UDC 581.524:635.716
DOI 10.56407/2313-092X/2022-26(4)-1

Ukrainian Black Sea Region Agrarian Science
Vol. 26, No. 4

Allelopathic activity of water-soluble and volatile secretions of *Crocus sativus* L. (Iridaceae) flowers in the Northern Black Sea region

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Abstract. The introduction of new crops to agrophytocenoses, to which *Crocus sativus* belongs, should be preceded by research into their ecological safety and place in crop rotation. When harvesting raw materials for obtaining saffron, up to 90% of by-products remain, which during decomposition can have a negative effect on the soil and indirectly on the plants that are grown after saffron. Therefore, the aim of the research was to study the allelopathic activity of water-soluble and volatile secretions of *Crocus sativus* flowers in the agroclimatic conditions of the Northern Black Sea region. The research was conducted in 2021 according to the generally accepted methodology, freshly picked flowers were used, from which individual elements were extracted, and flowers of different stages of flowering. The following research methods were used: field, laboratory, computational and statistical. The results of the research established that the water-soluble secretions of *Crocus sativus* flowers and their parts stimulate the energy of germination and inhibit the growth of one-day seedlings of *Lactuca sativum*. Water-soluble secretions of *Crocus sativus* flowers have a negative allelopathic effect. The index of allelopathic activity under the action of water-soluble secretions of flowers ranges from -0.26 for a flower with all parts to -0.01 for petals. The highest stimulating effect of volatile secretions on the growth of *Lactuca sativum* roots and the allelopathic activity index value is characteristic of the flower that has just bloomed and the stamens, and the lowest - for the pistils. The allelopathic activity of the volatile secretions of *Crocus sativus* flower parts is set at the level of 6.4 (pistil) and 28.8% (stamens). Substances that inhibit the germination of *Lactuca sativum* roots are found mainly in the stamens. It was determined that the volatile secretions of *Crocus sativus* flower parts reduce the energy

Article's History:
Received: 25.06.2022
Revised: 27.08.2022
Accepted: 29.11.2022

Suggested Citation:
Mykolaichuk, V., Panfilova, A., Korkhova, M., & Drobitko, A. (2022). Allelopathic activity of water-soluble and volatile secretions of *Crocus sativus* L. (Iridaceae) flowers in the Northern Black Sea region. *Ukrainian Black Sea Region Agrarian Science*, 26(4), 9-18.

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of seed germination of the test plant. The practical value of the research is that the results of the research can be used when determining the place of the crop in crop rotation and the duration of its cultivation in one field

Keywords: allelopathy; flowering; flower elements; inhibition; stimulation

INTRODUCTION

In connection with climate change in Ukraine, by the end of the century, an increase in the number of days with high temperatures, more than 100 tropical nights and up to 135 summer days per year, and a decrease in precipitation in the summer period are predicted for the Southern Steppe of Ukraine (World Bank..., 2021). This will lead to a decrease in the yield of certain crops (barley, corn, sunflower). For the stability of the country's agricultural production, it is important to study and attract new crops that would be adapted to rising temperatures in summer, increased aridity in the south and east of Ukraine, and other consequences of climate change. One of these crops is saffron (*Crocus sativus* L.), which belongs to the Crocus genus of the Crocoideae subfamily of the Iridaceae family (Cardone *et al*., 2020).

Crocus sativus L. is a herbaceous perennial monocotyledonous plant that reaches a height of 20-25 cm. Underground, it forms a tuber with a diameter of 2.5-3.0 cm, covered with mesh and fibrous scales and dark brown fibers from destroyed old scales. The leaves are linear 15-20 cm long and 2-3 mm wide with a longitudinal white stripe. Plants bloom for 7-10 days in October-November. The flowers are large, light purple with a strong aroma (Cardone *et al*., 2020). *Crocus sativus* is a sterile triploid (2n=3x=24), so it does not form fruits and seeds (Cardone *et al*., 2021). Cultivated mainly in Iran, Afghanistan, Morocco, India, Spain, Greece and Italy (Cardone *et al*., 2019). Today, Iran supplies about 90% of raw materials to the world market (Kheirabadi *et al*., 2020).

C. sativus was introduced into culture around 3000-2300 BC., does not occur in the wild (Nemati *et al*., 2020). Saffron is the most expensive spice, which is called "red gold", has beneficial properties for human health. Saffron is grown on different types of well-drained soils with a pH range from neutral to slightly alkaline (Ghanbari *et al*., 2019). According to the results of research (Mzabri *et al*., 2022), the productivity of the receptacles is affected by illumination: the highest productivity is observed at 30% shading. The culture is resistant to low and high temperatures and withstands their range from -22 to 40°C (Siney *et al*., 2020). According to O.O. Mykhaylenko (2019), to collect 1 kg of dry saffron, it is necessary to collect receptacles from about 167,000 flowers.

During the last time, *Crocus sativus* culture arouses the interest of Ukrainian farmers, but some elements of its agrotechnics of cultivation remain poorly studied. That is why the aim of the research was to establish the peculiarities of the allocation of generative organs of *Crocus sativus* in the climatic and soil conditions of the Northern Black Sea region in order to establish the safety of growing a new crop for the agrophytocenoses of Southern Ukraine. The peculiarity of the cultivation and processing of plant raw materials of the crop is that when harvesting *Crocus sativus*, other elements of flowers (petals, stamens) or blossomed flowers remain as a by-product, which can be found in the fields or disposed of (Mykolaichuk *et al*., 2021). Therefore, it became necessary to determine the allelopathic activity of water-soluble and volatile secretions of elements of flowers and flowers of different flowering periods.

