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The Influence of Aqueous Extracts from *Stellaria media* L. on the Growth of *Zea mays* L. Cultivars

Peiman ZANDI[1], Katarzyna MOŻDŻEŃ[2]*, Beata BARABASZ-KRASNY[2], Joanna PUŁA[3], Alina STACHURSKA-SWAKOŃ[4], Yaosheng WANG[1]

[1]*Chinese Academy of Agricultural Science, Institute of Environment and Sustainable Development in Agriculture, Beijing 100081, P. R. China; z_rice_b@yahoo.com; wangyaosheng@caas.cn*
[2]*Pedagogical University of Cracow, Institute of Biology, Podchorążych 2 St., 30-084 Kraków, Poland; katarzyna.mozdzen@up.krakow.pl (*corresponding author); beata.barabasz-krasny@up.krakow.pl*
[3]*University of Agriculture, Faculty of Agriculture and Economics, Mickiewicza 21 Ave, 31-120 Kraków, Poland; rrpula@cyf-edu.kr.pl*
[4]*Jagiellonian University, Institute of Botany, Gronostajowa 3, 30-387 Kraków, Poland; alina.stachurska-swakon@uj.edu.pl*

Abstract

Plants introduce chemicals into the environment that can be toxic, both for themselves and for other species. Weed infestation of crops is a competition for environmental resources, but at the same time is a source of chemical substances released into the soil, often reducing yield potential. The paper attempts to investigate the allelopathic interaction of aquatic extracts from dry shoots of chickweed *Stellaria media* L. on germination and development of maize *Zea mays* L. seedlings of 'San', 'Kidemos' and 'DKC 3441' cultivars. Along with the increase in the concentration of allelopathic substances, a decrease in the germination activity of all tested maize cultivars was observed. Germination percentage as like percentage of control was the highest for seeds germinating on substrates with 1% chickweed extracts and the lowest for seeds watered with 5% extracts. Biometric measurements of seedlings showed that the most sensitive cultivar of maize was 'DKC 3441', and the resistant cultivar 'San'. The relative water content was the highest for seedlings grown on the 5% extracts. Significant differences in the amount of fresh and dry masses of maize seedlings were demonstrated at the highest concentrations of extracts compared to the control. A significant increase in electrolyte leakage compared to the control sample was found in the 'Kidemos' cultivar. The lowest differences in the destabilization of the ionic transport through cell membranes for the 'DKC 3441' cultivar were demonstrated.

Keywords: allelopathy; fresh and dry mass; germination; seedlings morphology

Introduction

In agriculture, weeds are perceived as a threat to optimal growth and development of crop plants (Czuba and Wróbel, 1983; Duer, 1996; Marshall *et al.*, 2003; Gniazdowska, 2007). Their presence in crops is influenced by, among other types of crops (field: cereal, root crop, garden: vegetable or decorative), its intensity, forecrop, protective measures, type of habitat and associated soil type (Domaradzki and Rola, 2002). Traditional cultivation, crop rotation, direct sowing, shallowing of the plowing and their replacement by field disking or plough-less cultivation, increase weed biodiversity in crops (Radecki and Opic, 1995; Weber *et al.*, 1999; Lipa, 2005; Ciesielska and Rzeźnicki, 2007). Improperly performed or simplified agrotechnical activities may contribute to biological changes in the environmental properties of, for example, disturbances of soil processes and dependence between fauna, flora and microflora. Consequently, they may create more favorable conditions for the development of various weed communities (Kieć and Wieczorek, 2009).

Currently, however, two distinct phenomena can be observed in the crops and accompanying weed communities: the reduction of weed biodiversity and the expansion of the few species (Trzcińska-Tacik and Stachurska-Swakoń, 2010; Stachurska-Swakoń and Trzcińska-Tacik, 2014). In the first case, the reduction of weed biodiversity results from the abandonment of traditional methods of cultivation or the abandonment of the cultivation of some useful plant species. On the other hand, the expansion of some weeds is the result of their acquisition of resistance to applied herbicides and the spread of new invasive species (Trzcińska-Tacik and Stachurska-

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Swakoń, 2011). This phenomenon forces the search for other effective ways to fight with expansive weeds, which contribute to reducing yield (Adamczewski, 2000).

