

## Influence of ridge cultivation and phacelia intercrop on weed infestation of root vegetables of the Asteraceae family

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### ABSTRACT

The field experiment focused on three high-inulin vegetable crops: chicory (*Cichorium intybus* L. var. *sativum* Bisch.), black salsify (*Scorzonera hispanica* L.) and common salsify (*Tragopogon porrifolius* L.), and took into account two cultivation methods (flat soil and ridges) and a phacelia (*Phacelia tanacetifolia* L.) intercrop, the biomass of which was mixed with the soil during pre-winter ploughing. Cultivation without an intercrop served as the control. The studies aimed at evaluating the influence of ridge cultivation using a phacelia intercrop on the species composition and population of vegetable weeds as compared to traditional flat-soil cultivation with no intercrop. In total, 24 taxa in the primary and 31 taxa in the secondary weed populations (mostly characteristic for vegetable crops) were recorded in high-inulin species plantations. Monocarpic species such as *Senecio vulgaris*, *Chenopodium album* and *Lamium amplexicaule* dominated in the spring, while *Stellaria media*, *Capsella bursa-pastoris* and *Urtica urens* were most numerous at the end of the vegetation period. Applying phacelia as the intercrop and ploughing its biomass before winter significantly reduced the primary weed population for all of the cultivated crop species as compared to the no-intercrop cultivations. Phacelia grown as the intercrop reduced the occurrence of *Senecio vulgaris*, while favouring the development of *Lamium amplexicaule*. The cultivation system affected the primary weed infestation of vegetables, whereas it had no impact on the level of secondary weed infestation. At the beginning of the vegetation periods, fewer weeds grew in ridges than in the flat soil system. The crop species had no effect on the primary weed infestation, while it influenced weed numbers in the secondary. The lowest number of weeds was recorded in the secondary weed infestation of chicory, the well-developed leaf rosettes of which efficiently eliminated most of the weeds.

Key words: flat-soil cultivation, ploughing, catch-crop, chicory, black salsify, common salsify

### INTRODUCTION

Inulin is a valuable polysaccharide with specific dietary features. Species of the Asteraceae family are distinguished by high levels of inulin. This group includes chicory, black salsify and common salsify. These plants accumulate inulin in the roots,

thus achieving high yields of good-quality roots is a prerequisite in their cultivation. The ridge cultivation of root crops has been re-discovered lately, because it allows very beneficial conditions for growth. Elevating the plant's stand above the natural ground level contributes to higher soil temperatures, deeper root penetration, and their

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better development (Sady and Cebulak 2000, Konopiński 2003, Konopiński and Błażewicz-Woźniak 2008, Krause et al. 2009). However, due to drying, cultivation on ridges can be recommended mainly for wet or heavier soils, or with irrigation provided (Konopiński 2003, Babik et al. 2004, Adamicki et al. 2005). The intercrops, an excellent source of organic matter, also change the physical and chemical properties of the soil along with its biological activity. Modifying the soil environment affects not only the growth and yielding of a crop, but also the emergence and growth of weeds (Liebman and Dyck 1993, McGiffen et al. 2000, Błażewicz-Woźniak 2004, Błażewicz-Woźniak and Mitura 2004, Kęsik and Błażewicz-Woźniak 2007, Dhimaa et al. 2009, Kęsik et al. 2010). The present study aimed at evaluating the influence of ridge cultivation using a phacelia intercrop on the species composition and population of weeds in chicory, black salsify, and common salsify crops, as compared to traditional cultivation on flat soil with no intercrop.

## MATERIAL AND METHODS

The field experiments were carried out in 2006-2008 at the Felin Experimental Farm, University of Life Sciences in Lublin (Poland, 51°23'N, 22°56'E), on lessive soil developed from moderate dusty loam. The experimental plants were three high-inulin root vegetables species of the Asteraceae family: 'Polanowicka' chicory (*Cichorium intybus* L. var. *sativum* Bisch.), 'Duplex' black salsify (*Scorzonera hispanica* L.) and 'Mamut' common salsify (*Tragopogon porrifolius* L.). The experiment was set up by means of completely randomised blocks in four replicates. Each experimental plot was 20 m<sup>2</sup> in area.

The studies involved two cultivation methods: on flat soil and on ridges, as well as an intercrop made of phacelia (*Phacelia tanacetifolia* L.), the biomass of which was mixed with the soil during

pre-winter ploughing and applied. Plants with no intercrop served as the control.

Winter wheat was the fore-crop. In the year prior to vegetable cultivation, phacelia was sown in the amount of 50 kg ha<sup>-1</sup> in mid-August after the pre-sowing tillage set, which was according to the experimental design. Traditional deep ploughing (using a mouldboard plough) up to 25 cm in depth was made before the winter. In spring, after pre-sowing the tillage, ridges were formed in one half of the experimental plots. Mineral nutrition was applied in the spring in amounts of: N – 100 kg, P – 44 kg and K – 124.5 kg ha<sup>-1</sup>. Phosphorus in the form of triple superphosphate and potassium as potassium salt were introduced into the soil as a whole before sowing, while nitrogen, in the form of ammonium nitrate, was divided into two equal doses: half before sowing and half as topdressing.

