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Full Length Research Paper

Allelopathic appraisal effects of straw extract wheat varieties on the growth of corn

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Allelopathy is a process in which secondary metabolites produced by plants, micro-organisms, viruses and fungi control growth and development of other biological systems. Some plants may beneficially or antagonistically affect other plants through allelochemical compounds which may be released directly or indirectly from live or dead parts and cause allelopathic and phytotoxic effects. In Kerman province of Iran, cultivating corn after winter wheat usually causes less growth and yield, hence, this study was conducted to estimate the effects of different concentrations of two native Iranian wheat (Alvand and Falat) straw extracts on germination, radicle growth, coleoptile length, plant height, leaf area (LA), wet weight (WW) and dry weight (DW) of two hybrid corn varieties (single cross 704 and 647). Results showed that the straw extracts had significant negative allelopathic effects on both corn varieties' growth. Furthermore, based on the study results, we suggest that before corn cultivation, wheat straw and residues should be eliminated from the field by leaving no-till fields fallow to avoid negative allelopathic effects of wheat straw on corn growth.

Key words: Allelopathic, corn, wheat straw.

INTRODUCTION

Future agricultural research will need to incorporate ecological, physiological and molecular methods, in order to understand agricultural crops *in situ* and their interaction with the environment. In Kerman province, it is usual to culture corn after winter wheat or winter barley, but corn growth and final yield is not as good as after fallow. Hybrid corn is preferred by farmers over conventional native varieties because of its high grain yield as a result of heterosis (hybridization). Mulching and catch crop (wheat) residues are spread and left on the soil surface between successive crops. This practice is well-known and is recommended for soil and water conservation (Rahman et al., 2005). Allelopathy is known as the effects of plant(s) on other plant(s) through the release of chemical compounds into the environment via evaporation, leaching, spread out from roots and decomposition of plant residues; which has synergic or antagonistic effects such as auto toxicity and isolation (Weih et al., 2008). This definition includes both motivate and inhibitory effects depending on the concentration of the compounds. Allelopathy can play a beneficial role in various cropping systems such as mixed cropping, multiple cropping, cover cropping, crop rotations, minimum and no–till systems (Ben et al., 2001). Rotational or smother crops such as wheat (*Triticum aestivum* L.) which are classified as plants with allelopathic effects that spread out allelochemical compounds, have been reported to play an opposed reaction on other plants and even their own varieties.

MATERIALS AND METHODS

This study was conducted in growing season 2008 to 2009 at the research laboratory and field of the Agronomy Department, College of Agriculture, University of Shahid Bahonar, Kerman-Iran. The objective of this study was to estimate the effects of straw and stubble extracts of two Iranian wheat varieties (Falat and Alvand) prepared at harvest time on germination and growth of two corn

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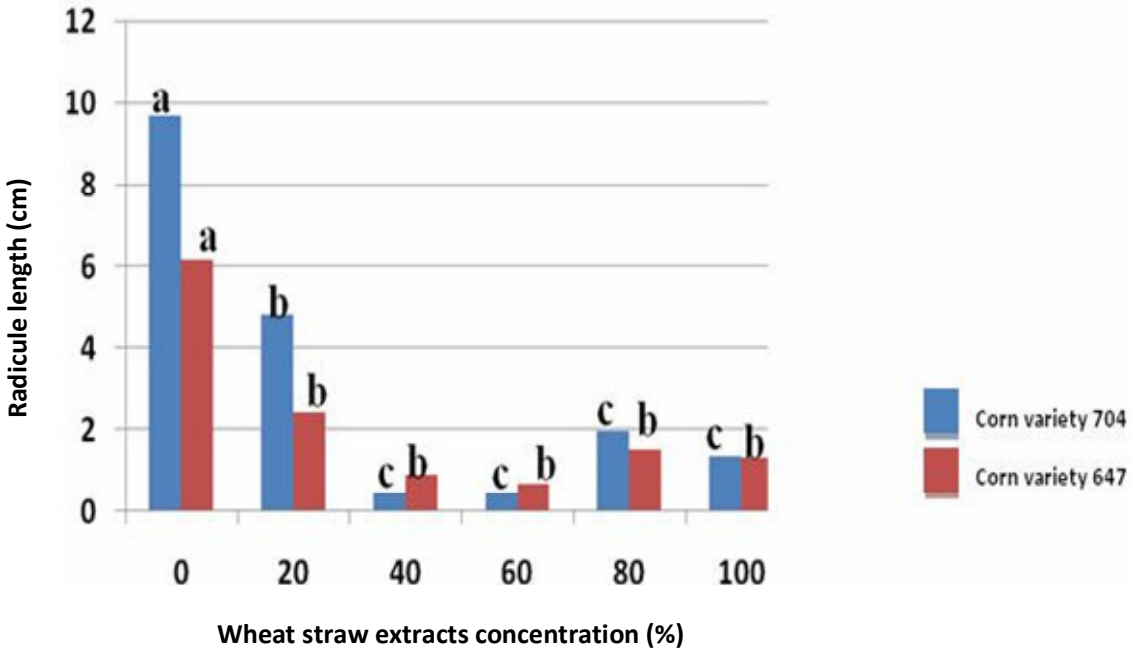

