AGROLOGY

Редакція

Хосе Мануель Ресіо Еспехо – доктор наук, професор, кафедра екології та фізіології рослин, Університет Кордови, Кордова, Іспанія

Хосе Ролдан-Каньяс – доктор наук, професор, кафедра гідротехніки, Університет Кордови, Іспанія

Hynek Roubík –PhD, As. Професор Чеського університету природничих наук у Празі, Прага, Чеська Республіка

Сон Михайло – к.б.н., старший науковий співробітник Інституту біології моря НАН України, Одеса, Україна

Світлана Ситник – д.т.н., проф., кафедра садово-паркового господарства, Дніпровський державний аграрно-економічний університет, Дніпро, Україна

Ілля Тромбіцький – PhD, старший науковий співробітник, виконавчий директор Міжнародної асоціації охоронців річок Eco-Tiras, Кишинів, Республіка Молдова

Iulian Voicea – PhD, старший науковий співробітник, керівник відділу випробувань, Інститут науково-дослідних розробок машин і установок, призначених для сільського господарства та харчової промисловості, Бухарест, Румунія

Джим Цзянь Ван – доктор філософії, професор екологічної хімії ґрунту Школи рослинництва, навколишнього середовища та ґрунтових наук Університету штату Луїзіана, Луїзіана, США.

Владислав Жежеря – к.б.н., старший науковий співробітник відділу гідрохімії прісних вод Інституту гідробіології НАН України, Київ, Україна

Олександр Жуков – д.т.н., проф., кафедра ботаніки і садово-паркового господарстваМелітопольського державного педагогічного університету імені Богдана Хмельницького, Мелітополь, Україна

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Effect of weeds on pea (*Pisum sativum*) seed germination

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S. E. Okrushko*, Y. M. Shkatyla*, D. V. Okrushko**
**Vinnytsia National Agrarian University, Vinnytsia, Ukraine*
***Khmelnytskyi National University, Khmelnytskyi, Ukraine*

Vinnytsia National Agrarian University, Vinnytsia City, 21008, Ukraine. Tel.: +38-097-96-11-947. E-mail: svitlanaokruzko@gmail.com

Khmelnytskyi National University, Khmelnytskyi, 29018, Ukraine. Tel.: +38-099-62-35-11. E-mail: okrdima@gmail.com

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Abstract. Segetal vegetation should be controlled both during crop growing season and after harvesting. The reason is that undesirable vegetation accumulates a significant mass, one that will later become a threat to the following crop in crop rotation. Mixtures of substances of biogenic origin, called allopathic, are constantly changing subject to abiotic factors and environmental conditions. Therefore, their effects on organisms are characterized by significant variability. According to the biotesting results, we found that allopathically active substances of all experimental weed species had a negative effect on pea seed germination. In the control variant, all seeds germinated in 4 days, but in some experimental variants 2–3% of the seeds were in the phase of swelling. Water extracts from different species and parts of weeds had significant inhibitory effect on the germination of pea seeds and further growth. The water-soluble extracts from the underground organs of perennial weeds such as *Elytrigia repens* L. and *Cirsium arvense* L. were particularly strong, leading to 58.2% and 53.1% reduction in the length of the embryonic root. Water-soluble extracts from the leaves of these weeds had slightly lower effects on pea germination, and the lags in root growth were 33.5% and 31.4%, respectively. Extracts from weed stems also inhibited pea germination and had an intermediate effect between the effect of water-soluble extracts from the underground part and leaf blades. The effect of extracts from roots of annual weeds on the length of the germinal root ranged 36.6% in common stork's-bill (*Erodium cicutarium* L.) to 13.9% in chickweed (*Stellaria media* L.). The allopathic effect of the substances from the leaves of chickweed (*Stellaria media* L.) and potato weed (*Galinsoga parviflora* Cav.) had the lowest effect on the growth of pea root. The lag of the indicator in the control was 7.2% and 12.9% for the variants.

Keywords: germination energy; alelopathy; pea seeds; weeds; phytotoxicity.

