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ALLELOPATHIC RELATIONS OF SELECTED CEREAL AND VEGETABLE SPECIES DURING SEED GERMINATION AND SEEDLING GROWTH

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ABSTRACT. Allelopathy is the direct or indirect harmful effect which one plant produces on another through the production of chemical compounds that escape into the environment. In the presence paper allelopathic relationships were determined in three cereals - wheat (*Triticum aestivum* L.), barley (*Hordeum vulgare* L.), oat (*Avena sativa* L.) and vegetable crops - spinach (*Spinacia oleracea* L.), radish (*Raphanus sativus* L.), pepper (*Capsicum annum* L.). In addition to the percentage of germination, allelopathic potential was tested measuring root and stem length of tested plant species germinated either alone or in combination with others. The obtained results showed that seed germination and plant growth of cereals and vegetables are depended on the presence of other plants in all tested combinations. In this study has proven largely inhibitory allelopathic effect on germination and plant growth.

Keywords: allelopathy, cereals, vegetables.

INTRODUCTION

Allelopathy is chemical and ecological phenomenon which refers to the fact that competing organisms produce chemicals that inhibit the growth of members of their own or other species (EICHORN *et al.*, 2014).

Allelopathy is an interference mechanism in which live or dead plant materials release chemical substances, called allelochemicals, which inhibit or stimulate the associated plant growth (MAY and ASH, 1990). According to PUTNAM (1988) chemical with allelopathic potential are presented (commonly in conjugated form) in almost all plants and in many tissues - leaves, stems, flowers, fruits, seeds and roots. Allelopathy may refers to beneficial or harmful effects, by release of chemicals from plant parts by leaching, root exudation, volatilization, residue decomposition and other processes in both natural and agricultural systems (CHOU, 1990; SINGH *et al*., 2001). Suitable manipulation of the allelopathy towards improvement of crop productivity and environmental protection through eco-friendly control of weeds, pests, crop diseases and synthesis of novel agrochemicals based of natural produce have gained attention of the scientists engaged in allelopathy research (SANG-UK *et al.*,2005).

Allelochemicals can act on the stage of germination, growth and development of sensitive plants. The most common changes causing the inhibition or retardation of germination, coleoptile elongation, root and shoot development of seedling (NARWAL, 1994).

Chemical compounds formed in plants are usually by-products of basic chemical processes in the life of plants. A frequent cause of their increased secretion in plants is the stress (impact of diseases, pests, abiotic factors). Allelochemicals may arise and decommissioning of plants that secrete them. The most frequently mentioned allelopathy effects include reduced seed germination and reduced growth of the seed coast and seedling growth (DAIZY *et al*., 2001; FERGUSON and RATHINASABAPATHI, 2003).

Because of the extreme importance in recent years which is given to allelopathy in plants important for human consumption, and in order to contribute to a better understanding of allelopathic relationship between certain grains and vegetables, as well as to improving organic production, the aim of present paper was to determine the presence of allelopathic relations during germination of seeds and seedling growth of three cereals and three vegetable species.

MATERIALS AND METHODS

Plant material

Six cereal and vegetable species [wheat (*Triticum aestivum* L.), barley (*Hordeum vulgare* L.), oat (*Avena sativa* L.), spinach (*Spinacia oleracea* L.), radish (*Raphanus sativus* L.) and pepper (*Capsicum annum* L.)] were used in this study. These species were selected due to their agronomic importance. Cereal seeds are obtained from the Center of Small Grains in Kragujevac and vegetable seeds are bought in agricultural pharmacy. Seeds of wheat-variety *Toplica*, barley – variety *Jadran* and oat – variety *Lovćen* were collected from the harvest of 2012, while seeds of papper, spinach and radish were with a date of production from 2013.

At the start of experiments, seeds were surface disinfected in order to remove the epiphytic microflora, which may be specific to certain types of seeds. Disinfection is performed by soaking seeds in a 0.1% solution of bleach (sodium hypochlorite NaClO) for 5-7 minutes. After disinfection, the seeds were washed five times with distilled water. Surface sterilized seeds are inoculated into Petri dishes.

Experimental procedure

Seeds from each species were placed on filter paper in 10 cm Petri dishes by the following layout:

1. 30 seeds of wheat
2. 30 seeds of barley
3. 30 seeds of oat
4. 30 seeds of pepper
5. 30 seeds of spinach
6. 30 seeds of radish
7. 15 seeds of wheat + 15 seeds of barley
8. 15 seeds of wheat + 15 seeds of oat
9. 15 seeds of barley + 15 seeds of oat
10. 10 seeds of wheat + 10 seeds of barley + 10 seeds of oat
11. 15 seeds of pepper + 15 seeds of spinach
12. 15 seeds of pepper + 15 seeds of radish
13. 15 seeds of spinach + 15 seeds of radish
14. 10 seeds of pepper + 10 seeds of spinach + 10 seeds of radish.

