Asian Journal of Agricultural Sciences 1(2): 25-28, 2009
ISSN: 2041-3890

Submitted Date: June 02, 2009 Accepted Date: August 05, 2009 Published Date: October 05, 2009

Study of Allelopathic Interaction of Wheat (*Triticum aestivum* L.) and Rye (*Secale cereal* L.) Using Equal-Compartment-Agar Method

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Abstract: There are many methods for weed management one of them is using allelopathy in weed management programs. Equal-compartment-agar method was used for studying allelopathic interaction of wheat and rye. In order to studying of sowing time (delayed sowing, synchronic sowing) on allelopathic interaction of wheat cultivars (Shiraz, Roshan, Tabasi, Niknejad) and rye (*Secale cereale*) on primary growth of rye and wheat, an experiment was done as factorial arrangement in a completely randomized design with 4 replications. According to the results, the inhibitory effect of wheat on rye was more than in synchronic sowing, compared to delayed sowing. Roshan had the highest allelopathic potential on rye, compared to other wheat cultivars. On the other hands, Roshan cultivar showed the highest sensitivity in the presence of rye. Root length showed the most sensitivity to released allelochemicals from wheat cultivars, because root has the most contact with allelochemicals.

Key words: Allelopathy, wheat, rye and equal-compartment-agar method

INTRODUCTION

Wheat (*Triticum aestivum*) is the main crop in most provinces of Iran. The grain yield reduction due to weed infestation, in no control situation, has been estimated 30%. The most prevalent weeds in wheat field are *Secale cereale*, *Galium tricornutum*, *Convolvulus arvensis*, *Avena ludoviciana*, *Phalaris minor*, *Vicia villosa* and *Sinapis arvensis* (Montazeri *et al*, 2005). Allelopathy refers to the beneficial or harmful effects of one plant on another plant, both crop and weed species, by the release of chemicals from plant parts by leaching, root exudation, volatilization, residue decomposition, and other processes in both natural and agricultural systems (Gibson and Liebman, 2003). The potential of crop residue allelopathy for weed suppression has been reviewed (Rice, 1984; An *et al*., 1998). If a weed species can be allelopathically suppressed by crop plants during seedling establishment period, crop plants will gain an advantage over weeds subsequently. Plant seedlings of various crops possess allelopathic potential or weed-suppressing activity, including wheat (Wu *et al*., 1999), oat (Fay and Duke, 1977), and rice (Dilday *et al*., 1994; Olofsdotter and Navarez, 1996). Aqueous extracts of wheat straw were allelopathic to the germination and growth of a number of weed species (Steinsiek *et al*., 1982; Liebl and Worsham, 1983).

Since the allelopathy of small grain cereals has been little studied, and on the other hand, there is no selective herbicide for rye control in wheat, this paper aims to observe the heterotoxicity of wheat varieties on rye. In addition, allelopathic potential of rye on wheat was also studied.

MATERIALS AND METHODS

This study was carried out in Weed Research Department, Iranian Crop Protection Research Institute. Seeds of wheat cultivars (Niknejad, Shiraz, Tabasi and Roshan) and rye were obtained from Karaj. Wheat and rye seeds were sterilized by soaking them in 70% ethanol for 2.5 min, followed by 4 times rinsing in sterilized distilled water. They were then soaked in 2.5% sodium hypochlorite solution for 15 min, followed by 5 times rinsing in sterilized distilled water.

Seed pre-germination: Surface-sterilized seeds of wheat and rye were each soaked in sterilized water in light at 25ºC for 24 h and then rinsed with sterilized water. Then, the wheat and rye seeds were incubated in light at 25ºC for 48 h.

General description of equal-compartment-agar-method (ECAM): A glass beaker (800 ml) containing 50 ml of 0.3% water agar (no nutrients) was autoclaved. For "delayed sowing", pre-germinated wheat seeds of each cultivar were uniformly selected and aseptically sown on one-half of the agar surface with the embryo up. The beaker was wrapped with parafilm and placed in a controlled environment growth cabinet with 25/18 ºC day

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and night temperature, respectively; 13/11 h light/dark period. After growth of wheat seedlings for 7 days, 16 pre-germinated seeds of rye were aseptically sown on the other half of the agar surface. After that the beaker were again wrapped with parafilm and placed back in the growth cabinet for 10 days. For "same-time" sowing, 16 pre-germinated wheat seeds were sown on one-half of the agar surface and the 16 pre-germinated rye seeds were simultaneously sown on the other half of the agar surface. Rye and wheat seedlings were harvested for measurement after 10 days of growth. The growth of wheat and rye alone served as control.

