Acta Sci. Pol. Hortorum Cultus, 22(3) 2023, 81–91

https://czasopisma.up.lublin.pl/index.php/asphc ISSN 1644-0692 e-ISSN 2545-1405 https://doi.org/10.24326/asphc.2023.4889

ORIGINAL PAPER

Accepted: 1.03.2023
Published: 30.06.2023

THE IMPACT OF SELECTED AGROTECHNICAL TREATMENTS ON THE GROWTH OF WILD GARLIC (*Allium ursinum* L.) LEAVES IN FIELD CULTIVATION

Marzena Błażewicz-Woźniak

Institute of Horticultural Production, University of Life Sciences in Lublin, Głęboka 28, 20-612 Lublin, Poland

ABSTRACT

Wild garlic (*Allium ursinum* L.) is a typical spring geophyte whose natural habitat is beech forests. The research aimed to assess the possibility of cultivating wild garlic in field conditions significantly different from those required by this plant, using environmentally friendly and unconventional treatments. This study aimed to evaluate the effect of selected agricultural practices (catch crop, shading plant, biopreparations) on the growth of wild garlic leaves grown in the field.

The results show that the biomass of catch crops and shade plants and biopreparations from marine algae are justified in cultivating wild garlic in field conditions regarding the leaf yield. Ploughing of phacelia biomass on a catchment soil with an unstable structure positively affected the growth of wild garlic, increasing the length of leaves, their number, and the length and width of the leaf blade. Winter turnip rape used as a shade plant caused an increase in the length of the leaves and the value of the F_V/F_M index (the quotient of the variable fluorescence to the maximum fluorescence), and also, depending on the year of the study, the length and width of the garlic leaf blade. Soaking the bulbs before planting in the 'Kelpak SL' solution increased the number of garlic leaves growing without turnip rape cover in the second and third years of cultivation. In the first year of vegetation, longer leaves with a larger leaf blade ensured the preparation was sprayed three times without pre-soaking the bulbs. Considering the biopreparations' positive effect on the growth of garlic leaves and the F_V/F_M ratio values, their use is prospective regarding the increasing occurrence of dry years and is an alternative to plant irrigation.

Key words: catch crops, *Phacelia tanacetifolia*, 'Bio-Algeen S90', shading plant, stressful conditions

INTRODUCTION

Wild garlic (*Allium ursinum* L.) is a typical spring geophyte whose natural habitat is beech forests. The plant grows best in shady places, in conditions typical for forest plants, with stable soil protection from water [Fijałkowski and Chojnacka-Fijałkowska 2009, Załuski et al. 2009]. Wild garlic leaves have been eaten for centuries, but their broader use in Poland has limited it, partially protected by species since 2004 [Dz. U. 2004, No. 168, item 1764]. Besides its medicinal properties, wild garlic is characterised by an excellent taste. It can be used as a seasoning ingredient for many dishes [Sobolewska et al. 2015, Hæggström et al. 2016, Bodó et al. 2021]. Garlic leaves, flowers and stalks are a source of health-promoting compounds and can be used as functional food ingredients, dietary supplements and additives [Lachowicz et al. 2018]. Obtaining wild garlic from natural sites is illegal in Poland. Its cultivation is usually amateur and boils

✉ marzena.wozniak@up.lublin.pl

down to imitating the conditions of the natural habitat of this species. Due to the high biological value, a significant increase in interest in growing this plant has been observed for several years. Therefore, it is crucial to develop the possibility of cultivating wild garlic in the field and to determine the adaptability of this plant to the conditions of the habitat due to the narrow range of ecological tolerance [Rola 2012, Grime et al. 2014, Hæggström et al. 2016, Sobolewska 2018]. Most of the research on wild garlic relates to the results obtained from wild plants (under uncontrolled conditions). Hence, research is also needed to explain the effect of growing conditions on bioactive compounds [Petropoulos et al. 2020].

In the research carried out so far on the cultivation of wild garlic in Poland, shade tubes and irrigation have been used most often [Błażewicz-Woźniak et al. 2011, Kęsik et al. 2011]. It entails the need to build unique structures and increases the cost of cultivation. The research aimed to assess the possibility of cultivating *A. ursinum* in field conditions significantly different from those required by this plant, using environmentally friendly and unconventional treatments. To improve soil conditions, a catch crop was used, the biomass of which was mixed with the soil, the shade was replaced with a shade plant, and to increase the resistance of garlic to stress, especially drought, biopreparations were used (Bio-Algeen S90 and Kelpak SL). Among the non-legume catch crops, the phacelia biomass was distinguished by the highest content of macro elements, especially calcium and potassium, and it provided much biomass [Kęsik et al. 2002, Płaza et al. 2009, Błażewicz-Woźniak and Wach 2012]; therefore a phacelia catch crop was decided.

Biostimulants are effective when plants are grown in unfavourable conditions [Mystkowska 2018]. Many researchers emphasise the importance of marine algae in counteracting the effects of stressors on crops, such as excessive salinity, high temperature, drought, and cold [Mancuso et al. 2006, Matysiak et al. 2012, Sharma et al. 2014, Bulgari et al. 2019, Hassan et al. 2021]. Among the three types of algae: brown algae (*Phaeophyta*), green algae (*Chlorophyta*) and red algae (*Rhodophyta*), the first has the most excellent biostimulatory properties. These include *Esklonia maxima*, the extract of which is used as a preparation Kelpak SL with a high concentration of auxins and cytokinins (11 mg l^{-1} and 0.031 mg l^{-1}, respectively). Bio-Algeen S90 preparation, qualified for use in organic farming in Poland, is produced from *Ascophyllum nodosum*, algae with a particularly beneficial effect on arable crops [Khan et al. 2009]. Bio-Algeen S90 contains 90 groups of organic compounds, including alginic acid, vitamins and amino acids [Truba et al. 2012, Mikiciuk and Dobromilska 2014]. The action of algae largely depends on the dose, treatment frequency and crop species [Matysiak et al. 2012, Mitura et al. 2014, Bulgari et al. 2019, Parađiković et al. 2019].