The dishes were moistened with 5 ml of distilled water and kept in growth chamber at 16/8 h photoperiod and 22±1^{o}C. Distilled water was added to each Petri dish, during the experiment according to seeds water requests. The number of the germinated seeds and length of seedlings (root and hypocotyl elongation) was determined after seven days. Germination percentage (GP) is estimate of the viability of seeds. The equation to calculate germination percentage is:

$$GP = \frac{\text{seed germinated}}{\text{total seed number}} \times 100$$

Statistical analyzes

All data were statistically evaluated with SPSS software package. The data are presented as mean values ± S.E.M. (n = 3). For comparison between samples, data was analyzed by the Student's *t* – test. p values < 0.05 were considered statistically significant.

RESULTS AND DISCUSSION

Seed germination

In order to determine possible allelopathic effects,different combinations of seeds are placed in favorable conditions for germination. Obtained values, determined as percentage of germination, are presented in Figure 1 for cereal and Figure 2 for vegetable species, respectively.

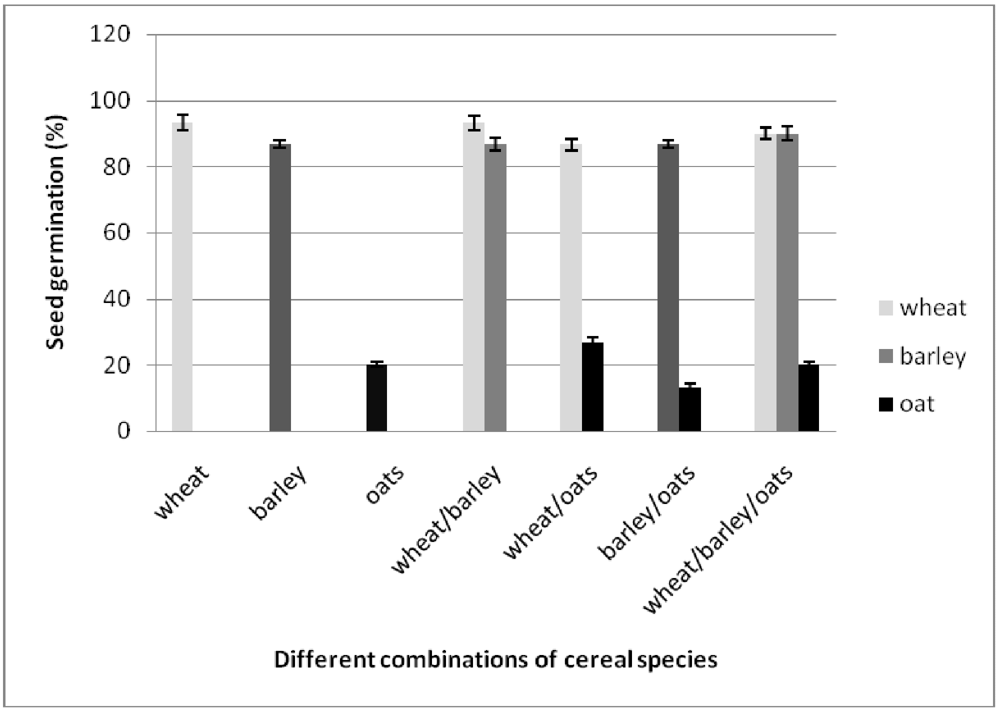

Figure 1. Allelopathic effect between selected cereals on seed germination.

On the basis of the obtained data, it is evident that there are allelopathic relations between the selected plant species. In the case of cereals, wheat seeds were inhibited to germinate in presence of oat (germination reduced 6.6%), as well as in triple combinations (wheat + barley + oat) were germination was reduced 3.33% (Figure 1). In the presence of barley, wheat seeds were germinated in the same percentage as in the absence of other seeds. Barley seeds have shown same percentage of germination alone, or in combination with wheat and oat (86.6%), while in triple combination is recorded slight increasing of germination (3.34%). Oat seeds germinated in great percentage in presence of wheat (increasing in germination for 6.66%), but in lower percentage in presence of barley seed.

