Allelopathy - element of an overall strategy for weed control

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Abstract: The changes in weed associations under the influence of a number of factors require exploring new options for weed control. This article summarizes the main technologies in the experimental methods to studying the allelopathic relationships in the system weed - cultural plant. The problems associated with methodical productions are discussed. Summarized are the results of ours and foreign studies related to the practical application of weed control by using: allelopathic protector, suffocation, or rotary allelopathic accompanying plants, toxic extracts of allelopathic plants, mulching or burial of crop residues etc. In allelopathic relationships the total destruction of all weed species in agrophytocenoses cannot be expected. Allelopathy should be seen as an element of the overall strategy for weed control. Profound theoretical studies on the methods for practical application of allelopathy in modern agriculture are required.

Key words: allelopathy, weeds, alternative weed control.
Introduction

Weeds are a constant and widespread companion of the agricultural production, inflicting substantial damages to it that often exceed the total losses caused by diseases and pests (UNCED, 1992).

A major problem with weeds is their great diversity of species, high biological and ecological plasticity, which facilitates their rapid adaptation and dissemination (Bruce and Ghersa 1992, Stoimenova and Alexieva 2003, Stoimenova et al. 2003, Zimdahl 2004, Booth et al. 2010).

The world experience shows that the introduction of industrial technologies in agriculture is impossible without highly efficient and rational weed control (Fennimore and Doohan 2008). The changes in weed associations under the influence of a number of factors require the exploring of new possibilities for weed control (Legere et al. 1993, Streibig et al. 1993). The integrated control is recognized as the preferred strategy in the program of the United Nations Conference on Environment and Development (UNCED, 1992). The advantages are in its complexity, the more effective destruction of weeds and lower risk of environmental pollution. Weed control for resistant populations according to Powels and Brandt (1996) requires the use of chemical and non-chemical methods and approaches. Scientific researches on weeds in recent years have focused mainly on the development of highly effective systems for integrated control.

In this respect, the search for alternative means of weed control is of utmost importance. There is a growing interest to allelopathy in agriculture at present, as this phenomenon could provide perspective alternative methods of weed control and help reduce the application of synthetic herbicides (Putnam and Defrank 1983, Delabays 2005, Peneva 2005).

Results and Discussion

Although allelopathy is under study by ecologists, chemists, soil scientists, agronomists, herborists, biologists, plant physiologists and molecular biologists the complicated interrelations in the "weed - crop plant" system are not fully understood (Macias et al. 2003b). The interaction between weeds and crops is simultaneous and / or sequential with a direct or indirect effect of one plant species to another, through the synthesis of various chemical compounds - allelochemicals that are released into the environment having inhibiting and/or stimulating effect on seed germination and the initial development of a number of weeds and crops (Rice 1974, Hunt 1982, Brown and Morra 1995, Chung et al. 1997, Moer and Huang 1997, Reigosa et al. 1999, Agraval et al. 2002, Chaniago 2003, Fujii 2003, Hong et al. 2003, Hoque et al. 2003, Iqbal et al. 2003,


The most commonly used method to demonstrate allelopathic interference in plant communities or in the "weed - crop plant" system is to establish the stimulating or inhibitory effect of extracted plant materials on test – plants or to study the effect of plant residues and their application in quartz sand and/or in the soil, under laboratory conditions (Topalov 1986, Kaworu et al. 2001, Adetayo et al. 2005, Paneva 2006).

In a number of studies (Moyer and Huang 1997, Bruce et al. 1999, Gill et al. 2000, Turk and Tawaha 2002, Hoque et al. 2003, Adetayo et al. 2005, Vasilakoglou et al. 2006, Ashrafi et al. 2007, Koloren 2007, Brooks 2008, Kayode and Ayeni, 2009) in order to determine the allelopathic interference between weeds and crop plants, extracted plant material from fresh or dry weed biomass was used, while the concentrations of the extracts were significantly higher than those occurring in the agrophytocenoses in the case of dropping and decomposition of weed biomass in the soil. The extraction is carried out with different carriers - distilled water or organic solvents (Stoimenova, 1990, Kaworu et al. 2001, Burda and Oleszek, 2004, Elemar and Filho 2005, Maigahani et al. 2007).

The extraction of plant materials however, does not take into account the fact that most of the solvents used can increase the diffusion of allelochemicals, and the release of such chemicals that may well not be released under field conditions (Putnam et al. 1983).