The most frequently used parameter for assessing the impact of stressful conditions on a plant is the index that determines the maximum photochemical efficiency of photosystem II (PSII). It is defined by the quotient of the variable fluorescence to the maximum fluorescence (F_V/F_M). Its high level (0.83–0.85 relative units) proves the good condition of plants and the absence of stress factors. A deficient level (0.20–0.30 relative units) indicates irreversible changes in the structure of PSII. The photochemical efficiency of the photosynthetic system II determined using the F_V/F_M ratio, allows for a reliable measurement of the activity of the photosynthetic apparatus [Cetner et al. 2016, Durlak 2019].

This study aimed to evaluate the effect of selected agricultural practices (catch crop, shading plant, biopreparations) on the growth of wild garlic leaves grown in the field.

MATERIAL AND METHODS

The field experiment was carried out in 2018–2020 at the experimental station Felin belonging to the University of Life Sciences in Lublin (Poland, 22°56'E, 51°23'N), on grey-brown podzolic soil (AP) developed from loess formations covering the createous marls with a granulometric composition corresponding to medium dusty loam (BN-178/9180-11). These soils are difficult to cultivate, easily susceptible to rain thickening, and easy-crusting during drought.

Before the establishment of the experiment, the soil contained 1.04–1.11% of humus in a 0–20 cm layer, 69 mg N, 27 mg P, 84 mg K, 563.5 mg Ca and 66 mg Mg dm^{-3} of soil, at pH in KCl 5.96–6.12. After pre-sowing tillage, on 23/06/2017, phacelia *Phacelia tanacetifolia* Benth. (catch crop) was sown in half of the field. Phacelia biomass was ground on August 30, and the field was cultivated on September 4 and prepared for planting. Every year fertilisation with P (superphosphate) and K (potassium sulphate) was used in autumn, while N (ammonium nitrate) in spring, supplementing nutrients to the level of (mg dm^{-3}): 120 N (NH_4 + NO_3), 70 P, 200 K [Kęsik et al. 2011, Sady 2012]. The experiment was set up using completely randomised blocks in 3 replications. The replicate was 15 plants. The area of a single plot was 3.52 m^2. *Allium ursinum* bulbs came from previously conducted field experiments, for which the permission of the Regional Director for Environmental Protection [J. of Laws of 2012, item 81 as amended]. The bulbs were planted into the ground on September 13, 2017, at a 30 × 30 cm distance. Then, the entire experiment was covered with a layer of pine bark, according to the results of the research by Kęsik et al. [2011] and Błażewicz-Woźniak et al. [2018]. Fifteen plants were replicated. The experimental design included the following factors: I. Catch crop: A/ no catch crop, B/ phacelia catch crop; II. Shading plant: a/ without plant, b/ winter turnip rape (*Brassica campestris* ssp. *oleifera f. biennis*); III. Biopreparations: 1/ control (without the use of preparations); 2/ Bio-Algeen S90 (spraying), 3/ Kelpak SL (spraying), 4/ Kelpak SL (soaking before planting at a concentration of 0.3% for 5 minutes + spraying). Winter turnip rape was sown every year on September 5–6. Spraying with preparations was applied three times with an interval of 7 days, starting from the phase of producing two leaves. Bio-Algeen S90 was applied at 2 l ha^{-1}, while Kelpak SL at the first spraying was 3 l ha^{-1} and the remaining 2 l ha^{-1}. Every year, during the growing season, the biometric measurements of all plants were performed twice: 1. one month after emergence; 2. before flowering (April 25 and May 8, 2018, April 19 and May 8, 2019, and April 7 and May 7, 2020). During this period, the leaves are typically harvested for consumption. No chemical protection was applied, and the weeds were removed manually. The level of chlorophyll fluorescence was assessed using an OS30p+ fluorimeter (Opti-Sciences, Inc. USA). The weather conditions during the vegetation of wild garlic in the

Table 1. Mean air temperatures (°C)during the experiment in years 2018–2020 in ES Felin

Year	Month and decade							
	April				May			
	1	2	3	Monthly	1	2	3	Monthly
2018	10.6	14.5	15.0	13.4	16.8	14.4	18.8	17.1
2019	7.8	7.1	13.5	9.5	9.8	13.8	16.2	13.4
2020	7.8	7.6	10.1	8.8	11.7	11.4	12.0	11.7
1951–2005 (mean)	–	–	–	7.4	–	–	–	13.0

Table 2. Amount of precipitation (mm) during the experiment in years 2018–2020 in ES Felin

Year	Month and decade							
	April				May			
	1	2	3	Monthly	1	2	3	Monthly
2018	34.1	5.3	9.1	48.5	0.0	56.0	0.1	56.1
2019	0.6	6.1	42.0	48.7	0.3	72.2	20.0	92.5
2020	0.0	0.4	25.3	25.7	21.0	5.7	77.6	104.3
1951–2005 (mean)	–	–	–	40.2	–	–	–	57.7

years 2018–2020 are shown in Table 1 and 2. Achieved results were statistically processed using analysis of variance (ANOVA). The difference significance was determined using Tukey's test at p = 0.05.

