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New Approach to Use Rice Straw Waste for Weed Control I. Efficacy of Rice Straw Extract Against Broad and Narrow Leaved Weeds in Cucumber (*Cucumis sativa* L.)

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ABSTRACT

Field trials were conducted in two successive seasons (2003/ 2004) to study the allelopathic potential of rice straw residues at different rates and dates of application for controlling weeds in cucumber (*Cucumis sativa* L.). Mixing ground straw into the soil at different concentrations (125 - 500 g m^{-2}) was consistently more effective in suppressing growth and development of a wide range of broad and narrow- leaved weeds than the intact straw, either applied simultaneously or three months prior to sowing of cucumber seeds. Applying the ground straw 3 months prior to sowing of crop seeds was the most effective treatment amongst others for controlling the weeds as well as increasing the cucumber productivity, irrespective of the rate of application. Eight phenolic acids were identified in the rice straw residues on TLC including cinnamic acid, salicylic acid, vanillic acid, p-hydroxybenzoic acid, 2, 5 dihydroxybenzoic acid, ferulic acid, o-coumaric acid and p-coumaric acid. It has been suggested that the phenolic acids might be considered the key factor of rice allelopathy against suppressing a wide range of mono- dicotyledonous weeds in different crops.

Key Words: Allelopathy; Herbicidal potential; Rice straw; Phenolic acids; Weeds; Barnyard grass; Jute; Crops; Wheat; Radish

INTRODUCTION

Rice (*Oryza sativa* L.) is considered one of the most economically cereal crops all over the world, serving as the daily basic source of nutrition for billions of people. The crop yields a large amount of rice straw, which from the standpoint of health and environmental pollution is considered one of the most agricultural critical problems in rice producing countries (FAO, 1982). A major portion of such agricultural wastes goes to burning causing a great hazard to public health and all environmental media including air, water and soil. Mendoza and Samson (1999) estimated that about 90% of all rice farmers (2 millions) in Philippine simply burn their rice straw, which was estimated at 8.17 million tons/ annual. In Egypt, the problem has recently emerged with increasing the demand on rice grains to meet the rapidly growing population leaving behind a huge quantity of rice straw (4 billion tons/ annual), particularly in Delta regions where the crop is extensively grown (Afify *et al*., 2002).

A considerable attention has been given to use such wastes in composting and feeding animals for being cheap and abundant (Abdelhamid *et al*., 2004). Mendoza (1989) demonstrated that recycling rice straw could substitute 2 - 4 bags of fertilizers per hectare per cropping or about 2.5 kg N per ton straw (Watanabe, 1978). However, new approaches of using rice straw for controlling weeds in different crops have been suggested by Mendoza and Samson (1999) who indicated that rice straw can be used for mulching, which benefits in prevent weed growth as well as supplies organic matter for N fixation by heterotrophic N-fixing micro-organisms, which could be absorbed by succeeding crop (Patnaik, 1978). The discovery of some rice cultivars capable of suppressing germination and development of ducksalad (*Hetherantera limosa*) weed under field conditions with something more likely to be chemical interaction than competition was the starting point for rice allelopathy research (Dilday *et al*., 1991). Dilday *et al*. (1998) found that 412 of these cultivars were highly allelopathic against ducksalad weed and 145 cultivars were allelopathic against redstem (*Purple ammannia*) weed in addition to 60 cultivars were allelopathic to both weed species. Hassan *et al*. (1998) showed that amongst 1000 of rice cultivars, which have been tested for their allelopathic activity, about 30 cultivars have promising allelopathic potential (50 – 90% weed reduction) against *E. crus-galli* and 15 cultivars were allelopathic (30 - 75% weed reduction) to *Cyperus difformis*, while five cultivars only showed strong allelopathic activity against both of the weeds. Recently, Olofsdotter (2001) revealed that allelopathic cultivars of rice can control both mono and dicot weeds under field conditions with some selectivity observed amongst such weeds, suggesting that certain compounds with selective action might be implicated in rice allelopathy (Olofsdotter *et al*., 2002).

