Allelopathy of weed extracts on yield and its components in four cultivars of rice (*Oryza sativa* L.)

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Abstract

Weeds are enemies to the crop plants and have harmful effects on agricultural crops due to several factors such as competition for space, light and nutrients. Allelopathic effects of weed extracts were studied on grain yield and yield components of rice. The experiment was carried out in the Rice Research Institute of Chaparsar, in 2006-2007, in Tonekabon, Iran (latitude 36°54' N, longitude 50° 40'E, level -20 m altitude), split plot on basis of randomized completely block design (RCBD) with 4 replications. Results showed highly significant differences suggesting substantial to moderate phenotypic variability in most parameters evaluated except number of empty grain and 1000 -grain weight. Also, most yield of single plant obtained from umbrella sedge extract (28.5 g). It seems that umbrella sedge had least minerals in water; it could be affected positively on important factors such as yield of single plant compared to other treatments. Correlation coefficient analysis revealed significant and negative correlation between number of empty grain and yield of single plant ($r=-0.42^{***}$). It's implies that grain yield magnitude of Nemat cultivar exhibiting the least number of empty grain. Although yield of single plant was not affected neither by plant height nor number of tiller. In addition, irrigation water due to existence of high mineral and chemical pesticides in upstream of station farms severely was reduced yield. Also, results of this research showed that weed extracts haven't very allelopathic effect on rice and in end of growing season, that's better, plant leftover return and remain in field.

Keywords: *Oryza sativa*, allelopathy, yield, pot experiment, cultivar

Introduction

Rice (*Oryza sativa* L.) is the second most important cereal after wheat in Iran, while it ranks second of the most growing crop in the word [22]. Weeds are undesirable plants which compete with main crops for nutrients, moisture, space, light and hamper the healthy growth ultimately reducing the growth and yield both qualitatively and quantitatively [3]. Water-soluble substances which leakage from different weed

parts especially leaves may adversely affect seedling growth due to the following reasons: (1) allelopathic effects as allelochemicals, (2) immobilizing N_2 and (3) increased microbial population and hence enhanced competition with plants [10 & 11]. Weeds are known to exhibit allelopathy by releasing water-soluble allelochemicals from leaves, stems, roots, rhizomes, flowers, fruits and seeds [1, 4, 6, 9 & 22]. Weeds which compete with main crops for nutrients and environmental variables besides appear to be toxic to the germination and seedling growth of the plants [18]. Barnyardgrass (*Echinochloa crus-galli*), umbrella sedge (*Cyperus difformis* L.), Monochoria (*Monochoria vaginalis*) and Water plantain (*Alisma Plantago-Aquatica* L.) are world's worst weeds of the rice (*Oryza sativa* L.) crop, decreasing yield up to 90% through season long competition with rice [16].

Inhibition of photosynthesis, interruption of dark respiration and ATP synthesis and disruption of amino acids metabolism were reported as some of the biochemical and physiological mechanisms that may be mediated by allelochemicals [24]. The reason of the high competitiveness of barnyardgrass is an efficient plant (C4 metabolism) as compared to rice (C3 metabolism). Moreover, it is morphologically very similar and has the same ecological requirement with rice. Hence, Barnyardgrass produces huge number of seeds per plant, which ensures its dispersals and reestablishment [15]. Batish *et al*., (2007) reported that residue of *Chenopodium murale* on the growth of chickpea (*Cicer ariethinum*) and pea (*Pisum sativum*) and found that their root and shoot length significantly decreased. Renewed interest in allelopathy has stemmed from the discovery that spotted knapweed (*Centaurea maculosa*), an invasive exotic weed introduced to North America, releases phytotoxic secondary metabolites into the environment that inhibit the growth and germination of North American plant species [5 & 21]. Weeds growing among crop plants adversely affect yield and quality of the harvest and increase production costs, resulting in high economic losses [2].

Kruse *et al*., (2000) showed that mixture solutions of allelochemicals have greater effect than the same concentrations of the compounds used separately. Furthermore, mixtures of some allelochemicals can possess allelopathic activity even though concentrations of individual compounds are significantly below their inhibitory levels [7 & 8].

Water extraction method [1 and 13] have been reported and tested for bioassays, because this method give a similar result when compared with field conditions.

The objective of the study was to analyze the allelopathic effects of weed extracts on yield, biomass production and partitioning of assimilates in four rice cultivars. The results of this study will propose a method to evaluate the allelopathic potential of weeds and reduction of reliance on herbicides for weed control.