RESULTS AND DISCUSSION

Depending on the date and year of the study, the height of the garlic leaf rosette ranged from 139 to 261 mm on average (Tab. 3). In the studies by Błażewicz-Woźniak and Michowska [2011], the height of the garlic leaf rosettes, depending on the year of research and the date of measurements (April, May), ranges on average from 104 to 337 mm. In the studies by Kęsik et al. [2011], the length of wild garlic leaves in the subsequent years of vegetation ranged on average from 107.3 to 210.0 mm in April and from 171.7 to 302.9 mm in May. The values obtained in the conducted research were lower, which proves the harsh growth conditions for wild garlic, which were caused not only by soil conditions and the lack of plant shading but also by the extreme weather conditions in 2018-2020 (drought and high temperatures) – Table 1 and 2. *Allium ursinum* inhabits mainly shady decid-

Table 3. Influence of experimental factors on the height (mm) of a garlic leaf rosette in 2018–2020

Experimental factors			2018		2019		2020		Mean	
catch crop	shading plant	preparation	April	May	April	May	April	May	April	May
without	without	mean	202	206	163	242	138	240	168	229
	turnip rape		217	224	166	270	130	238	171	244
	Mean		210	215	165	256	134	239	169	237
Phacelia	without	mean	209	209	165	257	147	266	174	244
	turnip rape		225	229	171	276	140	267	179	257
	mean		217	219	168	266	144	266	176	251
mean	without	without	206	216	163	257	135	244	168	239
		Bioalgeen	204	210	164	250	133	232	167	231
		Kelpak	205	197	159	235	151	264	172	232
		Kelpak 2x	206	208	170	256	150	271	175	245
		mean	205	208	164	249	142	253	171	237
	turnip rape	without	224	233	165	269	149	272	179	258
		Bioalgeen	229	222	174	269	143	264	182	252
		Kelpak	230	240	168	279	116	225	171	248
		Kelpak 2x	202	212	168	275	133	248	168	245
		mean	221	227	169	273	135	252	175	251
	mean	Without	215	225	164	263	142	258	174	249
		Bioalgeen	216	216	169	259	138	248	174	241
		Kelpak	217	218	163	257	134	245	171	240
		Kelpak 2x	204	210	169	266	142	260	172	245
		mean	213	217	166	261	139	253	173	244
$LSD_{0.05}$ for:	catch crop (A)		ns	ns	ns	8.10	1.47	1.56	2.92	14.01
	shading plant (B)		7.77	7.44	ns	8.10	1.47	ns	2.92	14.01
	biopreparation (C)		ns	ns	ns	ns	2.81	2.98	ns	ns
	year (D)		–	–	–	–	–	–	4.50	22.72
	A × B		ns	ns	ns	ns	2.81	2.98	ns	ns
	A × C		ns	23.05	ns	ns	4.80	5.11	10.36	ns
	B × C		24.07	23.05	ns	25.11	4.80	ns	10.36	ns
	A × B × C		ns	ns	ns	40.15	7.85	ns	17.33	ns

ns – not significant differences

uous forests and wet sites in Poland but with a well-drained substrate, usually with a high humus content [Rola 2012]. The mixing of phacelia biomass with the soil in the first year of garlic cultivation had a positive effect on the leaf length. Plants growing on plots with phacelia catch crops were, on average, 4% higher than those growing without phacelia in April and by 6% in May. This relationship was recorded in all years of the study, and in 2019 and 2020, the differences were statistically confirmed. It can be explained by the beneficial effect of phacelia biomass on the soil structure and its moisture [Błażewicz-Woźniak and Konopiński 2013]. Konopiński et al. [2001] noted a positive effect of catch crops on moisture and water supply in the soil, which was maintained during the vegetation period of vegetable plants until their harvest. Błażewicz-Woźniak et al. [2015] showed a positive effect of catch crop biomass on the carrot leaf rosette height and the phacelia intercrop on the leaf weight. Turnip rape seedbed as a shade plant significantly increased garlic leaf length in April, May 2018, and May 2019. In these months, the weather was dry and very sunny. The shadow created by the turnip rape compensated for the unfavourable conditions for cultivation in the open field for *A. ursinum*. Regardless of the year of the study, garlic rosettes growing with turnip rape were, on average, 2.3% higher in April than those growing without undersown and in May by 5.9%. The beneficial effect of turnip rape undersown as a shade plant indicates the possibility of using this type of natural plant covers increases biodiversity and is an alternative to shade blinds used in horticulture.

The reaction of wild garlic to the biopreparations used was ambiguous. Regardless of the year of the study, the rosettes of garlic growing with turnip rape and sprayed three times with Bio-Algeen S90 were significantly the highest in April. In the study by Dobromilska and Gubarewicz [2008], spraying plants with Bio-Algeen S90 stimulated the vegetative growth of the small fruit tomato cv. Conchita F1. Applying Bio-Algeen S90 increased the content of chlorophyll (*a*, *b*, and total) and carotenoids in the leaves of small-sized tomato cv. Bianka F1 [Mikiciuk and Dobromilska 2014].

On the other hand, in 2018, the highest were the *A. ursinum* leaf rosettes sprayed three times with Kelpak SL growing with turnip rape seeding (230–240 mm), and the lowest when additionally soaking the bulbs in this preparation (202–212 mm), or Kelpak SL spraying with cultivation without undersowing (197 mm). On the other hand, in May 2019, the plants growing with turnip rape and sprayed three times with Kelpak SL, and those whose bulbs were pre-soaked were the highest (279 and 275 mm, respectively). Kelpak SL treatment successfully improved the growth parameters of okra (*Abelmoschus esculentus*) seedlings in a deficiency of P and K [Papenfus et al. 2013]. Carrots also improved after this preparation [Gupta et al. 2021]. The beneficial effect of Kelpak spraying on the growth of onion leaves was reported by Szczepanek et al. [2017], who reported that "Almost in each treatment, the aboveground part of onion was higher than without biostimulant, whereas the number of leaves increased after the triple application from the three-leaf stage, in doses of 3 + 2 + 2 dm^3 ha^{-1}".