Vegetable seeds were sown on 10 May into rows with 50 cm spacing and 1.5 cm deep in the amounts of: chicory – 5 kg ha<sup>-1</sup>, black salsify – 12 kg ha<sup>-1</sup> and common salsify – 20 kg ha<sup>-1</sup>. The experiment was carried out using the recommended protective measures and fertilisation for the tested species. After sowing, Kerb 50WP herbicide (propryzamide 50%) was applied by spraying (2 kg ha<sup>-1</sup>). Manual weed control was performed twice a year during the vegetation period. The following fungicides were used against fungal diseases: Bravo 500SC (chlorotalonil) (10 July) and Nimrod 25EC (bupirymat) (18, 27 July and 29 August). The first vegetable seedling emergence was recorded 10-12 days after the sowing date. Thinning was carried out a month after the emergence. The weather conditions during the cultivation period are shown in Table 1.

The weed numbers were determined every year on two dates. The first weed number assessment was performed at the beginning of the plant vegetation period (21 June 2006, 18 June 2007 and 11 June 2008) by determining the "primary

**Table 1.** Mean monthly air temperatures and amount of precipitation at ES Felin in the years 2006-2008

Month	Temperature (°C)				Amount of precipitation (mm)			
	2006	2007	2008	Mean for 1951-2000	2006	2007	2008	Mean for 1951-2000
IV	8.7	8.7	9.3	7.5	30.3	17.4	55.8	40.6
V	13.6	15.0	12.8	13.0	59.5	81.5	101.6	58.3
VI	16.9	18.1	17.7	16.5	37.9	87.8	25.9	65.8
VII	21.9	19.2	18.3	17.9	6.8	87.0	77.1	78.0
VIII	17.4	18.4	19.3	17.3	132.6	37.6	55.0	69.7
IX	15.7	13.0	12.6	12.9	11.0	129.8	102.2	52.1

weed infestation”, whereas the “secondary weed infestation” was evaluated on 20 September 2006, 18 September 2007 and 20 September 2008. The number of weeds of each species, divided into short-term and perennial ones, was counted per square metre by means of the quantitative method (frame method) in four replications. The results were statistically processed by means of variance analysis. Difference significance was determined using the Tukey test at  $p = 0.05$ .

## RESULTS AND DISCUSSION

### *Primary weed infestation*

In total, 24 weed species were recorded as the primary weed infestation in 2006-2008, including 17 monocarpic and seven polycarpic ones (Tabs 2 and 3). *Senecio vulgaris* L., *Chenopodium album* L. and *Lamium amplexicaule* L. were the most numerous representatives. Amongst the perennial species, *Taraxacum officinale* F.H.Wigg. and *Artemisia vulgaris* L. dominated. Applying the phacelia intercrop had no influence on weed species number recorded in the studied objects. However, differences in species composition were found. *Senecio vulgaris* was the most numerous (19.33 plants per  $m^2$ , on average) when cultivated without any intercrop. Phacelia reduced the number of this weed species up to 6.22 plants per  $m^2$ , while it exerted no impact on the occurrence of *Chenopodium album*, which grew as numerous as in cultivation without the intercrop. Lamb's quarters is an expansive weed with great abilities to adapt to habitat conditions and produces large quantities of seeds that can germinate during the entire vegetation period (Wesołowski 1981, Rola and Rola 1996). The phacelia intercrop favoured the occurrence of *Lamium amplexicaule*, which was almost twice as common in these objects as in traditional cultivation. When soil was mixed with rye and *Vicia villosa* L., Anyszka and Dobrzański (2008) reported lower *Lamium amplexicaule* weed numbers in leek as compared to cultivation with no cover crops. Many crops, due to the allelopathic substances released, may have inhibitive interaction towards selected weed species (Khalid et al. 2002). Of the perennial species grown without an intercrop, *Artemisia vulgaris* was the most numerous, while the largest numbers of *Taraxacum officinale* plants were recorded in combination with phacelia.

When the phacelia intercrop was ploughed before winter, it significantly decreased the primary

weed infestation amongst the studied vegetables, from 46.2 plants per  $m^2$  with no intercrop cultivation to 31.4 plants when the intercrop was applied (Tab. 4). Such dependence was observed for all of the experimental plant species, while it was the most prominent for chicory, where phacelia application lowered the primary weed number by over half. A reduction in the influence of phacelia manifested namely in the case of monocarpic weed species. For perennial weeds, such effects were not statistically confirmed. Other studies (Ngouajio et al. 2003, Błażewicz-Woźniak 2003, 2004, Teasdale et al. 2007) confirmed a lower primary weed infestation on the vegetable growth after applying cover crops and mixing their biomass with the soil as compared to cultivation with no intercrop. Applying the phacelia intercrop in carrot cultivation lowered the weed number from 94.5 plants without intercrop up to 27.8 plants per  $m^2$  (Błażewicz-Woźniak 2004). Franczuk et al. (2008, 2010) reported a beneficial effect of phacelia in reducing the weed number in cabbage. The intercrop plants produce large quantities of biomass and create compact canopies, by which they inhibit weed development and show weed control properties towards successive plants (Płaza et al. 2008).