An example of a very expansive plant, which is a troublesome weed for many crops, is chickweed *Stellaria media* L. This one-year or two-year species from the Cariophyllaceae Juss. family is considered to be characteristic of *Stellarietea mediae* R.Tx., Lohm. Et Prsg 1950 class, i.e., communities of weeds in crop fields and ruderal areas (Matuszkiewicz, 2006). It is flowering from May to October, and often throughout the year, showing the germinate capacity to even under the snow (van der Vegte, 1978). One specimen of this plant produces up to 25.000 seeds that remain viable for up to 20 years. It belongs to species with a circumpolar range - it grows from lowlands to mountains. Chickweed produces low, dense groups, covered with bright yellow leaves and white flowers. It prefers fertile, moist and nitrogen-rich soils. In addition to such weeds as cockspur grass (*Echinochloa crus-galli* L.), white goosefoot (*Chenopodium album* L.), field pansy (*Viola arvensis* Murray) and couch grass (*Agropyron repens* L.), it is quite common in sweet corn cultivations, fodder and industrial (Waligóra and Jakubiak, 2003).

The study undertaken here aims to analyse the effect of aqueous extracts from *S. media* shoots of various concentrations on germination (1), the development of seedlings (2) *Zea mays* L. in cultivars: 'San', 'Kidemos' and 'DKC 3441'. Besides, it will allow deepening the knowledge of adverse interaction "weed-crop plant" and the indication of maize cultivars most resistant to this type of interaction.

Materials and Methods

Plant material

Maize seeds (*Zea mays* L.) were obtained as seed material: 'San' cultivar from the Kennel Station in Smolice (Middle-Western Poland), 'Kidemos' from KWS Polska Sp.z.o.o. and 'DKC 3441' from Dakalb. Chickweed (*Stellaria media* L.) shoots were collected in the Suchoraba 49°58′37″N 20°11′49″E, in the south-eastern part of the Lesser Poland Voivodeship (Southern Poland).

Extracts reparation

The aqueous extracts of chickweed shoots, in concentrations of 1, 3, 5%, were made from the dried and crumbled aboveground plant parts. Each of the extracts, depending on the concentration, was flooded with an appropriate amount of cold distilled water (1 g - 99 ml, 3 g - 97 ml, 5 g - 95 ml) and left for 24 hours at room temperature (around 25 °C) to extract allelopathic compounds. After this time, the aqueous extracts were filtered and stored in a refrigerator at 8 °C for the duration of the experiment.

Germination indexes

The germination capacity of maize seeds, under the conditions of interaction with chickweed aqueous extracts, were carried out on the basis of different coefficients. Germination indicators, that is, germination index (GI), mean germination time (MGT), germination percentage (% of control), germination energy (GE), time required for 50% germination (T_{50}), germination seedling vigour index (SVI), and coefficient of the rate of germination (CRG) were calculated from the same data (Islam and Kato-Noguchi, 2014).

Biometric analysis

The maize seedlings grown on aqueous chickweed extracts, after 8 days from the beginning of the experiment, were measured with an analog caliper (Alfa L-150, Poland), with an accuracy of 1 mm. Lengths of seedlings were determined according to Islam and Kato-Noguchi (2012): $IP = [1 – (LE / LC)] \times 100$, where IP = inhibition%, LE = length of seedlings in aqueous plant extract, LC = length of seedlings in control (distilled water).

Relative water content, fresh and dry mass

Seedlings relative water content (RWC) was computed following the method described by Mullan and Pietragalla (2012) with some modifications. One seedling for each replicate was weighted (fresh mass - FM) (1600 C Medicat, Poland) and incubated for 24 h at 25 °C in 25 ml falcon tube filled with 20 ml of distilled water. After incubation, the turgid mass (TM) was taken and leaf samples were dried at 105 °C for 48 h (Termaks 8430, Poland), and successively weighted (dry mass – DM). RWC parameter was calculated by formula: $RWC = [(FM – DM)/(TM – DM)] \times 100$. In addition, based on the recorded fresh and dry mass values, the water content in percentage (% H_2O) was determined according to formula % $H_2O = 100 – [(DM \times 100) / FM]$.

Electrolyte leakage

The electrolyte leakage, on 3-day seedlings of all maize cultivars, were measured according to the method used by Zandi *et al.* (2018).