The plant- derived compounds from rice straw or even survival plants are another promising issue where it could be serves as a renewed source of natural herbicides or probably as a good skeleton to build up new groups of synthetic herbicides (Olofsdotter *et al*., 1997; Duke *et al*., 2002). Research evolving good results has seriously been conducted on the isolation and identification of rice phytotoxins, however, in the majority of cases they were found to be as phenolic compounds. Chou (1980) isolated six phenolic acids e.g. salicylic, p-coumaric, vanillic, syringic, ferulic and mandolic acids from decomposed rice straw and paddy soil, which have been described as highly allelopathic compounds in many plant species (Lydon and Duke, 1989; Duke, 1992). Moreover, 16 potential allelochemicals were also identified and recognized as strong inhibitors and because of that finding the phytotxicity existed in different rice body parts of certain cultivars has found reasonable explanation (Olofsdotter *et al*., 1995). Mattice *et al*. (1997) attributed the herbicidal activity of different allelopathic rice cultivars to containing significantly higher level of the phenolic derivatives (3-hydroxyhydrocinnamic acid, 4-hydroxybenzoic acid, 3-4 dihydroxycinnamic acid and 4-hydroxyphenylacetic acid) when compared with non-allelopathic cultivars such as rexmund species. Meanwhile, Chung *et al*. (2001) found more than one type of phenolic substances (e.g. p-hydroxybenzoic acid, p-coumaric acid, ferulic acid) to be responsible for the allelopathic influences in different rice cultivars, referring to the fact that the concentration and composition of such allelochemicals, and hence their allelopathic capability were return in the first standing to the rice phenotype itself not the surrounding situations or any other affecting factors.

The objective of the present work was to study the effect of rice straw residues on controlling weeds and the yield of cucumber plants under field condition.

MATERIALS AND METHODS

Field trial. Two field experiments were conducted within two successive seasons (2003/2004) at El-Behera Governorate, Egypt. Dry rice straw (*Oryza sativa* c.v. Sakha 101, 50 kg) was collected at harvest stage; half of the straw was ground thoroughly while the remainder straw was used as intact plant. Half of feddan (2100 m^2) were divided into 64 experimental units (4 x 5 m/ each). The intact or ground straw (32 units/ each) were applied thoroughly into the soil at 125, 250, 375 and 500 g m^{-2}, either mixed simultaneously with sown crop seeds or added into the soil 3 months prior to sowing.

Cucumber seeds (*Cucumis sativa*, Beit alpha) were sown on 15th March each season at rates of 4 seeds/ hill, in 5 ridges, each 4 m long x 1 m width. Four replicates were used for each treatment and controls. The experiments were set up in a completely randomized block design. Some morphological characteristics on growth and development of crop and weeds were recorded including plant height (cm), fresh and dry weights (g) at seedling and flowering stages (20; 45 days from sowing, respectively). Cucumber yield (Ton/fed.), number and weight (g) of fruits/ plant were collected at three-daily intervals. The biological activity on growth and development of weeds and crop was estimated according to Itokawa *et al*. (1982) equation. The data obtained were statistically analyzed of standard variances at LSD $_{0.05}$ (Snedecor and Cochran, 1967).

Biological Activity

(A) Allelopathic effect (*In vitro*) of rice straw on the germination characteristics of some crop and weed seeds. Dry rice straw (250 g) obtained from field was ground and soaked in one liter of warm methanol (40^{o}C) in a dark screw-bottle for 24 hrs. The methanol extract was taken and the rice residues were re-washed three times with an equal volume of methanol. The methanol extracts were bulked, filtered by using filter paper (Whatman No. 1) and evaporated to dryness under vacuum (50^{o}C). The residue (13.35 g) was re-dissolved in 5% aqueous acetone to make up serial concentrations of 2.66, 5.32 and 10.64 mg/ ml of distilled water. These aqueous solutions were tested *in vitro* for their biological activity by using bioassay test.