The tillage system also affects the weed amounts through the transfer of weed seeds within the soil profile (Carter and Ivany 2006). When a plant is developed, weed seeds are distributed in a different way than at traditional spring cultivation. In the analysed experiment, there were three weed species more in the plants cultivated in a traditional manner than amongst the plants grown in ridges (Tabs 2 and 3). During flat soil cultivation, *Chenopodium album*, *Senecio vulgaris* and *Gnaphalium uliginosum* L. were more abundant, while *Lamium amplexicaule* grown in ridges increased its number only in combination with intercrop application; without the intercrop, the species was more numerous in the flat soil cultivation system. Soil in ridges is more dried out, thus species with greater water requirements – such as *Gnaphalium uliginosum* – were more numerous in flat cultivation in the spring. More perennial species were recorded in ridges than in traditional cultivation. *Artemisia vulgaris* was more numerous, as was *Taraxacum officinale* in combination with phacelia. Energetic tillage during ridge formation caused the cutting of the runners and roots of perennial weeds. The absence of *Stellaria media* (L.) Vill., *Conyza canadensis* (L.) Cronq. and *Thlaspi arvense* L. in ridges and *Lamium purpureum* L. and *Elymus repens* (L.) Gould in flat

**Table 2.** Effect of tillage without intercrop on the species composition of the primary weed infestation of chicory, black salsify and common salsify, expressed as plant number per m<sup>2</sup> (mean 2006-2008)

Plant species	Chicory				Black salsify				Common salsify				Mean		
	*A	B	Mean	A	B	Mean	A	B	Mean	A	B	Mean	A	B	Mean
<i>Tillage</i>															
<i>Senecio vulgaris</i> L.	36.00	31.33	33.67	10.33	14.67	12.50	6.33	17.33	11.83	17.56	21.11	19.33			
<i>Chenopodium album</i> L.	8.33	10.00	9.17	9.00	18.00	13.50	9.33	15.33	12.33	8.89	14.44	11.67			
<i>Lamium amplexicaule</i> L.	0.00	2.33	1.17	4.00	4.67	4.33	0.00	12.67	6.33	1.33	6.56	3.94			
<i>Galinsoza ciliata</i> (Raf.) S.F. Blake.	1.33	3.67	2.50	1.67	2.67	2.17	0.67	5.67	3.17	1.22	4.00	2.61			
<i>Gnaphalium uliginosum</i> L.	0.67	0.67	0.67	1.33	3.67	2.50	0.00	2.00	1.00	0.67	2.11	1.39			
<i>Capsella bursa-pastoris</i> (L.) Med.	2.00	1.33	1.67	0.00	2.33	1.17	0.33	1.00	0.67	0.78	1.56	1.17			
<i>Matricaria chamomilla</i> L.	0.00	2.00	1.00	0.33	0.67	0.50	0.00	0.67	0.33	0.11	1.11	0.61			
<i>Echinochloa crus-galli</i> (L.) P.Beauv.	0.00	1.33	0.67	1.00	0.00	0.50	1.00	0.00	0.50	0.67	0.44	0.56			
<i>Galinsoza parviflora</i> Cav.	0.00	0.00	0.00	0.67	0.00	0.33	0.00	0.33	0.17	0.22	0.11	0.17			
<i>Chenopodium polyspermum</i> L.	0.00	0.33	0.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.11	0.06			
<i>Coryza canadensis</i> (L.) Cronq.	0.00	0.00	0.00	0.00	0.33	0.17	0.00	0.00	0.00	0.00	0.11	0.06			
<i>Stellaria media</i> (L.) Vill.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.17	0.00	0.11	0.06			
<i>Lamium purpureum</i> L.	0.33	0.00	0.17	0.00	0.00	0.00	0.00	0.00	0.00	0.11	0.00	0.06			
<i>Sinapis arvensis</i> L.	0.00	0.00	0.00	0.00	0.33	0.17	0.00	0.00	0.00	0.00	0.11	0.06			
Number of annual species	6	9	10	8	9	11	5	9	10	10	13	14			
<i>Artemisia vulgaris</i> L.	4.00	3.33	3.67	2.33	1.33	1.83	4.00	0.00	2.00	3.44	1.56	2.50			
<i>Taraxacum officinale</i> F.H. Wigg.	1.33	1.67	1.50	0.67	1.67	1.17	1.67	3.00	2.33	1.22	2.11	1.67			
<i>Elymus repens</i> (L.) Gould.	0.67	0.00	0.33	0.00	0.00	0.00	0.00	0.00	0.00	0.22	0.00	0.11			
<i>Cirsium arvense</i> (L.) Scop.	0.00	0.33	0.17	0.33	0.00	0.17	0.00	0.00	0.00	0.11	0.11	0.11			
<i>Sonchus arvensis</i> L.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.17	0.00	0.11	0.06			
Number of perennial species	3	3	4	3	2	3	2	2	3	4	4	5			
Number of total species	9	12	14	11	11	14	7	11	13	14	17	19			

\* A – tillage on ridges, B – flat tillage

**Table 3.** Effect of tillage with phacelia intercrop on the species composition of the primary weed infestation of chicory, black salsify and common salsify, expressed as plant number per m<sup>2</sup> (mean from 2006–2008)