LITERATURE REVIEW

In Ukraine, commercial plantings of *C. sativus* for food purposes were established in 2015 in the Kherson region (Mykhaylenko, 2019). After that, cultivation of this crop was also started in other regions.

Recently, the demand for saffron has been increasing, and this is due to the discovery of biologically active substances in various plant organs that have pharmacological properties (Jadouali *et al*., 2019; Chen *et al*., 2020). Extracts and pure substances from *C. sativus* have been shown to have antioxidant, antiparasitic, hypolipidemic, hypotensive, immunomodulatory, antimicrobial, antitumor, and antidepressant effects. The range of actions is determined by the composition of biologically active substances contained in the capsules (Chen *et al*., 2020; Soukrat *et al*., 2019). Among the volatile aromatic substances, monoterpene aldehydes (isophorone, safranal and their isomers), as well as non-volatile compounds of various nature, are the main ones. Among which: crocetin, crocin, lycopene, zeaxanthin, α, β, γ-carotene; p-coumaric, vanillic, 3-hydroxy-4-methoxybenzoic acids, pyrogallol, gallic acid, mangi-crocin, emodin, 2-hydroxyemodin, safranal, β-pinene, 1,8-cineole, picrocrocin; crocuses; 3-hydroxy-β-ionone, sugars, calcium, potassium, phosphorus, etc. The composition of saffron essential oil includes pinnen, prineol, fatty oils, B vitamins, flavonoids, sugars, gums, etc. Freshly collected flowers of *C. sativus* contain the glycoside protocrocin, which, when dried, splits into crocin and picrocrocin. According to M.A. Shajari & P.R. Moghaddam (2022), crocin predominates in the receptacles, (Ghanbari *et al*., 2019) found mainly flavonoids in the petals and leaves. As a result of research (Ghanbari *et al*., 2019) it was established that the volatile organic compounds of the *C. sativus* flower, in addition to safranal, include 11 compounds, including acetic acid, 2(5H)-furanone, isobutanal, a fragment of biogenic aldehyde, 4-ketoisoferon, acetaldehyde, butyrolactone.

During the last decade, intensive studies of the biochemical composition of *C. sativus* organs and their allelopathic activity have been conducted. It is known that *C. sativus* can grow in one place for up to 12 years, but after 5-6 years the plantations thin out, the yield of the receptacles decreases (Ghanbari *et al*., 2019). Releases of *C. sativus* have an inhibitory effect on seedlings and tested plants. The main volatile substances of saffron that have an inhibitory effect are safranal, D-limonene and isophorone (Mardani *et al*., 2019). Safranal (2,6,6-trimethyl-1,3-cyclohexadiene-1-carboxaldehyde), which is the main component of saffron volatile compounds, is known for its inhibitory effect on cell division (Mardani *et al*., 2019). The stimulating effect of the water extract of the petals on the growth of eggplant seedlings was revealed (Khoulati *et al*., 2020). The prospect of using saffron by-products has been studied by a number of scientists (Lahmass *et al*., 2018; Shadmehri *et al*., 2019). Saffron leaf and tuber extract has an allelopathic effect on germination and shoot and root length of Datura stramonium and depends on saffron phenological phases (Barkhordari *et al*., 2018).

During the production of saffron, for each kilogram of spices produced, about 53 kg of perianth leaves remain, which is up to 90% of the by-products that end up in waste (Menghini *et al*., 2018). Scientific studies have proven that some water-soluble metabolites of perianth leaves have a positive effect on plant growth, influencing the activity of photosynthesis (Lahmass *et al*., 2018).

A study of the biochemical composition of saffron grown in Ukraine showed that in terms of the content of the main compounds (crocin, picrocrocin, saffron), the raw material meets the international standards of ISO 3632 and belongs to category I (Mykhaylenko, 2019). Research on the allelopathic activity of saffron flowers in Ukraine was conducted on the basis of Mykolaiv National Agrarian University. The stimulating effect of water-soluble secretions of individual parts of *C. sativus* flowers of different concentrations on the germination energy of *L. sativum* seeds was established. The highest indicators of allelopathic activity of water-soluble secretions of flowers were found at a concentration of 0.02% (Mykolaichuk *et al*., 2021).

MATERIALS AND METHODS

To establish the allelopathic activity of water-soluble and volatile secretions of *C. sativus* flower parts of flowers of different flowering periods, laboratory studies were carried out in the laboratories of the department of plant breeding and horticulture of the Mykolaiv National Agrarian University in 2021. *C. sativus* was grown in accordance with recommendations, the plot was planted in 2019 on at the base of the branch of the department with coordinates 46°58′31″ north latitude 31°59′37″ east longitude, at an altitude of 42 m above sea level. The material for research was collected in the third decade of October 2021.

To study the allelopathic activity of flower parts, freshly picked flowers were used, from which the generative organs (stamens and pistil) were removed in accordance with the recommendations for the collection of saffron raw materials.