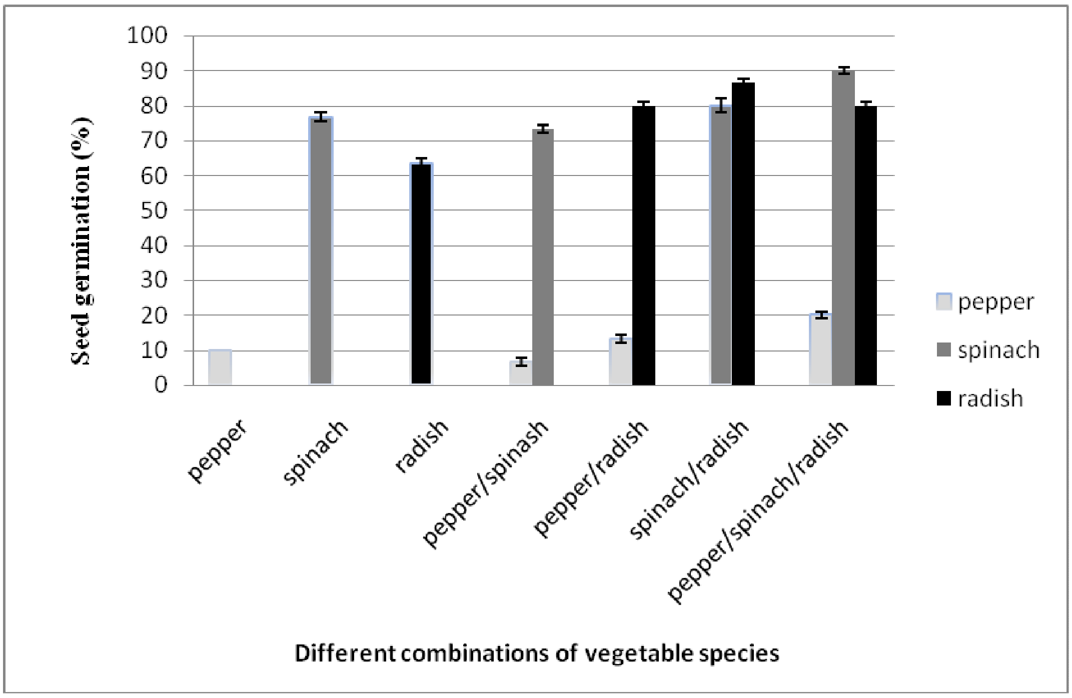

Figure 2. Allelopathic effect between selected vegetables on seed germination.

The seeds from vegetable species (pepper, spinach and radish) showed stronger allelopathic effects than the cereal seeds (Figure 2). Pepper seeds were stimulated to germinate in presence of radish seeds, especially in triple combination (germination increased for 10%), while in presence of spinach seeds, germination was inhibited. Spinach seeds germinated in greater percentage in presence of radish seeds (germination increased for 3.34%), and in the highest percentage in presence both spinach and radish (germination increased for 13.34%). In the case of radish seeds, germination percentage was higher in all combinations with other vegetables, with the highest values obtained in combination with spinach (germination increased for 23.33%).

Seedling growth (elongation of root and stem)

The inhibition in seedling growth was recorded in most of the tested seeds. Results for the root and stem length are presented in Table 1. The root elongation is very influenced by the presence of other cereal species - allelopathic effects are expressed in the combination of all three plants, particularly in the case of oats (root length was decreased by 80.67% compared with seeds alone), but in the other combinations was presented markedly inhibitory allelopathic effect. Stimulatory allelopathic effect was recorded only in the root elongation of barley in combination with wheat (for 5.25%).

When it comes to vegetable species, completely opposite effect was registered. The root elongation of spinach was very stimulated in the presence of the other two species, particularly in combination with radish where the root length was 89.2% more than in the case of radish alone. Unlike spinach, root elongation in pepper and radish were inhibited in combination with other species. Spinach had the strongest inhibitory effect on root elongation of pepper (root length was 53.7% less than in the case of pepper alone).

Allelopathic effects were confirmed in the case of stem elongation, as well as root elongation (Table 1). The investigated cereal species have shown negative correlation in stem elongation, where are no stimulatory effects recorded in any case. Elongation of oat stem was remarkably inhibited in the presence of other cereals. In all combinations obtained values were lower (80-90% longer than seeds alone). The young plants of barley and wheat were less sensitive on effects from other cereals; however, reduction in length was approximately 10%, except in combination barley + wheat, where the growth of both plants was inhibited by the presence of the other.