Plant species	Chicory			Black salsify			Common salsify			Mean		
	*A	B	Mean	A	B	Mean	A	B	Mean	A	B	Mean
<i>Tillage</i>												
<i>Chenopodium album</i> L.	7.67	11.00	9.33	8.67	18.33	13.50	9.00	8.33	8.67	8.44	12.56	10.50
<i>Lamium amplexicaule</i> L.	8.67	3.33	6.00	9.33	3.33	6.33	12.67	6.00	9.33	10.22	4.22	7.22
<i>Senecio vulgaris</i> L.	2.00	6.67	4.33	6.67	13.67	10.17	2.67	5.67	4.17	3.78	8.67	6.22
<i>Galinoga ciliata</i> (Raf.) S.F. Blake.	2.00	3.00	2.50	1.33	0.33	0.83	1.00	1.67	1.33	1.44	1.67	1.56
<i>Gnaphalium uliginosum</i> L.	0.00	0.67	0.33	0.33	1.67	1.00	0.33	2.33	1.33	0.22	1.56	0.89
<i>Capsella bursa-pastoris</i> (L.) Med.	0.33	0.33	0.33	1.00	1.00	1.00	1.33	1.00	1.17	0.89	0.78	0.83
<i>Matricaria chamomilla</i> L.	0.33	1.33	0.83	0.33	0.00	0.17	0.00	0.00	0.00	0.22	0.44	0.33
<i>Echinochloa crus-galli</i> (L.) P.Beauv.	1.00	0.33	0.67	0.00	0.00	0.00	0.67	0.33	0.50	0.56	0.22	0.39
<i>Galinosa parviflora</i> Cav.	0.67	0.00	0.33	0.00	0.00	0.00	1.00	0.67	0.83	0.56	0.22	0.39
<i>Conyza canadensis</i> (L.) Cronq.	0.00	1.00	0.50	0.00	0.33	0.17	0.00	0.00	0.00	0.00	0.44	0.22
<i>Stellaria media</i> (L.) Vill.	0.00	0.33	0.17	0.00	0.33	0.17	0.00	0.00	0.00	0.00	0.22	0.11
<i>Sonchus oleraceus</i> L.	0.33	0.00	0.17	0.00	0.00	0.00	0.00	0.00	0.00	0.11	0.00	0.06
<i>Thlaspi arvense</i> L.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.17	0.00	0.11	0.06
<i>Amaranthus retroflexus</i> L.	0.00	0.00	0.00	0.00	0.33	0.17	0.00	0.00	0.00	0.00	0.11	0.06
Number of annual species	9	10	12	7	9	10	8	9	9	10	13	14
<i>Taraxacum officinale</i> F.H. Wigg.	1.33	2.33	1.83	2.33	0.67	1.50	4.67	1.33	3.00	2.78	1.44	2.11
<i>Artemisia vulgaris</i> L.	0.67	0.00	0.33	0.00	0.00	0.00	0.33	0.00	0.17	0.33	0.00	0.17
<i>Tanacetum vulgare</i> L.	0.33	0.00	0.17	0.00	0.00	0.00	0.00	0.67	0.33	0.11	0.22	0.17
<i>Cirsium arvense</i> (L.) Scop.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.17	0.00	0.11	0.06
<i>Sonchus arvensis</i> L.	0.00	0.00	0.00	0.33	0.00	0.17	0.00	0.00	0.00	0.11	0.00	0.06
<i>Equisetum arvense</i> L.	0.33	0.00	0.17	0.00	0.00	0.00	0.00	0.00	0.00	0.11	0.00	0.06
Number of perennial species	4	1	4	2	1	2	2	3	4	5	3	6
Number of total species	13	11	16	9	10	12	10	12	13	15	16	20

\*Explanations: see Table 1

soils was observed. The presence of *Elymus repens* in ridge cultivation can be also explained by the fact that the soil in a ridge is looser and better aerated, which makes good conditions for couch grass runner growth.

Ridge cultivation decreased the primary weed infestation in vegetable crops from 44.4 plants per m<sup>2</sup> in flat soil to 33.2 plants in the ridge cultivation system (Tab. 4). Weed seed germination in dry soil is more difficult (Dobrzański 2009), therefore a larger number of weeds can usually be found in rainy summers or on heavy soils in ridge cultivation. The influence of ridge cultivation on weed number was prominent when plants grew without an intercrop.

In plants grown in the traditional way (i.e. in flat soil and without phacelia), the average number of weeds was 55.7 plants per m<sup>2</sup>, whereas there were only 36.6 plants in the ridge system. When phacelia biomass was covered by ploughing before winter, the influence of ridge formation on primary weed infestation was not as obvious.

When comparing the species composition of the primary weed infestation among the studied vegetable crops, no differences in the number of weed species grown (from 12 to 14 taxa) were recorded. The same species dominated in all of the cultivation combinations, and their number was more modified by the phacelia intercrop application

**Table 4.** Effect of tillage and intercrop on the size of the primary weed infestation of chicory, black salsify and common salsify (plants per m<sup>2</sup>) in the years 2006-2008