Statistical analysis

The results are mean values of 5 replicates (for 20 seeds on Petri dish), for each concentration of extract and control (distilled water). Statistical analysis was carried out using the parametric Duncan test $p < 0.05$. Statistica 13.1 for Windows was used in the calculations.

Results

Germination capacity

The germination index (GI) of maize seeds was significantly inhibited for the 'Kidemos' cultivar, in all concentrations of chickweed extracts (Fig. 1). For the other two 'San' and 'DKC 3441' cultivars, the most inhibitory effect of the 5% extracts was observed. Compared to the control group (distilled water), the mean germination time (MGT) was the lowest for three maize cultivars (Fig. 2).

With increasing of the chickweed aqueous extracts concentrations, the seedling vigour index (SVI) values decreased (Table 1). The lowest SVI values for underground and aboveground parts and whole maize seedlings watered with the 5% extracts from *Stellaria media* were observed. In the case of the coefficient of the rate of germination (CRG), no significant changes in the values of this parameter were revealed, while the germination energy (GE) values significantly decreased at the highest concentration of the 'San' cultivar, and increased in 'DKC 3441' at 3 and 5% concentrations (Table 2).

In the case of the time required for 50% germination (T50), the values of this parameter were decreased in the 'San' and 'Kidemos' cultivars, relative to the control (Table 3). Germination percentage as a percentage of control was the highest for 'DKC 3441' maize seeds germinating on the 1% chickweed extracts, and the lowest for 'Kidemos' seeds watered with 3% extracts.

Table 1. Seedling vigour index for *Zea mays* L. 'San', 'Kidemos' and 'DKC 3441' seedlings treatment the aqueous extracts from *Stellaria media* L. organs of different concentrations (1, 3, 5%)

Organ	Seedling vigour index (SVI)			
	Control	1%	3%	5%
		San		
Whole seedling	22.94 a ± 5.84	9.42 c ± 9.35	12.78 b ± 12.31	2.31 d ± 0.90
Root	17.00 a ± 10.37	7.66 b ± 6.29	10.02 b ± 12.90	1.48 c ± 2.64
Coleoptyl	0.59 a ± 0.76	0.18 b ± 0.39	0.28 bc ± 0.64	0.08 cd ± 0.18
		Kidemos		
Whole seedling	7.82 a ± 11.96	1.36 b ± 1.45	0.34 c ± 0.22	0.26 d ± 1.55
Root	4.26 a ± 6.97	2.82 b ± 1.40	2.07 b ± 0.17	0.09 bc ± 0.52
Coleoptyl	0.36 a ± 0.65	0.03 b ± 0.01	0.01 b ± 0.01	0.02 b ± 0.10
		DKC 3441		
Whole seedling	13.70 a ± 9.60	13.34 a ± 15.30	9.84 b ± 10.82	3.28 c ± 4.40
Root	10.38 a ± 7.35	10.82 a ± 15.24	8.53 ab ± 9.57	2.17 c ± 4.14
Coleoptyl	0.33 a ± 0.41	0.30 a ± 0.33	0.13 b ± 0.30	0.11 b ± 0.16

Note: values (±SD) marked (a, b, c) differ significantly according to Duncan test at $p < 0.05$

Table 2. Values of CRG – coefficient of the rate of germination and GE – germination index for *Zea mays* L. 'San', 'Kidemos' and 'DKC 3441' seedlings treatment the aqueous extracts from *Stellaria media* L. organs of different concentrations (1, 3, 5%)

Maize cultivars	Coefficient of the rate of germination (CRG)				Germination energy (GE)			
	Control	1%	3%	5%	Control	1%	3%	5%
San	19.05 a ± 0.05	18.89 a ±0.06	18.89 a ±0.11	18.30 b ±0.28	49.00 a ±2.92	41.66 a ±2.70	45.73 a ±4.19	27.54 b ±7.64
Kidemos	10.45 b ±3.07	9.59 b ±3.63	17.94 a ±0.62	11.45 b ±4.49	28.00 b ±4.06	44.67 a ±6.29	20.00 b ±2.00	27.58 b ±3.56
DKC 3441	16.23 a ±2.72	13.34 ab ±1.16	18.92 a ±0.25	18.91a ±0.15	49.00 a ±3.31	30.00 b ±3.54	53.40 a ±7.29	53.35 a ±6.17