Figure 1. Effect of straw extract of Falat wheat variety on radicle length (cm) at laboratory. Means followed by the same letter in the same column are not significantly different using Duncan's new multiple range test; α = 0.05.

varieties: single cross 704 (precocious) and single cross 647 (not precocious) in laboratory and field. To prepare the wheat straw extract, cut straw was powdered, then 5 g of this powder was mixed with 100 ml of distilled water in an Erlenmeyer flask and was left on a stirrer for 12 h at maximum speed, then this suspension was filtered and the prepared emulsion was put in a centrifuge at 3000 rps for 15 min. This was the basic medium. Then 0 (distilled water), 20, 40, 60, 80 and 100% concentrations of the centrifuged medium were made since the irrigated seeds in Erlenmeyer flask and experimental pots were with different concentrations of the medium for 28 days.

Control pots were irrigated with distilled water. The corn seeds were sterilized using an approved protocol as follows: The corn seeds were immersed in Benlate 0.2% (v/v) fungicide solution and placed on a shaker for 15 min and then washed gently under running tap water with 5% (v/v) teepol solution. Then the seeds were immersed in 70% (v/v) ethanol solution for three minutes and rinsed three times with sterile distilled water. This was followed by shaking in 20% (v/v) Clorox solution containing 5 drops of Tween 20 for another 15 min and finally, the seeds were gently washed five times with sterile distilled water and dried on filter paper to eliminate remaining water on seed surface that may have caused infection during culture time. The basic medium used for the experiment was MS (Murashige and Skoog, 1962) medium supplemented with 30 gl^{-1} (w/v) sucrose and 3.79 gl^{-1} gelrite agar as solidifying agent. The pH of the medium was adjusted to 5.7 and the medium was dispensed at 50 ml volume into a 250-ml Erlenmeyer flask. Leaf area measurements were carried out with LAM (leaf area meter) which after gathering leaves and stems, where wrapped in aluminum foil and kept for 48 h in an oven at 70°C, then weighed with a digital scale. The experiment was arranged in a completely randomized design (CRD) with six treatments and one replication per treatment. Each replicate was represented by one corn explant. Data obtained from the experiments were subjected to analysis of variance (ANOVA). Means were separated by Duncan's new multiple range test (DNMRT) at the 5% level of significance and bar charts were created by using excel software to show the difference between treatments graphically. The statistical analysis program used was MSTAT-C.

RESULTS

Laboratory studies

It was observed that straw extract from both wheat varieties at different concentrations had significant effect on both corn varieties. As seen in Figure 1, Falat wheat straw extract caused a significant reduction in radicle length of corn hybrid 647 at concentrations of 20, 40, 60, 80 and 100%. It was observed that at 80 and 100% concentrations of Alvand wheat residue extract, corn radicle growth significantly decreased (Figure 2). The significant decline of coleoptile length started from 20 to 40% concentrations of wheat straw extract in both the corn hybrids (Table 2). These results indicate that increasing concentrations of Falat and Alvand wheat straw extract decreased coleoptile length in both hybrids. Highest allelopathic effects on coleoptile height appeared at 80 to 100% wheat straw extract (Table 3).