Factors		Chicory			Black salsify			Common salsify			Mean		
		*S	*P	Total	S	P	Total	S	P	Total	S	P	Total
Number of weeds per m <sup>2</sup>													
Tillage without intercrop													
Tillage	Ridges	48.7	6.0	54.7	28.3	3.3	31.6	17.7	5.6	23.3	31.6	5.0	36.6
	Flat	53.0	5.3	58.3	47.3	3.0	50.3	55.3	3.3	58.6	51.9	3.8	55.7
Years	2006	26.5	4.0	30.5	32.5	4.0	36.5	32.2	4.5	36.7	30.4	4.2	34.6
	2007	20.0	3.5	23.5	15.0	2.0	17.0	12.0	4.0	16.0	15.7	3.2	18.8
	2008	106.0	9.5	115.5	66.0	3.5	69.5	65.4	5.0	70.4	79.1	6.0	85.1
Mean		50.8	5.7	56.5	37.8	3.2	41.0	36.5	4.5	41.0	41.7	4.4	46.2
Tillage with phacelia intercrop													
Tillage	Ridges	23.0	2.7	25.7	27.7	2.6	30.3	28.7	5.0	33.7	26.4	3.4	29.8
	Flat	28.0	2.3	30.3	39.3	0.7	40.0	26.3	2.3	28.6	31.2	1.8	33.0
Years	2006	28.0	5.0	33.0	34.0	1.5	35.5	23.5	6.0	29.5	28.5	4.2	32.7
	2007	11.5	2.5	14.0	11.5	1.0	12.5	9.5	2.0	11.5	10.8	1.8	12.7
	2008	37.0	0.0	37.0	55.0	2.5	57.5	49.5	3.0	52.5	47.2	1.8	49.0
Mean		25.5	2.5	28.0	33.5	1.7	35.2	27.5	3.7	31.2	28.8	2.6	31.4
Mean													
Tillage	Ridges	35.9	4.4	40.2	28.0	3.0	31.0	23.2	5.3	28.5	29.0	4.2	33.2
	Flat	40.5	3.8	44.3	43.3	1.9	45.2	40.8	2.8	43.6	41.6	2.8	44.4
Years	2006	27.3	4.5	31.8	33.3	2.8	36.0	27.9	5.3	33.1	29.5	4.2	33.6
	2007	15.8	3.0	18.8	13.3	1.5	14.8	10.8	3.0	13.8	13.3	2.5	15.8
	2008	71.5	4.8	76.3	60.5	3.0	63.5	57.5	4.0	61.5	63.2	3.9	67.1
Mean		38.2	4.1	42.3	35.7	2.4	38.1	32.0	4.1	36.1	35.3	3.5	38.8
LSD <sub>0.05</sub> for:													
tillage		n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	9.1	8.7	n.s.	10.3
intercrop		n.s.	n.s.	13.1	n.s.	n.s.	n.s.	n.s.	n.s.	9.1	8.7	n.s.	10.3
species		-	-	-	-	-	-	-	-	-	n.s.	n.s.	n.s.
years		n.s.	n.s.	24.5	n.s.	n.s.	17.1	n.s.	n.s.	16.9	19.6	n.s.	20.9

\*S – annual weeds, P – perennial weeds, n.s. – no significant differences

than the vegetable species itself. No significant differences in the amount of primary weed infestation in chicory, black salsify or phacelia were observed. The number of both short-term and perennial weed species in these cultivations was similar. Differences in the primary weed infestation were present in subsequent years of the experiment. The largest number of weeds grew in the field in 2008, while the lowest was in 2007.

### **Secondary weed infestation**

In autumn, the weed infestation in vegetables plots increased as compared to the primary weed number (Tabs 5 and 6). In total, 31 weed taxa were recorded. The number of short-term species increased to 22, while perennial ones to nine. *Capsella bursa-pastoris* (L.) Medik. and *Stellaria media*, which flower and fruit massively throughout the year, dominated. *Urtica urens* L., which can produce seeds able to germinate even 5-7 weeks after emergence, appeared quite numerously (Dobrzański 2009). Compared to the spring, the populations of *Chenopodium album*, *Senecio vulgaris* and *Lamium amplexicaule* decreased. Riemens et al. (2004) reported that these species require light, because the light deficiency reduces their emergence remarkably. In turn, poor light had no significant impact on the emergence of *Urtica urens* in studies performed by Andersson et al. (1997), which could explain its occurrence in the secondary weed population, when spaces were shielded by vegetable leaves. Among the perennials, the number of *Taraxacum officinale* decreased, while new species appeared, e.g. *Epilobium adenocaulon* Hausskn. and *Urtica dioica* L., which are a typical species within vegetable crops and the *Polygono-Chenopodietalia* order (R.Tx. et Lohm. 1950) J.Tx. 1961 (Matuszkiewicz 2008), and belong to orchard and ruderal habitats, similar to *Conyza canadensis*, *Erigeron annuus* L., *Artemisia vulgaris* or *Tanacetum vulgare* L. (Lisek 1998).

The phacelia intercrop lowered the number of monocarpic weed species by four as compared to the cultivation without any intercrop. *Chenopodium glaucum* L., *Erigeron annuus* L., *Galium aparine* L., *Lamium purpureum* L., *Polygonum persicaria* L. and *Solanum nigrum* L. were absent, whereas *Thlaspi arvense* L. and *Plantago maior* L., which had not grown before in the control cultivation, were recorded. The positive influence of phacelia on the reduction of weed numbers was weakened when compared to the initial vegetable vegetation

period, and no considerable decrease of weed number was recorded in crops where the intercrop was applied before winter. Only a tendency to larger weed infestation in vegetables grown without an intercrop was observed.

The number of weed species grown in ridges increased in relation to the spring and it was even higher on flat soil, both with and without the intercrop, but no univocal regularity in particular species occurrence was found. *Artemisia vulgaris* was more abundant in ridges rather than in the flat soil system, while *Taraxacum officinale* was more frequent in traditional cultivation. Ridges make specific growing conditions for weeds. Taxa with higher water requirements grow in better-wetted furrows between ridges, while those requiring more warmth and light grow better on ridge tops. The higher weed numbers in the furrow result from a more abundant seed bank in that part of the ridge profile (Dobrzański 2009). The tillage system had no significant effect on the number of secondary weeds in the studied vegetable species. Unlike in the spring, slightly more weeds were grown in ridges than on flat soil, which can be explained by the strong shading of the spaces by vegetables that were grown in the traditional manner, in flat soil system.

The species of cultivated plant significantly affected the secondary weed infestation (Tab. 7). The largest amount of weeds grew in black salsify (30.8 plants per m<sup>2</sup>) and common salsify (21.8 plants), while the smallest was found in chicory cultivation (only 2.2 plants). Well-leaved plants efficiently shaded the soil, making weed growth impossible. The leaf rosettes of black and common salsify with more fragile and narrow leaves were not capable of reducing the weed numbers to the same degree. In particular, many weeds in these vegetable species were recorded in the no-intercrop cultivations. When the phacelia biomass was ploughed, the number of secondary weeds in black and common salsify decreased. In the case of chicory, the secondary weed infestation was so low that the influence of other experimental factors was not prominent.