In the current experiment, the number of garlic leaves increased from year to year with the age of the plants (Tab. 4). In the first year of cultivation, the bulbs produced from 1.9 to 3.3 pcs of leaves, and in the third, from 13.1 to 28.4 pcs (in May). From April 2019 to May 2020, significantly more leaves were determined in plants cultivated after using phacelia intercrop than in cultivation without intercrop. Phacelia and oat mulches also created the best conditions for the cultivation of parsley [Błażewicz-Woźniak 2005]. Regardless of the year of research in cultivation with a catch crop, garlic produced in May by an average of 1.2 leaves more than without a catch crop. There was no significant effect of turnip rape on garlic foliage. However, in 2020 most leaves were produced by garlic growing without turnip rape seeding and sprayed with Kelpak SL, whose bulbs were pre-soaked in this preparation (on average 27.8 pcs.), while three times spraying with Kelpak SL or Bio-Algeen S90 preparation did not give a good effect this year (average 19.8 and 18.4 pcs., respectively). Also, in April 2018, the highest number of leaves was determined in the Kelpak SL sprayed plants and pre-soaked bulbs. Pre-harvest foliar application of seaweed (*Ascophylum nodosum*) extract significantly increased plant height, the number of leaves and the leaf area of bell pepper (*Capsicum annuum* L.) [Khan et al. 2018]. After foliar application of biostimulants, an increase in the num-

Table 4. Influence of experimental factors on the number of garlic leaves (pcs.) in 2018–2020

Experimental factors			2018		2019		2020		Mean	
catch crop	shading plant	preparation	April	May	April	May	April	May	April	May
without	without	mean	2.5	2.5	4.6	7.4	10.7	20.9	6.0	10.3
	turnip rape		2.4	2.5	4.7	7.2	8.2	18.1	5.1	9.3
	mean		2.5	2.5	4.7	7.3	9.5	19.5	5.5	9.8
Phacelia	without	mean	2.5	2.4	5.3	8.5	11.4	21.3	6.4	10.7
	turnip rape		2.5	2.4	6.3	8.8	11.1	22.5	6.7	11.2
	mean		2.5	2.4	5.8	8.6	11.3	21.9	6.5	11.0
Mean	without	without	2.5	2.4	4.8	8.8	9.0	16.6	5.4	9.3
		Bioalgeen	2.6	2.5	5.0	7.6	9.2	16.5	5.6	8.9
		Kelpak	2.5	2.4	4.5	6.4	11.7	23.5	6.2	10.8
		Kelpak 2x	2.4	2.5	5.5	9.1	14.3	27.8	7.4	13.1
		mean	2.5	2.4	5.0	8.0	11.1	21.1	6.2	10.5
	turnip rape	without	2.3	2.7	5.8	9.2	12.0	24.5	6.7	12.1
		Bioalgeen	2.2	2.5	5.5	8.4	10.5	20.2	6.1	10.4
		Kelpak	2.3	2.3	5.5	7.6	7.1	16.2	5.0	8.7
		Kelpak 2x	3.0	2.4	5.1	6.8	9.1	20.4	5.7	9.9
		mean	2.4	2.4	5.5	8.0	9.7	20.3	5.9	10.3
	mean	without	2.4	2.5	5.3	9.0	10.5	20.6	6.1	10.7
		Bioalgeen	2.4	2.5	5.3	8.0	9.9	18.4	5.9	9.6
		Kelpak	2.4	2.3	5.0	7.0	9.4	19.8	5.6	9.7
		Kelpak 2x	2.7	2.5	5.3	8.0	11.7	24.1	6.6	11.5
		mean	2.5	2.4	5.2	8.0	10.4	20.7	6.0	10.4
$LSD_{0.05}$ for:	catch crop (A)		ns	ns	0.51	0.82	1.67	1.32	0.87	1.08
	shading plant (B)		ns	ns	ns	ns	1.67	ns	ns	ns
	biopreparation (C)		ns	ns	ns	1.52	ns	2.52	ns	ns
	year (D)		–	–	–	–	–	–	1.35	1.66
	A × B		ns	ns	ns	ns	3.18	2.52	ns	ns
	A × C		ns	0.86	ns	ns	ns	4.31	ns	ns
	B × C		ns	ns	ns	2.54	5.44	4.31	ns	3.82
	A × B × C		ns	ns	ns	ns	ns	ns	ns	ns

ns – not significant differences

ber of leaves and height of garlic (*Allium sativum* L.) plants [Shalaby and El-Ramady 2014] and onion (*Allium cepa* L.) [Ahmed et al. 2015, Shafeek et al. 2015].

The length of the garlic leaf blade, depending on the date and year of the study, ranged from 112 to 172 mm on average (Tab. 5). Regardless of the year of the research, mixing phacelia biomass with soil positively affected the length of the leaf blade in April. In the first year of garlic cultivation, the leaf blades of plants in plots with phacelia catch crops were 6 mm longer than those without catch crops. The beneficial effect of phacelia biomass was also seen in April and May in the third year of cultivation. The positive effect of phacelia intercrops on onion growth and the subsequent effect of phacelia intercrops (in the second year after application) on carrot yield was demonstrated in the studies by Kęsik and Błażewicz-Woźniak [2008]. In 2018 and 2019, longer leaf blades were formed by garlic growing near the turnip rape (by 5.4–6.1% in May). The applied preparations did not significantly affect the length of the leaf blade, as assessed independently of the year of the study, but in April 2018, the most extended blades were determined in plants sprayed three times with Kelpak SL and the shortest in plants sprayed with this biostimulant, whose bulbs were pre-soaked. In April 2019, the longest plaques were in the Kelpak SL sprayed plants, the bulbs of which were pre-soaked, and the shortest at the control, and in April and May 2020, the longest plaques were in the Kelpak SL sprayed plants, the bulbs of which were pre-soaked, and the shortest after three multiple Kelpak SL spraying without soaking the bulbs. Soaking seed potatoes for 5 minutes before planting in a Kelpak SL solution with a concentration of 0.2–0.4% or spraying with a working liquid at a concentration of 0.5% during planting is recommended in potato cultivation [Mitura et al. 2014]. In the first year of vegetation, garlic produced the most extended leaf blades in the combination of phacelia + turnip rape + Kelpak SL (an average of 184 mm). In the analysed studies, there was no significant effect of using Bio-Algeen S90 on the size of garlic leaves, while in the studies by Jamiołkowska [2014], the treatments with Bio-Algeen S90 had a positive effect on the size of leaves of sweet pepper relative to the control.