Field experiments

Table 1 shows the effect of 28 days' irrigation with straw extract. It was observed that Falat wheat residue extract had a significant effect on radicle length of corn hybrids

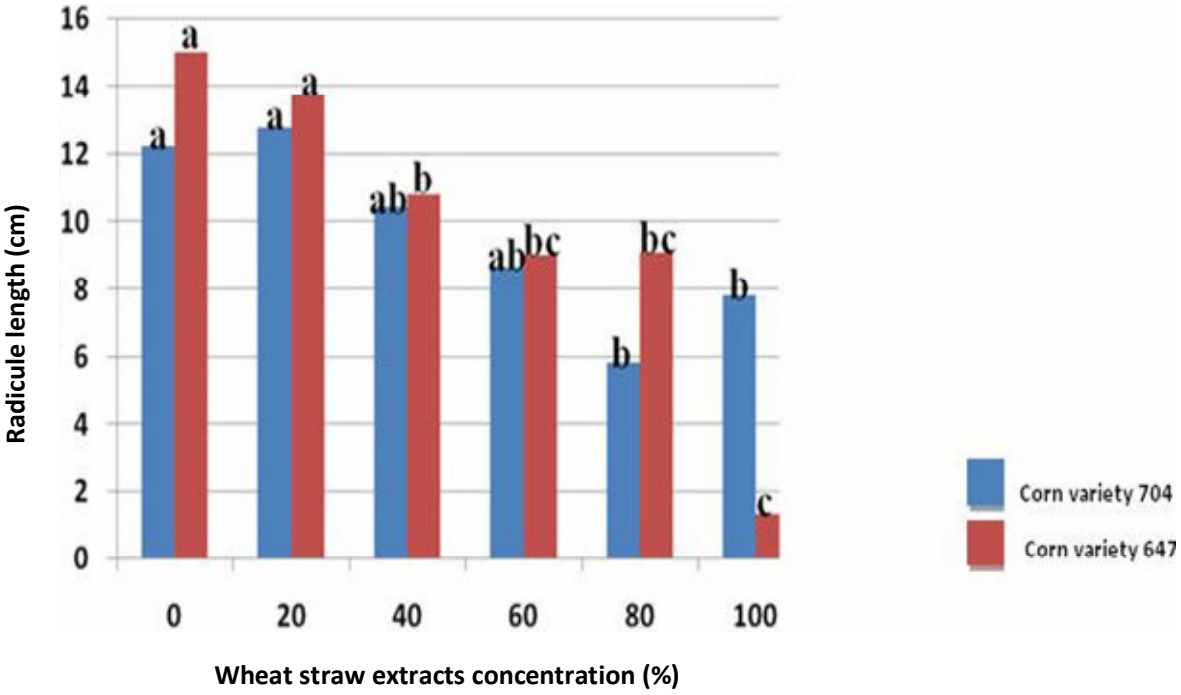

Figure 2. Effect of straw extract of Alvand wheat variety on radicle length (cm) at laboratory. Means followed by the same letter in the same column are not significantly different using Duncan's new multiple range test; α = 0.05.

Table 1. Effect of straw extract of Alvand and Falat wheat varieties on radicle length (cm) at field.

Wheat straw extracts concentration (%)	RL 704 Falat	RL 704 Alvand	RL 647 Falat	RL 647 Alvand
0	12.58a	13.04a	14.32a	14.07a
20	7.13b	12.53a	8.61b	11.69a
40	4.6bc	8.51b	8.68b	11.31a
60	3.48c	4.58c	6.14bc	9.8ab
80	2.87c	3.93c	5.62bc	3.8b
100	2.72c	2.9c	3.89c	6.28b

RL = Radicle length; 704 and 647 = corn single cross varieties; Alvand and Falat = wheat varieties.
Means followed by the same letter in the same column are not significantly different using Duncan's new multiple range test; α = 0.05.

704 and 647. The effect of Alvand wheat straw extract was similar to that of Falat extract on coleoptiles height which gradually decreased from 20% wheat straw concentration on coleoptiles length (Figure 3). The allelopathic effects started appearing from concentration of 40%; and coleoptile height was significantly reduced at 80 to 100% wheat straw extracts (Figure 4). The results in Table 4 which compare the effect of wheat straw extract of Falat and Alvand varieties on corn, showed significant leaf area reduction from 40 to 60% concentration. Results indicated that wheat straw extracts from Alvand and Falat varieties tended to suppress growth and development, reduce proliferation and regeneration of plant parts and eventually reduce plant weight of corn hybrids 647 and 704. The allelopathic effects of extracts of Alvand and Falat wheat straw on wet and dry weight can be seen in Tables 5 and 6, which showed that 40% or higher concentration had negative allelopathic effects on wet and dry weight of corn varieties.

DISCUSSION

High yield can be achieved in sustainable agriculture by identifying and eliminating factors that reduce the yield of agricultural produce. This study aimed to show that the straw/stubble extract of wheat varieties Falat and Alvand had significant negative effects on growth of corn hybrids 647 and 704. Previous researchers have mentioned that wheat straw extract has phenolic compounds that appear

Table 2. Effect of straw extract of Alvand and Falat wheat varieties on coleoptile length (cm) in laboratory.