When performing experiments under greenhouse conditions the addition of plant residues into the soil, can result in changes in the structure of the culture medium and/or its ability to retain water in comparison with the control variant (Qasem and Hill 1998). The changes in the structure of the medium may have influence on the forming of the root system of the test - plants. In this case the problem can be overcome by adding nutrient solutions after insertion of the plant material. This, on the one hand, can compensate for the exported quantities of
nutrients and mask the studied allelopathic effect on the other, as the allelopathic impact of weeds is more pronounced at lower fertility (Rice 1995). The inevitable variation in the results when performing allelopathic studies in laboratory conditions, is due to microorganisms that grow relatively well in the extracts and their activity may degrade or alter individual allelochemicals (Putman and De Frank 1983, Nair et al. 1990, Weidenhamer 1996) and to have an effect on the pH of the medium (Marinov-Serafimov and Dimitrova 2007). The problem in this case can be overcome by the addition of thymol in the preparation of extracts (Marinov-Serafimov et al. 2007a). The variation in the results of the laboratory tests is due to the suboptimal amounts of water and/or water extract required for seed germination in allelopathic studies in laboratory conditions (Wolk et al. 1989, Suriyong et al. 2002, Marinov-Serafimov et al. 2007b, Golubinova and Vasilievska 2008).

The allelopathic effect in the “weed - crop plant” system is studied via "stair step apparatus". This method, developed by Bell and Koeppe (1972) and modified by Lovett and Jokinen (1984), allows the addition of the filtrates from the root system of the weed - crop plant to the circulating solution. When using a "stair step apparatus" it is to be taken into account that the amount of the filtered nutrients from weeds may be less compared to those of the crops. Therefore, the filtrates may differ in content of nutrients, minerals concentration and allelochemicals.

According to Qasem and Hill (1998), Rice (1995), if the added nutrients to the "stair stepped apparatus" cannot compensate for the inhibitory effect on the development of the test plants, including weeds, this is an evidence of allelopathic interaction; whereas if the addition of nutrients to the "stair stepped apparatus" stimulates the development of weed species rather than crop plants, in this case the interaction between the test plants can be defined as a competition.

Over the last decades, the scientific research on determining the chemical structure of allelochemicals is expanding. Various allelochemicals have been identified - phenolic acids, coumarins, terpenoids, flavonoids, alkaloids, glycosides, glikozinolats, terpenes, phenols, derivatives of tropine with esterified hydroxyl group - O - acetyl tropine etc. (Rice 1995, Richard 1999), through which the allelopathic interference in the systems “crop plant – weed” and “weed-crop plant” as well as the incompatibility between crop plants is more accurately determined.

According to Blum (1996), the allelopathic interference between the plant species is a result of the combined action of the allelochemicals on the physiological processes of the acceptor plants. It has been established that the allelopathic interrelations in the plant communities are variable and are strongly limited by abiotic (temperature, precipitation, solar radiation, nutrients etc.) and biotic (diseases, pests etc.) environmental factors (Chou 1990, Alsaadawi 1992). Einhelling has found in his experimental work Einhelling (1996) that the
synthesis of allelochemicals in the plant organisms increases under the influence of stress factors, and thereby increases their allelopathic potential.

According to the summarized results of Rice (1995) and Ahmed (2004), some allelochemicals have been studied in detail and those that are more perspective are already being manufactured in laboratories or in semi-factory conditions and used in agricultural production with promising results. Therefore, the allelochemicals as natural products provide opportunities for weed control, and their practical application will not cause contamination to the agricultural produce and the environment, since this mechanism of biological interaction between two or more plant species could be used as an alternative method of regulating weed density, as well as helping to reduce the introduction of synthetic herbicides (Murphy 2001, Macías et al. 2003a, Macías et al. 2003b, Reigosa et al. 2006, Brooks 2008, Kruidhov 2008).

According to the studies of Olofsdotter et al. (1995), Hwu et al. (1999), allelopathy plays a key role in regulating the weed density in the artificial plant communities (agrophytocenoses) under field conditions and the possible correlation between the allelopathic potential and the physiological and morphological characteristics, which are important from an agronomic point of view.


The studies of Peters (1986), Dimitrova (1993), Liebman and Gallandt (1997), Dimitrova (2003) have established that the use of Avena sativa as cover crop is an effective biological tool for weed control in the seed production of Dactylis glomerata L. and Lolium perenne L. This is probably due to its ability to accumulate and release the allelochemicals "scopoletin" which inhibits the growth of weeds.