Materials and Methods

Experimental Design: This study was carried out in the Rice Research Institute of Chaparsar, Iran (latitude 36°54′ N, longitude 50° 40′ E, elevation of 20 m above mean sea level) during 2006 and 2007. The climate data of region are representing in Table 1. The experimental design was split plot on basis of randomized completely block design (RCBD) with 4 replications. Four rice cultivars consist of Dasth, Nemat, Deylamanie and Number III (Ramzanali Tarom) were applied in main plots and subplots which consisted of split application of weed extracts at seven levels [1- use of tap water; 2- soluble extracts of Barnyardgrass (*Echinochloa crus-galli*); 3- soluble extracts of Umbrella sedge *(Cyperus difformis* L.); 4- soluble extracts of Monochoria (*Monochoria vaginalis*); 5- soluble extracts of Water plantain (*Alisma Plantago-Aquatica* L.); 6- mixture solution of weed and 7- Irrigation water].

Table 1. Climatic data of experimental farm of Rice research station in Chaparsar in 2006-7 (in growth period)*

Months	Total Rainfall (mm)	Min Temp. (°C)	MeanAverage Temp. (°C)	Max Temp. (°C)	Relative Humidity (%)
2006					
May	37.9	15.8	18	20.2	85.7
June	2.1	21.5	25.02	28.4	70.3
July	38.4	21.8	25.4	29	70.35
August	0.0	23.3	27.1	31.3	70.7
September	238.1	20.5	23.4	26.4	77.8
October	220.2	18.2	20.6	23.8	82.8
2007					
May	26.2	15.6	18.8	22	79.1
June	35.7	20.8	23.9	27	73.6
July	58.8	22.1	25	27.9	77.7
August	16.2	24.1	27.3	30.7	74.5
September	182.6	21.4	24.7	28.1	75.8
October	53.6	16.2	19.7	23.2	77.3

Preparation of weed Extracts: The weeds mentioned in rice cultivation were separated and collected from paddy farms, before and after the transplanting. Then they were dried in open air and sun light (72 hours) and milled to place in tap water in a proportion of 1 to 20 for a time about 36 to 48 hours, aiming to remove the

substances solute within. The same solution was used for the irrigation of the rice pots based on the amount needed (1 kg extract/ 20 liter water). The soil used in pots was taken from the farm and washed several times to remove any plant remaining. The amount of chemical fertilizer used in the combination of the soil in pots was

calculated on a basis of 200 kg of urea and 150 kg of ammonium phosphate per hectare (2 g urea and 1.5 g ammonium phosphate). Four healthy and even-sized seedlings were placed in each pot. All of the information pertaining to the growth was recorded during the time between the transplanting to harvest of the crop.

Agronomic traits: The agronomic traits included number of tiller (NT) (number of panicle bearing tillers), number of filled and empty grain (NFG&NEG), plant height (measured as average number of centimeters from the ground to the tip of the tallest panicle), 1000-grain weight (GW) (measured in grams as average of three different samples of 1000 fully filled grains), days to panicle emergence and 50% flowering (time taken in days from sowing to panicle emergence and 50% of the plants came to flowering, respectively) and yield plant (measured through NT × NFG × GW) were all measured according to the standard evaluation system. For determining of flag leaf area, length of flag leaf (LF) (measured in average number of centimeters from the flag leaf auricle to the leaf tip), width of flag leaf (WF) (measured in average number of centimeters at the widest middle part of the flag leaf) evaluated and finally flag leaf area (FLA) calculated (measured LF × WF × 0.75) [12].

Statistical Analysis: The analysis of variance for all data was conducted using the general linear model procedure of the Statistical Analysis System (SAS) program. Correlation and pooled mean values were separated based on least significant difference (LSD) at the 0.05 probability level [23].

Results and Discussion

Effect of cultivars and weed extracts and their interactions were significant on most of traits (Table 2). The cultivar × weed extracts interaction for width of flag leaf, flag leaf area, yield of single plant, number of empty grain and days to 50% flowering was significant as observed in the Table 2.

