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Department of Horticultural Nursery and Seed Production
Faculty of Horticulture and Landscape Architecture
University of Life Sciences in Lublin, S. Leszczyńskiego str. 58, 20-068 Lublin
e-mail: andrzej.borowy@up.lublin.pl

ANDRZEJ BOROWY, PIOTR KICZOROWSKI, IRENA WÓJCIK

Evaluation of fluazifop-P-butyl and napropamide usefulness for weed control in borage (*Borago officinalis* L.) cultivation

Ocena przydatności fluazifop-P-butylu i napropamidu do zwalczania chwastów w uprawie ogórecznika lekarskiego (*Borago officinalis* L.)

Summary. Fluazifop-P-butyl 187.5 g · ha^{-1} applied after borage emergence was selective to cultivated plants and very efficient in farmyard grass and couch grass control in one year field experiment. Napropamide 900 g · ha^{-1} and 1350 g · ha^{-1} mixed with the top 3–5 cm soil layer immediately before seed sowing was slightly toxic to some borage seedlings but did not affect further plant growth. It controlled the annual grasses and some dicotyledonous weeds well during 10 weeks after seed sowing. Herbicides did not influence borage emergence, the plant fresh weight, the yield of fresh borage herb, the number of seeds sett on one plant, 1000 seeds weight and the seed oil content. The content of gamma-linolenic acid in the oil obtained from seeds set on plants growing on plots treated with napropamide 900 g · ha^{-1} and the content of erucic acid in the oil obtained from seeds set on plants growing on plots treated with fluazifop-P-butyl 187.5 g · ha^{-1} and on plots treated with napropamide 1350 g · ha^{-1} were significantly lower.

Key words: growth, yield, seeds, oil, gamma-linolenic and erucic acids

INTRODUCTION

Borage is an annual plant in the Boraginaceae family native to the Mediterranean region and naturalized in some other parts of Europe, among others in Poland [Gupta and Singh 2010, Pieszak *et al*. 2012]. It grows well in warm places and on enough wet soils [Król 2010]. Traditionally borage was cultivated for culinary and medicinal use of the leaves, flowers, and seeds [Beaubaire and Simon 1987]. Borage with a cucumber-like smell [Pieszak *et al*. 2012] is used in selected salads, soups, some vegetable and meat dishes and its blue to purple flowers are often candied and added to confections [Simon *et al*. 1984]. In Spain borage is commonly cultivated as a vegetable for basal leaf petioles which contain considerable amounts of potassium, iron, protein, fiber and about 94% of water [Medrano *et al.* 1992]. Green parts of borage contain also substantial amounts of omega-3 and omega-6 fatty acids, which are essential for human nutrition [Río-Celestino *et al*. 2008]. The plant is reputed as antispasmodic, antihypertensive, antipyretic, aphrodisiac, demulcent and diuretic. It is also considered useful to treat asthma, bronchitis, cramps, diarrhea, palpitations and kidney disorders [Gilani *et al*. 2007, Pieszak *et al*. 2012]. Today borage is cultivated mainly for seed oil [El Hafid *et al*. 2002, Gupta and Singh 2010] which is used as a treatment for various degenerative diseases. Its many useful properties are attributed to high gamma-linolenic acid content [Tasset-Cuevas *et al*. 2013]. Borage seeds contain from 27 to 37% of oil [Muuse *et al*. 1988, Janick *et al*. 1989, Gunstone 1992, Río *et al*. 1993, Haro-Bailón and Río 1998] and unsaturated fatty acids make up to 60% of the oil [Król 2010]. Borage oil is the richest plant source of gamma-linoleic acid [Beaubaire and Simon 1987, El Hafid *et al*. 2002]. In studies conducted by Río *et al.* [1993], oil content in seeds of 185 white and blue flowered, wild and cultivated borage populations varied from 26.7 to 38%. Content of GLA in the oil varied from 8.7 to 28.6%. In experiment curried out by Berti *et al*. [1998], content of oil in borage seeds and content of GLA in the oil was dependent on maturity stage and varied from 31.5 to 33.1% and from 17.30 to 18.46% respectively. In another studies conducted by Berti *et al*. [2002] in conditions more suitable for borage cultivation, content of GLA in the oil varied from 22.2 to 29.1% in dependence on seeding date. Content of GLA in the oil extracted from borage seeds by El Hafid *et al*. [2002] ranged from 23.2 to 30%. In studies curried out in Poland by Zadernowski *et al*. [1999], borage seeds contained 34% of oil and GLA made about 23% of the oil. Oil obtained from mature borage seeds contains GLA more than oil obtained from semi mature or immature seeds [Berti *et al*. 2002]. Borage oil contains also small quantities (0.6–3.3%) of erucic acid [Río *et al*. 1993, Berti *et al*. 1998]. In one year experiment carried out by Beaubaire and Simon [1987], fresh weight of one borage plant was depended on plant spacing and harvest time and ranged from about 200 to 1100 g and the highest yield of harvested borage seeds amounted to 753.5 kg · ha^{-1}. Seed yield harvested in different locations by Berti *et al*. [2002] ranged from 66.4 to 431.1 kg · ha^{-1} with the potential yield reaching 474 kg · ha^{-1}. El Hafid *et al*. [2002] harvested in two years' experiment from 2891 to 6277 kg · ha^{-1} of total above-ground dry weight plant biomass and from 61 kg · ha^{-1} to 794 kg · ha^{-1} of borage seeds in dependence on seeding and harvesting dates. In two years' study conducted by Mordalski *et al*. [2003], yield of borage raw material harvested on weeded plots ranged from 160.1 to 173.6 kg · ha^{-1}.