No differences in the secondary weed infestation level were recorded in the studied vegetable species in the different experimental years. The influence of experimental factors, namely the crop species, on weed number was greater than the differences in weather conditions between the different years of the study.

**Table 5.** Effect of tillage without intercrop on the species composition of the secondary weed infestation of chicory, black salsify and common salsify, expressed as plant number per m<sup>2</sup> (2006-2008)

Plant species	Chicory			Black salsify			Common salsify			Mean		
	*A	B	Mean	A	B	Mean	A	B	Mean	A	B	Mean
<i>Stellaria media</i> (L.) Vill.	0.00	0.67	0.33	3.33	3.67	3.50	6.00	6.33	6.17	3.11	3.56	3.33
<i>Chenopodium album</i> L.	0.33	0.00	0.17	5.67	7.00	6.33	4.33	1.33	2.83	3.44	2.78	3.11
<i>Capsella bursa-pastoris</i> (L.) Med.	0.33	0.00	0.17	3.33	4.00	3.67	4.00	3.67	3.83	2.56	2.56	2.56
<i>Urtica urens</i> L.	0.00	0.33	0.17	0.00	6.00	3.00	0.00	4.67	2.33	0.00	3.67	1.83
<i>Lamium amplexicaule</i> L.	0.00	1.67	0.83	0.00	3.33	1.67	1.67	2.00	1.83	0.56	2.33	1.44
<i>Senecio vulgaris</i> L.	0.00	0.00	0.00	2.00	1.67	1.83	0.67	1.33	1.00	0.89	1.00	0.94
<i>Coryza canadensis</i> (L.) Cronq.	0.00	0.00	0.00	3.00	2.00	2.50	0.00	0.00	0.00	1.00	0.67	0.83
<i>Gnaphalium uliginosum</i> L.	0.00	0.00	0.00	0.67	1.00	0.83	3.33	0.00	1.67	1.33	0.33	0.83
<i>Galinsoga ciliata</i> (Raf.) S.F. Blake.	0.00	0.00	0.00	1.67	1.67	1.67	0.00	1.00	0.50	0.56	0.89	0.72
<i>Matricaria chamomilla</i> L.	0.00	0.00	0.00	0.67	0.33	0.50	1.00	1.33	1.17	0.56	0.56	0.56
<i>Poa annua</i> L.	0.00	0.33	0.17	0.67	0.33	0.50	0.67	0.33	0.50	0.44	0.33	0.39
<i>Echinochloa crus-galli</i> (L.) P.Beauv.	0.00	0.00	0.00	0.33	0.33	0.33	0.33	0.33	0.33	0.22	0.22	0.22
<i>Chenopodium polyspermum</i> L.	0.00	0.00	0.00	1.00	0.00	0.50	0.00	0.33	0.17	0.33	0.11	0.22
<i>Erigeron annuus</i> (L.) Pers.	0.00	0.00	0.00	1.00	0.00	0.50	0.00	0.00	0.00	0.33	0.00	0.17
<i>Galium aparine</i> L.	0.00	0.00	0.00	0.67	0.33	0.50	0.00	0.00	0.00	0.22	0.11	0.17
<i>Galinsoga parviflora</i> Cav.	0.00	0.00	0.00	0.00	0.67	0.33	0.00	0.00	0.00	0.00	0.22	0.11
<i>Lamium purpureum</i> L.	0.00	0.00	0.00	0.00	0.00	0.00	0.67	0.00	0.33	0.22	0.00	0.11
<i>Amaranthus retroflexus</i> L.	0.00	0.00	0.00	0.33	0.00	0.17	0.00	0.00	0.00	0.11	0.00	0.06
<i>Polygonum persicaria</i> L.	0.00	0.00	0.00	0.00	0.33	0.17	0.00	0.00	0.00	0.00	0.11	0.06
<i>Solanum nigrum</i> L.	0.00	0.00	0.00	0.33	0.00	0.17	0.00	0.00	0.00	0.11	0.00	0.06
Number of annual species	2	4	6	15	15	19	10	11	13	17	16	20
<i>Artemisia vulgaris</i> L.	0.33	0.00	0.17	4.00	2.33	3.17	0.67	0.33	0.50	1.67	0.89	1.28
<i>Taraxacum officinale</i> F.H. Wigg.	0.00	0.00	0.00	1.00	1.00	1.00	0.33	0.67	0.50	0.44	0.56	0.50
<i>Epilobium adenocaulon</i> Hausskn.	0.00	0.00	0.00	0.33	0.00	0.17	1.33	0.33	0.83	0.56	0.11	0.33
<i>Urtica dioica</i> L.	0.00	0.00	0.00	0.67	0.67	0.67	1.00	0.33	0.17	0.56	0.33	0.44
<i>Tanacetum vulgare</i> L.	0.00	0.00	0.00	0.67	0.33	0.50	0.00	0.33	0.17	0.22	0.22	0.22
<i>Cirsium arvense</i> (L.) Scop.	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.00	0.17	0.11	0.00	0.06
<i>Sonchus arvensis</i> L.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.17	0.00	0.11	0.06
Total of perennial species	1	0	1	5	4	5	5	6	7	6	6	7
Total number of weeds	3	4	7	20	19	24	15	17	20	23	22	27