Wheat straw extracts concentration (%)	CL 704 Falat	CL 704 Alvand	CL 647 Falat	CL 647 Alvand
0	5.51a	6.01a	4.38a	6.06a
20	3.32b	5.28ab	1.83b	6.12a
40	0.59c	5.22ab	0.93b	5.17b
60	0.58c	4.42ab	0.68b	4.52bc
80	1.1c	3.33b	1.22b	4.63bc
100	0.9c	3.63b	1.11b	4.45c

CL = Coleoptile length; 704 and 647 = corn single cross varieties; Alvand and Falat = wheat varieties.
Means followed by the same letter in the same column are not significantly different using Duncan's new multiple range test; α = 0.05.

Table 3. Effect of straw extract of Alvand and Falat wheat varieties on coleoptile heigth (cm) in laboratory.

Wheat straw extracts concentration (%)	CH 704 Falat	CH 704 Alvand	CH 647 Falat	CH 647 Alvand
0	5.85a	5.79a	6.39a	7.25a
20	5.82a	6.22a	4.6a	6.06ab
40	3.28b	4.26b	6.1a	6.19ab
60	2.91b	4.11b	4.8a	5.49ab
80	1.88b	3.17b	3.9a	4.4b
100	2.36b	2.12c	2.39b	4.57b

CH = Coleoptile height; 704 and 647 = corn single cross varieties; Alvand and Falat = wheat varieties.
Means followed by the same letter in the same column are not significantly different using Duncan's new multiple range test; α = 0.05.

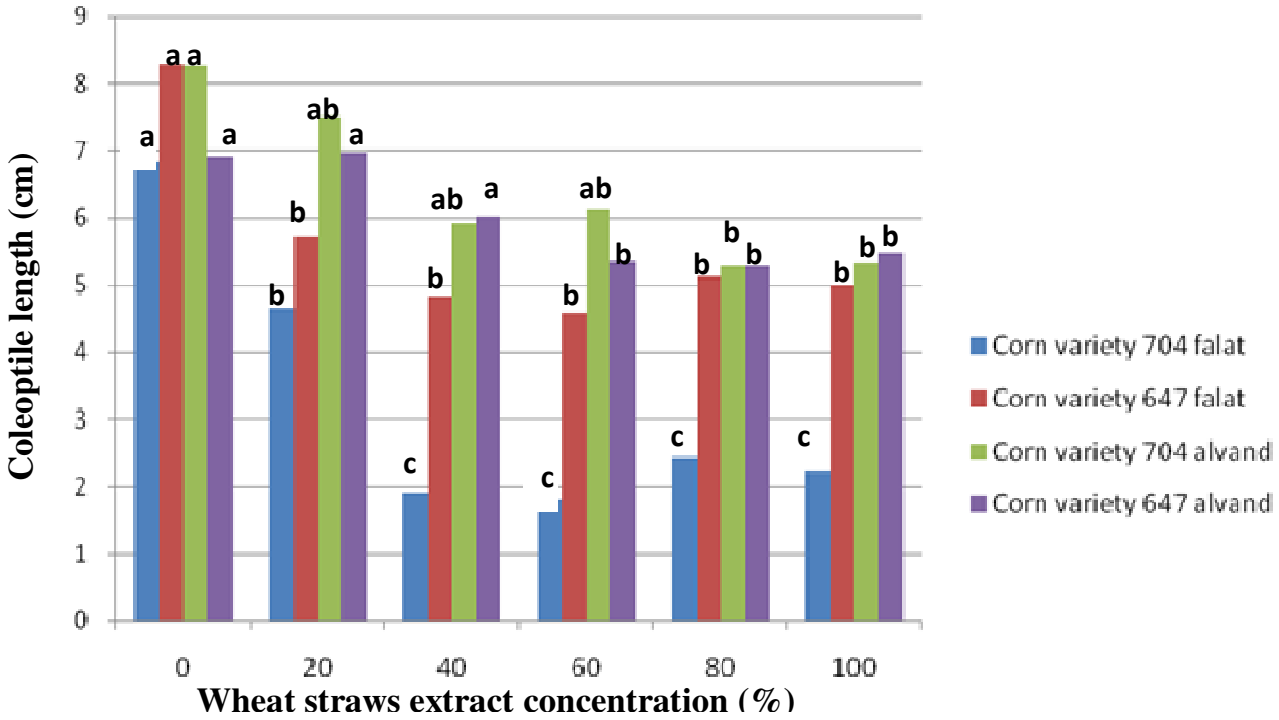

Figure 3. Effect of straw extract of Alvand and Falat wheat varieties on coleoptile length (cm) in field. Means followed by the same letter in the same column are not significantly different using Duncan's new multiple range test; α = 0.05.