The shortest plant height was found in Dasht and the highest in Number III (Ramzanali Tarom) (Table 3). Generally, dwarf rice cultivars are more desirable due to the tolerance against lodging and also the high potential of receiving fertilizers. Nemat cultivar produced the most grain yield in comparison with other cultivars (Table 3). Among of weed extract treatments, most value of number of tiller and yield of single plant obtained from tap water (25.4) and umbrella sedge extract (28.5 g), respectively (Table 3). Umbrella sedge and tap water could be affected positively on important factors such as number of tiller and yield of single plant compared to other treatments.

Table 2: Analysis of variance for Yield and yield components of rice cultivars as affected by weed extract treatments in combined analysis of 2007-2008 and 2006-2007 data

SOV	df	Plant height (cm)	Number of tiller	Length of flag leaf (cm)	Width of flag leaf (cm)	Flag leaf area (cm2)	Yield of single plant (g)	Number of filled grains	Number of empty grains	Days to panicle emergence (day)	Days to 50% flowering (day)	1000 - Grain weight (g)
Y	1	311.14*	6.79ns	86.25ns	0.006ns	90.48 ns	19423***	11328.7***	14836***	308.7**	335.16**	5478. 6***
Rep (Y)	6	7.54	15.05	29.73	0.011	32.08	60.19	264.98	155.93	51.4	11.53	2.56
V	3	19998 ***	303.04***	394.29***	3.25***	1185.2***	678.69***	1732.79**	591.58ns	1429.5***	1280.7***	265.85***
V×Y	3	187.65*	19.32ns	161.51**	0.174***	233.94**	709.11***	478.64ns	320.5ns	148.2*	125.37*	41.06**
Error	18	78.9	20.2	33.62	0.003	39.94	82.11	508.9	170.3	50.3	51.48	8.3
E	6	168.57*	45.45**	82.6*	0.46***	287.13***	242.49**	505.39ns	172.34ns	114.1*	135.33**	4.85ns
E×Y	6	195.47**	56.44**	52.32ns	0.78***	335.45***	162.09*	336.92ns	320.02ns	50.4ns	160.41**	16.49*
E×V	18	67.85ns	12ns	43.97ns	0.31***	229.39***	97.74*	271.96ns	584.91**	70.5*	73.17*	5.12ns
E×V×Y	18	74.76ns	24.94*	39.86ns	0.162 ***	138.21***	105.06*	463.42ns	510.43*	41.6ns	44.72ns	10.15ns
Error	223	57.97	13.52	31.13	0.004	37.23	58.39	353.78	254.7	39.7	35.65	5.93
CV %		6.95	15.88	22.91	5.8	26.43	30.42	28.08	54.65	13.03	12.1	9.55

ns= nonsignificant; * significant at the 5%; ** significant at the 1%; and *** significant at 0.1 % levels of probability

((Note: Y—year effect; V— Variety effect; E— Extract effect; YV, EY, EV, EVY represent interaction terms between the treatment factors).

Table 3. Mean comparison of simple effects for Yield and yield components of rice cultivars as affected by weed extract treatments in combined analysis of 2007-2008 and 2006-2007 data.

Treatment	Plant height (cm)	Number of tiller	Length of flag leaf (cm)	Width of flag leaf (cm)	Flag leaf area (cm2)	Yield of single plant (g)	Number of filled grains	Number of empty grains	Days to panicle emergence (day)	Days to 50% flowering (day)	1000 - Grain weight (g)
V1	92.8 c	22.6 b	20.6 b	1.2 b	19.4 c	23.7 b	74.2 a	33.6 a	53.3 a	53.3 a	25.6 b
V2	93.9 c	24.1 ab	24.6 a	1.15 c	22.44 b	28.3 a	66.6 ab	25.9 b	52.1 a	52 a	28.4 a
V3	121 b	25.6 a	26.8 a	0.95 d	20.75 c	27.5 a	66.3 ab	29.2 ab	43.3 b	43.8 b	23.3 c
V4	129.9 a	20.1 c	25.2 a	1.53 a	29.73 a	20.8 b	60.6 b	27.9 b	44.7 b	46.1 b	24.5 bc
LSD 5%	3.52	1.78	2.3	0.02	2.5	3.59	8.95	5.18	2.8	2.8	1.14
TW	109 abc	25.4 a	25.6 ab	1.32 ab	25.16 a	27 ab	64.8 ab	30.8 a	48.1 abc	46.3 c	25.5 a
BG	110.5 ab	23.5 b	25.8 a	1.34 a	26.33 a	26.4 ab	71.5 a	28.5 a	48.6 ab	48.4 bc	25.7 a
US	111.4 ab	22.8 b	24.8 ab	1.21 c	23.73 a	28.5 a	70.1 ab	26.4 a	46.8 bc	48 bc	25.8 a
MC	112.3 a	21.8 b	21.3 c	1.03 d	17.67 b	26.7 ab	70.8 a	26.7 a	45.2 c	48.4 bc	26 a
WP	105.4 c	23.4 b	25.1 ab	1.29 b	24.62 a	23.3 bc	61.5 b	28 a	51 a	49.4 b	24.9 a
MSW	108.9 abc	22.4 b	24.5 ab	1.19 c	23.55 a	22 c	66.7 ab	31.7 a	49.6 ab	49.5 b	25.1 a
IW	108.2bc	22.3 b	23 bc	1.07 d	20.5 b	21.5 c	63.2 ab	32 a	49.2 ab	52.9 a	25.2 a
LSD 5%	3.76	1.8	2.75	0.03	3.01	3.77	9.29	7.88	3.1	2.95	1.2