Depending on the date and year of the study, the garlic leaf width ranged from 32 to 54 mm on average (Tab. 6). Similar results in studies on garlic ecotypes

Table 5. Influence of experimental factors on the length of the garlic leaf blade (mm) in 2018–2020

Experimental factors			2018		2019		2020		Mean	
catch crop	shading plant	preparation	April	May	April	May	April	May	April	May
without	without	mean	157	167	134	165	109	155	133	162
	turnip rape		162	176	137	175	109	153	136	168
	mean		160	172	136	170	109	154	135	165
Phacelia	without	mean	162	161	135	169	117	167	138	166
	turnip rape		170	172	140	177	115	157	142	169
	mean		166	167	137	173	116	162	140	167
mean	without	without	158	167	130	168	105	156	131	164
		Bioalgeen	162	168	133	171	112	156	136	165
		Kelpak	160	158	132	163	117	163	136	161
		Kelpak 2x	160	164	142	165	117	170	140	166
		mean	160	164	134	167	113	161	136	164
	turnip rape	without	168	175	134	172	119	161	140	169
		Bioalgeen	166	173	140	176	113	155	140	168
		Kelpak	178	185	143	182	100	144	140	170
		Kelpak 2x	152	164	139	175	115	160	135	166
		mean	166	174	139	176	112	155	139	169
	mean	without	163	171	132	170	112	158	136	166
		Bioalgeen	164	170	137	174	113	155	138	166
		Kelpak	169	171	137	173	109	154	138	166
		Kelpak 2x	156	164	140	170	116	165	137	166
		mean	163	169	136	172	112	158	137	166
$LSD_{0.05}$ for:	catch crop (A)		5.96	ns	ns	ns	1.26	1.24	4.99	ns
	shading plant B)		5.96	6.48	4.16	5.22	ns	1.24	ns	ns
	biopreparation (C)		11.97	ns	7.72	ns	2.41	2.37	ns	ns
	year (D)		–	–	–	–	–	–	7.83	7.91
	A × B		ns	ns	ns	ns	2.41	2.37	ns	ns
	A × C		ns	ns	ns	ns	ns	4.06	ns	ns
	B × C		20.01	20.08	ns	ns	ns	4.06	ns	ns
	A × B × C		31.99	ns	20.63	25.85	6.75	ns	ns	ns

ns – not significant differences

are reported by Błażewicz-Woźniak and Michowska [2011] when the width of garlic leaves, depending on the year of research and the date of measurements (April, May), was on average from 24 to 59 mm. In the studies by Kęsik et al. [2011], the width of wild garlic leaves in the subsequent years of vegetation was, on average, from 39.2 to 55.4 mm in April and from 49.2 to 60.7 mm in May. Regardless of the year of the research, mixing phacelia biomass with the soil had a beneficial effect on the width of the leaf blade, especially in May. In the first year of garlic cultivation, the leaf blades of the plants in the plots with the phacelia intercrop were 11.8% wider than without the intercrop. The beneficial effect of phacelia biomass was also seen in April and May in the third year of cultivation. In 2018 and 2019, wider leaf blades were formed by garlic growing near the turnip rape (by 4.8–12.0%). In all years and dates of measurements, the wider gills were produced by garlic grown in the combination of phacelia × turnip rape, while the narrowest in cultivation without phacelia and turnip rape. The applied preparations did not significantly affect the width of the leaf blade, as assessed independently of the year of the study. In contrast, in April 2018, the widest blades were determined in the Bio-Algeen S90 sprayed plants and the narrowest in the Kelpak SL sprayed plants, whose bulbs were pre-soaked. In May 2019, the widest gills were in the Kelpak SL sprayed plants, and the narrowest in the Kelpak

Table 6. Influence of experimental factors on the garlic leaf width (mm) in 2018–2020

Experimental factors			2018		2019		2020		Mean	
catch crop	shading plant	preparation	IV	V	IV	V	IV	V	IV	V
without	without	mean	48	48	41	51	30	50	40	50
	turnip rape		55	53	43	57	30	49	43	53
	mean		51	51	42	54	30	49	41	51
Phacelia	without	mean	53	54	43	53	33	56	43	55
	turnip rape		57	59	45	57	33	49	45	55
	mean		55	57	44	55	33	53	44	55
mean	without	without	48	52	40	52	31	49	40	51
		Bioalgeen	53	55	43	54	33	52	43	54
		Kelpak	50	50	43	56	32	59	42	55
		Kelpak 2x	51	48	41	47	30	52	41	49
		mean	50	51	42	52	32	53	41	52
	turnip rape	without	54	54	42	58	33	48	43	53
		Bioalgeen	62	53	45	55	31	47	46	52
		Kelpak	61	65	44	58	29	47	45	57
		Kelpak 2x	47	54	45	57	34	53	42	55
		mean	56	56	44	57	32	49	44	54
	mean	Without	51	53	41	55	32	48	41	52
		Bioalgeen	57	54	44	54	32	50	44	53
		Kelpak	55	57	43	57	30	53	43	56
		Kelpak 2x	49	51	43	52	32	53	41	52
		mean	53	54	43	54	32	51	42	53
$LSD_{0.05}$ for:	catch crop (A)		ns	3.82	ns	ns	1.54	1.00	ns	3.90
	shading plant (B)		3.68	3.82	2.05	2.99	ns	1.00	ns	ns
	biopreparation (C)		6.82	ns	ns	5.05	ns	1.91	ns	ns
	year (D)		–	–	–	–	–	–	5.69	ns
	A × B		ns	7.09	3.80	5.05	2.94	1.91	ns	ns
	A × C		ns	11.85	6.36	ns	5.03	3.27	ns	ns
	B × C		11.41	11.85	ns	ns	ns	3.27	ns	ns
	A × B × C		18.24	18.95	10.1	14.8	ns	ns	ns	ns

