J. Appl. Environ. Biol. Sci., 5(8)285-290, 2015
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ISSN: 2090-4274
Journal of Applied Environmental and Biological Sciences
www.textroad.com

Soil factors affecting the allelopathic activities of some plant species

Y. Norouzi[1] G. R. Mohammadi[1*] and I. Nosratti[1]

[1]Department of crop production and breeding, Faculty of Agriculture and Natural Resources, Razi University, Kermanshah, Iran

Received: April 11, 2015
Accepted: June 22, 2015

ABSTRACT

The effectiveness of allelochemicals in soil is strongly controlled by the soil physicochemical properties and organisms. Outdoor pot experiments were conducted at the Faculty of Agriculture and Natural Resources, Razi University, Kermanshah, Iran, during the summer of 2013, to evaluate the effects of soil microorganisms and pH on activity of potential allelopathic crops on emergence and early growth of some weed species. The allelopathic effects of powdered below – and above ground organs of alfalfa (*Medicago sativa* L.), sorghum (*Sorghum bicolor* L.) and tobacco (*Nicotiana tabacum*) on emergence and early growth of weed species including Johnson grass, barnyard grass and redroot pigweed were studied in sterilized and non-sterilized soils and different soil pH levels. Results showed that phytotoxicity of allelochemicals was significantly influenced by soil sterilization varied in sterilized and non- sterilized soil. Presence of microorganisms in soil decreased the inhibitory effects of allelopathic plant tissues on weed growth (77.79 in strilized vs. 59.96% in non-strilized soil). Alfalfa had significant higher growth inhibitory effect (83 to 91%) than all other studied allelopathic plants followed by tobacco and sorghum. Generally, lowering pH resulted in higher allelopathic activities of plant species.
KEYWORDS: Alfalfa, barnyard grass, Johnson grass, redroot Pigweed, sorghum, tobacco.

INTRODUCTION

Allelopathy has a great impact on the weed biology and management practices [10, 13, 20, 22]. It is well documented that allelochemicals found in the tissues of some plant species can reduce weed growth and seed germination [8, 9, 18, 24, 27, 28]. Entrance to the soil is the fate of all allelochemicals for being effective in agriculture which makes it necessary to study their behavior in soil environment [8, 29]. Therefore to have a good insight on how allelochemicals can affect plant growth in soil, we should improve our knowledge regarding factors influencing the phytotoxic activity and fate of allelochemicals in soil.

Soil physicochemical properties and microflora could influence allelopathy phenomenon in soil [10, 20, 40, 45]. Soil microbes greatly influence bio-activity and -availability of allelochemicals in soil environment [11]. Accumulation of allelochemicals at phytotoxic levels in soil is largely determined by the presence of microorganisms. Soil microorganisms generally utilize allelopathic compounds as carbon sources [5, 36].

Soil pH also affects adsorption, desorption and transport in soil and the metabolism of allelochemicals which in turn could result in modification of expressed response on growth of receiver plants [20]. Therefore, the aim of this work was to assess the effects of soil microorganisms and pH on allelopathic ability of alfalfa (*Medicago sativa* L.), sorghum (*Sorghum bicolor* L.) and tobacco (*Nicotiana tabacum*) to reduce the germination and early growth of some weed species including Johnson grass (*Sorghum halepense*), barnyard grass (*Echinochloa crus-galli*) and redroot pigweed (*Amaranthus retroflexus*).

MATERIALS AND METHODS

Two separate outdoor pot experiments were conducted at the Faculty of Agriculture and Neutral Resources, Razi University, Kermanshah (34°18′51″N, 47°03′54″E; elevation 4557 ft.), Iran during June to September of 2013. During the experiments, the mean temperature and relative humidity were 26.6° C and 12.8%, respectively.

In the first trial, the role of microorganisms on allelopathy was evaluated. Ten seeds of johnsongrass, redroot pigweed and barnyardgrass were sowed in plastic pots with a dimeter of 13 and a height of 19 cm containing sterilized and non-sterilized soil treated with powdered plant tissues of alfalfa, tobacco or sorghum. According to Romeo and Weidenhamer [34], using sterilized soil in experiments may help in assessing the role of microorganisms in allelopathy. Soil sterilization was carried out by placing the soil collected from the farm in an oven at 105° C for 48 hours.

*Corresponding author: G. R. Mohammadi, Department of crop production and breeding, Faculty of Agriculture and Natural Resources, Razi University, Kermanshah, Iran. E-mail address: mohammadi114@yahoo.com

In the second trial, the effect of soil pH on allelopathy was investigated. Two levels of elemental sulfur (4 and 8 g) were added to the pots which were on equal with 3000 and 6000 kg ha^{-1} of sulfur, respectively. The initial pH of examined soil (control) was 7.52. The soil pH values after the application of 3000 and 6000 kg ha^{-1} of sulfur were 7.12 and 7.08, respectively. Then seeds of weed species including Johnson grass, redroot pigweed and barnyard grass were sowed in the pots filled with soil having the above mentioned acidities along with the powdered aerial parts of Tobacco, sorghum and alfalfa.