Determination of the allelopathic activity of water-soluble and volatile secretions of individual parts of the flower of *C. sativus*, the energy of germination and growth of the roots of seedlings of the biotester plant was carried out by the bioassay method of A.M. Grodzinsky (1991). The test object was *L. sativum* seeds, which were sown in sterile Petri dishes on filter paper moistened with distilled water and placed for 24 hours in a thermostat at a temperature of +23-24°C. Seedlings of *L. sativum* whose root length reaches 2 mm are considered suitable for research.

To detect the allelopathic activity of the generative organs of *C. sativus* flowers, fertile and sterile elements were separated (variants of the experiment: "petals", "flower", "petals+stamens", "petals+pistil"). The mass of stamens was 0.025±0.003 g, pistils – 0.035±0.002 g, petals – 0.376±0.013, and flowers – 0.435±0.016 g. They were placed in distilled water in the ratio of 1 g of the studied material per 100 ml (0.01%) of water and kept for 24 hours at a temperature of +23-24°C in a thermostat (Fig. 1). The solution was filtered through filter paper No. 2. After a day, 100 seedlings of *L. sativum* were transferred to filter paper in Petri dishes and 3-4 ml of filtrate was added.

Figure 1. *Setting up an experiment with water-soluble secretions of C. sativus flowers*
Source: *developed by the authors*

To determine the allelopathic activity of volatile secretions of the flower and its separate parts, they were removed from the flower and placed on a plastic rise in a Petri dish. At the same time, the flower and its parts did not touch the surface of the filter paper, which was moistened with 3-4 ml of distilled water and where 100 seedlings of *L. sativum* were transferred (Fig. 2). Petri dishes were placed for 24 hours in a thermostat at a temperature of +23-24°C. The experiment was carried out in five repetitions.

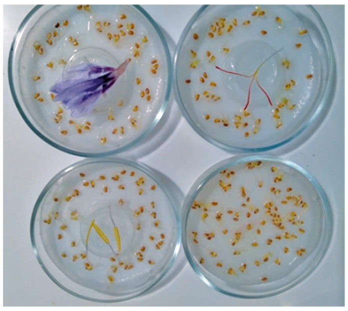

***Figure 2**. Setting up an experiment with volatile secretions of C. sativus flower parts*
***Source**: developed by the authors*

To determine the allelopathic activity of volatile secretions of flowers of different ages, buds, a blooming flower, and a faded flower that bloomed 1 day ago were used. The experiment was carried out in five repetitions (Fig. 3).

***Figure 3**. Setting up an experiment with volatile secretions of C. sativus flowers of different ages (a – wilted, b – blossomed flower, c – faded flower)*
***Source**: developed by the authors*

During the day, the growth length of the roots of the seedlings was measured with the help of a caliper. To determine the energy of germination, the percentage of *L. sativum* seeds with developed roots was calculated after one day of exposure to volatile extracts of *C. sativus*.

Germination energy was determined as the ratio between the number of germinated seeds and their total number in percentage. The statistical analysis of the obtained results (the length of the roots of the seedlings of the biotester plant) was performed using Microsoft Excel and Statistica 7.0 programs. The average, minimum and maximum length of the roots were determined. The degree of trait variability was determined according to the method of S.A. Mamaev (1972): very low at <7%, low 8-12%, medium 13-20%, elevated 21-30%, high 31-40% and very high >40%. Graphs were constructed using Excel 7.0 software.

Allelopathic activity was determined according to the method of A.M. Grodzinsky (1991) as the ratio between the length of the roots in the experiment to the length of the roots of *L. sativum* in the control (on distilled water), expressed as a percentage.

The allelopathic activity index (RI) was used to quantify the allelopathic effect, which was determined by the formula: $RI=1-C/T$,

where C are control indicators, T are indicators obtained in the experiment. If $RI>0$, then there is a stimulation effect, $RI<0$ indicates inhibition.

RESULTS AND DISCUSSION

As a result of the research, it was established that the water-soluble and volatile secretions of *C. sativus* flowers are allelopathically active. Taking into account that during the collection of *C. sativus* receptacles, other morphological elements of flowers (petals, stamens) remain as a by-product, it became necessary to determine the allelopathic activity of water-soluble secretions of flowers and their elements, which in the future can be washed by water into the soil and affect other types of plants and crops in crop rotation. Considering the results of research by O. Mykhaylenko (2019) regarding the quality of saffron plant raw materials obtained in Ukraine, it meets international standards ISO 3632 and belongs to category 1, the content of safranal, crocin and picrocrocin does not differ from the standards.

According to the research results, it was found that the water-soluble secretions of *C. sativus* flowers inhibit the growth of *L. sativum* root length, compared to the control (Table 1).

Among the variants of the experiment, the largest indicators of root length were registered in the "petal" variant, and the smallest – in the "flower". Statistically significant differences are typical for the variants "flower" with control, "petals+pistil" and "petals" ($p<0.05$). The coefficients of variation in the length of roots of *L. sativum* range from high ("petals+pistil") (38.9%) to very high (>40%), which is characteristic of other variants.

Water-soluble secretions of the flower of *C. sativus* and their parts do not affect the energy of seed germination of the biotestor plant. The germination energy is slightly lower in the "petals+pistil" variant compared to other variants.