Borage is seeded directly in the field and in Poland the best term of its sowing is second half of April [Suchorska and Osińska 1997c]. The seeds are seeded in rows 40–45 cm apart at rate of 7–10 kg · ha^{-1} and emergence starts 2–3 weeks after seeding [Senderski 2009]. Weeds emerge earlier and compete with borage well in the first half of cultivation period. In experiment conducted by Mordalski *et al*. [2003], weeds reduced yield of borage raw material by 60–69%. When weather conditions are unfavorable the emergence is not uniform and continues longer and threat of weed competition increases [Borowy 2007]. In a pot experiment carried out by Suchorska and Osińska [1997a], germination of borage seeds started 3 to 13 days after seeding in dependence on temperature, age of seeds and type of bed (limed sphagnum peat, river sand). In field cultivation, borage seed germination and emergence depends on weather conditions and is often unsatisfactory [Suchorska and Osińska 1997b, c, Borowy 2007]. After emergence, borage seedlings grow fast and the plants cover soil surface well. In May, June and July borage develops strong, 60–80 cm high stems brunched in its upper part and in this time it competes with the weeds well [Suchorska and Osińska 1997b, Król 2010]. Weather conditions during vegetation period have significant influence on course of borage flowering and then on setting and ripening of seeds [Suchorska and Osińska 1997c]. Ripe borage seeds shatter easily and the best time for their harvest is first half of August [Suchorska and Osińska 1997c]. In two two years' experiments carried out by Suchorska and Osińska [1997b, c] the weight of 1000 matured seeds varied from 10,0 to 38,5 g in dependence on the year and time of harvest with the most frequent values about 20 g. In studies conducted by Río *et al*. [1993], 1000 borage seeds weight ranged from 9.3 to 20.1 g.

Weeds compete with cultivated plants for light, water and mineral nutrients what leads to yield reduction [Błażewicz-Woźniak *et al*. 2013]. Borage is a minor crop and therefore the information related to chemical weed control in its cultivation is scanty. In experiment curried out by Mordalski *et al*. [2003], linuron 675 g $\cdot$ ha^{-1} and metobromuron 750 g $\cdot$ ha^{-1} applied immediately after seeding and fluazifop-P-butyl 187.5 g $\cdot$ ha^{-1} applied before barnyard grass tillering were useful in borage cultivation, however linuron and metobromuron caused slight transient growth inhibition of borage plants. In one year experiment conducted by Borowy [2007], fluazifop-P-butyl 187.5 g $\cdot$ ha^{-1} was selective to borage and controlled 97% of barnyard grass. Metolachlor 1440 and 1728 g $\cdot$ ha^{-1} and napropamide 900 and 1350 g $\cdot$ ha^{-1} controlled weeds well also but they caused slight transient damages of the first true leaves developed by some borage plants. Actually in Poland fluazifop-P-butyl and napropamide are registered for use in cultivation of several medicinal plants [Kucharski *et al*. 2014]. Fluazifop-P-butyl inhibits lipid biosynthesis and napropamide inhibits cell division [Reade and Cobb 2002]. Fluazifop-P-butyl controls annual and perennial grasses and napropamide controls majority of annual grasses and some dicotyledonous weeds [Praczyk and Skrzypczak 2004]. Murawa *et al*. [2000] stated higher lipid content in seeds of two spring oilseed rape cultivars treated with metazachlor 1200 g $\cdot$ ha^{-1} and trifluralin 875 g $\cdot$ ha^{-1} in one year experiment. No distinct effects of several herbicides on oil yield and composition of fatty acids in the oil were found in other studies conducted by Murawa *et al*. [1996, 1997, 2000].

