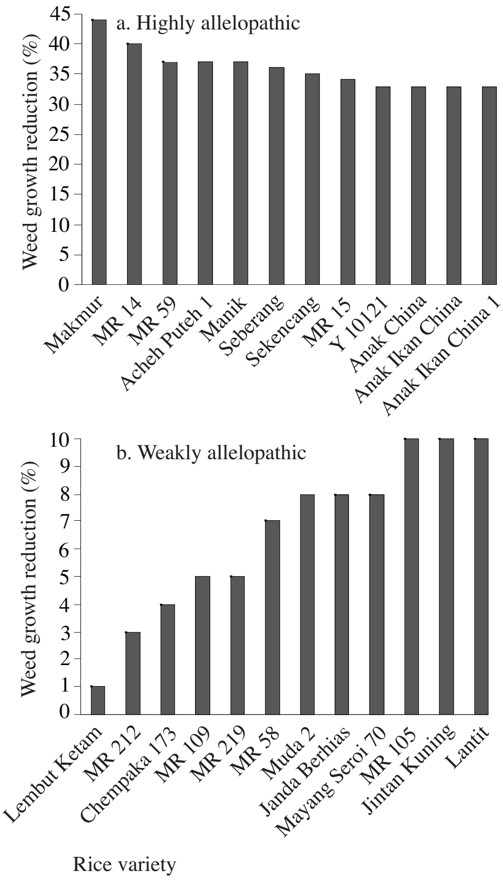

Figure 2. Rice varieties that are highly allelopathic and weakly allelopathic to ***Echinochloa crus-galli***

Therefore, based on the results obtained, the rice varieties could be grouped into five categories according to their allelopathic activity in terms of the 'effect factor' and percentage of growth reduction of *E. crus-galli*. The first group, where more than 40% growth inhibition took place, included only one variety, Makmur which caused 44% reduction (EF = 0.56) with the lowest EF equalled to 0.56. The second group, which caused 30–40% growth inhibition was represented by 17 varieties namely MR 14 (40% reduction; EF 0.60), Acheh Puteh (00008) (37%), MR 59 (37%) and Manik (37%) to name a few. The third group, which caused 20–29% growth inhibition was represented by 54 varieties, among them were Pulut Siding (29%), Jambok (28%), Amur (28%), Acheh Puteh (28%) and Anak Didek-3 (28%). The fourth group which caused 10–19% growth inhibition was represented by 60 varieties, some of them being Anak Ikan Kelubi (19%), Anak Ikan Tinggi (19%), Haji Harun 10 (19%), Jintan Puteh (19%), MR 214 (19%), Nyandal (19%) and Sambug (19%). The fifth group, which caused less than 10% inhibition was represented by 13 varieties, including Lembut Ketam (1%), MR 212 (3%) and Chempaka 173 (4%).

Figure 2 shows the 12 rice varieties which had the highest and the lowest allelopathic effects. This variation in their effects on the weed growth might be due to the differences in their genetic constitution, since all other environmental conditions and experimental procedures were kept constant.

Conclusion

These results clearly showed that some rice varieties exert a considerable allelopathic effect on *E. crus-galli*. Varieties such as Makmur (44% reduction) and MR14 (40% reduction) may therefore, provide very important gene resources for breeding rice cultivars with high allelopathic potential. Exploitation of allelopathic varieties needs special consideration as herbicide usage can be reduced in the agricultural sector in the future. Therefore, identification of rice varieties, which have allelopathic potential on various noxious weeds, needs to be further explored.

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Abstrak

Sejumlah 148 varieti padi telah diuji keupayaan alelopati terhadap *Echinochloa crus-galli* menggunakan teknik semaian benih ulangan. Selepas tujuh hari percambahan benih padi, biji benih *E. crus-galli* yang tidak dorman diletakkan bersebelahan dengan benih padi tersebut. Faktor kesan varieti padi adalah dikira sebagai (panjang akar relatif + panjang tunas relatif + berat kering benih relatif)/3 dan ia digunakan sebagai indikator potensi alelopati varieti padi. Penurunan pertumbuhan rumpai dikira sebagai (1 – faktor kesan) x 100 dengan nilai 1 ialah 'faktor kawalan' yang bermaksud tiada penurunan berlaku.

Hasil kajian menunjukkan terdapat perbezaan yang signifikan antara varieti padi dengan faktor kesan berdasarkan kesannya terhadap panjang akar, panjang tunas dan berat kering. Terdapat juga 12 varieti padi yang mempunyai kesan halangan yang paling tinggi terhadap pertumbuhan rumpai. Peratus penurunan pertumbuhan mengikut varieti-varieti padi ialah Makmur (44 %), MR 14 (40 %), Acheh Puteh (37%), Manik (37 %), MR 59 (37%), Seberang (36%), Sekencang (35%), MR 15 (34%), Anak China (33%), Anak Ikan China (33%), Anak Ikan China (33%) dan Y1021 (33%). Alelopati varieti padi yang lemah dan menunjukkan kesan penurunan pertumbuhan ialah Lembut Ketam (1%), MR 212 (3%), Chempaka 173 (4%), MR 109 (5%), MR 219 (5%) dan MR 58 (7%). Tiga varieti padi seperti Janda Berhias, Muda 2 dan Mayang Seroi 70 menunjukkan kesan penurunan pertumbuhan sebanyak 8%.

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