Introduction

Peas are a popular legume crop with high yield potential (Didur et al., 2021; Mazur et al., 2021; Mostovenko et al., 2022). Weeds are a serious threat to crop production as they interfere with the crop growth and development and result in significant crop losses (Kakhki et al., 2022; Khamare et al., 2022). Early adaptative nature, rapid growth, and fast spread of weeds make them able to inhibit growth of desired crops and reduce the final estimated yields. (Morderer et al., 2018; Shah et al., 2022; Zareen et al., 2022). Weeds that invade crops contest for-environmental resources alongside releasing certain chemicals into the soil, thereby lowering yield potential (Lalbiakdika et al., 2022). Therefore, more and more attention has been paid to the study of chemical interactions between plants in recent decades. The allopathic effect is an object of interest for physiologists, herbologists, and ecologists. Macro effects of crop productivity have already been studied, so it is reasonable to focus on microeffects. Allelopathy is transfer of chemicals from one plant to another. Allelopathy is a larger area of ecological and physiological processes. According to modern research, depending on different concentrations, allelochemicals had positive or negative effects on plants. Allelochemicals are also known as secondary metabolites, compounds like phenol, alkaloids, steroids etc. (Shah et al., 2022). Every plant produces certain substances over the course of its life. Thus, it affects neighboring species, i.e., it forms an environment according to its needs (Gorelov, 2012; Tsytsiura, 2022). The composition of allelechemicals changes over time (Lalbiakdika et al., 2022).

Allelochemicals also depend on the plant parts, stages, and application method. The efficacy of allelochemicals is dose-dependent; different concentrations determine the extent of suppression of weed (Afrin et al., 2016; Fozia et al., 2020; Janusauskaite, 2023; Sahrir et al., 2023). Competitive relations between crops and weeds begin when seeds germinate Studies of the conditions of seed germination in crops have shown an inhibitory or stimulating effect of allelochemicals from weeds (Kadioglu et al., 2004; Janusauskaite, 2023). Germination of some crop species was delayed when the crop seeds were surrounded by weed seeds on filter paper (Gressel & Holm, 2006). Germination inhibitors, which inhibit the germination of seeds, spores, and other plant reproductive material, are abundant in the plant kingdom and include phenols, cyanides, alkaloids, essential oils, amino acids, etc. These inhibitors can be classified as germination destructors and germination retarders depending on whether they harm the morphology, structure, and physiology of the seed (Chenyin et al., 2023).

Germination destructors are mostly harmful substances that can injure seeds. For instance, after treating mustard seed with extract from sunflower leaf, the seed's H_2O_2 level significantly increased, ROS accumulation increased, and the cell membrane was damaged, ultimately leading to the seed's death (Oracz et al., 2007).

Today, the achievements of allopathy make it possible to study chemical interactions between plants, both in natural phytocenoses and in the growing of crops (Harbovska et al., 2020). This interaction consists in inhibition or stimulation of seed germination, growth, and development of plants of the same species and neighboring species of this phytocenosis. Allelopathic activity is an important feature of species competition and survival in a particular area (Levchyk et al., 2021).

Crop plants also have a certain impact on weed growth. Their life and postmortem extracts have various effects depending on their chemical composition and concentration. Analysis of the allelopathic powder ща pea seed at the applied rates revealed presence of phenolic compounds and flavonoids (El-Rokiek et al., 2019). The role of intercropping and cover crops should be studied to develop allopathy as a science. Their lifetime or postmortem extracts can have an impact on later crops in the crop rotation or on weeds. Cover crops can reduce soil moisture while actively growing but conserve soil moisture after termination, resulting in time-dependent effects. Similarly, decaying legume cover crops can release nitrogen into the soil, potentially aiding weeds. (Sias et al., 2021). Allopathic substances from weeds can have inhibitory effects on the seed germination of other weed species. Therefore, they can be used as bioherbicides (Kostina-Bednarz et al., 2023) or for improving the phytosanitary state of agrophytocenoses (Erez & Battal, 2022). It should be noted that different varieties of crop plants may have a different reaction to phytotoxic weed extracts. Cultivation of varieties tolerant to allelopathic compounds is a promising addition to the current strategy of weed control, especially in organic production (Georgieva et al., 2021).