Table 1. *The effect of water-soluble secretions of the flower of C. sativus on root growth (mm) and germination energy (%) of L. sativum (N=100)*

Option	M±m	min-max	Cv, %	The energy of germination	RI
Control (distilled water)	8.18±0.49	2.0-18.0	52.5	100	-
Flower	6.48±0.36	2.0-13.0	49.5	100	-0.26
Petals + pistil	7.75±0.37	2.0-18.0	38.9	99	-0.06
Petals + stamens	7.29±0.41	2.0-15.0	45.8	100	-0.12
Petals	8.10±0.42	2.0-15.0	45.7	100	-0.01

Source: *developed by the authors*

The index of allelopathic activity indicates that the water-soluble secretions of *C. sativus* flowers have negative indicators ranging from -0.26 for the flower with all elements to -0.01 for the petals. It was established that the allelopathic activity of the water-soluble secretions of the *C. sativus* flower and its elements is in the range from -21.4% ("flower") to -1.0%, which is typical for the petals (Fig. 4). Comparison of allelopathic activity indicators with the index of allelopathic activity of the elements of the *C. sativus* flower confirms that, with different approaches to their determination, which we used, the water-soluble secretions of the flower and its individual elements are allelopathically active. Analyzing the obtained results, it can be assumed that the substances that cause inhibition of the growth of the roots of *L. sativum* seedlings are found mainly in the stamens.

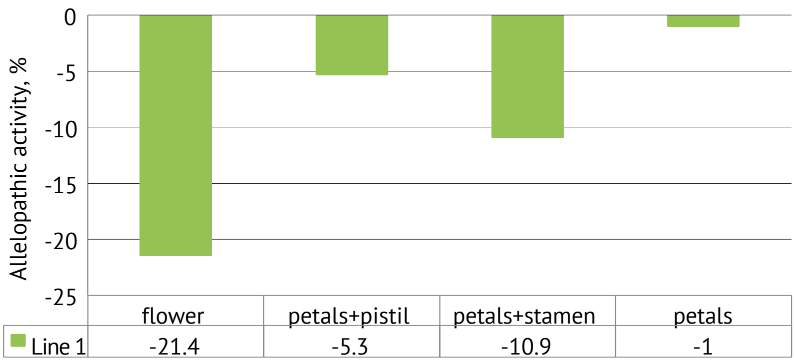

Figure 4. *Allelopathic activity of water-soluble extracts of C. sativus flower, %*
Source*: developed by the authors*

According to the research results, it was established that the volatile secretions of individual parts of the flower of *C. sativus* have a stimulating effect, and their allelopathic activity ranges from 6.4% for the volatile secretions of the pistil to 28.8% for the volatile secretions of the stamens compared to the control.

Volatile secretions of individual parts of the *C. sativus* flower have a slight stimulating effect on the growth of *L. sativum* roots compared to the control. The length of seedling roots exceeded the control in all variants, but the highest values were observed under the influence of volatile secretions of stamens and flowers (28 and 37%, respectively). The smallest increase in length is characteristic under the influence of volatile secretions of the pistil (6%). Statistically significant differences are characteristic of the "stamen" and "flower" options with the control ($p<0.05$), there is no significant difference between the other options. The length of the roots in all variants has high variability, it is characterized by a coefficient of variation that is >40%.

Volatile secretions of individual parts negatively affect the germination energy of *L. sativum* seeds, which is in the range from 57.6% (stamens) to 72.2% (pistil) and is less than the control by 42.4 and 27.8%, respectively (Table 2). The results obtained by us coincide with the results (Mardani *et al.*, 2019) regarding the inhibitory effect of volatile extracts of *C. sativus* on the growth of root length of seedlings.

Table 2. *Effect of volatile secretions of flower parts of C. sativus on root growth (mm) and germination energy (%) of L. sativum (N=100)*

Option	M±m	min-max	Cv, %	The energy of germination	RI
Control (distilled water)	5.66±0.31	2,0-13.0	42.7	100	-
Stamens	7.29±0.67	2,0-15.0	53.5	57.6	0.22
Pistil	6.02±0.54	2.0-14.0	58.5	72.2	0.06
Petals	6.51±0.54	2.0-13.0	51.3	66.1	0.13
Flower	7.75±0.37	2.0-18.0	58.0	62.3	0.24

Source: *developed by the authors*

The index of allelopathic activity of volatile secretions of individual parts of the flower indicates that they have a stimulating effect and range from 0.06 (pistil) to 0.24 (flower).

According to the results of research, it was established that the volatile secretions of individual parts of the flower of *C. sativus* plants grown in the Northern Black Sea region have a stimulating effect, which ranges from insignificant – 6.4% (pistil) to medium – 37.0% (flower) (Fig. 5). The low allelopathic activity of the volatile secretions of the uterus is due to the fact that it contains the largest amount of physiologically active substances (safranal, D-limonene and isophorone (Mardani *et al.*, 2019; Shadmehri *et al.*, 2019), which have an inhibitory effect.