Note: values (±SD) marked (a, b, c) differ significantly according to Duncan test at $p < 0.05$

Table 3. Values of T_{50} – time required for 50% germination and G% – germination percentage of control for *Zea mays* L. 'San', 'Kidemos' and 'DKC 3441' seedlings treatment the aqueous extracts from *Stellaria media* L. organs of different concentrations

Maize cultivars	Time required for 50% germination (T_{50})				Germination percentage (% of control)		
	Aqueous extracts of *Stellaria media* L. [%]						
	Control	1	3	5	1	3	5
San	7.95 a ±0.38	7.05 a ±0.27	7.58 a ±0.56	6.13 b ±0.71	82.21 b ±0.59	94.49 a ±0.84	51.39 c ±1.44
Kidemos	5.92 ab ±0.28	7.77 a ±0.99	3.60 b ±0.90	2.85 b ±1.77	18.87 b ±0.58	5.25 b ±0.15	10.12 b ±1.58
DKC 3441	7.99 ab ±0.49	6.05 c ±0.26	9.28 a ±1.25	9.27 a ±1.49	100.00 a ±0.40	65.75 b ±1.72	56.78 b ±1.44

Note: values (±SD) marked (a, b, c) differ significantly according to Duncan test at $p < 0.05$

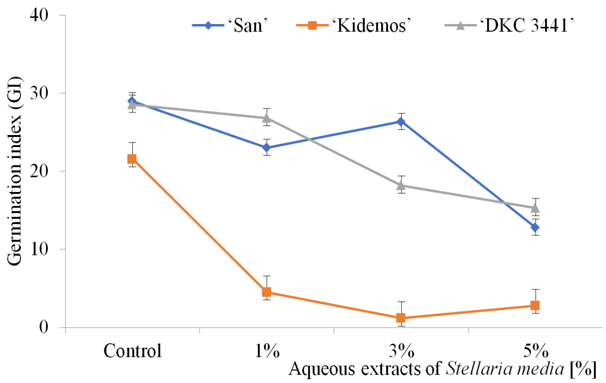

Fig. 1. Germination index of *Zea mays* L. ‘San’, ‘Kidemos’ and ‘DKC 3441’ seeds after 8 days watered with *Stellaria media* L. aqueous extracts of different concentrations (1, 3, 5%)

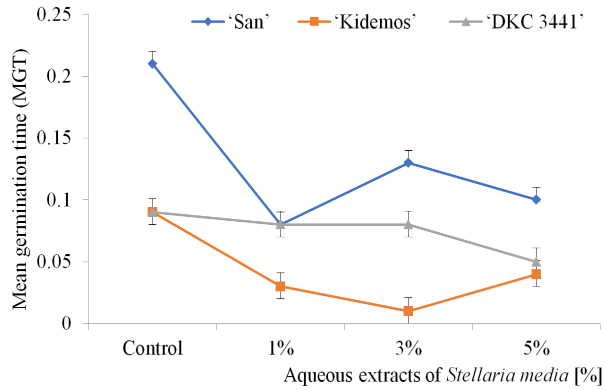

Fig. 2. Mean germination time of *Zea mays* L. ‘San’, ‘Kidemos’ and ‘DKC 3441’ seeds after 8 days watered with *Stellaria media* L. aqueous extracts of different concentrations (1, 3, 5%)

Biometric analysis

In relation to the seedlings roots from the control, the biometric analysis revealed a statistically significant inhibition the length of this organ on 5% extracts from chickweed shoots for each of the tested *Zea mays* cultivars (Fig. 3).

The root growth of maize seedlings was observed at 1 and 3% concentrations of extracts, in ‘Kidemos’ and ‘DKC 3441’ cultivars. Compared to the control, regardless of the maize cultivar and extract concentration, the increase in coleoptile was clearly inhibited. The growth of whole maize seedlings, the most susceptible cultivar on the *S. media* extracts was the ‘San’ and the least - ‘DKC 3441’.