For "delayed sowing", 16 pre-germinated seeds of wheat were sown 7 days prior to the sowing of 16 pre-germinated rye seeds in the beaker pre-filled with 30 mL of 0.3% water agar. For "same-time sowing", 16 pre-germinated wheat seeds were sown on one-half of the agar surface and 16 pre-germinated rye seeds were simultaneously sown on the other half of the agar surface. Rye and wheat seedlings were harvested for measurement after 10 days of growth (Wu *et al*., 2000).

Statistical analysis: This experiment was established in a factorial design, completely randomized with three replications. Four wheat cultivars (Niknejad, Shiraz, Tabasi and Roshan) and two sowing methods (delayed and same-time sowing) of rye were the experimental treatments. The data were subjected to analysis of variance using the statistical program of SAS Version 9.1. The mean differences were adjudged using Duncan Multiple Range Test. Percentage inhibition of rye and wheat was calculated as treatment × 100/ control (Wu *et al*., 2000).

RESULTS and DISCUSSION

Allelopathic potential of wheat on rye

Rye length: Means comparison showed that Roshan cultivar caused the highest inhibition of whole and root length of rye. However, this cultivar did not show significant difference with the other wheat cultivars (Table 1). Some authors (e.g. Wu *et al*., 1998a, 1998b, and 2000; Li *et al*., 2000; Perez, 1990; Olofsdotter and Navarez, 1996; Guenzi *et al*., 1967; He *et al*., 2004; Dilday *et al*., 1992) reported variation in allelopathic potential among crop cultivars. Spruell (1984) reported that five wheat accessions produced root exudates inhibited the root growth of the receiver plant that.

Pre-germinated wheat seeds with same-time sowing with rye, caused maximum inhibition of rye length, compared to the control (Table 1). This result is in disagreement with Wu *et al.* (2000) who concluded that pre-germinated wheat seeds that sown a week earlier than ryegrass, significantly inhibited ryegrass root elongation, compared to the same-time sowing, and the control. Pre-germinated wheat seeds sown a week earlier than rye significantly inhibited rye root elongation, in comparison with the same-time sowing and the control (Table 1). There were no significant differences between the same-time sowing and the control, indicating that allelochemical did not accumulate when wheat and rye seeds were sown at the same time. Therefore, rye root growth was completely affected by wheat seedlings during 10 days of co-growth. Although delayed-sowing technique had a significant effect on rye root growth, there were no significant differences between the treatments on rye shoot growth.

Rye dry weight: The effect of sowing time and wheat cultivar were not significant on rye root, shoot, and whole plant dry weight (Table 1). This result disagrees with the findings of Olfsdotter and Navarez (1996) and Olfsdotter *et al.* (1999). Cheema *et al.* (1988) reported that wheat straw aqueous extract caused 15-20% inhibition of seed germination of cotton, but stimulated shoot and root growth and dry matter production.

Allelopathic potential of rye on wheat

Wheat length: Wheat length change was significantly depended on wheat cultivar and sowing time. Roshan cultivar showed the highest sensitivity in the presence of rye (Table 2). Rye produces several compounds in its root exudates that apparently inhibit growth of crops as wheat (Sattell *et al.* 1998).

Pre-germinated wheat seeds with delayed sowing showed maximum inhibition in shoot length, compared to the control. There were no significant differences between different sowing times and the control (Table 2). Wheat root length had the significant correlation with rye root length ($r = 0.381^{*}$) and dry weight ($r = 0.360^{*}$). Wheat shoot length was significant correlated with rye whole plant ($r = -0.529^{**}$) and shoot length ($r = -0.610^{**}$) (Table 3). Alam *et al.* (1990) demonstrated that aqueous extract of fresh leaves of purple nutsedge significantly reduced seed germination, shoot and root lengths of wheat.

Wheat dry weight: Sowing time and wheat cultivar had no significant effect on wheat root, shoot, and total dry weight (Table 2). Wheat total dry weight had the significant correlation ($r = 0.366^{*}$) with rye total dry weight. Wheat root dry weight had significant correlation ($r = 0.340^{*}$) with rye total dry weight (Table 3). Hussain and Abidi (1991) have reported that *Lolium multiflorum*, *Sorghum almum*, *Cynodon dactylon, Imperata cylindrical* caused reduction in seed germination, seedling growth and shoot and root dry weight of various crop plants under laboratory and field conditions.

According to Belz and Hurle (2004), wheat root length had the highest sensitivity to allelochemicals. Therefore, root length may be a key parameter to verify allelopathic strength of different wheat varieties. The higher inhibition of roots compared with shoots may be due to their more intimate contact with the treated filter paper. Results of this study are in agreement with those of Al Hamdi *et al.* (2001), Inderjit *et al.* (2001), and Lin *et al.* (2000) who found that root length is more affected than shoot growth.