A good alternative, from an economic and environmental perspective, is the cultivation of alfalfa in mixed crops with perennial grasses including Dactylis glomerata L., Bromus inermis L., Agropyron desertorum Fisch. Schult. In this instance, the crop has higher weed suppressing capacity as compared to its independent growing, receiving three times lesser herbicide treatments. Weeds are at a manageable level, suppressed at the lowest level of the grass compositions, not reaching the phases of seed formation.
The mixed crops of the three types of cultures have good mutual tolerability and a higher productivity (22% to 35%). These studies show that the cultivation of alfalfa with some perennial grains in mixed crops and the use of oats as cover crop, in its capacity of biological mean of weed control, is an alternative to building a system of good plant protection practices (Dimitrova 1998; 2005). The perennial grass mixtures of *Medicago sativa* L. with some perennial cereals (*Dactylis glomerata* L., *Bromus inermis* L., *Agropyron desertorum* Fisch. Schult.) reduce the density and the formation of surface biomass of the perennial weeds (*Sorghum halepensis* L. Pers. and *Cirsium arvense* L.) as a result of which their invasion is limited (Dimitrova and Marinov-Serafimov 2007a; 2007b).

In the system of an environmentally friendly agriculture, the usage of certain cereals cover crops (*Hordeum sativum, Avena sativa, Secale cereale*) in a year of establishment of alfalfa crops could be a successful alternative to conventional technology.

The cover crops have the ability to suppress weeds, they allow for the more efficient use of land during the first year of alfalfa growing, when its rate of growing and development is slow. Under the certain conditions of the study in ascending order of aggressiveness the cover crops are as follows: *Hordeum sativum, Avena sativa, Secale cereale* (Baker and Smith, 1987, Dimitrova 2008). Biological incompatibility between *Medicago sativa* L. and *Festuca arundinacea* Scherb is observed. Similar results were also obtained in the experimental work of Marinov-Serafimov 2010, Marinov-Serafimov *et al.* 2010, according to whom the usage of oats as allelopathic-mulching culture in the soybean crop reduces the degree of weed infestation and the amount of accumulated dry biomass of late spring weeds, but has a pronounced negative effect on the soybean plants.

In modern agriculture the problem of weed control and the use of chemical substances for plant protection remains. The integrated system of weed control to the greatest extent complies with the principle of ecology and environmental protection (Olygarenko and Tkacheva 1999, Stoimenova *et al.* 2008). The use of allelopathy jointly with other plant potential (e.g. early vitality, leaf size, plant height and tillering) is an important step towards the further development of systems for sustainable crop production, relying less on the applications of herbicides Lemerle *et al.* (1996). In allelopathic relationships the total destruction all of weed species in the agrophytocenoses cannot be expected. Allelopathy should be seen as an element of an overall strategy for weed control. Extensive theoretical studies on the methods for practical application of allelopathy in modern agriculture are required.
Conclusion

The allelopathy plays a key role in regulating the weed density in the artificial plant communities (agrophytocenoses). Studies on allelopathy in the systems crops - weeds were studied, and allelopathy has become a reality in agricultural practice, using cover crops, green manures, intercropping, etc. However, allelopathy is a dynamic process that involves interaction between weeds and crop plants in the agrophytocenoses, under the influence of number of factors - climate conditions, soil type, temperature, precipitation, solar radiation, nutrients, previous crops, accompany crops, diseases, pests and many other factors are determinants of the occurrence of allelopathic interaction.

Future allelopathic research is desirable to focus: a) to determine the role of allelopathy in the agrophytocenoses; b) to identify allelopathic compounds in weed and culture plants; c) to develop new methods for isolating allelopathic chemicals in weed and culture plants; d) to determine the impact of allelopathic chemicals onto the initial development of a number of weeds and crops plants; e) to developing experimental methods and new techniques through which the distinction between allelopathy and competition in plant communities to be differentiated; f) to determine the allelopathic interference in the systems “crop plant D weed” and “weed-crop plant” as well as the incompatibility between crop plants; g) to developed the methods for practical application of allelopathy in modern agriculture.

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ALELOPATIJA – ELEMENT SVEUKUPNE STRATEGIJE ZA SUZBIJANJE KOROVA
- pregledni rad -

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Rezime

Ključne reči: alelopatija, korovi, alternativno suzbijanje korova.