V1, V2, V3 and V4: Dasht, Nemat, Deylamani and Number III, respectively.

TW, BG, US, MC, WP, MSW and IW: Tap water, Barnyardgrass, Umbrella sedge, Monochoria, Water plantain, Mixture solution of weed and Irrigation water, respectively.

Mean followed by the same letter(s) in each column (between to horizontal lines) are not significantly different (LSD 5%).

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Result showed that the weed extracts may not affect on plant morphological characteristics and traits such as more plant height in Number III (Ramzanali Tarom) cultivar (129.9 cm) and further length of flag leaf in Deylamani cultivar (26.8 cm) been genetic and weed extracts have no effect on them (Table 3). Most number of tiller in and maximum yield of single plant obtained from Deylamani (25.6) and Dasht (28.3 g) cultivars, respectively (Table 3).

At this experiment, weed extracts were inhibitory to some cultivars and stimulatory to some others. The interaction of cultivars with weed extracts indicated that maybe phytotoxic effects were more than one chemical component in different weed extracts and the cultivars react differently to these compounds. Umbrella sedge extract resulted in highest rate of Yield of single plant in Deylamani cultivar (Table 4).

Correlation between traits: The significant and negative correlation between number of empty grain and yield of single plant (r= -0.42***) (Table 5) implies that grain yield magnitude of Nemat cultivar exhibiting the least number of empty grain. Although yield of single plant was not affected neither by plant height nor number of tiller.

Yield of single plant was significantly correlated with 1000-grain weight (r= 0.6 p< 0.01) and number of filled grain (r= 0.51 p< 0.01). This is expected to occur where more assimilates were available to seed development associated with more vegetative growth. These results were consistent with findings of Nematzadeh *et al*. (2006). Yield of single plant significantly correlated with length of flag leaf, number of empty and filled grains and 1000-grain weight. These results revealed the importance of these traits as a criterion for rice yield improvement.

Therefore, selection for increasing grain yield through these traits might be more successful. We suggest that these traits are important characters under conditions of various weed extracts. Regarding plant height, correlation study revealed that in general, the association between plant height and the other characters showed consistent trend. It was positively correlated with flag leaf area, length of flag leaf and width of flag leaf. Obviously, plant height has negative correlation with days to 50 % flowering and number of tiller.

The results obtained in this present research were in agreement with the findings Kihupi (1998) for filled grains per panicle and Oad *at el*. (2002) for 1000 grain weight. In this study, different treatments did not negatively impact on the natural process of growth (increased height and number of tiller) in different cultivars of rice. In addition, irrigation water due to existence of high mineral and chemical pesticides in upstream of station farms severely was reduced yield. Umbrella sedge extract with tap water had the least minerals as could allocate highest yield of single plant. Therefore, the results showed that irrigation water of rice fields must have at least the minerals and chemicals.