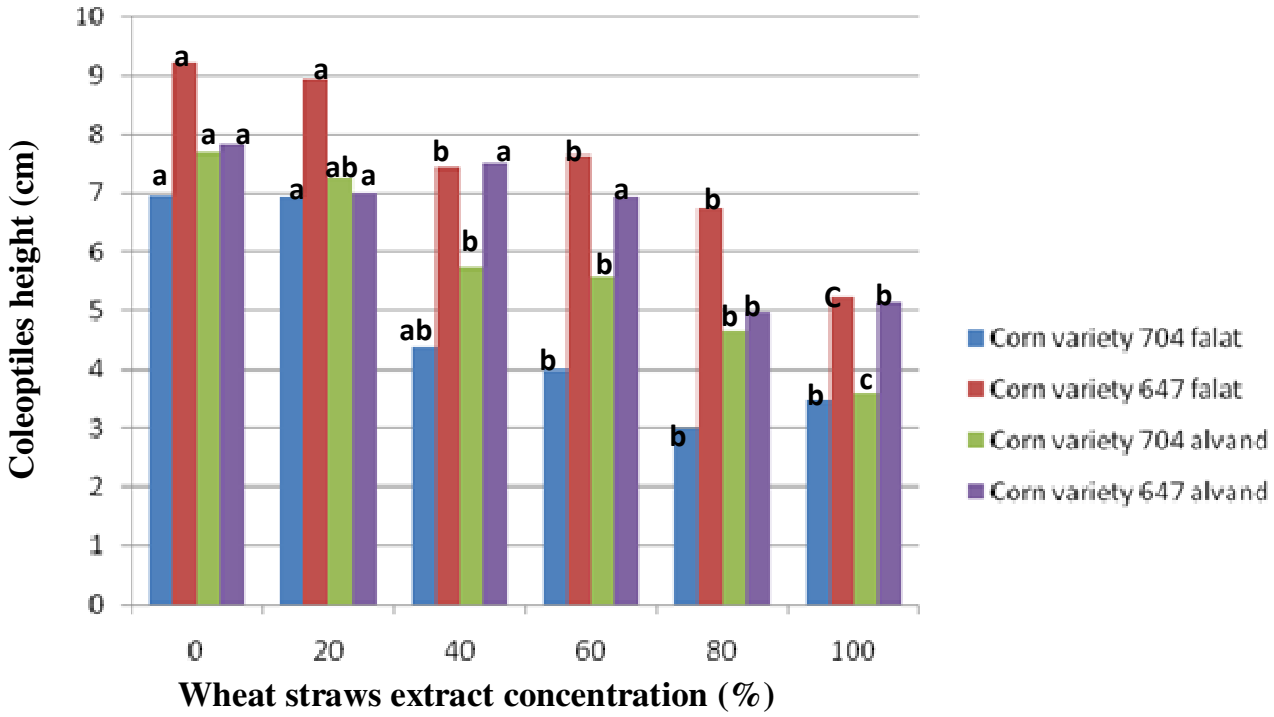

Figure 4. Effect of straw extract of Alvand and Falat wheat varieties on coleoptile height (cm) in field. Means followed by the same letter in the same column are not significantly different using Duncan's new multiple range test; α = 0.05.

Table 4. Effect of straw extract of Alvand and Falat wheat varieties on leaf area (cm) in field.

Wheat straw extracts concentration (%)	LA Falat 704	LA Falat 647	LA Alvand 704	LA Alvand 647
0	88.57a	118.23a	111.01a	93.5a
20	59.31ab	101.63a	100.67ab	94.36a
40	24.43ab	47.14b	84ab	80.63ab
60	23.22b	44.67b	62b	43.73b
80	31.25b	50.31b	32.39b	43.3b
100	28.44b	48.9b	32.66b	47.17b

LA = Leaf area; 704 and 647 = corn single cross varieties; Alvand and Falat = wheat straw extract varieties. Means followed by the same letter(s) in the same column are not significantly different using Duncan's new multiple range test; α = 0.05.