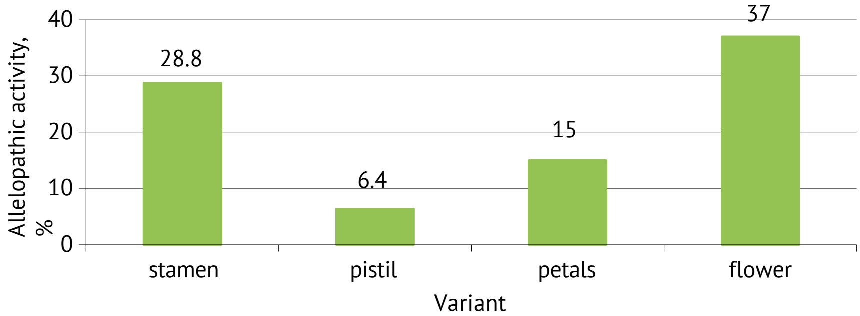

Figure 5. *Allelopathic activity of volatile secretions of flower parts C. sativus, %*
Source*: developed by the authors*

The analysis of the effect of volatile secretions of flowers at different stages of flowering (from the bud to the flower that has bloomed) shows their stimulating effect on the growth of the roots of biotester plants, compared to the control. The increase in seedling root length ranged from 46.2% (open flower) to 65.9% (bud) compared to the control. Statistically significant differences are characteristic of the options "blossomed flower" and "bloomed flower" with control and "bud" with "bloomed flower" ($p<0.05$), there is no significant difference between other options. The volatile secretions of the *C. sativus* flower bud have a greater stimulating effect on root growth, compared to the control and other variants (Table 3). The coefficients of variation of root length for all variants are very high (>40 %).

Table 3. *Effect of volatile secretions of C. sativus flowers at different stages of flowering on root growth (mm) and germination energy (%) of L. sativum (N=100)*

Option	M±m	min-max	Cv, %	The energy of germination	RI
Control	5.64±0.43	2.0-20.0	81.3	100	-
Bud	6.43±0.36	2.0-19.0	55.1	58.8	0.33
A blossomed flower	7.75±0.37	2.0-18.0	58.0	62.3	0.24
A bloomed flower	7.29±0.41	2.0-17.0	56.4	57.0	0.27

Source: *developed by the authors*

Volatile secretions of *C. sativus* flowers of different stages of flowering negatively affect the energy of seed germination, which was lower than the control and ranged from 43% (bloomed flower) to 36.7% (bloomed flower) compared to the control (Table 3). The results obtained coincide with the results of research by H. Mardani (2019), regarding the inhibitory effect of volatile secretions of *C. sativus* flowers on certain processes in *L. sativum*. At the same time, the index of allelopathic activity of volatile secretions of flowers, which was determined by the increase in the length of the roots of the seedlings of the test plant, has positive indicators and ranges from 0.24 (blooming flower) to 0.33 (bud).

Volatile secretions of flowers of different degrees of flowering are allelopathically active, their effect is stimulating, and the values are in the range from 30.7% (bloomed flower) to 48.2% (bud), compared to the control (Fig. 6).

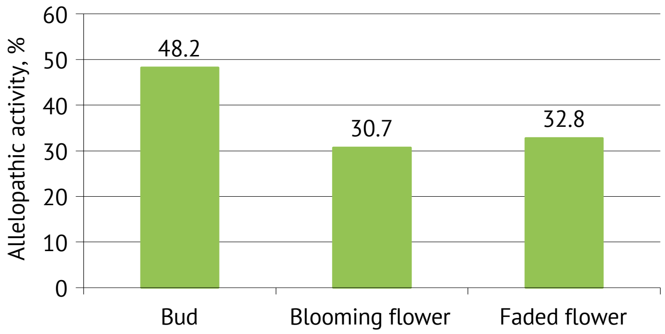

***Figure 6**. Allelopathic activity of volatile secretions of C. sativus flowers at different stages of flowering, %*
***Source**: developed by the authors*

It is known that the main factors causing the allelopathic effect are the content of volatile substances in the flowers of *C. sativus*, among which safronal and other compounds are isolated. We assume that the content of these compounds is the lowest in flower buds, compared to blooming and faded flowers, therefore the indicators of allelopathic activity of volatile secretions of buds prevail over the control and other variants of the experiment.

Research results confirm the presence of biologically active substances in *C. sativus* flowers that have allelopathic properties, this is also confirmed by the research of other scientists (Mardani *et al*., 2019).

According to the results of research (Khoulati *et al*., 2020) it was established that the water-soluble secretions of the perianth of *C. sativus* plants grown in Morocco, the activity of water-soluble secretions also depends on the concentration of biologically active substances: at a dilution of 2 mg/ml, it stimulates plant height and chlorophyll content, but reduces the antioxidant property and content of malondialdehyde. When the concentration is increased to 3 mg/ml, the opposite effect is observed: inhibition of plant growth and an increase in the concentration of ascorbic acid. Based on this, the authors suggest taking these phenomena into account and using aqueous extracts at a dilution of 2 mg/ml of perianth (petals) as biostimulants. The water-soluble secretions of the petals of *C. sativus*, which were grown in the Northern Black Sea region of Ukraine, when diluted to 1 g/100 ml of distilled water, have a slight inhibitory effect on the seedlings of biotester plants. At the same time, they do not affect the energy of seed germination of the biotestor plant. This indicator is slightly lower in the "petals+pistil" variant compared to other variants. The obtained results coincide with the results of studies (Abbasi-Alikamar *et al*., 2007), which established that the petals of *C. sativus* flowers do not significantly affect the germination of plants.