Table 1: Mean comparison of allelopathic activity of wheat seedlings and rye time sowing on rye (% control)

	Rye length			Rye dry weight		
	whole	root	shoot	whole	root	shoot
Rye sowing time						
Control	100 a	100 a	100 a	100 a	100 a	100 a
Delayed sowing	88.88 b	75.69 b	101.27 a	99.77 a	93.33 a	103.81 a
Same time sowing	79.40 c	75.26 b	85.86 b	91.87 a	79.94 a	100.98 a
Wheat cultivar						
Control	100 a	100 a	100 a	100 a	100 a	100 a
Niknejad	83.53 b	74.25 b	92.77 a	94.22 a	91.34 a	96.49 a
Roshan	83.41 b	69.35 b	94.46 a	88.03 a	75.39 a	95.85 a
Shiraz	86.01 b	82.17 b	92.01 a	103.00 a	92.48 a	114.45 a
Tabasi	83.73 b	76.19 b	94.91 a	97.92 a	86.65 a	103.47 a

Means with the same letter in each column are not significantly different at probability level of 5% using DMRT

Table 2: Mean comparison of allelopathic activity of rye seedlings and rye time sowing on wheat (% control)

	Wheat length			Wheat dry weight		
	whole	root	shoot	whole	root	shoot
Rye sowing time						
Control	100 a	100 a	100 ab	100 a	100 a	100 a
Delayed sowing	92.84 a	90.11 a	92.10 b	115.92 a	141.34 a	107.65 a
Same time sowing	98.15 a	94.23 a	109.88 a	87.15 a	83.61 a	103.71 a
Wheat cultivar						
Control	100 a	100 a	100 a	100 a	100 a	100 a
Niknejad	99.34 a	95.71 a	101.75 a	88.51 a	97.66 a	99.81 a
Roshan	88.13 b	80.29 b	102.49 a	94.41 a	78.37 a	103.46 a
Shiraz	94.28 ab	91.79 ab	97.36 a	132.04 a	115.63 a	115.75 a
Tabasi	99.15 a	99.34 a	102.08 a	94.09 a	102.74 a	104.68 a

Means with the same letter in each column are not significantly different at probability level of 5% using DMRT

Table 3: Correlation between wheat and rye traits

		whole plant length	root length	shoot length	whole plant dry weight	root dry weight	shoot dry weight
Rye	whole plant length	0.012 ^{ns}	0.289 ^{ns}	−0.529 $^{\times\times}$	0.195 ^{ns}	0.211 ^{ns}	−0.232 ^{ns}
	root length	0.233 ^{ns}	0.381 $^{\times}$	−0.296 ^{ns}	0.132 ^{ns}	0.178 ^{ns}	−0.221 ^{ns}
	shoot length	−0.196 ^{ns}	0.131 ^{ns}	−0.610 $^{\times\times}$	0.106 ^{ns}	0.096 ^{ns}	−0.189 ^{ns}
	whole plant dry weight	0.177 ^{ns}	0.306 ^{ns}	−0.026 ^{ns}	0.291 ^{ns}	0.340 $^{\times}$	0.011 ^{ns}
	root dry weight	0.202 ^{ns}	0.360 $^{\times}$	−0.173 ^{ns}	0.297 ^{ns}	0.322 ^{ns}	0.075 ^{ns}
	shoot dry weight	−0.116 ^{ns}	0.157 ^{ns}	0.048 ^{ns}	−0.073 ^{ns}	−0.078 ^{ns}	0.001 ^{ns}

ns, × and ××: not significant, significant at probability levels 5% and 1%, respectively

Rye seed sowing was delayed 1 week after seed sowing of donor wheat, thereby providing a short period of root establishment and the release of allelochemicals into the agar medium before/or during the growth of rye. The pre-accumulation of the released allelochemicals prior to rye seed sowing, enables immediate allelopathic action once rye is sown. Delayed sowing produced much stronger inhibition than the same-time sowing on rye root growth (Table 1).

The substantial variations in allelopathic potential of wheat accessions offer a sufficient genetic pool to select novel genotypes and to transfer this allelopathic trait into modern cultivars for weed suppression. Further research is needed to determine the genetic control of crop allelopathic activity before any breeding programs can be initiated to develop crop cultivars with allelopathic potential. Further field screening is always advisable to substantiate laboratory results.

CONCLUSION

According to the results, the inhibitory effect of wheat on rye was more than in synchronic sowing, compared to delayed sowing. Roshan had the highest alleloathic potential on rye, compared to other wheat cultivars. On the other hands, Roshan cultivar showed the highest sensitivity in the presence of rye. Root length showed the most sensitivity to released allelochemicals from wheat cultivars, because root has the most contact with allelochemicals.

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