Material and methods

In the Laboratory of Plant Physiology of the Vinnytsia National Agrarian University, 10 pea seeds and 3 mL of aqueous extract of 1:10 concentration from different organs of the most common weed species were placed in Petri dishes according to the experimental scheme. The germination variant with distilled water in the same amount served as the control. One mL of the corresponding extract or water was added every 2 days. The temperature in the thermostat with the experimental samples was maintained at 20 ºC. Peas, like all legumes, absorb 110–120% of their own weight during germination. For the experiment, the most harmful and widespread species of pea agrophytocenoses in Vinnytsia Oblast were selected. Perenial weeds were field bindweed, field thistle, and couch grass. Representatives of subgroups of annual weed species, i.e., spring ephemeral and winter ephemeral were as follows: chickweed (*Stellaria media* L.), which produces 3–4 generations per growing season and is present in all crops, withstanding shading; early spring weeds were lamb's quarters (*Chenopodium album* L.), cleavers (*Galium aparine* L.); late spring weeds were potato weed (*Galinsoga parviflora* Cav.), yellow foxtail (*Setaria glauca* L), and redroot amaranth (*Amaranthus retroflexus* L). Overwintering weeds included Canadian horseweed (*Erigeron canadensis* L.), shepherd's purse (*Capsella bursa pastoris* L.), and common stork's-bill (*Erodium cicutarium* L.). Underground and aboveground (stems and leaves separately) weed parts were taken for the experiment. Samples of rhizomes, stems, and leaves were collected from the rhizomatous weed. Samples of root sprouts were collected from root-sprouting weeds in addition to stems and leaves. Annual weeds were also separated into root systems, stems, and leaves.

The research program included an assessment of pea seed germination resulting from the action of aqueous extracts from 12 weeds. The aqueous solutions were prepared in the concentration of 1:10, because our previous studies have shown its highest allopathic effect. Dry segetal plants were used for this purpose. The green mass of the studied weed species had been collected in summer during the flowering phase of plants and was immediately dried to an air-dry state. The leaf mass of the weeds was crushed into 5-mm particles and the stems and roots into 3–4 mm particles before the experiment was set up. We placed 10 g of raw materials for each species in conical flat-bottomed flasks with 100 mL of warm distilled water per flask to ensure the quality of extraction of physiologically active substances from weeds. The content of each flask was stirred for one minute to ensure better contact of the plant mass with water. Then, the flasks were heated in a water bath at 60 °C for 15 minutes. The extract was cooled for 45 minutes according to the guidelines for the preparation of infusions. The aqueous solutions were filtered through paper filters in 24 hours (Lalbiakdika et al., 2022; Tsytsiura, 2022).

Indicators of germination energy of pea seeds were determined in 4 days after the experiment. The statistical analysis of the data was carried out by calculating the arithmetic mean (x) ± standard deviation (SD) for each variant.

Results

A seed is a living organism that regularly undergoes biochemical processes. The germination energy of seeds is a measure of the uniformity of normal seedling growth over time in crops, and the viability of seeds which can impact the germination rate. Seeds with high germination energy produce early and uniform germination. The period of seed germination is characterized by intense reactions in seeds. These reactions may vary in rates depending on quality of the aqueous solution and its chemical composition. As a result, the growth processes and the formation of seedling organs are affected (Gressel & Holm, 2006; Chenyin et al., 2023).

Plants and soil microbiota produce biologically active substances throughout their lives. Usually, their role is protection from pests, decomposion of hard-to-reach compounds, and suppression of competitors. Other plant species absorbing such substances integrate them into their metabolism. Biologically active substances have a stimulating, neutral, or inhibitory effect, depending on the level of concentration, chemical composition, and other factors (Afrin et al., 2016; Fozia et al., 2020; Janusauskaite, 2023; Sahrir et al., 2023).

Mostly, weeds are considered to have a negative allopathic effect on crops (Gressel & Holm, 2006; Okrushko, 2022).

The soils are saturated with physiologically active water-soluble substances from the weed residues from the previous crop (Erez & Battal, 2022). A person places pea seeds in this environment while sowing. They transfer from a dormant state to the activation of vital processes, i.e., they absorb them with soil moisture while germinating. Allopathic compounds react with the substances in the seeds, affecting the germination rate (Oracz et al., 2007).

When a germinal root appears, it will absorb both water and substances soluble in it. Their chemical composition will determine the growth rate of this new plant (Sobko et al., 2023).

Substances such as alkaloids, glycosides, tannins, organic acids, saponins, and essential oils shape the weeds' effect on neighboring plants in the phytocoenosis (Chenyin et al., 2023). Over the course of evolution, these complex chemical compounds have been formed by different species for their own protection from pests, resilience to unfavorable weather conditions, and for interaction with other species (Sahrir et al., 2023).