to have toxic effects on corn seedlings. These effects were most probably due to phenolic compounds like ferulic acid, coumaric acid, vanillic acid and hydroxyl benzoic acid which influenced cell divisions on corn varieties, 647 and 704; they also restricted their leaf areas (Dias, 1991; Weih et al., 2008). It seems that extracts prepared at harvest time impede water absorption by the corn root and radicle due to the presence of phenolic compounds which may ultimately reduce plant photosynthesis and cause reduction of wet and dry weight. These results were similar to those of other researchers who have studied the effect of wheat straw extract on corn. Rizvi et al. (2000) reported that different wheat straw extracts have different allelopathic effects on wild oat in which root length of corn seedlings decreased by 25 to 45 and 47 to 62%. Rahman et al. (2005) reported that winter wheat and rye have allelopathic effect on following wheat culture, this was specially observed in no-till systems which clearly show allelopathic effect(s) due to presence of wheat straw on soil surface. In tilled systems, there were no reports of allelopathic effects of wheat straw on corn growth, because most residues are eliminated. Also, results of this study were not always consistent with those of previous research investigations since Ben et al. (2001) reported that floating wheat seeds in barley straw extract for 24 to 48 h has no effect on wheat seed germination. The results of this study are consistent with Oussama (2003) who estimated the effect

Table 5. Effect of straw extract of Alvand and Falat wheat varieties on dry weight (g) in field.

Wheat straw extracts concentration (%)	DW Falat 704	DW Falat 647	DW Alvand 704	DW Alvand 647
0	0.33a	0.54a	0.51a	0.47a
20	0.25ab	0.37b	0.57a	0.48a
40	0.18ab	0.25bc	0.38ab	0.4ab
60	0.15ab	0.07c	0.21b	0.09b
80	0.11b	0.11c	0.1b	0.04b
100	0.08b	0.15c	0.18b	0.2b

DW = Dry weight; 704 and 647 = corn single cross varieties; Alvand and Falat = wheat varieties.
Means followed by the same letter in the same column are not significantly different using Duncan's new multiple range test; α = 0.05.

Table 6. Effect of straw extract of Alvand and Falat wheat varieties on wet weight (g) field.

Wheat straw extracts concentration (%)	WW Falat 704	WW Falat 647	WW Alvand 704	WW Alvand 647
0	2.21a	3.36a	3.33a	2.18a
20	4.48ab	2.32b	3.02ab	2.2a
40	0.61b	1.34bc	2.52ab	1.88ab
60	0.58b	1.39bc	1.86b	1.02b
80	0.78b	1.43bc	1.18b	1.01b
100	0.71b	1.27c	1.19b	1.1b

WW = Wet weight; 704 and 647 = corn single cross varieties; Alvand and Falat = wheat varieties.
Means followed by the same letter in the same column are not significantly different using Duncan's new multiple range test; α = 0.05.

of allelopathy in two durum wheat varieties (Triticum durum L.). Based on the results in Table 3, it was observed that straw extract of wheat variety Falat at 60% concentration showed highest negative effect on coleoptile height of corn hybrid 647, and it is concluded that this extract had high concentration of allelopathic compounds that prevented coleoptile growth. These results were consistent with those of Rizvi et al. (2000) who reported the effect of wheat straw extract on wild oat. Based on present results regarding the effects of wheat straw extract on coleoptile length (Table 2), it appeared that wheat straw extract has special compounds that reduce plant height which prevent the action of gibberellins (GA3) and indole acetic acid (IAA) because these natural growth regulators play a role in plant height increase; hence, it appears that phenolic compounds suppress their action (Dias, 1991; Oussama, 2003).

Conclusion

Possible joint action of chemicals in determining allelopathic activity is an area of study that largely remains neglected with utilized molecular and biothecnological tools such as gene mapping and QTL (quantitative trait loci) (Su et al., 2006) to study the genetic control of quantitative characteristics. It is possible that biotechnology may eventually make possible the production of highly allelopathic crops through the use of transgenic technology to increase allelochemical production adequate enough to effectively control plant (weeds) growth and development. Majority of farmers in Kerman province usually cultivate corn after wheat harvest without removal of wheat straw and stubble from the field which may probably prevent high yield amount; so based on this study, researchers or farmers interested in higher yield of corn can be advised to take appropriate action to eliminate allelopathic and phytotoxic effects of wheat residues, hence, deep disking may eliminate wheat straw residues from the field and make wheat-corn rotation more sustainable and economical in this area.

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