ns – not significant differences

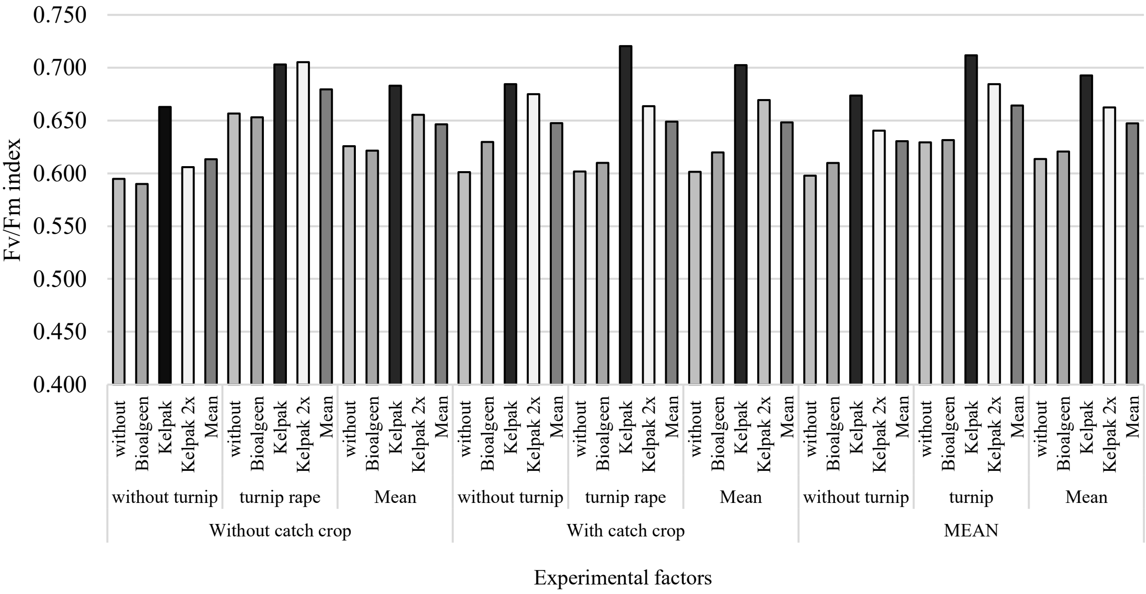

Fig. 1. Influence of experimental factors on the F_V/F_M ratio values (average 2018–2020)

SL sprayed plants, whose bulbs were pre-soaked. In May 2020, both Kelpak SL application methods positively affected the lamina's width, while the narrowest leaves were in control.

Chlorophyll fluorescence parameters differed depending on the treatments used to cultivate garlic (Fig. 1). Turnip rape used as a shade plant increased the F_V/F_M ratio value compared to cultivation without turnip rape. It was evident in 2018 (average 0.701 and 0.619, respectively). The highest F_V/F_M ratio value was recorded in the combination of phacelia catch crop + turnip rape (0.740). In 2019, the highest F_V/F_M ratio value was found after spraying with Kelpak SL (0.703) and the lowest without biopreparations (0.570). This tendency occurred on average, regardless of the year of the study.

CONCLUSIONS

The obtained results show that the biomass of catch crops and shade plants and biopreparations from marine algae are justified in cultivating wild garlic in field conditions regarding the leaf yield.

Ploughing phacelia biomass on catchment soil with an unstable structure positively affected the wild garlic growth by increasing the length of leaves, their number, and the length and width of the leaf blade.

Winter turnip rape used as a shade plant caused an increase in the length of the leaves and the value of the F_V/F_M index, and also, depending on the year of the study, the length and width of the garlic leaf blade.

Soaking the bulbs before planting in the Kelpak SL solution increased the number of garlic leaves growing without turnip rape cover in the second and third years of cultivation. In the first year of vegetation, longer leaves with a larger leaf blade ensured the preparation was sprayed three times without pre-soaking the bulbs.

Considering the biopreparations' positive effect on the growth of garlic leaves and the F_V/F_M ratio values, their use is prospective in terms of the increasing occurrence of dry years and is an alternative to plant irrigation.

SOURCE OF FUNDING

Research supported by the Ministry of Science and Higher Education of Poland as part of the statutory activities of the Institute of Horticultural Production, University of Life Sciences in Lublin.

REFERENCES

Ahmed, M.E.M., Farm, E. (2015). Response of garlic plants (*Allium sativum* L.) to foliar application of some bio-stimulants. Egypt. J. Hort., 42(1), 613–625. https://doi.org/10.21608/ejoh.2015.1318

Błażewicz-Woźniak, M. (2005). Effect of no-tillage and mulching with cover crops on yield of parsley. Folia Hortic., 17(2), 3–10. Błażewicz-Woźniak, M., Budzińska, J., Mucha, S., Wach, D., Baltyn, M., Pitura, K. (2018). Impact of growing conditions and foliar nutrition on growth and development of Spanish bluebell (*Hyacinthoides hispanica* (Mill.) Rothm.). Acta Sci. Pol. Hortorum Cultus, 17(3), 137–146. https://doi.org/10.24326/asphc.2018.3.14

Błażewicz-Woźniak, M., Kęsik, T., Michowska, A.E. (2011). Flowering of bear garlic (*Allium ursinum* L.) cultivated in the field at varied nitrogen nutrition and mulching. Acta Sci. Pol. Hortorum Cultus, 10(3), 133–144.