Un-extracted ground straw was also examined *in vitro* for their biological activity on growth and development of crop/ weed seeds by placing the straw into Petri dishes (12.5 cm diameter; 3 g/ each), containing filter paper (Whatman No. 1) and wetted by 10 ml of distilled water. Wheat (*Triticum aestivum* L., Sakha 69), radish (*Raphanus sativa* L.), barnyard-grass (*Echinochloa crus-galli* L.), and jute (*Corchorus olitorius* L.) seeds (20/ each) were laid out over the wet surface of rice straw and left to stand at room temperature. The dishes were watered with distilled water as required. Three replicates were used for each treatment; distilled water and extracted rice straw with methanol were used as controls. Data on germination (%), root and shoot elongation (cm) were recorded within 20 days of the experiment.

(B) Isolation of phenolic acids from straw residue. Isolation and identification of phenolic acids from rice straw was achieved by acid hydrolysis of methanol straw extract with 2M HCl for 0.5 hr. to release phenolic aglycones from their corresponding glycosides (Harborne, 1973). The hydrolyzed methanol extract was then partitioned consequently with ether and ethyl acetate and evaporated to dryness under vacuum (40^{o}C). Half of the residue (6 g) was washed with distilled water (3 x 50 ml), dissolved in 5% aqueous acetone solution (20 ml) and examined for their biological activity at different concentrations. The remainder residue was re-dissolved in 5 ml aqueous methanol 80%. The extracts containing free phenolic compounds were developed on TLC plates (Silica gel 60, F 254 Merck) in two dimensions by using a mixture of solvents system, acetic acid-chloroform (1:9 v/ v) and ethyl acetate-benzene (4.5: 5.5 v/ v). Identification of phenolic acids was achieved by using diazotised sulphinilic acid reagent and standard of phenolic acids was used as references.

(C) Bioassay test. The biological activity of rice straw extract was examined on some crop/weed seeds such as wheat (*T. aestivum* L., Sakha 69), radish (*R. sativa* L.) barnyard-grass (*E. crus-galli* L.) and jute (*C. olitorius* L.). The assayed seeds (10 seeds/ each) were placed in Petri dishes (8.5 cm diameter), containing filter paper (Whatman No. 1). The aqueous solutions (2.66, 5.32, 10.64 mg/ ml) were added (2 ml/ each) at the beginning of the experiment. An additional 1 ml was added three days later as required. Three replicates were used for each treatment and controls (distilled water). The dishes were arranged in a completely randomized design. The germination (%) was estimated within 5 days of germination and the seedling development including root and shoot elongation (cm) was recorded 5 days later. The biological activity of rice straw extract was estimated according to Itokawa *et al*. (1982) The data obtained were subjected to standard analysis of variances at LSD $_{0.05}$ according to Snedecor and Cochran (1967).

RESULTS AND DISCUSSION

Mixing intact or ground rice straw into the soil at different concentrations either simultaneously or three months prior to sowing of cucumber seeds significantly inhibited the shoot biomass growth of broad leave weeds such as purslane (*Portulaca oleracea*), spurge (*Euphorbia geniculata*), jute (*Corchorus olitorius*), mallow (*Hibiscus trionum*) and nightshade (*Solanum nigrum*) as well as narrow leaves such as sandbur (*Cenchrus ciliaris*), growfootgrass (*Dactyloctenium aegyptium*), jungle rice (*Echinochloa colonum*), goose-grass (*Eleusine indica*) and stink-grass (*Eragrostis cilianensis*) associated with cucumber. However, mixing the ground straw into the soil, either simultaneously or 3 months prior to sowing of crop seeds was relatively more effective in suppressing shoot biomass of both broad and narrow- leaved weeds than applying the intact straw or control. The ground straw substantially inhibited the fresh and dry weights of shoot biomass of broad leaves weed by up to 89.6% and in narrow leaves by up to 86.6%. The intact rice straw showed less response in suppressing the fresh and dry weights of shoot biomass of broad or narrow leaves weed, which was estimated by up to 77.9 and 73.2%, respectively (Table I). Applying ground or intact rice straw at the higher concentrations (375; 500 g m^{-2}) was more effective in inhibiting broad- narrow leaved weeds than the lower concentrations (125; 250 g m^{-2}), either mixed with the soil simultaneously or 3 months prior to sowing of crop seeds. Meanwhile, applying ground straw 3 months prior to sown crop seeds was recognized, at all levels, as the most effective treatment amongst others in controlling such weeds accompanying cucumber.