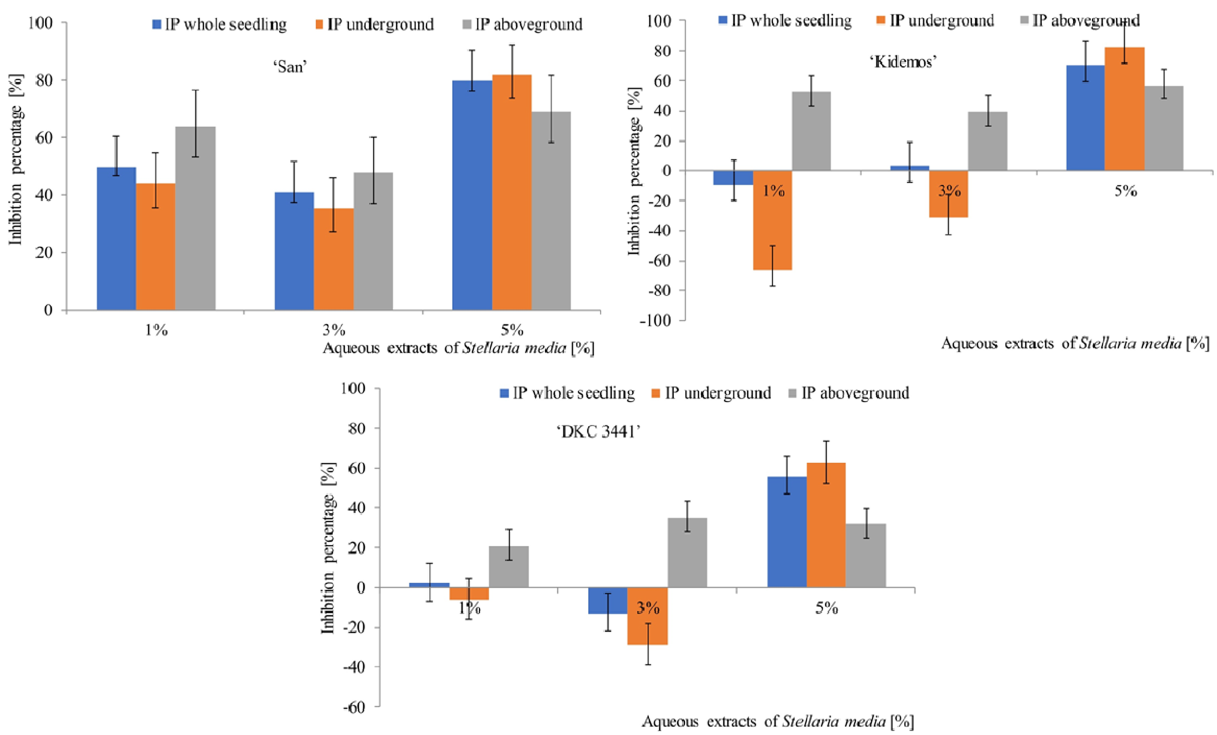

Fig. 3. Inhibition percentage index of *Stellaria media* L. extracts on *Zea mays* L. ‘San’, ‘Kidemos’ and ‘DKC 3441’ seedlings growth; a negative value (-) on the Y axis indicates the promotion of growth, and a positive value (+) indicates the inhibition of *Z. mays* growth

Relative water content, fresh and dry mass, total water content

At each of the used concentrations of aquatic chickweed extracts, relative water content (RWC) reached values greater or close to the values in control. For seedlings grown on substrates with 5% extracts from *S. media,* the highest increase in RWC was found (Table 4).

At all concentrations of extracts used, fresh masses of maize seedlings were lower, compared to the mass of seedlings under control conditions. At 5% concentration of *S. media* extracts for the three studied maize cultivars, the lowest values of this parameter were noted. In the dry mass determination of maize seedlings for 'San' cultivar no significant influence of chickweed extracts was demonstrated. However, for the 'Kidemos' and 'DKC 3441' cultivars, some differences in dry mass values were found. In compare to the control, an increase in dry mass of seedlings on Petri dishes with 5% of *S. media* extracts was observed. Total water content in all three maize cultivars decreased with increasing concentrations of extracts compared to the control.