In the last years in Poland, medicinal plants are cultivated on an area of 14 000 ha what makes the country one of the biggest herb producers in Europe. The biggest cultivation area with the highest number of herb farms is in the Lublin region [Olewnicki *et al*. 2015].

The aim of this experiment was to study the effect of fluazifop-P-butyl and napropamide on weeds and on growth and yield of borage cultivated in the Lublin region. Moreover, content of oil in borage seeds and content of gamma-linolenic and erucic acids in the oil were also determined.

MATERIAL AND METHODS

The experiment was conducted in Felin Experimental Farm of the Life Sciences University in Lublin in 2008. It was established on podzolic soil developed from dusty medium loam containing 1.6% of organic matter and with pH (in H_2O) of 6.6. On April 24th the field was fertilized with 30 kg N · ha^{-1} (ammonium nitrate), 60 kg P_2O_5 · ha^{-1}(superphosphate) and 90 kg K_2O · ha^{-1} (potassium salt) and then tilled using cultivator with surface roller. Next day seeds of blue flowered borage (*Borago officinalis* L.) were sown 1–2 cm deep by hand in 8 rows 3 m long on each plot with 40 cm distance between rows (9,6 m^2 plot area) and 6 cm distance between seeds in the row (400 seeds · $plot^{-1}$, 11 kg of seeds · ha^{-1}). One-year old seeds with 60% germination capacity were obtained from Lewandowski Herbal Firm located in Kruszynek in Kujawy region. Two weeks after emergence borage plants were top dressed with 30 kg N · ha^{-1} (ammonium nitrate). Napropamide 900 g · ha^{-1} and 1350 g · ha^{-1} was mixed with the top 3–5 cm soil layer immediately before seed sowing and fluazifop-P-butyl 187.5 g · ha^{-1} was applied on May 20th when majority of borage plants was in 2–4 true leaves stage, barnyard grass (*Echinochloa crus-galli* (L.) P. Bauv.) was in 3 leaves – beginning of tillering and couch grass (*Elymus repens* (L.) Gould.) was in 4 leaves stage. Fluazifop-P-butyl was applied at the 24°C air temperature, cloudy weather and good soil moisture. Herbicides were sprayed using a back-pack sprayer mounted with XR TeeJet® 80° nozzle at 1.5 bars pressure and 300 l of water · ha^{-1}. On May 22nd all emerged borage plants were counted. Number and fresh weight of weeds growing on 0,5 m^2 area of control plots and of plots treated with napropamide were determined 29 (May 23rd) and 74 (July 7th) days after borage seed sowing. Immediately after first measurement, control and napropamide treated plots were weeded by hand. On plots treated with fluazifop-P-butyl, weed flora was determined immediately before spraying and then the effect of herbicide on grasses was evaluated visually. On June 3rd length of the longest rosette leaf of 20 plants on each plot was measured. The plants were cut by hand at the soil surface in the beginning of flowering on June 30th and then their fresh weight of 10 plants and of all plants from each plot was determined. Moreover, on each plot 5 plants were left to continue the vegetation and they were cut on July 29th when first mature seeds started to drop. After cutting, the plants were dried in a glasshouse during 15 days and then the seeds were separated and their number and weight of matured 1000 seeds were determined. During period of borage cultivation, air temperature and rainfall were measured in meteorological station placed in Felin Experimental Farm (Tab. 1).