Table 4. Mean comparison of interaction effects for Yield and yield components of rice cultivars as affected by weed extract treatments in combined analysis of 2007-2008 and 2006-2007 data.

cultivar	weed extract	Mean Flag leaf area (cm/ m2)	Number of filled grains	Number of empty grains	Number of tiller	Plant height (cm)	Yield of single plant (g)
Dasht	Tap water	26.8a	68a	49a	26.8a	93.8ab	31.5a
	Barnyardgrass	22.2b	79.8a	28.3ab	22.2b	97a	22.8abc
	Umbrella sedge	22.1b	76.7a	29.3ab	22.1b	92.5ab	27.8ab
	Monochoria	22b	72.5a	44.6ab	22b	98.6a	25.7abc
	Water plantain	21.5b	79a	24b	21.5b	87.5b	17.9c
	Mixture Extract of weed	22b	72.1a	30.6ab	22b	91.1ab	20.9bc
	Irrigation water	22b	71.3a	29.5ab	22b	89b	19bc
Nemat	Tap water	25.7a	69.6ab	20.6a	25.7a	93.7ab	30.4a
	Barnyardgrass	24a	81a	26.3a	24a	94.5ab	33a
	Umbrella sedge	22.2a	69.6ab	30a	22.2a	101.1a	29.2a
	Monochoria	22.8a	67.3ab	18.5a	22.8a	96.5ab	33.4a
	Water plantain	25.2a	57.3b	23.2a	25.2a	89.1b	27.9a
	Mixture Extract of weed	24.7a	68.5ab	26.1a	24.7a	89.3b	21.1a
	Irrigation water	24a	52.7b	36.8a	24a	93b	22.9a
Deylamani	Tap water	28.3a	62a	30.3a	28.3a	119.7a	25a
	Barnyardgrass	27ab	64.5a	36.8a	27ab	117a	26.7a
	Umbrella sedge	26.1ab	72.2a	21.2a	26.1ab	122.5a	35.9a
	Monochoria	24.6ab	73.2a	27.2a	24.6ab	123.7a	24.1a
	Water plantain	26ab	60.2a	36.6a	26ab	119.8a	28.6a
	Mixture Extract of weed	22.6b	66.2a	28.6a	22.6b	122.6a	27.1a
	Irrigation water	24.6ab	66a	23.5a	24.6ab	121.5a	25.3a
Number III	Tap water	20.8a	59.6ab	23.2abc	20.8a	128.7ab	21.3a
	Barnyardgrass	21.1a	60.8ab	22.3bc	21.1a	133.6a	23.2a
	Umbrella sedge	21a	61.8ab	25.2abc	21a	129.6ab	21.3a
	Monochoria	18a	70.2a	16.6c	18a	130.3ab	23.5a
	Water plantain	21a	49.3b	28.5abc	21a	125.1ab	18.7a
	Mixture Extract of weed	20.5a	60ab	41.5a	20.5a	132.6b	18.9a
	Irrigation water	18.6a	62.7ab	38.3ab	18.6a	129.3ab	18.8a

Mean followed by the same letter(s) in each column (between to horizontal lines) are not significantly different (LSD 5%)

Table 5. Correlation Coefficients between characters calculated from four rice cultivars in 2006-7.

Characters	(12)	(11)	(10)	(9)	(8)	(7)	(6)	(4)	(3)	(2)
(1) Plant height	-0.5***	0.28***	0.23**	0.23**	0.05ns	-0.48***	-0.1ns	-0.07ns	-0.06ns	-0.17**
(2) Number of tiller	-0.07ns	-0.01ns	0.11ns	-0.13*	0.08ns	0.048ns	-0.007ns	0.09ns	-0.03ns	1
(3) Number of filled grains	-0.12ns	0.02ns	0.06ns	-0.06ns	0.51***	0.053 ns	0.39***	-0.41***	1	
(4) Number of empty grains	0.06ns	0.08ns	0.02ns	0.13*	-0.42***	-0.033ns	-0.47***	1		
(6) 1000- Grain weight	-0.04ns	0.03ns	0.02ns	0.008ns	0.6***	0.209**	1			
(7) Days to emergence panicle	0.64***	-0.1 ns	-0.16*	-0.019ns	0.026ns	1				
(8) Yield of single plant	-0.03ns	0.03ns	0.14*	-0.1ns	1					
(9) Width of flag leaf	-0.05ns	0.75***	0.27***	1						
(10) Length of flag leaf	-0.19**	0.81***	1							
(11) Flag leaf area	-0.14*	1								
(12) Days to 50 % flowering	1									

ns, * , ** and ***: nonsignificant, significant at the 5%, 1% and 0.1 % levels of probability, respectively.

Overall results obtained showed that weed extracts have some different effects on measured traits and influence on plant that its reasons could be chemical (cross-sectional effect), genetic, or both.

In addition, results of this research showed that weed extracts haven't very allelopathic effect on rice and in end of growing season, that's better, plant leftover return and remain in field.

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