The chemical composition of the underground part of most species of experimental weeds includes tannins, glycosides, and alkaloids. The leaves of annual weeds contain vitamins and essential oils and leaves of perennial weeds contain organic acids (Kadioglu et al., 2004; Chenyin et al., 2023). Thus, the hypothesis of our research was that water-soluble extracts of aboveground and underground organs of segetal vegetation have different effects of on germination of pea seeds (Georgieva et al., 2021).

Changes in metabolic processes and their intensity begin to occur in plants after allopathically active substances are absorbed by the root system. These changes are eventually reflected in the physiological level and external plant condition (Fozia et al., 2020; Janusauskaite, 2023). Agrarians noted growth and developmental lag of crops in weedy areas (Georgieva et al., 2021).

Alkaloids, glycosides, and tannins in plants have evolved to protect them from damage by pathogens, so it will be difficult for the soil microbiota to break down plant residues of weed species to inorganic elements. It means that the soil will contain weed particles for much longer than usual. They will affect the seed germination conditions of crops for a long period of time. Essential oils also have the ability to inhibit the processes during seed germination. Weed residues in the soil provide a gradual supply of physiologically active substances to the crop bed (Afrin et al., 2016).

We evaluated the energy of pea seed germination during the experiment. The number of germinated seeds was counted on the 4th day after the beginning of the experiment. The effect of secondary phytometabolites of weeds was assessed by the length of the crop embryonic root (Afrin et al., 2016). Seeds have only begun to germinate in Petri dishes containing water extracts from the underground parts of couch grass (by 58.2%), field thistle (by 53.1%), field bindweed (by 43.3%), and common stork's-bill (by 36.6%). Seeds germinated faster in the variants with water extracts from the weed leaves. Allelopathic substances from the root system of other weed species also had an inhibitory effect on the processes of pea seed germination (Table 1). The data in Table 1 demonstrate the pea seed reaction to allelechemicals. As an acceptor, pea reacted with changes in growth parameters showing that allelopathic compounds of aqueous extracts from the experimental weed species inhibit the growth of the germinal root (Sobko et al., 2023).

The data on the effects of stem extracts from the experimental weeds hold an intermediate position. However, there was observed tendency for perennial weeds to have a higher impact on pea growth compared to annual weeds (Lalbiakdika et al., 2022).

Table 1
Effect of aqueous extracts of weed parts on the length of pea germinal root, cm (x ± SE, n = 10, duration of experiment – 4 days)

Weed species	Length of pea germinal root, cm		
	aqueous extract from the weed underground part	aqueous extract from the weed stem	aqueous extract from the weed leaves
Control (distilled water)	1.94 ± 0.12	1.94 ± 0.12	1.94 ± 0.12
Elytrigia repens L.	0.81 ± 0.03*	1.11 ± 0.05*	1.29 ± 0.04*
Convolvulus arvensis L.	1.10 ± 0.04*	1.25 ± 0.05*	1.38 ± 0.04*
Cirsium arvense L.	0.91 ± 0.04*	1.16 ± 0.04*	1.33 ± 0.04*
Stellaria media L.	1.67 ± 0.09	1.76 ± 0.10	1.80 ± 0.10
Chenopodium album L.	1.46 ± 0.07	1.55 ± 0.07	1.67 ± 0.06
Galium aparine L.	1.28 ± 0.05	1.38 ± 0.06	1.42 ± 0.05
Galinsoga parviflora Cav.	1.52 ± 0.07	1.60 ± 0.08	1.69 ± 0.10
Setaria glauca L.	1.39 ± 0.05	1.43 ± 0.07	1.58 ± 0.07
Amaranthus retroflexus L.	1.31 ± 0.05	1.42 ± 0.07	1.54 ± 0.06
Erigeron canadensis L.	1.36 ± 0.05	1.46 ± 0.08	1.56 ± 0.07
Capsella bursa pastoris L.	1.28 ± 0.05	1.39 ± 0.07	1.50 ± 0.06
Erodium cicutarium L.	1.23 ± 0.05*	1.30 ± 0.06*	1.40 ± 0.05*

The phytotoxic effect of water-soluble extracts from different parts of weeds inhibited the pea seed germination. In the experimental variants, the germination energy was lower than in the control. The pea seed germination was most inhibited under the effect of extracts from underground parts of perennial weeds. They contain significant amounts of alkaloids and tannins. These compounds are characterized by the highest allopathic activity.