Table 1. Average monthly air temperatures and sums of rainfalls during borage cultivation for April–July in 2008 compared to the long term average (1951–2005)
Tabela 1. Średnie miesięczne temperatury powietrza i sumy opadów podczas uprawy ogórecznika w okresie kwiecień–lipiec w roku 2008 na tle średnich wieloletnich (1951–2005)

Month/ Miesiąc	Temperature/ Temperatura (°C)		Rainfalls/ Opady (mm)	
	2008	1951–2005	2008	1951–2005
April/ Kwiecień	7.8	7.4	43.1	40.2
May/ Maj	14.9	13.0	80.5	57.7
June/ Czerwiec	18.1	16.2	87.8	65.7
July/ Lipiec	19.1	17.8	87.0	83.5

In October in Central Laboratory of Life Sciences University in Lublin, oil content in samples of borage seeds was determined. The seeds were grinded and then the oil was extracted with petroleum ether for 10 min, followed by soxhlet extraction [Krełowska-Kułas 1993]. Content of GLA and erucic acid in the oil was determined twice after fats initial saponification and esterification of acids according to PN-EN-ISO-150-5508:1996 and PN-EN-ISO-12966-2:2011 norms using gas chromatograph Varian 450-GC fitted with a flame ionization detector (FID) and heptadecanoic acid as an internal pattern.

The plots were arranged in a randomized complete block design with four replications. The results were studied by analysis of variance and significance of differences was determined using Tukey's test at 0.05 probability level.

RESULTS

Emergence of weeds started 6 days after seed sowing. Three weeks later, 202 weeds representing 14 dicotyledonous and 3 monocotyledonous species of 141.5 g fresh weight grew on 1 m^2 of control plot (Tab. 2) and majority of them were in first 2–4 true leaves stage. In this time the weeds covered about 10% of soil surface. Farmyard grass and lamb's quarters (*Chenopodium album* L.) dominated in the experiment and they were sensitive and medium sensitive to napropamide respectively. Total number and fresh weight of weeds growing on plots treated with napropamide 900 and 1350 g · ha^{-1} were reduced by 71 and 83% and by 81 and 85% respectively. Six weeks later, efficacy of napropamide in weed control remained almost unchanged (Tab. 2). Two weeks after emergence, yellowish colouring of first true leaves was observed on some borage plants growing on plots treated with this herbicide. The colouring decayed gradually during three following weeks and did not affect further growth of plants.

Next day after spraying with fluazifop-P-butyl 187.5 g · ha^{-1}, the base of leaves of farmyard grass started to become mat and yellow and then these symptoms intensified gradually and covered whole leaf blade. In a few following days the leaves became chlorotic and decayed (necrosis). Twenty days after treatment 97% of farmyard grass was killed. Remained few plants protected by borage leaves during fluazifop-P-butyl spraying. Effect of herbicide on couch grass was similar but more slowly. Other weeds occurring in the experiment were resistant and therefore its total efficacy (43% of weed control) was fairly good. Fluazifop-P-butyl 187.5 g · ha^{-1} was selective to borage plants.

Borage seeds were seeded into well tilled and moist soil. Their emergence started 9 days later and continued two weeks. An average number of emerged borage plants ranged from 108 plants on plots treated with napropamide 1350 g · ha^{-1} to 121 plants on plots treated with fluazifop-P-butyl 187.5 g · ha^{-1} with the differences being insignificant (Tab. 3). After emergence borage seedlings grew fast. In May the plants formed ground leaf rosette and the herbicides did not influence the length of its longest leaf (Tab. 3). Fresh weight of borage plant measured at the beginning of flowering ranged from 539.8 to 624.5 g and the yield of fresh borage herb ranged from 613.4 to 670.8 kg · 100 m^{-2} with the differences being not depended on herbicide treatment (Tab. 3). Plants left on plots grew and flowered intensively. The flowers were visited often by the bees. Number of seeds setted by one plant varied from 651 to 734; 1000 seeds weight varied from 20.9 to 22.5 g. These measurements were also not influenced by herbicides.