The effects of rice straw at different dates and rates of application on the plant height and shoot biomass of cucumber plants at seedling and flowering stages are shown in (Table II). Mixing the ground or intact straw into the soil at different concentrations significantly increased the plant height, fresh and dry weights of shoot biomass of cucumber plants at both stages of growth; irrespective of the date of application as compared with control. However, mixing the ground straw into the soil was, in whole, the most effective treatment in increasing the shoot elongation and fresh and dry weights of cucumber plants either mixed simultaneously or 3 months prior to sowing of crop seeds as compared with control. Less response was obtained with intact straw particularly at the lower concentrations.

Obviously, the rice straw gave promising results in

Table I. Effect of rice straw residues on developing shoot biomass of weeds infested cucumber plants (Combined analysis of two seasons)

Treatments (Rice straw waste)	Type of application	Rate (g straw m^{-2})	Weeds development: Broad leaves Fr. Wt. (g)	Broad leaves Dr. Wt. (g)	Broad leaves Inhibition (%) of control Fr. Wt.	Broad leaves Inhibition (%) of control Dr. Wt.	Narrow leaves Fr. Wt. (g)	Narrow leaves Dr. Wt. (g)	Narrow leaves Inhibition (%) of control Fr. Wt.	Narrow leaves Inhibition (%) of control Dr. Wt.
Ground straw	Mixing simultaneously with sown crop	125	386.00	90.00	0.17	Nil	180.00	55.33	10.00	14.42
		250	240.00	60.66	39.92	32.60	126.66	36.66	36.67	43.30
		375	180.00	38.66	53.44	57.04	80.00	22.66	60.00	65.59
		500	120.00	22.66	68.96	74.88	60.00	16.66	70.00	74.23
	Mixing 3 months prior to sown crop	125	216.66	52.00	43.96	42.22	133.33	42.66	33.33	34.02
		250	80.00	24.66	79.30	72.60	116.66	26.66	41.67	58.76
		375	70.00	21.33	81.89	76.30	66.66	13.33	66.67	79.38
		500	40.00	16.66	89.63	81.48	50.00	8.66	75.00	86.60
Intact straw	Mixing simultaneously with sown crop	125	353.33	81.33	8.61	9.63	186.66	60.00	6.67	7.76
		250	320.00	64.00	17.23	28.88	150.00	44.66	25.00	30.93
		375	207.33	50.00	46.37	44.44	112.00	30.00	44.00	53.60
		500	170.00	38.00	56.03	57.77	96.66	24.00	51.67	62.88
	Mixing 3 months prior to sown crop	125	326.66	77.33	15.51	14.07	160.00	50.66	20.00	21.65
		250	223.33	51.33	42.24	42.96	126.66	39.33	36.67	39.17
		375	166.66	44.66	56.89	50.37	100.6	22.66	49.67	64.95
		500	85.33	26.66	77.93	70.37	76.66	17.33	61.67	73.19
Control			386.66	90.00	--	--	200.00	64.66	--	--
L.S.D. $_{0.05}$			48.07	11.67	--	--	24.84	11.32	--	--

increasing the yield and its components including the number and weight of fruits/ plant either applied simultaneously or 3 months prior to sown crop seeds. It was found that mixing ground rice straw into the soil in particular 3 months prior to sowing of crop seeds remarkably increased the yield and its constituents (by up to 95.7%) as compared with other treatments or control. Applying intact straw showed less response in increasing cucumber yield and its components, either mixed simultaneously or 3 months prior to sown crop seeds (Table III).

In vitro effects of extracted and un-extracted straw residue on the seed germination (%) and seedling development of broad and narrow leaves crop or weed at the germination stage are shown in (Fig. 1). Both residues remarkably reduced the seed germination (%) and root and shoot elongation of crops (wheat; radish) as well as the weeds (barnyard-grass; jute) as compared with control. However, the un-extracted straw residue was more effective in inhibiting such characterizations of seed germination and growth development of broad- narrow leave seedlings irrespective of their types or their affiliation to any of either crop or weed groups than the extracted one. The inhibitory effect was clearly pronounced on root and shoot elongation rather than the seed germination (%), either of broad or narrow- leaved tested plants as compared with control. No significant differences were found between crop and weed species in terms of their response to the extracted or un-extracted residues, except jute weed seeds which showed more susceptibility to the straw residue than barnyard-grass weed or even other crop seeds.