\*Explanations: see Table 1

**Table 6.** Effect of tillage with phacelia intercrop on the species composition of the secondary weed infestation of chicory, black salsify and common salsify, expressed as plant number per m<sup>2</sup> (mean from 2006–2008)

Plant species	Chicory			Black salsify			Common salsify			Mean		
	*A	B	Mean	A	B	Mean	A	B	Mean	A	B	Mean
<i>Capsella bursa-pastoris</i> (L.) Med.	0.00	0.67	0.33	6.67	3.33	5.00	2.33	1.33	1.83	3.00	1.78	2.39
<i>Stellaria media</i> (L.) Vill.	0.00	1.33	0.67	3.67	2.67	3.17	2.00	3.33	2.67	1.89	2.44	2.17
<i>Urtica urens</i> L.	0.00	0.00	0.00	1.00	6.00	3.50	2.67	4.67	3.67	1.22	3.56	2.39
<i>Chenopodium album</i> L.	0.33	1.00	0.67	4.67	2.67	3.67	2.33	1.00	1.67	2.44	1.56	2.00
<i>Senecio vulgaris</i> L.	0.00	0.67	0.33	3.00	1.00	2.00	4.00	0.33	2.17	2.33	0.67	1.50
<i>Lamium amplexicaule</i> L.	0.00	0.00	0.00	1.33	3.67	2.50	1.33	2.00	1.67	0.89	1.89	1.39
<i>Galinoga ciliata</i> (Raf.) S.F. Blake.	0.00	0.00	0.00	1.33	1.67	1.50	0.67	1.33	1.00	0.67	1.00	0.83
<i>Galinoga parviflora</i> Cav.	0.00	0.00	0.00	2.00	1.33	1.67	0.33	0.00	0.17	0.78	0.44	0.61
<i>Poa annua</i> L.	0.00	0.00	0.00	0.67	1.33	1.00	1.00	0.67	0.83	0.56	0.67	0.61
<i>Matricaria chamomilla</i> L.	0.00	0.00	0.00	0.67	0.00	0.33	0.00	1.00	0.50	0.22	0.33	0.28
<i>Gnaphalium uliginosum</i> L.	0.00	0.00	0.00	0.00	0.67	0.33	0.33	0.67	0.50	0.11	0.45	0.28
<i>Conyza canadensis</i> (L.) Cronq.	0.00	0.00	0.00	1.00	0.00	0.50	0.33	0.00	0.17	0.44	0.00	0.22
<i>Echinochloa crus-galli</i> (L.) P.Beauv.	0.33	0.00	0.17	0.00	0.00	0.00	0.00	0.33	0.17	0.11	0.11	0.11
<i>Thlaspi arvense</i> L.	0.00	0.00	0.00	0.00	0.33	0.17	0.00	0.33	0.17	0.00	0.22	0.11
<i>Sonchus asper</i> L.	0.00	0.00	0.00	0.33	0.33	0.33	0.00	0.00	0.00	0.11	0.11	0.11
Number of annual species	2	4	5	12	12	14	11	12	14	14	15	15
<i>Taraxacum officinale</i> F.H. Wigg.	0.00	0.33	0.17	0.33	1.00	0.67	0.00	1.00	0.50	0.11	0.78	0.44
<i>Cirsium arvense</i> (L.) Scop.	0.00	0.00	0.00	0.00	0.67	0.33	0.33	0.00	0.17	0.11	0.22	0.17
<i>Epilobium adenocaulon</i> Hausskn.	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.33	0.33	0.11	0.11	0.11
<i>Urtica dioica</i> L.	0.00	0.00	0.00	0.67	0.00	0.33	0.00	0.00	0.00	0.22	0.00	0.11
<i>Artemisia vulgaris</i> L.	0.00	0.00	0.00	0.33	0.00	0.17	0.00	0.00	0.00	0.11	0.00	0.06
<i>Tanacetum vulgare</i> L.	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.00	0.17	0.11	0.00	0.06
<i>Plantago major</i> L.	0.00	0.00	0.00	0.33	0.00	0.17	0.00	0.00	0.00	0.11	0.00	0.06
Number of perennial species	0	1	1	4	2	5	3	2	4	7	3	7
Number of total species	2	5	6	16	14	19	14	14	18	21	18	22

\*Explanations: see Table 1

**Table 7.** Effect of tillage and intercrop on the size of the secondary weed infestation of chicory, black salsify and common salsify (plants per m<sup>2</sup>) in the years 2006-2008