Table 2. Effect of napropamide on number (pcs · m^{-2}) and fresh weight (g · m^{-2}) of weeds growing on plots 29 and 74 days after borage seeding
Tabela 2. Wpływ napropamidu na liczbę (szt. · m^{-2}) i świeżą masę (g · m^{-2}) chwastów rosnących na poletkach 29 i 74 dni po siewie ogórecznika

Weed species Gatunek chwastu	29 days after seeding 29 dni po siewie			74 days after seeding 74 dni po siewie		
	Napropamide		Control Kontrola	Napropamide		Control Kontrola
	900 g · h^{-1}	1350 g · h^{-1}		900 g · h^{-1}	1350 g · h^{-1}	
Amaranthus lividus L.	1	0	1	0	0	1
Amaranthus retroflexus L.	2	1	8	0	0	4
Capsella bursa-pastoris (L.) Med.	3	2	5	5	4	16
Chenopodium album L.	22	16	65	7	4	34
Echinochloa crus-galli (L.) P. Beauv.	19	12	86	4	2	28
Elymus repens (L.) Gould	2	1	6	15	10	49
Galinsoga ciliata (Raf.) S.F. Blake	3	1	8	22	14	113
Galinsoga parviflora Cav.	1	0	1	3	2	2
Lamium amplexicaule L.	0	0	5	0	0	3
Poa annua L.	1	0	6	0	0	0
Polygonum persicaria L.	1	1	1	0	0	0
Senecio vulgaris L.	0	0	1	0	0	1
Solanum nigrum L.	0	0	4	0	0	3
Sonchus oleraceus L.	1	1	3	1	0	1
Stellaria media (L.) Vill.	1	0	0	2	3	4
Urtica dioica L.	0	0	2	0	0	1
Urtica urens L.	1	2	1	2	3	3
Total number of weeds Całkowita liczba chwastów	59	38	202	61	42	263
Fresh weight of weeds Świeża masa chwastów	24.6	20.8	141.5	40.2	37.1	218.4
LSD $_{0.05}$/ NIR $_{0,05}$:						
Number of weeds/ Liczba chwastów	78.6			147.9		
Weight of weeds/ Masa chwastów	48.8			94.3		

Table 3. Emergence of borage (pcs · plot^{-1}), length of rosette leaf (cm), plant fresh weight (g) and yield of fresh herb (kg · 100 m^{-2})
Tabela 3. Wschody ogórecznika (szt. · poletko^{-1}), długość liścia rozetowego (cm), świeża masa rośliny (g) i plon świeżego ziela (kg · 100 m^{-2})

Treatment Kombinacja	Emergence Wschody	Leaf length Długość liścia	Plant fresh weight Świeża masa rośliny	Herb fresh weight Plon świeżego ziela
Fluazifop-P-butyl 187.5 g · ha^{-1}	121	21.7	560.2	650.7
Napropamide 900 g · ha^{-1}	114	22.4	624.5	662.9
Napropamide 1350 g · ha^{-1}	108	21.8	539.8	613.4
Check/ Kontrola	116	23.1	592.9	670.8
$LSD_{0.05}$/ $NIR_{0,05}$	n.s./ n.i.	n.s./ n.i.	n.s./ n.i.	n.s./ n.i.

Table 4. Number of seeds setted by one borage plant, 1000 seeds weight (g), content of oil in seeds (%) and content of gamma-linolenic (GLA) and erucic acids in oil (%)
Tabela 4. Liczba nasion zawiązanych na roślinie ogórecznika, masa 100 nasion (g), zawartość oleju w nasionach (%) oraz zawartość kwasu gamma-linolenowego (GLA) i kwasu erukowego w oleju (%)

Treatment Kombinacja	Number of seeds setted by plant Liczba nasion zawiązanych na roślinie	1000 seeds weight Masa 1000 nasion	Content of oil in seed Zawartość oleju w nasionach	Content of GLA in oil Zawartość GLA w oleju	Content of erucic acid in oil Zawartość kwasu erukowego w oleju
Fluazifop-P-butyl 187.5 g · ha^{-1}	734	20.9	28.0	17.5	2.1
Napropamide 900 g · ha^{-1}	651	22.5	28.2	17.4	2.3
Napropamide 1350 g · ha^{-1}	668	21.3	27.9	17.5	2.2
Check/ Kontrola	723	21.7	27.9	17.6	2.3
$LSD_{0.05}$/ $NIR_{0,05}$	n.s./ n.i.	n.s./ n.i.	n.s./ n.i.	0.13	0.02