The influences of methanol straw extract on the seed

Table II. Effect of rice straw residues on the growth and development of cucumber (Combined analysis of two seasons)

Treat-ments (Rice straw waste)	Type of application	Rate (g straw m^{-2})	Crop development											
			Seedling stage (30 days from sowing)						Flowering stage (65 days from sowing)					
			Plant height (cm)	Fr. Wt. (g)	Dr. Wt. (g)	Increase (%) over control: Plant height	Fr. Wt.	Dr. Wt.	Plant height (cm)	Fr. Wt. (g)	Dr. Wt. (g)	Increase (%) over control: Plant height	Fr. Wt.	Dr. Wt.
	Mixing	125	8.25	4.93	1.28	22.22	35.43	30.61	50.66	55.63	6.53	18.75	25.85	19.81
	simultaneously	250	9.58	5.36	1.36	41.92	47.25	39.45	56.50	60.56	7.38	32.44	37.21	35.41
	with sown crop	375	10.08	5.58	1.43	49.33	53.29	45.91	61.00	66.35	8.51	42.99	50.11	56.14
Ground		500	10.83	6.00	1.55	60.44	64.83	58.16	68.33	74.70	9.20	60.17	69.00	68.80
straw	Mixing 3 months	125	8.00	4.96	1.35	18.51	36.26	37.75	54.00	60.53	7.22	26.58	36.94	32.24
	prior to sown crop	250	9.91	6.00	1.53	46.81	64.83	56.12	60.00	68.16	8.42	40.64	54.20	54.44
		375	10.41	6.23	1.65	54.22	71.15	68.36	64.33	74.06	9.26	50.79	67.55	69.90
		500	11.95	6.60	1.75	77.03	81.31	78.57	75.00	79.83	10.20	75.80	80.61	87.15
	Mixing	125	7.05	4.00	1.06	4.44	9.89	8.16	45.66	50.50	6.36	7.03	14.25	16.69
	simultaneously	250	7.10	4.53	1.25	5.18	24.45	27.55	49.00	54.43	7.06	14.86	23.14	29.35
Intact	with sown crop	375	8.00	5.14	1.42	18.51	41.20	44.89	55.00	58.23	7.53	28.92	31.17	38.16
straw		500	8.60	5.50	1.48	27.40	51.09	51.02	56.33	60.80	7.71	32.04	37.55	41.46
	Mixing 3 months	125	6.83	4.50	1.16	9.33	23.62	18.36	49.00	50.83	6.56	14.86	15.00	20.36
	prior to sown crop	250	8.50	5.31	1.39	25.92	45.87	41.83	52.00	58.26	7.60	21.89	31.80	39.33
		375	9.63	5.83	1.52	42.66	60.16	55.10	61.66	60.63	7.91	44.53	37.17	45.13
		500	9.83	6.03	1.70	45.62	65.65	68.36	66.33	65.50	8.41	55.48	48.19	54.31
Control			6.75	3.64	0.98	--	--	--	42.66	44.20	5.45	--	--	--
L.S.D. $_{0.05}$			0.87	0.95	0.22	--	--	--	5.40	1.60	0.52	--	--	--

Table III. Effect of rice straw residues on yield and its components (Combined analysis of two seasons)