Błażewicz-Woźniak, M., Konopiński, M. (2013). Impact of cover crops and tillage on porosity of podzolic soil. Int. Agrophysics, 27(3), 247–255. https://doi.org/10.2478/v10247-012-0092-9

Błażewicz-Woźniak, M., Michowska, A. (2011). The growth, flowering and chemical composition of leaves of three ecotypes of *Allium ursinum* L. Acta Agrobot., 64(4), 171–180. https://doi.org/10.5586/aa.2011.058

Błażewicz-Woźniak, M., Wach, D. (2012). The fertilizer value of summer catch crops preceeding vegetables and its variation in the changing weather conditions. Acta Sci. Pol. Hortorum Cultus, 11(3), 101–116.

Błażewicz-Woźniak, M., Wach, D., Konopiński, M., Patkowska, E., Baltyn, M. (2015). Effect of cover crops on emergence and growth of carrot (*Daucus carota* L.) in no-plow and traditional tillage. Acta Agrobot., 68(1), 63–73.

Bodó, A., Farkas, Á., Nagy, D.U., Rudolf, K., Hoffmann, R., Kocsis, M., Morschhauser, T. (2021). Soil humus, iron, sulphate and magnesium content affect nectar traits of wild garlic (*Allium ursinum* L.). Plants, 10(3), 597, 12.

Bulgari, R., Franzoni, G., Ferrante, A. (2019). Biostimulants application in horticultural crops under abiotic stress conditions. Agronomy, 9(6), 306, 30.

Cetner, M.D., Dąbrowski, P., Samborska, A., Łukasik, I., Swoczyna, T., Pietkiewicz, S., Bąba, W., Kalaji, H.M. (2016). Zastosowanie pomiarów fluorescencji chlorofilu w badaniach środowiskowych [Chlorophyll fluorescence measurements in environmental studies]. Kosmos, 65(2), 197–205.

Dobromilska, R., Gubarewicz, K. (2008). Influence of Bio-algeen S-90 on the yield and quality of small-sized tomato. In: Biostimulators in modern agriculture: solanaceous crops, Dąbrowski, T. (ed.). Wieś Jutra, Warsaw, 7–12.

Durlak, W. (2019). Wykorzystanie metody termicznej sap-flow do określenia przepływu wody w pędach *Physocarpus opuli*folius (L.) Maxim. i *Spiraea japonica* L. [The use of the sap-flow thermal method to determine the water flow in the shoots of *Physocarpus opulifolius* L. (Maxim.) and *Spiraea japonica* L. and methods of water stress limiting in these plants cultivated in containers]. Rozpr. Nauk. Uniw. Przyr. Lublin, 397.

Fijałkowski, D., Chojnacka-Fijałkowska, E. (2009). Rośliny lecznicze na Lubelszczyźnie [Medicinal plants in the Lublin region]. LTN, Wyd. Olech, Lublin, 48–50.

Grime, J.P., Hodgson, J.G., Hunt, R. (2014). Comparative plant ecology: a functional approach to common British species. Springer.

Gupta, S., Stirk, W.A., Plačková, L., Kulkarni, M.G., Doležal, K., Van Staden, J. (2021). Interactive effects of plant growth-promoting Rhizobacteria and a seaweed extract on the growth and physiology of *Allium cepa* L.(onion). J. Plant Physiol., 153437. https://doi.org/10.1016/j.jplph.2021.153437

Hæggström, C.A., Hæggström, E., Carlsson, R., von Numers, M. (2016). *Allium ursinum* (*Alliaceae*) in Finland. Memor. Soc. Fauna Flora Fen., 92, 54–78.

Hassan, S.M., Ashour, M., Sakai, N., Zhang, L., Hassanien, H.A., Gaber, A., Ammar, G. (2021). Impact of seaweed liquid extract biostimulant on growth, yield, and chemical composition of cucumber (*Cucumis sativus*). Agriculture, 11(4), 320. https://doi.org/10.3390/agriculture11040320

Jamiołkowska, A. (2014). Effect of some biotechnical preparations on the growth of sweet pepper plants in the field production. Ann. UMCS. Sec. EEE, Horticultura, 24(4), 61–70.

Kęsik, T., Konopiński, M., Błażewicz-Woźniak, M., Mitura, R. (2002). Residual effect of no-tillage and cover crops in vegetables cultivation on soil aggregates formation and soil structure. Rocz. Akad. Rol. Pozn., Ogrodn., 35, 83–88.

Kęsik, T., Błażewicz-Woźniak, M. (2008). The after-effect of conservation tillage of onion with mulch utilization made of spring rye and common vetch on the yield of carrot roots. Veg. Crops Res. Bull., 69, 39–50.

Kęsik, T., Błażewicz-Woźniak, M., Michowska, A. E. (2011). Influence of mulching and nitrogen nutritionon bear garlic (*Allium ursinum* L.) growth. Acta Sci. Pol. Hortorum Cultus, 10(3), 221–233.

Khan, W., Rayirath U.P., Subramanian, S., Jithesh M.N., Rayorath, P., Hodges, D.M., Critchley A.T., Craigie, J.S., Norrie, J., Prithiviraj B. (2009). Seaweed extracts as biostimulants of plant growth and development. J.

Plant Growth Reg., 28(4), 386–399. https://doi.org/10.1080/01904167.2018.1504966

Khan, R.I., Hafiz, I.A., Shafique, M., Ahmad, T., Ahmed, I., Qureshi, A.A. (2018). Effect of pre-harvest foliar application of amino acids and seaweed (*Ascophylum nodosum*) extract on growth, yield, and storage life of different bell pepper (*Capsicum annuum* L.) cultivars grown under hydroponic conditions. J. Plant Nutr., 41(18), 2309–2319.