For both trials, the allelopathic plant materials were prepared from the plants grown in the field condition and harvested just before flowering stage. Above- and below-ground parts of allelopathic plants were air-dried in shade and ground. The amount of powdered allelopathic plant tissues added to each pot was 16g. This amount was the lowest effective concentration which was determined based on the results of the preliminary experiments (data not shown). After emergence, the weed plants were thinned to 5 plants in each pot and were irrigated as needed throughout the trials.

Each trial was conducted as a factorial based on a completely randomized desigan with three replications and was repeated twice. The first factor was allelopatic plant including alfalfa tobacco, sorghum and the second was soil condition (sterilized and non–sterilized) or pH level (7.52, 7.12 and 7.08). Six non-treated pots were also included as control. Weed traits including emergence percentage and shoot and root dry weights were determined at the end of the experiments (35 days after the start of each trial). Data were subjected to ANOVA, and means were separated using Fisher's Protected LSD test at the 0.05 level of probability.

RESULTS AND DISCUSSION

Results for each trial are presented separately. There was no significant difference between two repetitions for each trial, therefore, results presented are averaged across two repetitions. No significant interaction effect was found between soil condition and allelopathic plants for emergence percentage, shoot and root dry weights. Results showed that presence of microorganisms in soil (non-sterilized condition) decreased the inhibitory effects of allelopathic plant tissues on both Johnson grass and barnyard grass emergence, and shoot and root dry weights (Table 1) (on average , 77.79 versus 59.96% for all measured traits).

Table 1. Effect of presence (non-sterilized soil) and absence (sterilized soil) of microorganisms in the soils treated with different allelopathic plant species on Johnson grass emergence, root and shoot dry weight and barnyard grass root and shoot dry weights.

Soil condition	Johnson grass			Barnyard grass	
	%Emergence reduction	% Root dry weight reduction	% Shoot dry weight reduction	% Root dry weight reduction	% Shoot dry weight reduction
Sterilized	81.77	78.60	69.84	79.33	79.46
Non-sterilized	67.96	55.81	49.20	63.82	63.06
LSD (0.05)	9.85	22.00	15.85	12.00	14.63

Emergence and seedling growth of Johnson gross and redroot pigweed were significantly influenced by the type of the allelopathic plant species. In redroot pigweed the highest reductions in shoot and root dry weights were achieved by alfalfa followed by tobacco and sorghum. There were no significant differences between tobacco and sorghum in terms of these traits (Table 2). In Johnson grass, the lowest emergence percentage occurred when soil was treated by alfalfa plant tissue followed by tobacco and sorghum (Table 2). Moreover, alfalfa showed the highest reducing effect on Johnson gross root dry weight and other two allelopathic plants have a significant lower and nearly similar decreasing influence on this trait (Table 2). Alfalfa showed the highest inhibitory effects on the emergence and seedling growth of both weed species. The allelopathic effects of alfalfa on germination and seedling growth of a number of weed species have been reported by other workers [6, 46]. This can be attributed to the presence of a number of allelochemicals in alfalfa such as medicarpin, sativan, canavanine, saponins and different phenolic acids [38].

Table 2. Effect of allelopathic plant species on redroot pigweed and barnyard grass plant traits.

Allelopathic plant species	Redroot pigweed		Johnson grass	
	% Shoot dry weight reduction	% Root dry weight reduction	%Emergence reduction	% Root dry weight reduction
Tobacco	46.12	38.95	61.91	69.29
Alfalfa	91.91	94.19	83.33	85.59
Sorghum	28.24	31.09	33.33	69.69
LSD (0.05)	37.71	33.49	19.41	12.06

A significant two-way interaction (allelopathic plant species × soil condition) was also observed for the emergence percentages of redroot pigweed and Johnson grass. The allelopathic plants responded differently to soil condition and in relation to weed species. As, the presence of soil microorganisms (non- sterilized soil) decreased alfalfa inhibitory effects on the weed species, but sorghum showed a higher allelopathic influence when soil was sterilized (Table 3). This may be explained by different composition rates of these crops. Alfalfa is a legume crop with a lower C/N ratio. This can lead to the more degradability and consequently lower inhibitory effect of alfalfa plant tissue in the presence of soil microbial community. Blum and Shafer [1] reported that a lower activity is expected when the allelochemicals released by plants can readily be metabolized by soil microorganisms especially in the presence of adequate mineral nutrients. However, the resposne of tobacco to soil condition was highly dependent on the studied weed species, so that, soil sterilization increased tobacco inhibitory effect on redroot pigweed emergence. In other words, in the absence of microorganisms tobacco plant material showed a high suppressing effect on the emergence of this weed species. According to Inderjit and Weiner [14] the allelochemicals released by plants are subject to destruction, soil adsorption and inactivation, and transformation by soil microflora. However, the presence of microorganisms in the soil treated with tobacco plant tissue led to the more reduced barnyard grass emergence (Table 3).

Table 3. Effect of allelopathic pant species and presence (non-sterilized soil) or absence (sterilized soil) of soil microorganisms on redroot pigweed and barnyard grass emergence percentage.