Treatments (Rice straw waste)	Type of application	Rate (g straw m^{-2})	Yield					
			No. of fruits/plant	Wt. of fruits/plant (kg)	Yield (Ton/feddan)	Increase (%) over control: No. of fruits/plant	Wt. of fruits/plant	Yield
	Mixing	125	4.07	0.46	5.79	2.27	4.54	3.57
	simultaneously	250	5.04	0.54	6.92	27.27	22.73	23.79
	with sown crop	375	5.81	0.58	7.41	46.71	31.82	32.55
Ground straw		500	6.28	0.63	8.03	58.58	43.18	43.64
	Mixing 3	125	5.10	0.51	6.37	28.78	15.90	13.95
	months prior to	250	6.17	0.65	8.25	55.80	47.72	47.58
	sown crop	375	6.86	0.69	8.75	73.23	56.81	56.52
		500	7.75	0.80	10.08	95.70	81.81	80.03
	Mixing	125	4.00	0.44	5.63	1.01	Nil	0.71
	simultaneously	250	4.94	0.50	6.34	24.74	13.63	13.41
	with sown crop	375	5.22	0.56	7.01	31.81	27.27	25.40
Intact straw		500	5.82	0.59	7.49	46.92	34.09	33.98
	Mixing 3	125	4.14	0.46	5.83	4.54	4.54	4.29
	months prior to	250	5.35	0.58	7.31	35.10	31.81	30.76
	sown crop	375	5.42	0.62	7.83	36.86	40.90	40.07
		500	6.33	0.66	8.36	59.84	50.00	49.79
Control			3.96	0.44	5.59	--	--	--
L.S.D. $_{0.05}$			0.55	0.05	0.62	--	--	--

germination (%) and seedling development (*In vitro*) on the tested crop/ weed seeds at different concentrations is given in Fig. (2). It was obvious that the methanol extract inhibited the seed germination (%), root and shoot length of all tested seeds including wheat, radish, barnyard-grass and jut seeds, irrespective of the rates of concentration as compared with controls. Current inhibitory effect was more pronounced on seedling root and shoot elongation rather than the seed germination (%), either in crop or weed species and substantially aggravated as the concentration increased. Applying the rice straw extract at different concentrations inhibited the seed germination by 3.41 - 24.12% and seedling root and shoot length by 51.27 - 91.41% and 17.74 - 93.33%, respectively in both examined broad- leaved types, crop or weed species. In narrow leaved crop or weed species, the reduction in seed germination (%) was estimated by 10.71 - 38.52% and in the seedling root and shoot growth by 27.45 - 92.12% and 46.21 - 89.67%, respectively. Significant differences were not found between weed and crop species in their response to the phytotoxic action of rice straw extract. However, the little variations observed between examined seeds has extracted jute weed seeds as the most sensitive organ as compared with control.

Fig. (3) shows the *in vitro* effect of ether and ethyl acetate extracts at different concentrations on seed germination (%) and seedling root and shoot development of different crops (wheat; radish) and weeds (barnyard-grass; jute) seed. The ether and ethyl acetate extracts at different concentrations potentially inhibited the seed germination (%) and seedling growth of all tested seeds. However, the ether extract was more effective in this regard than ethyl acetate extract. It was found that the ethyl acetate extract inhibited the seed germination (%) and seedling growth of crop seeds by up to 37.5 and 94.96%, respectively and in weed seeds by up to 20 and 92.75%, respectively. However, the ether straw extract exceeding that by inhibiting the seed germination by up to 51.45% and seedling development by up to 98.09% of all tested crop/weed seeds *in vitro* at lower and moderate concentrations (2; 4 mg/ ml). This influence was magnified at the highest concentration (6 mg/ ml), which in particular entirely killed jute weed seeds with keeping some superiority upon other species as compared with other treatments or control. Few numbers of phenolic acids were detected on TLC plates either in ether or ethyl acetate extracts. It was found that 5 phenolic acids were detected in ether extract and identified as cinnamic acid, salicylic acid, p-hydroxybenzoic acid, vanillic acid and 2,5 dihydroxybenzoic acid. Meanwhile, 3 phenolic acids were existed in ethyl acetate extract i.e. ferulic acid, p-coumaric acid and o-coumaric acid.

Applying rice straw waste simultaneously or 3 months prior to sowing of crop seeds gave promising results in suppressing growth and development of a wide range of broad and narrow- leaved weeds in the same time with increasing yield productivity of cucumber, which might be

Fig. 1. *In vitro* allelopathic effect of rice straw on germination and seedling development of some weed/crops at germination stage.