Electrolyte leakage

The electrolytes leakage from *Z. mays* seedlings in each cultivar increased with the concentration of extracts, compared to the control (Fig. 4). On the 1% extracts of chickweed shoots, the percentage of electrolytes out of seedlings of each maize cultivar was similar to the control. For seedlings watered with 5% extracts from *S. media*, the highest disturbances in ionic cell metabolism were found. The most sensitive cultivar was 'Kidemos', in which 5% extract caused a 3-fold increase in electrolyte leakage compared to the control. However, in the 'DKC 3441' cultivar the lowest changes in the destabilization of the transport of ions through cell membranes were demonstrated.

Table 4. Relative water content, fresh and dry masses, and water content of maize *Zea mays* L. cv 'San', 'Kidemos' and 'DKC 3441' seedlings treatment the aqueous extracts from *Stellaria media* L. organs of different concentrations

Maize cultivars	Aqueous extracts of *Stellaria media* [%]			
	Control	1	3	5
	Relative water content [%]			
San	61.39 b ± 1.97	61.36 b ± 3.12	64.44 b ± 2.14	72.54 a ± 4.66
Kidemos	67.02 a ± 4.37	59.66 ab ± 6.10	63.03 a ± 2.89	68.97 a ± 6.42
DKC 3441	52.53 c ± 1.97	41.14 cd ± 5.25	74.02 a ± 5.63	63.52 bc ± 1.73
	Fresh mass [g]			
San	1.10 a ± 0.58	0.86 b ± 0.07	0.76 b ± 0.05	0.61 bc ± 0.02
Kidemos	0.42 a ± 0.03	0.44 a ± 0.02	0.37 b ± 0.01	0.37 b ± 0.01
DKC 3441	0.74 ab ± 0.02	0.67 bc ± 0.02	0.84 a ± 0.07	0.67 bc ± 0.05
	Dry mass [g]			
San	0.25 a ± 0.02	0.23 a ± 0.02	0.23 a ± 0.01	0.24 a ± 0.01
Kidemos	0.14 b ± 0.01	0.13 b ± 0.01	0.14 b ± 0.01	0.17 a ± 0.01
DKC 3441	0.20 b ± 0.03	0.23 ab ± 0.01	0.18 bc ± 0.03	0.27 a ± 0.02
	Total water content [%]			
San	77.48 a ± 1.24	72.85 b ± 1.14	70.35 bc ± 0.92	60.76 d ± 1.71
Kidemos	66.67 ab ± 2.91	69.57 a ± 2.66	61.35 c ± 1.02	52.02 cd ± 5.07
DKC 3441	73.55 a ± 3.35	64.98 bc ± 2.05	77.83 a ± 3.70	59.52 c ± 1.12

Note: values (±SD) marked (a, b, c) differ significantly according to Duncan test at $p < 0.05$

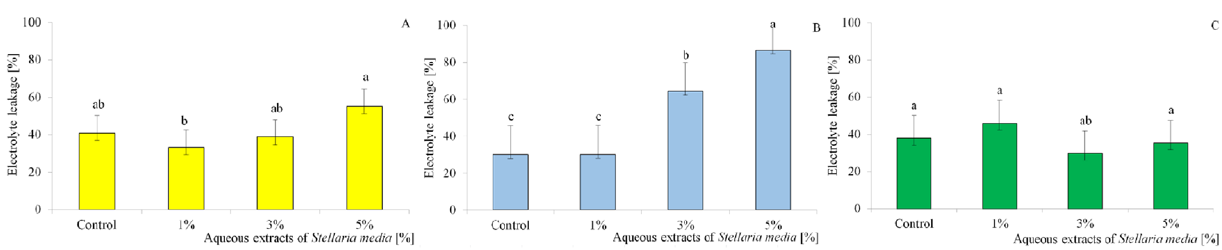

Fig. 4. Electrolyte leakage from *Zea mays* L. 'San' (A), 'Kidemos' (B) and 'DKC 3441' (C) seedlings treatment the aqueous extracts *Stellaria media* L. of different concentrations (1, 3, 5%); values (mean±SD) marked with different letter(s) differ significantly according to Duncan test, $p < 0.05$

Discussion

Maize is the most widely grown grain crop throughout the Americas, with 361 million metric tons grown in the United States in 2014, the highest in the world. One-third of the production is used for corn ethanol. In addition, it is used for fodder purposes, in the milling industry and for the production of biogas. In the initial stages of vegetation, it is a very sensitive species to the competitive effects of weeds. Due to the morphology and the initial slow growth, for a longer time, the inter-row of its crops is not covered, which facilitates germination and rapid growth of weeds (Waligóra *et al*., 2008). The weeds that accompany its cultivation belong to the largest group of agrophags, and have a significant impact on the quality and quantity of crop (Adamczewski *et al*., 1997). In addition to weeds, also simplified surface cultivations and direct sowing, as compared to traditional plow farming, negatively affect the yielding of maize (Machul, 1993; Dubas and Menzel, 1999). According to Ismail *et al*. (1994) and Kapusta *et al*. (1996) reduction of negative reactions of maize to direct sowing occurs under long-term use of this type of sowing.