Allelopathic plant species	Soil condition	Redroot pigweed	Barnyard grass
		% emergence reduction	
Tobacco	Non-sterilized	40.23	62.50
	Sterilized	72.41	41.67
Alfalfa	Non-sterilized	90.80	75.00
	Sterilized	67.82	70.83
Sorghum	Non-sterilized	54.02	25.00
	Sterilized	58.62	66.67
LSD (0.05)		25.00	19.00

There are several and incosistent reports on the importance of soil microbial metabolism on allelopathic activities [4, 21, 26, 35]. Many researchers have reported the enhancement of phytotoxicity of allelopathic compounds by microbial decomposition [19, 31,37]. However, in our study, the presence of microorganisms led to the different results with relation to the species of allelopathic plants and weeds. This reveals that the microorganism effects on allelochemical activity is highly species-dependent regarding to the allelopathic plant material and target weed species. Other researchers also found that the chemical effect of phytotoxins released from decomposing plant tissues impacts weed species selectively [3, 25, 33, 43].

These inconsistency can also be attributed to the presence of different types of microorganisms in the soils. Differential utilization of allelopathic residue by various soil microorganisms in soil have previously been observed [32]. It can be concluded that the allelochemicals released by plant materials can be disappeared as they can be consumed by soil microorganism [15, 23], transformed to more toxic compounds [17, 26], or even to other substances with growth stimulatory effects [30]. However, environmental factors such as temperature and moisture and soil condition can highly affect the activity of decomposing microbial community.

According to Table 4, inhibitory effects of allelopathic plants on the weed traits under study were intensified in response to decreasing soil pH level, so that, at the lowest pH (7.08), reduction percentages of redroot pigweed shoot and root dry weights and barnyard grass emergence were increased by 29.2, 27.7 and 16.7%, respectively as compared with control (pH=7.52) (Table 4).

Table 4. Effect of different soil pH levels on redroot pigweed and barnyard grass plant traits.

Soil pH level	Redroot pigweed		Barnyard grass
	% Shoot dry weight Reduction	% Root dry weight reduction	% Emergence reduction
7.52	67.42	70.41	48.61
7.12	90.88	92.76	73.61
7.08	96.66	98.13	65.28
LSD (0.05)	21.45	20.30	12.15

The inhibitory effects of the allelopathic plant species on redroot pigweed emergence increased in response to decreasing soil pH level (Table 5). Moreover, for all three pH levels, alfalfa showed higher reducing effects on this trait when compared with other plant species under study (Table 5). So that, at the lower pH levels (7.08 and 7.12) all redroot pigweed seeds failed to emerge in the pots treated with alfalfa plant tissue (Table 5).

However, the effectiveness of alfalfa on barnyard grass root dry weight was not significantly affected by soil pH, although, decreasing pH level reduced negative effects of tobacco and sorghum on root dry weight of barnyard grass (Table 5).

pH is one of the most important factors that influences the size and effectiveness of soil microbial community. Moreover, this factor can notably affect the soil chemical reactions. Therefore, it is expected that the time and rate of allelochemical effectiveness to be varied under different soil pH levels. According to Wang et al. [42] the phytotoxicity of both aqueous leaf leachates and dry leaf litter from *W. trilobata* significantly increased under lower pH treatments. Brand et al. [2] suggested that soil pH can indirectly influence immobilization and uptake of allelochemicals through its effect on microbial activities.

Table 5. The effects of allelopathic plant species on redroot pigweed emergence and barnyard grass root dry weight under different soil pH levels.

Allelopathic plant species	Soil pH level	Redroot pigweed	Barnyard grass
		% Emergence reduction	%Root dry weight reduction
Tobacco	7.52	35.63	87.86
	7.12	90.80	74.76
	7.08	100.00	69.78
Alfalfa	7.52	95.40	82.61
	7.12	100.00	87.54
	7.08	100.00	88.43
Sorghum	7.52	49.43	90.73
	7.12	86.21	73.58
	7.08	95.40	51.61
LSD (0.05)		9.63	15.14

The main processes controlling the toxic levels of allelochemical in soil water is adsorption-desorption balance which in turn is depending on different soil factors like pH, organic matter and texture [7, 16, 40]. All these factors together would contribute to different phytotoxic activity among soils and plants.

Different susceptibility between weeds was also observed which is similar to the findings of other researchers [39, 44]. Thus, for getting benefit from allelopathic activity in practical, the Knowledge on the target weed species is important. In addition, allelochemicals affect different physiological processes in various plant species [12]. In other words, the weed suppressing effect of these compounds is highly species-dependent.

Conclusion

In general, results of this experiment re-emphasis that allelopathy is a very complicated phenomenon and it is difficult to attribute observed growth responses in receiver plants to only one factor. After incorporation allelopathic compounds into the soil, they probably undergo microbial decay. Furthermore, soil physicochemical characteristics might modify the microbe's activity in soil and behavior of allelochemicals after the microbial decomposition of allelopathic plant tissues. Therefore, it is important to emphasize that laboratory studies on allelopathic activity can reveal only the potential activity of the allelochemicals, while field studies are required for understanding the factors affecting their phytotoxic activities in a real condition.

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