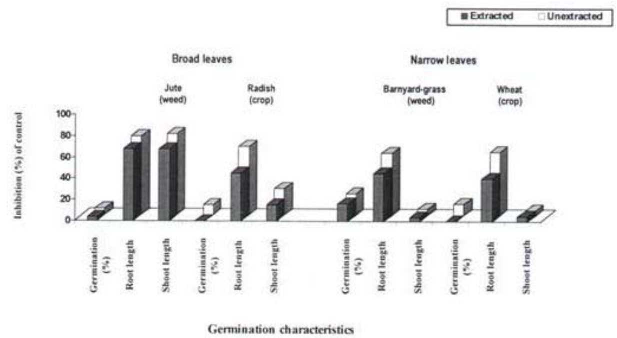
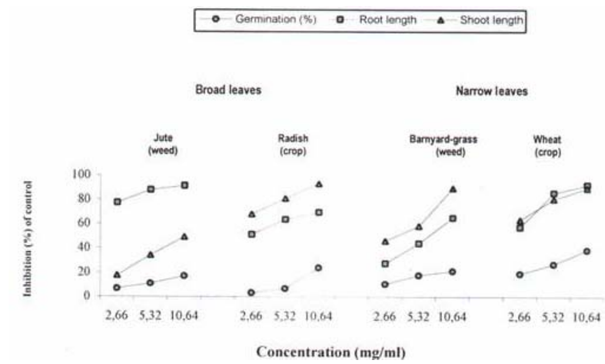


Fig. 2. *In vitro* effect of methanol straw extract on the germination and seedling development of some weed/crop seeds.

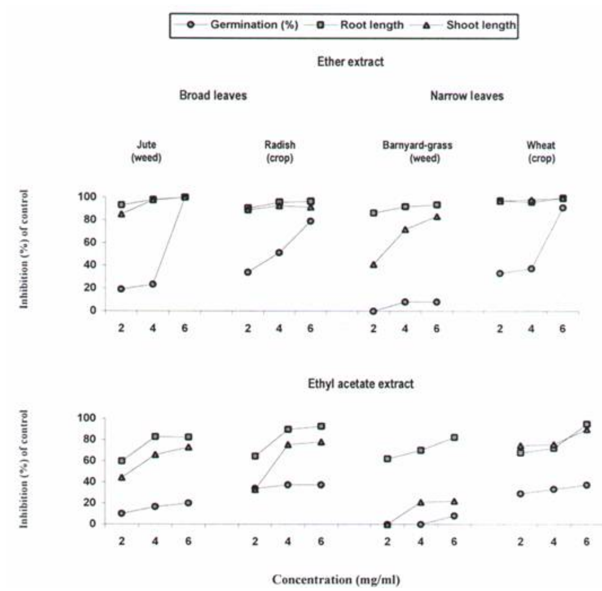


referred to the highly allelopathic potential of rice straw against developmental processes and progression of associated weeds. These results could be explained in term of that rice straw might possess and release certain phytotoxin compounds which in aid of other agro-ecosystem factors have the ability to accumulate into the soil medium in sufficient amount and probably with enough persistence to attain such notable reduction on weeds growth and subsequent increasing in crop yield. This suggestion might be reconcile with the results obtained by many authors, who indicated that allelochemicals are present in all plants involving different origins and tissues (Cheema and Khaliq, 2000; Hamdi *et al*., 2001; Ben-Hammouda *et al*., 2001; Chung *et al*., 2003). Such allelopathic substances commonly exist in conjugated form; however, under certain conditions i.e. decomposition they released into the surrounding environment (rhizospher or atmosphere) in sufficient amount and most likely with enough persistence to affect neighboring or more farness succeeding plants (Putnam, 1988; Chou, 1990). Hassan *et al*. (1998) found that several rice cultivars strongly inhibited (30 - 90%) the growth and development of *E. crus-galli* and *C. difformis* weeds under field conditions, suggesting that allelopathy in rice cultivars could play a key role for weed control under field conditions as they can actively release certain phytotoxins during their growth or even after dying via straw degradation (Chung *et al*., 2001). However, Fujii (1992) reported that the allelopathic activity in rice cultivars was species-specific and depended on the concentration and composition of the phytotoxic components (Ebana *et al*., 2001). Recently, Chung *et al*. (2003) found that rice straw was the most effective organ amongst other body parts such as leaves, stem and hull in controlling the most problematic weed in rice, (barnyard-grass, *E. crus-galli*).