According to (Serrano-Díaz *et al*., 2013), inhibition or stimulation of plant growth by water-soluble secretions of parts of the flower of *C. sativus* depends on the content of various compounds (amino acids, fibers and necessary minerals) that stimulate growth.

Research (Feizi *et al*., 2018) showed that the allelopathic activity of *C. sativus* plants is determined not only by the concentration of solutions, but also by plant organs (flower, bulb, leaves). The research results showed that the leaves and bulbs of *C. sativus* had an inhibitory effect on the germination and vital activity indicators of safflower and sugar beet seeds. Increasing the concentration of the extract reduced all germination characteristics, including the percentage and rate of germination, hypocotyl, seedling and root length, seedling and root weight, as well as seed viability index of the studied crops. Therefore, there is a possibility of allelopathic action of all plant organs of *C. sativus* on plants cultivated in crop rotation with it.

(Barkhordari *et al*., 2018) determined that aqueous and alcoholic extracts of flavonoids of various organs of saffron, regardless of the phase of plant growth and development, have allelopathic potential, influencing the germination characteristics of *Datura stramonium* seeds. Thus, saffron concentration and phenological stage had a significant effect on *Datura stramonium* germination percentage, but the main effect of organ type on this trait was insignificant. The aqueous extract of saffron had no significant effect on the germination of *Datura stramonium* at the stage of formation of new bulbs at a concentration of 2 g/l, but at a concentration of 4 g it significantly reduced seed germination.

Research results (Kheirabadi *et al*., 2020) established that *C. sativus* bulbs also have substances that cause allelopathic effects. Thus, the allelopathic activity of bulb bulb residues and soil water extracts on the germination of lettuce seeds showed that the highest inhibition was associated with bulb extract. The minimum germination percentage (82.0% and 86.5%) was obtained in extracts with a concentration of 75% and 100%, respectively. The average time of germination of lettuce seeds was significantly increased with respect to different concentrations of aqueous bulb extract. The combination of activated carbon and tuber bulb residues reduced the average germination time. However, there were no significant differences in the average seed germination time. The length of the root and hypocotyl did not show significant fluctuations according to different concentrations of the solutions. The allelopathic effect of saffron tuber residues caused growth imbalance between the lettuce shoot and roots. According to biochemical analyses, the use of adsorbents increased the content of carotenoids and the chlorophyll index of lettuce by 23.33% and 5.25%, respectively.

The obtained results indicate that in the conditions of the Northern Black Sea region of Ukraine, water-soluble and volatile secretions of *C. sativus* plants have allelopathic properties. Further research should establish the influence of the introductionr's secretions on crops common in the agrocenoses of Ukraine, the possibility of reducing the negative impact on them, and the study of the phenomenon of soil fatigue on perennial plantations of *C. sativus*.

CONCLUSIONS

Research on the allelopathic activity of water-soluble and volatile secretions of flowers of *C. sativus* plants grown in the agroclimatic conditions of the Northern Black Sea region of Ukraine was conducted for the first time, so the results obtained are original. It was established that the water-soluble secretions of flowers and their elements do not have a negative effect on the germination energy of *L. sativum* seeds, but it was found that they inhibit the growth of the roots of seedlings of the biotester plant. The highest inhibition rates are characteristic of water-soluble secretions of a flower with all morphological elements, the lowest – for petals (-21.4 and -1.0%, respectively).

Volatile secretions of *C. sativus* flowers inhibit the energy of germination of *L. sativum* seeds by 42.4 and 27.8% compared to the control in variants of exposure to stamen and pistil secretions. However, the volatile secretions of individual elements of the flower have a stimulating effect on the growth of roots, which are in the range of 6-28.8%. The index of allelopathic activity of volatile secretions of individual parts of the flower indicates their stimulating effect and is in the range of 0.06-0.24.

Water-soluble secretions of flowers have a stimulating effect on the germination energy of *L. sativum* seedlings, but an inhibitory effect on the growth of the roots of test plants and have a negative allelopathic effect and index of allelopathic activity.

It was established that the volatile secretions of *C. sativus* flowers of different stages of flowering inhibit the energy of seed germination, the blossomed flower and bud have a greater inhibitory effect compared to the control, the indicators of which are 43.0 and 36.7% less than the control. However, they stimulate the growth of seedling roots compared to the control from 46.2% (open flower) to 65.9% (bud). The index of allelopathic activity ranges from 0.24 (blossomed flower) to 0.33 (bud).

Water-soluble and volatile extracts of *C. sativus* flowers grown in the Northern Black Sea region are allelopathically active. Their effect is stimulating and inhibiting on the germination energy and root growth of *L. sativum* seedlings.

Further studies of the allelopathic activity of *C. sativus* plants should establish their influence on common field crops of Southern Ukraine, primarily winter wheat.

ACKNOWLEDGMENTS

None.

CONFLICT OF INTEREST

The authors declare that the study was conducted in the absence of any commercial or financial relationships that could be interpreted as a potential conflict of interest.

REFERENCES

[1] Abbasi-Alikamar, R., Eskandari, M., Tatari, M., & Ahmadi, M.M. (2007). The effect of water extract of saffron's petals on germination and seedling growth of wheat (cultivar: Azar2). *Acta Hortic*, 739, 209-214. doi: 10.17660/ActaHortic.2007.739.26.