Content of oil in the seeds made from 27.9 to 28.2% with the differences being insignificant. Oil obtained from control seeds contained 17.6% of gamma-linolenic acid and oil obtained from seeds setted by plants treated with napropamide 990 g · ha^{-1} contained 17.4% of GLA with the difference being significant. Other treatments differed not significantly. Oil obtained from control seeds contained 2.3% of erucic acid and in the oil obtained from seeds setted by plants treated with fluazifop-P-butyl 187.5 g · ha^{-1} and napropamide 1350 g · ha^{-1} content of this acid was significantly lower (Tab. 4).

DISCUSSION

Experimental field was used several years for vegetables cultivation and therefore weeds occurring in the experiment were characteristic to this crop [Błażewicz-Woźniak *et al*. 2013]. Some of them, e.g. farmyard grass and lamb's quarters dominated also in borage cultivated by Mordalski *et al*. [2003]. In the experiment weeds emerged a few days earlier and grew in considerable bigger intensity than borage. Moreover, some of them were tall growing and of big competitive ability, e.g. farmyard grass, lamb's quarter, redroot pigweed (*Amaranthus retroflexus* L.) what caused a threat in regard to cultivated plant [Błażewicz-Woźniak *et al*. 2013]. In the experiment borage was seeded early in the spring according to Suchorska and Osińska [1997c] recommendation. Delayed seeding makes possible pre-seeding weed control by cultivation but causes significant decrease of borage seed yield and often also of biomass yield [Suchorska and Osińska 1997c, El Hafid *et al*. 2002]. Napropamide controlled annual grasses well during 10 weeks after borage seeding. However, its activity upon dicotyledonous weeds was lower and depending on species. These results agree with those obtained by Hetman *et al*. [1987] and Borowy [1993a, 2007] in the same natural conditions. They confirm also considerable persistence of napropamide and risk of damage of plants sensitive to this herbicide and cultivated after borage harvest, e.g. cereals [Borowy 1993b]. Borage plants emerged on plots treated with napropamide showed slight phytotoxicity symptoms and this agrees with preliminary observations made by Borowy [2007]. There is no other information in the literature about borage reaction to napropamide. Fluazifop-P-butyl was selective to borage and very efficacy in couch grass and farmyard grass control and this is in line with the results obtained by Mordalski *et al*. [2003]. Fluazifop-P-butyl is selective to dicotyledonous plants [Reade and Cobb 2002] however some of these species can be damaged by this herbicide [Borowy 1996].