Analyzing the results obtained for stem elongation of vegetable species, it can be noticed the lack of growth of pepper stem in all combinations. Unlike peppers, at spinach seeds was noted an increase in the length of the stem in all combinations, especially in the presence of radish, when the measured values were 58% higher. The pepper and the spinach had inhibitory effect on radish, whit reduction of length of 10-20%.

Crop plants are known to release a diversity of allelochemicals into environment (phenolics or terpenoids) which generally represent secondary metabolites and provide plants defense strategies. However, some crops are less active in allelopathy because they are highly selected for physiological specialization of enhancing yields rather than developing endogenous chemicals for defense purposes (BATISH *et al*., 2001).

Upon release into crop environment, because of complex environmental conditions and microbial action, the nature and concentration of allelochemicals may change. Their action is often synergistic and their detrimental effects are dependent upon several abiotic and biotic factors (EINHELLING, 1996). Allelopathic activity of decomposing wheat and oat straw on some crop species has been reported by FAY *et al*. (1997) and DIAS (1991). In cereals such as wheat and barley a variety of allelochemicals have been identified including hydroxamic acids, cumarines, alkaloids, flavonoids and phenolic acids (WU *et al*., 2001b). The allelopathic activity of these cereals may arise from one or the combined action of a group of allelochemicals. Hydroxamic acids appear to be responsible for the allelopathic effect of wheat, maize and rye (SICKER *et al*., 2000; WU *et al*., 2001a; MACIAS *et al*., 2005;COPAJA *et al*., 2006) and indole alkaloids in allelopathic effect of barley (BRAVO *et al*., 2010).

Capsaicin is a compound of *Capsicum* plant and several reports have shown the potential allelopathic effects of *Capsicum* plants on germination and plant growth (CHO *et al*., 1992; GONZÁLEZ *et al*., 1997); however, the physiological mechanism behind the *Capsicum* allelopathy needs further elucidation (SIDDIQUI *et al*., 2005). KABIR *et al*. (2010) have demonstrated spinach sensitivity on allelochemicals while allelopathic potential of wild radish was demonstrated by NORSWORTHY (2003).

The results of this study demonstrated that selected cereals, as well as vegetables contain some phytochemicals capable to affect seed germination and seedling growth of the tested species. The latitude of effects seemed to be dependent on the combinations of seeds, etc. involved species in allelopathy. Stronger allelopathic effect between vegetables is connected with the presence of higher concentrations of allelochemicals.

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Table 1. Allelopathic effects of selected cereals and vegetables on growth parameters.

	Root lenght (cm)	Reduce (%)	Stem lenght (cm)	Reduce (%)
Cereal species				
wheat	4.86 ± 0.84		2.36 ± 0.55	
barley	8.18 ± 0.21		4.83 ± 0.04	
oat	2.38 ± 0.23		0.77 ± 0.19	
wheat/barley	3.65 ± 0.58/ 8.61 ± 0.91	24.78/ 5.25	1.66 ± 0.2/ 4.15 ± 0.3	29.67/ 14.07
wheat/oat	3.09 ± 0.18/ 1.42 ± 0.08	36.42/ 40.33	2.17 ± 0.59/0.14 ± 0.02	8.10/ 81.81*
barley/oat	7.23 ± 0.35/0.92 ± 0.04	11.61/ 61.34	4.35 ± 0.27/0.08 ± 0.02	9.93/ 89.61*
wheat/barley/oat	3.77 ± 0.35/7.34 ± 0.38/ 0.46 ± 0.05	22.4/ 10.26/ 80.67*	2.14 ± 0.27/4.37 ± 0.36/ 0.12 ± 0.01	9.32/ 9.52/ 84.41*
Vegetable species				
pepper	1.21 ± 0.06		0.56 ± 0.02	
spinach	2.78 ± 0.18		0.62 ± 0.03	
radish	7.47 ± 0.78		6.25 ± 0.36	
pepper/spinach	0.56 ± 0.15/ 4.58 ± 0.85	53.7*/ 64.7	0/0.74 ± 0.02	100/19.4
pepper/radish	1.12 ± 0.19/6.1 ± 0.35	7.4/ 18.3	0/5.63 ± 0.93	100/ 10
spinach/radish	5.26 ± 0.27/6.53 ± 0.33	89.2/ 12.5	0.98 ± 0.08/6.07 ± 0.35	58 /2.9
pepper/spinach/radish	1.1 ± 0.09/4.36 ± 0.45/4.47 ± 0.7	9.1/ 56.8/ 40.2*	0/0.90 ± 0.39/4.93 ± 0.87	45.52/ 21.1

a - values are expressed as means ± S.E.M.; $*p < 0.05$