[2] Barkhordari, K., Sorooshzadeh, A., & Mokhtassi, B.A. (2018). Allelopathic effect of extraction solution of leaves and corms of saffron (Crocus sativus) in phenological stages on seed germination of jimson weed (Datura stramonium). *Journal of Biotechnology*, 9(2), 233-239. Retrieved from http://biot.modares.ac.ir/article-22-15749-en.html.

[3] Cardone, L., Castronuovo, D., Perniola, M., Cicco, N., & Candido, V. (2019). Evaluation of corm origin and climatic conditions on saffron (Crocus sativus L.) yield and quality. *Journal of the Science of Food and Agriculture*, 99(13), 5858-5869. doi: 10.1002/jsfa.9860.

[4] Cardone, L., Castronuovo, D., Perniola, M., Cicco, N., & Candido, V. (2020). Safron (Crocus sativus L.), the king of spices: An overview. *Scientia Horticulturae*, 272, 109560. doi: 10.1016/j.scienta.2020.109560.

[5] Cardone, L., Castronuovo, D., Perniola, M., Cicco, N., Molina, R.V., Renau-Morata, B., Nebauer, S.G., & Candido, V. (2021). Crocus sativus L. Ecotypes from Mediterranean countries: Phenological, morpho-productive, qualitative and genetic traits. *Agronomy*, 11(3), 551. doi: 10.3390/agronomy11030551.

[6] Cardone, L., Castronuovo, D., Perniola, M., Serano, L., Cicco, N., & Candido, V. (2020). The influence of soil physical and chemical properties on saffron (Crocus sativus L.) growth, yield and quality. *Agronomy*, 10(8), 1154. doi: 10.3390/agronomy10081154.
[7] Chen, D., Xing, B., Yi, H., Li, Y., Zheng, B., Wang, Y., & Shao, Q. (2020). Effects of different drying methods on appearance, microstructure, bioactive compounds and aroma compounds of safron (Crocus sativus L.). *LWT*, 120, 1-7. doi: 10.1016/j.lwt.2019.108913.
[8] Feizi, H., Salari, A., & Gharari, F. (2018). Study of the allelopathic effect of saffron (Crocus sativus L.) organs' aqueous extract on the seed germination and seedling growth of sugar beet and safflower at different concentrations. *Journal of Medicinal and Spice Plants*, 22(4), 156-161. Retrieved from https://www.researchgate.net/publication/330501300.
[9] Ghanbari, J., Khajoei-Nejad, G., & van Ruth, S.M. (2019). Effect of saffron (Crocus sativus L.) corm provenance on its agro-morphological traits and bioactive compounds. *Scientia Horticulturae*, 256, 108605. doi: 10.1016/j.scienta.2019.108605.
[10] Grodzinsky, A.M. (1991). *Alelopathy of plants and soil fatigue*. Kyiv: Naukova Dumka.
[11] Jadouali, S.M., Atifi, H., Mamouni, R., Majourhat, K., Bouzoubaâ, Z., Laknifli, A., & Faouzi, A. (2019). Chemical characterization and antioxidant compounds of flower parts of Moroccan Crocus sativus L. *Journal of the Saudi Society of Agricultural Sciences*, 18(4), 476-480. doi: 10.1016/j.jssas.2018.03.007.
[12] Kheirabadi, M., Azizi, M., Taghizadeh, S.F., & Fujii, Y. (2020). Recent advances in saffron soil remediation: Activated carbon and zeolites effects on allelopathic potential. *Plants*, 9(12), 1714. doi: 10.3390/plants9121714.
[13] Khoulati, A., Ouahhoud, S., Mamri, S., Meziane, M., Choukri, M., Asehraou, A., & Saalaoui, E. (2020). Valorization of Moroccan Crocus sativus L. by-products: Foliar spraying of aqueous tepal extract stimulates growth and confers antioxidant properties in Eggplant Seedling under Greenhouse Conditions. *BioMed Research International*, 8812157. doi: 10.1155/2020/8812157.
[14] Lahmass, I., Ouahhoud, S., Elmansuri, M., Sabouni, A., Elyoubi, M., Benabbas, R., Choukri, M., & Saalaoui, E. (2018). Determination of antioxidant properties of six by-products of Crocus sativus L. (saffron) plant products. *Waste and Biomass Valorization*, 9(8), 1349-1357. doi: 10.1007/s12649-017-9851-y.
[15] Mamaev S.A. (1972). *Forms of intraspecific variability of woody plants*. Kyiv: Science.
[16] Mardani, H., Maninang, J., Appiah, K.S., Oikawa, Y., Azizi, M., & Fujii, Y. (2019). Evaluation of biological response of lettuce (Lactuca sativa L.) and weeds to safranal allelochemical of saffron (Crocus sativus L) by using static exposure method. *Molecules*, 24, 1788-1082. doi: 10.3390/molecules24091788.
[17] Menghini, L., Leporini, L., Vecchiotti, G., & Locatelli, M. (2018). Crocus sativus L. stigmas and byproducts: Qualitative fingerprint, antioxidant potentials and enzyme inhibitory activities. *Food Research International*, 109, 91-98. doi: 10.1016/j.foodres.2018.04.028.
[18] Mykhailenko, O.O. (2019). Investigation of the biological active compounds of Crocus sativus L stigmas (saffron) from Ukraine. *Pharmaceutical Journal*, 74(6), 70-76. doi: 10.32352/0367-3057.6.19.08.
[19] Mykolaichuk, V.G., Korolyova, O.V., & Korkhova, M.M. (2021). Allelopathic activity of water-soluble secretions of Crocus sativus L. (Iridaceae) flowers when introduced in the Northern Black Sea region. *Ukrainian Journal of Medicine, Biology and Sport*, 6(3), 340-346. doi: 10.26693/jmbs06.03.340.
[20] Mzabri, I., Rimani, M., Charif, K., Kouddane, N., & Berrichi, A. (2022). Effect of shade on agro-morphological parameters and weed flora of saffron (Crocus sativus L.) cultivation in the Semiarid Zone of Eastern Morocco. *Scientific World Journal*, 15, 9954404. doi: 10.1155/2022/9954404.
[21] Nemati, Z., Harpke, D., Gemicioglu, A., Kerndorff, H., & Blattner, F.R. (2019). Saffron (Crocus sativus L) is an autotriploid that evolved in Attica (Greece) from wild Crocus cartwrightianus. *Molecular Phylogenetics and Evolution*, 136, 14-20. doi: 10.1016/j.ympev.2019.03.022.
[22] Serrano-Díaz, J., Sánchez, A.M., Martínez-Tomé, M., Winterhalter, P., & Alonso, G.L. (2013). A contribution to nutritional studies on Crocus sativus flowers and their value as food. *Journal of Food Composition and Analysis*, 31(1), 101-108. doi: 10.1016/j.jfca.2013.03.009.
[23] Shadmehri, A.A., Namvar, F., Miri, H., Yaghmaei, P., & Moghaddam, M.N. (2019). Cytotoxicity, antioxidant and antibacterial activities of Crocus sativus L petal extract. *International Journal of Research in Applied and Basic Medical Sciences*, 5(1), 69-76. Retrieved from https://ijrabms.umsu.ac.ir/article-1-82-en.pdf.
[24] Shajari, M.A., & Moghaddam, P.R. (2022). Are the apocarotenoids content and colorimetric traits of saffron (*Crocus sativus* L.) affected by some post harvesting operations? *Journal of Stored Products Research*, 97, 101967. doi: 10.1016/j.jspr.2022.101967.
[25] Shajari, M.A., & Moghaddam, P.R. (2022). Are the apocarotenoids content and colorimetric traits of saffron (*Crocus sativus* L.) affected by some post harvesting operations? *Journal of Stored Products Research*, 97, 101967. doi: 10.1016/j.jspr.2022.101967.
[26] Siney, S.M.A., Jolgeh, A.A., Behroozeh, M., & Soltani, M. (2020). Evaluation of planting date and corm weight effects on flower, stigma and daughter corms characters of saffron (Crocus sativus L.) under South Kerman climatic conditions. *Journal of Saffron Agronomy & Technology*, 8(1), 3-18. doi: 10.22048/JSAT.2019.168153.1334.