There is a strong evidence to support that the allelopathic effect of ground straw is more efficient in controlling weeds than the intact plant which might be partially due to that the micro-organisms are capable to decompose the ground residues more easily, fastly and efficiently than in case of intact form. This definitely resulting in reaching and in subsequent reflection accumulating more of allelochemicals into the soil to the extent that the growth and development of associated or even succeeded plants will be seriously affected. On this assumption Ebana (2001) mentioned that allelopathic activity in rice was species-specific and depended on the concentration and composition of allelopathic implicated substances. Many workers have indicated that the allelopathic influences of remaining debris of several important crops such as rice, sorghum, barley, rye and wheat under field condition is mainly due to the self-degradation otherwise the spontaneous decomposition of died cell components, which resulted in total in exerting several phytotxic agents into the rhizospher (Barnes and Putnam, 1983; Chou, 1990; Ben-Hammouda *et al*., 2001; Wu *et al*., 2001; Kato-Noguchi *et al*., 2002). Wang *et al*. (1968) explained that soil is a very dynamic system and the allelopathic residues as well as allelochemicals can be quit transitory by soil microflora. Patrick *et al*. (1964) suggested that allelochemicals in soils are subjected to several chemical and mechanical alterations e.g. destruction, soil absorption and transformation because of several abiotec or biotic factors, however, this does not preclude their harming effects on plant growth during decomposition and often sustained toxicity may occur as new toxic products are formed in some transformation processes. On the other hand, Mandava (1985) mentioned that once death of any plant part occurs, materials compartmentalized in cells are quickly released into the environment (atmosphere or rhizosphere) and because of they are being water soluble components in the majority great damage was expected in opposite (Colton & Einhellig 1980).

Over above, the inhibitory effect of extracted and un-extracted rice straw on reducing the seed germination and seedling development of certain weeds and crops *in vitro* can be explained in the term of that the rice straw might contain certain phenolic acids and/or some of other un-known phytotxic agents, which undoubtedly considered the key factor for allelopathic activity in rice straw for controlling a wide range of mono and dicotyledonous weeds

Fig. 3. *In vitro* effect of ether and ethyl acetate extracts of rice straw on seed germination and seedling development of some crop/weed seeds.



in different crops. These results were reinforced by those of Mattice *et al*. (1997) and Olofsdotter *et al*. (1997) who attributed the phytotoxicity within different rice cultivars to those naturally occurring phenolic substances, which consistently varied in their concentrations and compositions based on the type of rice cultivar. In this context, Chou (1980) found six of simple phenols e.g. p-salicylic acid, p-coumaric acid, vanillic acid, syringic acid, ferulic acid, and mandelic acid to be responsible for the inhibitory influences in rice straw wastes as *in vitro* assessment declared. Moreover, a total of 16 potential allelochemicals were also identified from rice allelopathic tissues (Olofsdotter *et al*., 1995). Recently, Chung *et al*. (2001) attributed the phytotoxicity of certain rice straw extracts to the higher levels of the phenolic acids p-hydroxybenzoic, p-coumaric and ferulic acids as well as o-coumaric acid, when compared with the extract obtained from the non-allelopathic cultivars (Chung *et al*., 2003). Olofsdotter *et al*. (1997) stated that one reason why phenols are released in higher concentration from their sources of rice allelopathic cultivars is briefly could be a higher activity of the general defense mechanisms of those plants. However, there is strong evidence that the phenolic compounds possibly are not the principle component for the allelopathic activity in rice plants (Mattic *et al*., 2001; Olofsdotter *et al*., 2002).

These evidences might suggest that applying rice straw wastes at suitable rate and date could serve as a new strategy for eliminating growth of weeds creating problem in different crops or in much more deeper view in producing new group of natural herbicides.

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