Seed germination is a complex process and often defined in various ways (Higashiyama *et al*., 2003). It is a series of steps that usually occurs earlier than the development of the radicle from the seed coat (Joshi, 2018). Regardless of the definition adopted, the seed germination is subject to modifications caused by both endogenous and exogenous factors, which may be caused by the presence of chemical substances in the soil, produced by weeds. Weeds are an important link in trophic chains, because numerous plant diseases, affect the quality of crops, hamper mechanical agrotechnical measures, and as a result increase the costs of agricultural production (Jaskulski and Jaskulska, 2004). The chemical substances contained in them are released from both living and dead aboveground and underground parts (Rice, 1984).

In this study, germination indexes of maize seeds, regardless of the cultivar, decreased with increasing concentrations of aqueous extracts from *Stellaria media* shoots were found (Figs. 1-2; Tables 1-3). The germination of seeds was (only) similar to the control group (on distilled water) on petri dishes with 1% extracts. The most changes in germination parameters were found among maize seeds watered with 5% extracts. Similarly, in Duer's (1996) studies on the allelopathic effect of *S. media* on cereals, it was noted that at low concentrations aqueous extracts did not influence the germination of winter wheat seeds (*Triticum* sp.), spring barley (*Hordeum* sp.) and rye (*Secale* sp.). Majchrzak (2007) confirmed that the germination of wheat seeds with increasing of concentrations weed extracts was inhibited. In the experiments of Kwiecińska-Poppe *et al*. (2011) reduction in germination energy of rye and winter triticale (×*Triticosecale* sp.) was directly proportional to the increase in the concentration of aqueous extracts from fresh and dry sticky weed shoots (*Galium aparine* L.). As it grows weed infestation, in crop plants the number of branches or propagations, the number and area of leaves are decreased. There are occurring also changes in the development and functioning of the root system and the whole plant (Aldrich, 1997). In this study, aqueous extracts of *S. media* shoots significantly influenced the increase in elongation of roots, coleoptiles and whole seedlings of maize cultivars (Fig. 3). The biometric analysis revealed that compared to the control sample, the growth of the *Zea mays* roots of cultivars 'Kidemos' and 'DKC 3441' on 1 and 3% extracts was stimulated. Regardless of the concentration of the extract and the maize cultivar, the coleoptiles growth was inhibited. On aquatic extracts from chickweed shoots, the most sensitive maize was 'San' cultivar (Fig. 3). Besides, changes in the seedlings length influenced the increase of their biomass and the water content in cells (Table 4). The results obtained here coincide with what they noted in the experiments Kwiecińska-Poppe *et al*. (2011) and Aziz *et al*. (2008). They revealed that aqueous extracts from weeds negatively influenced the growth of the first leaf of winter rye, winter triticale and wheat. Chickweed has the potential to contribute water-soluble phenolics to its immediate vicinity that would affect wheat growth (Inderjit and Dakshini, 1998).

The allelopathic interactions are probably the result of mixtures of different compounds, not just a single substance (Einhellig, 1996; Inderjit *et al*., 1997; Veronneau *et al*., 1997). Vanhaecke *et al*. (2008) showed that *S. media* contains many oligosaccharides from the raffinose family that participate in the translocation and use of coal and fulfil the protective functions against abiotic stress caused by frost, drought or the presence of salts in the soil. In addition, it is a source of saponins, flavonoids (rutin) in glycoside form, protein, provitamin A - β-carotene, vitamins B1, B2, C, E, PP, para-aminobenzoic acid (PABA), triterpene glycosides, sugar alcohol (pinitol) as well as mineral salts – in the form of phosphorus, potassium, iron, magnesium, zinc, manganese, copper, chromium, selenium, iodine and silicon compounds (Vanhaecke *et al*., 2006; Hu *et al*., 2009). Under field conditions, additive or partially antagonistic effects of whole groups of chemical compounds are more pronounced even at low concentrations, as compared to the effects of individual substances. Even if the concentrations of compounds are well below their inhibitory levels, mixtures of allelopathic substances and other organic compounds may cause an allelopathic inhibitory effect (Blum, 1996). The analyses carried out here show that the aquatic extracts of chickweed have a clear allelopathic potential that affects the germination, growth, mass and the destabilization of the ionic transport through cell membranes of maize seedlings.