[27] World Bank. (2021). Ukraine: Building climate resilience in agriculture and forestry. Retrieved from https://openknowledge.worldbank.org/handle/10986/36939

Алелопатична активність водорозчинних та летких виділень квіток *Crocus sativus* L. (Iridaceae) в Північному Причорномор'ї

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Анотація. Введенню в агрофітоценози нових культур, до яких належить *Crocus sativus*, повинні передувати дослідження їх екологічної безпечності та місця в сівозміні. При збиранні сировини для отримання шафрану залишається до 90% побічних продуктів, які при розкладанні можуть негативно впливати на ґрунт і опосередковано на рослини, які вирощуються після шафрану. Тому метою досліджень було вивчення алелопатичної активності водорозчинних та летких виділень квіток *Crocus sativus* в агрокліматичних умовах Північного Причорномор'я. Дослідження проводили у 2021 р. за загальноприйнятою методикою, використовували свіжозібрані квітки, з яких вилучали окремі елементи, та квітки різного ступеню квітування. Використовували такі методи досліджень: польовий, лабораторний, розрахунковий та статистичний. Результатами досліджень встановлено, що водорозчинні виділення квіток *Crocus sativus* та їх частин стимулюють енергію проростання та пригнічують приріст однодобових проростків *Lactuca sativum*. Водорозчинні виділення квіток *Crocus sativu*s мають негативну алелопатичну дію. Індекс алелопатичної активності за дії водорозчинних виділень квіток знаходиться в межах від -0,26 для квітки з усіма частинами до -0,01 для пелюсток. Найвища стимулююча дія летких виділень на приріст коренів *Lactuca sativum* та значення індексу алелопатичної активності характерна для квітки, яка щойно розквітла, та тичинок, а найменша – для маточок. Алелопатична активність летких виділень частин квітки *Crocus sativus* встановлена на рівні 6,4 (маточка) та 28,8% (тичинки). Речовини, які інгібують проростання коренів *Lactuca sativum* знаходяться переважно в тичинках. Визначено, що леткі виділення частин квітки *Crocus sativus* знижують енергію проростання насіння тест-рослини. Практична цінність досліджень, полягає в тому, що результати досліджень можуть бути використані під час визначення місця культури в сівозміні і тривалості вирощування її на одному полі

Ключові слова: алелопатія; квітування; елементи квітки; інгібування; стимулювання