Konopiński, M., Kęsik, T., Błażewicz-Woźniak, M. (2001). Wpływ mulczowania międzyplonowymi roślinami okrywowymi i uprawy zerowej na kształtowanie wilgotności i zagęszczenia gleby. Acta Agrophys., 45, 105–116.

Lachowicz, S., Oszmiański, J., Wiśniewski, R. (2018). Determination of triterpenoids, carotenoids, chlorophylls, and antioxidant capacity in *Allium ursinum* L. at different times of harvesting and anatomical parts. Europ. Food Res. Technol., 244(7), 1269–1280. https://doi.org/10.1007/s00217-018-3042-3

Mancuso, S., Azzarello, E., Mugnai, S., Briand, X. (2006). Marine bioactive substances (IPA extract) improve ion fluxes and water stress tolerance in potted *Vitis vinifera* plants. Adv. Hortic. Sci., 20, 156–161.

Matysiak, K., Kaczmarek, S., Kierzek, R. (2012). Wpływ wyciągu z alg morskich *Ecklonia maxima* (Kelpak SL) na rośliny rzepaku ozimego [Effect of algae *Ecklonia maxima* (Kelpak SL) on winter oilseed rape]. Rośl. Ol., 33(1), 81–88. https://doi.org/10.5604/12338273.1058592

Mikiciuk, M., Dobromilska, R. (2014). Assessment of yield and physiological indices of small-sized tomato cv. 'Bianka F_1' under the influence of biostimulators of marine algae origin. Acta Sci. Pol. Hortorum Cultus, 3(1), 31–41.

Mitura, K., Lipińska, K.J., Świtkowski, M., Spychaj-Fabisiak, E. (2014). Bioregulator Kelpak – charakterystyka oraz zastosowanie [Kelpak bioregulator – characteristics and application]. In: Nauka niejedno ma imię. Część II. Nauki przyrodnicze [Science has many names. Part II. The natural sciences], Wyd. UTP w Bydgoszczy, 2, 125–134.

Mystkowska, I.T. (2018). Biostimulators as a factor affecting the yield of edible potato. Acta Agroph., 25(3), 307–315. https://doi.org/10.31545/aagr/95109

Papenfus, H.B., Kulkarni, M.G., Stirk, W.A., Finnie, J.F., Van Staden, J. (2013). Effect of a commercial seaweed extract (Kelpak®) and polyamines on nutrient-deprived (N, P and K) okra seedlings. Sci. Hortic., 151, 142–146. https://doi.org/10.1016/j.scienta.2012.12.022

Parađiković, N., Teklić, T., Zeljković, S., Lisjak, M., Špoljarević, M. (2019). Biostimulants research in some horticultural plant species — A review. Food Energy Sec., 8(2), e00162. https://doi.org/10.1002/fes3.162

Petropoulos, S.A., Di Gioia, F., Polyzos, N., Tzortzakis, N. (2020). Natural antioxidants, health effects and bioactive properties of wild *Allium* species. *Current Pharmac. Des.*, *26*(16), 1816–1837. https://doi.org/10.2174/1381612826666200203145851

Płaza, A., Ceglarek, F., Próchnicka, M. (2009). Wpływ międzyplonów ścierniskowych na plon i strukturę plonu bulw ziemniaka [The influence of stubble catch crop on the yield and yield structure of potato tubers]. Fragm. Agron., 26(3), 137–145.

Rola, K. (2012). Taxonomy and distribution of *Allium ursinum* (*Liliaceae*) in Poland and adjacent countries. Biologia, 67(6), 1080–1087.

Sady, W. (2012). Nawożenie warzyw polowych [Fertilization of field vegetables]. Kraków, Plantpress.

Shafeek, M.R., Helmy, Y.I., Omar, N.M. (2015). Use of some bio-stimulants for improving the growth, yield and bulb quality of onion plants (*Allium cepa* L.) under sandy soil conditions. Middle East J. Appl. Sci., 5(1), 68–75. https://doi.org/10.21608/hjsc.2018.59099

Shalaby, T.A., El-Ramady, H. (2014). Effect of foliar application of bio-stimulants on growth, yield, components, and storability of garlic (*Allium sativum* L.). Austr. J. Crop Sci., 8(2), 271–275.

Sharma, S.H.S., Fleming, C., Selby, Ch., Rao, J.R., Trevor, M. (2014). Plant biostimulants: a review on the processing of macroalgae and use of extracts for crop management to reduce abiotic and biotic stresses. J. Appl. Phycol*.*, 26, 465–490. https://doi.org/10.1007/s10811-013-0101-9

Sobolewska, D. (2018). Czosnek niedźwiedzi *Allium ursinum*: wielki powrót. Wyd. OSDW Azymut, Łódź.

Sobolewska, D., Podolak, I., Makowska-Wąs, J. (2015). *Allium ursinum*: botanical, phytochemical and pharmacological overview. Phytochem. Rev., 14(1), 81–97. https://doi.org/10.1007/s11101-013-9334-0

Szczepanek, M., Wszelaczyńska, E., Pobereżny, J., Ochmian, I. (2017). Response of onion (*Allium cepa* L.) to the method of seaweed biostimulant application. Acta Sci. Pol. Hortorum Cultus, 16(2), 113–122.

Truba, M., Jankowski, K., Sosnowski, J. (2012). The plants reaction on biological preparations treatment. Ochr. Środ. Zas. Nat., 53, 41–52.

Załuski, T., Gawenda-Kempczyńska, D., Paszek, I., Łazowy-Szczepanowska, I. 2009. Stan zachowania i sposoby ochrony rzadkich składników flory Gorznieńsko-Lidzbarskiego Parku Krajobrazowego [Conservation status and protection methods of rare flora's elements of Górzno-Lidzbark Landscape Park]. Przegl. Przyr., 20(3–4), 87–104.