The lowest effect on pea germination energy was observed under the influence of water-soluble extracts from the root system of chickweed (*Stellaria media* L.) – 13.9% and potato weed (*Galinsoga parviflora* Cav.) – 21.6%, which is explained by their chemical composition, namely the lack of glycosides and low tannins.

Discussion

When pea seeds germinate, the bud and root absorb several times more water than such parts as the endosperm and cotyledons (Khatami & Ahmadinia, 2018). The transformation of reserve substances in the seed is carried out with the help of enzymes. Alos, they are activated by phytohormones with water (Aghamir et al., 2016). Phytotoxic substances released from weeds can inhibit the growth of the embryonic root. Therefore, on weedy fields, pea seedlings do not sprout above the soil surface at the same time. Crop seedlings are negatively affected by allopathic compounds and may be thinned out (Shah et al., 2022). The rates of crop formation above the soil surface and their optimal density are the basis for high initial competition with weeds (Okrushko, 2022).

Weeds, classified as perennials, contain a large supply of nutrients in their underground organs. They form a significant vegetative mass that is a threat to the normal growth of crops throughout the growing season and after their death and decomposition.

For spring crops, the impact of miasmic changes will depend on soil moisture, temperature, conditions for microorganisms, the depth of weed residues in the soil and their chemical composition. Allelopathically active substances tend to impair the capabilities of the edaphic environment (Janusauskaite, 2023). Symptoms and mechanisms of allelopathy require detailed consideration regarding the threat level (Khamare et al., 2022).

However, not all substances present in weeds are harmful to crops. Plant growth stimulants contain vitamins, phytohormones, amino acids, trace elements, and other substances. Their effect on plants depends on the level of concentration, duration of exposure, and species characteristics of the crop. In addition, biologically active substances released by weeds into the soil can react with other compounds. Then, their effect on germination and crop growth will change (Fozia et al., 2020; Janusauskaite, 2023).

The effect of allelopathic substances from weed leaves on peas was weaker than the effect of underground plant parts in variants with perennial weeds. Obviously, this is because the chemical composition of the leaves of most weed species includes organic acids and vitamins having a positive effect on seed germination and they mitigate the inhibition of crop growth by phytotoxic compounds (Georgieva et al., 2021; Zareen et al., 2022).

High concentrations of weed aqueous extracts (1:10) are found only in weedy fields and in places of close contact with crop seeds. Our previous studies have proven the stimulating role of low concentrations (1:1000) of aqueous extracts from weeds on the seed germination of crops (Okrushko, 2022). In the field, the moisture content of the soil and microorganisms that decompose organic matter and thus change the concentration of the extracts should also be considered. However, our laboratory studies demonstrated the inhibitory effect of all parts of the tested weed species.

Allelopathy is a complex ecological phenomenon that has a multifaceted effect. Therefore, it must be taken into account when planning crop rotation, filling it with intermediate crops, and in developing measures to regulate the weeds number and harmfulness (Kadioglu et al., 2004). A specific allopathic level is established on each field, which will depend on the vital products of all living components of the agroecosystem (Khamare et al., 2022; Shah et al., 2022).

Conclusions

Extracts from various parts of the studied weed species in the concentration of 1:10 reduced the energy of pea seed germination. The highest phytotoxicity was recorded for extracts from rhizomes of couch grass (*Elytrigia repens* L.) and root sprouts of field thistle (*Cirsium arvense* L.) and field bindweed (*Convolvulus arvensis* L.). The difference from the control variant was 58.2%, 53.1%, and 43.3%, respectively. The allopathic substances in the roots of annual weeds showed less inhibition of crop growth: the lag from the control ranged 36.6% in the variant with common stork's-bill (*Erodium cicutarium* L.) to 13.9% in the variant with chickweed (*Stellaria media* L.). Phytotoxicity of the substances from the leaves of medium chickweed (*Stellaria media* L.), potato weed (*Galinsoga parviflora* Cav.) and lamb's quarters (*Chenopodium album* L.) had the least effect on the growth of pea embryonic root. The lag from the control was 7.2%, 12.9% and 13.9%. The research results suggest that the phytotoxic effect of water-soluble extracts from weed parts should be ranked in descending order of phytotoxicity: underground organs (rhizome and root sprouts of perennial species; root system of annual species) > stem > leaves.

The authors have declared they have no competing interests.

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