Germination capacity of borage seeds used in the experiment was low and only about 30% of them emerged in the field. This is generally in line with the results obtained by other authors [Borowy 2007, Suchorska and Osińska 1997a, b, c]. Napropamide did not affect emergence of borage what confirms the results obtained by Borowy [2007]. Fluazifop-P-butyl was applied after borage emerged. Fresh weight of one borage plant in beginning of flowering stage was similar to that stated by Beaubaire and Simon [1987] in USA and yield of borage fresh herb corresponded with dry weight biomass harvested by El Hafid *et al*. [2002] in Canada. Weight of 1000 seeds setted in the experiment by one blue flowered borage plant was considerable higher than weight of 1000 seeds of many wild blue flowered and cultivated white flowered borage populations collected in southern Spain [Río *et al*. 1993] and a little higher than weight of 1000 seeds collected in Poland [Suchorska and Osińska 1997c]. Number of seeds setted by one plant was considerably lower than that stated by Suchorska and Osińska [1997c] at early seeding, however these authors harvested seeds a few times as they matured. Borage growth, development, flowering and then setting and maturing of seeds depends significantly on precipitation and air temperature [Suchorska and Osińska 1997b, c]. Results presented in this study were obtained in a year characterized by weather conditions favorable to borage cultivation (Tab. 1). Oil content in seeds harvested in the experiment was lower than in seeds setted by many Spanish borage populations [Río *et al*. 1993] and in seeds analyzed by Berti *et al.* [1998] in Chile and by Zadernowski *et al*. [1999] in Poland. In the experiment seeds were harvested at high air temperatures (Tab. 1) and according to Bartkowiak-Broda *et al*. [2005] temperature higher than optimal for a region decreases content of oil in seeds. Content of GLA in borage oil was similar to that stated by Beaubaire and Simon [1987] and Berti *et al*. [1998] and lower in comparison to that found by Zadernowski *et al*. [1999], Berti *et al*. [2002] and El Hafid *et al*. [2003]. An average GLA content in oil obtained from seeds setted by Spanish borage populations was higher, however oil obtained from seeds of some populations contained GLA considerable less than oil obtained from seeds harvested in this experiment. Several authors stated that GLA content increases as temperature decreases during seed development [Levy *et al*. 1993, Berti *et al*. 1998, Fieldsen and Morison 2000, El Hafid *et al*. 2002] and there was an opposite situation in the experiment. Content of erucic acid in borage oil obtained in this experiment was lower than that stated by Berti *et al*. [1998] and higher than in oils obtained from seeds of majority borage populations studied by Río *et al*. [1993]. All these data show that oil content in seeds as well as content of GLA and erucic acid in the oil depend on borage ecotype and also on environmental conditions of its cultivation. Results obtained in this experiment refer to Polish ecotype of borage and to natural conditions of south-eastern part of Poland. Herbicides studied in the experiment did not affect the content of oil in borage seeds and this agrees with the results referring to rapeseed and obtained by Murawa *et al*. [1997, 2000]. However, significant negative effect of some herbicide treatments on GLA and erucic acid content in borage oil is not in line with other data of the same authors [Murawa *et al*. 1997, 2000]. Results presented in this paper were collected in one year experiment and they should be confirmed in further studies.

CONCLUSIONS

1. Fluazifop-P-butyl 187.5 g · ha^{-1} was selective to borage and very effective in post emergence farmyard grass and couch grass control. It can be useful on fields infested with these weeds.

2. Napropropamide 900 and 1350 g · ha^{-1} was slightly phytotoxic to borage seedlings but did not influence further plant growth. It controlled annual grasses very well and in a less degree also dicotyledonous weeds during 10 weeks after borage seed sowing. It can be applied to limit weed infestation in borage crop.

3. Studied herbicides did not affect the content of oil in borage seeds. Content of gamma-linoleic acid in the oil was lower in seeds setted by plants growing on plots treated with napropamide 900 g · ha^{-1} and content of erucic acid in the oil was lower in seeds setted by plants growing on plots treated with fluazifop-P-butyl 187.5 g · ha^{-1} and also on plots treated with napropamide 1350 g · ha^{-1}.

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Streszczenie. W rocznym doświadczeniu polowym fluazifop-P-butyl stosowany w dawce 187,5 g · ha^{-1} po wschodach ogórecznika był selektywny wobec rośliny uprawnej i zwalczał bardzo skutecznie chwastnicę jednostronną oraz perz. Napropamid stosowany w dawkach 900 i 1350 g · ha^{-1}, mieszany z wierzchnią 3–5-centymetrową warstwą gleby bezpośrednio przed siewem nasion, powodował przemijające przebarwienia pierwszego liścia niektórych siewek ogórecznika, co nie miało wpływu na dalszy wzrost roślin. Dobrze zwalczał roczne trawy i niektóre chwasty dwuliścienne podczas 10 tygodni po siewie. Herbicydy nie miały wpływu na wschody ogórecznika, świeżą masę rośliny, plon świeżego ziela, liczbę nasion zawiązanych na roślinie, masę 1000 nasion i zawartość oleju w nasionach. Olej pochodzący z nasion roślin rosnących na poletkach traktowanych napropamidem w dawce 900 g · ha^{-1} zawierał mniej kwasu gamma-linolenowego, a uzyskany z nasion zawiązanych przez rośliny rosnące na poletkach traktowanych napropamidem w dawce 1350 g · ha^{-1} oraz fluazifop-P-butylem w dawce 187,5 g · ha^{-1} zawierał mniej kwasu erukowego.

Słowa kluczowe: wzrost, plon, nasiona, olej, kwas gamma-linolenowy i erukowy