Cell membranes are organelles that are primarily exposed to the effects of stress factors. They are responsible for the integrity and stability of all cell structures (Matuszak-Slamani and Mila, 2017). The electrolyte leakage method used in this experiment determines the total amount of all substances dissolved in the solution (Kocheva *et al*., 2014). These types of measurements illustrate how extracts, depending on their concentration, influence on the physiological activity of the cell. In this experiment, aqueous extracts of *S. media* shoots caused destabilization of the ionic transport through cell membranes of germinated maize seeds (Fig. 4). Probably, the increase of the natural chemicals concentration contained in the extracts caused disturbances in ion transport. The literature data show that changes in the permeability of cell membranes under the influence of stress are accompanied by the generation and accumulation of reactive oxygen species (ROS) (Demidchik *et al.*, 2014). These changes induce peroxidation of membrane lipids, thus affecting changes in membrane permeability, composition and structure. In extreme cases, this leads to programmed cell death (Gill and Tuteja, 2010; Demidchik *et al.*, 2014; Kocheva *et al.*, 2014).

In the environment, many factors interact simultaneously, and thus it is impossible to isolate the effects of each of them separately. This study shows that the allelopathic potential of *S. media* is one of many factors that interfere in the physiology of maize cultivars. Changing economic conditions of agricultural production impose the search for new methods of simplified cultivation systems, which sometimes contributes to weed infestation (Dzienia *et al.*, 2006; Gawrońska-Kulesza, 1997). At the same time, it forces the development of new pro-ecological ones weeding strategy. Mechanical removal of chickweed from corn crops is quite easy, due to its weak and short root system (Heydel *et al.*, 1999; Hruszka, 2003; Liszka-Podkowa and Sowiński, 2009). However, these activities are laborious and not always practical, because this plant is very easy to rooting again. Therefore, prophylactic treatments are still an effective way to eliminate this species, consisting of precise and systematic field works (using clean seed, nitrogen fertilisation in optimal doses, etc.). Although chickweed is sensitive to a wide range of chemical plant protection products (acetochlor, bentazone, bifenox, chlorsulfuron, dicamba, ammonium glufosinate, linuron, metazachlor, tembotrione), their use should be a last resort, especially in feed and food crops from maize.

Conclusions

Germination indexes for the *Zea mays* L. seeds showed that the most sensitive cultivar on the aqueous extracts from the dry shoots of *Stellaria media* L. was the 'Kidemos'. Compared to the control, at low concentrations of allelopathic compounds, the seeds germinated similarly to the distilled water, but at higher concentrations, the germination was inhibited.

The growth of roots, coleoptiles and whole seedlings of analysed maize cultivars decreased with increasing concentrations of allelopathins; the growth of all organs, regardless of the concentration of *S. media*, in the 'San' cultivar was inhibited; the values of fresh and dry mass, the relative water content and the water content were differed for each of the cultivars, depending on the applied extract concentration; the electrolyte leakage values increased with increasing concentrations of *S. media* extracts - it may indicate changes in the permeability of cell membranes under the influence of allelopathins.

The obtained results indicate a significant effect of chickweed extracts on the early stages of the development of maize seeds. This study showed that this weed produces chemical substances which negatively affect crop plants. On substrates with *S. media* shoot extracts the lowest germination for 'Kidemos' cultivar was observed while investigating the growth of whole maize seedlings, it was shown that the most susceptible cultivar was 'San' and the least - 'DKC 3441'. This information can be useful in the conditions of the threat of maize crops with the mass appearance of chickweed.

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Conflicts of interest

The authors declare that there are no conflicts of interest related to this article.

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