Factors		Chicory			Black salsify			Common salsify			Mean		
		*S	*P	Total	S	P	Total	S	P	Total	S	P	Total
Number of weeds per m <sup>2</sup>													
Tillage without intercrop													
Tillage	Ridges	0.7	0.3	1.0	24.7	6.6	31.3	22.7	3.6	26.3	16.0	3.6	19.6
	Flat	3.0	0.0	3.0	32.7	4.3	37.0	22.7	2.3	25.0	19.4	2.2	21.6
Years	2006	2.5	0.0	2.5	32.0	15.5	47.5	7.5	4.1	11.6	14.0	6.5	20.5
	2007	2.5	0.0	2.5	27.5	1.0	28.5	31.0	3.2	34.2	20.3	1.4	21.7
	2008	0.5	0.5	1.0	26.5	0.0	26.5	29.5	1.6	31.1	18.8	0.7	19.5
Mean		1.8	0.2	2.0	28.7	5.5	34.2	22.7	2.5	25.2	17.7	2.9	20.6
Tillage with phacelia intercrop													
Tillage	Ridges	0.7	0.0	0.7	26.3	1.7	28.0	17.3	1.0	18.3	14.8	0.9	15.7
	Flat	3.7	0.3	4.0	25.0	1.7	26.7	17.0	1.3	18.3	15.2	1.1	16.3
Years	2006	0.0	0.0	0.0	18.0	3.5	21.5	11.5	2.5	14.0	9.8	2.0	11.8
	2007	6.0	0.6	6.6	25.5	1.6	27.1	16.0	0.5	16.5	15.8	0.9	16.7
	2008	0.5	0.0	0.5	33.5	0.0	33.5	24.0	0.5	24.5	19.3	0.2	19.5
Mean		2.2	0.2	2.4	25.7	1.7	27.4	17.2	1.2	18.3	15.0	1.0	16.0
Mean													
Tillage	Ridges	0.7	0.2	0.9	25.5	4.2	29.7	20.0	2.3	22.3	15.4	2.3	17.7
	Flat	3.4	0.2	3.5	28.9	3.0	31.9	19.9	1.8	21.7	17.3	1.7	19.0
Years	2006	1.3	0.0	1.3	25.0	9.5	34.5	9.5	3.3	12.8	11.9	4.3	16.2
	2007	4.3	0.3	4.6	26.5	1.3	27.8	23.5	1.9	25.4	18.1	1.2	19.2
	2008	0.5	0.3	0.8	30.0	0.0	30.0	26.8	1.1	27.8	19.1	0.4	19.5
Mean		2.0	0.2	2.2	27.2	3.6	30.8	20.0	1.9	21.8	16.4	2.0	18.3
LSD <sub>0.05</sub> for:													
tillage		n.s	n.s	n.s	n.s	n.s	n.s	n.s	n.s	n.s	n.s.	n.s.	n.s.
intercrop		n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	0.6	n.s
species		-	-	-	-	-	-	-	-	-	12.6	0.9	12.9
years		n.s.	n.s.	n.s.	n.s.	2.5	n.s.	n.s.	n.s.	n.s.	n.s.	0.9	n.s.

\*S – annual weeds, P – perennial weeds, n.s. – no significant differences

## CONCLUSIONS

1. In total, 24 taxa in the primary and 31 taxa in the secondary weed infestation (mostly characteristic for vegetable crops) were recorded in high-inulin species plantations. Monocarpic species with the most numerous; *Senecio vulgaris*, *Chenopodium album* and *Lamium amplexicaule* dominated in the spring, while *Stellaria media*, *Capsella bursa-pastoris* and *Urtica urens* dominated at the end of the vegetation period.
2. Applying phacelia as an intercrop and ploughing its biomass before winter significantly reduced the primary weed population for all of the cultivated crop species as compared to the no-intercrop cultivations.
3. Phacelia grown as an intercrop reduced the occurrence of *Senecio vulgaris*, while favouring the growth of *Lamium amplexicaule*.
4. The cultivation system affected the primary weed infestation of vegetables, whereas it had no impact on the secondary weed population level. At the beginning of the vegetation periods, fewer weeds grew in ridges than in the flat soil system.
5. The crop species had no effects on the primary weed population, while it influenced the secondary weed infestation. The lowest numbers of weeds were recorded in the secondary weed

infestation in chicory, the well-developed leaf rosettes of which efficiently eliminated most of the weeds.

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WPLYW UPRAWY NA REDLINACH  
I MIĘDZYPLONU Z FACELII NA  
ZACHWASZCZENIE WARZYW  
KORZENIOWYCH Z RODZINY ASTERACEAE

Streszczenie: W doświadczeniu polowym z uprawą trzech gatunków warzyw korzeniowych o wysokiej zawartości inuliny: cykoria korzeniowa (*Cichorium intybus* L. var. *sativum* Bisch.), skorzonera (*Scorzonera hispanica* L.) i salsefia (*Tragopogon porrifolius* L.) uwzględniono dwie metody uprawy: uprawę płaską i na redlinach a także zastosowano międzyplon z facelii błękitnej (*Phacelia tanacetifolia* L.), której biomasa została wymieszana z glebą orką przedzimową. Kontrolę stanowiła uprawa bez międzyplonu. Celem badań, było określenie wpływu uprawy na redlinach przy zastosowaniu międzyplonu z facelii na skład gatunkowy i liczebność zachwaszczenia warzyw, w porównaniu z tradycyjną uprawą płaską bez międzyplonu. W zachwaszczeniu pierwotnym oznaczono łącznie 24 taksony a w zachwaszczeniu wtórnym 31, w większości charakterystycznych dla upraw warzywnych.

Dominowały gatunki monokarpiczne, wśród których wiosną najliczniej występowały *Senecio vulgaris*, *Chenopodium album* i *Lamium amplexicaule*, a pod koniec wegetacji: *Stellaria media*, *Capsella bursa-pastoris* i *Urtica urens*. Zastosowanie facelii, jako rośliny międzyplonowej i przyoranie jej biomasy przed zimą, istotnie ograniczyło stopień zachwaszczenia pierwotnego wszystkich uprawianych gatunków w porównaniu z uprawą bez międzyplonu. Facelia zastosowana w międzyplonie ograniczyła występowanie *Senecio vulgaris* a sprzyjała *Lamium amplexicaule*. System uprawy roli wpłynął na stopień zachwaszczenia pierwotnego warzyw, ale nie oddziaływał na zachwaszczenie wtórne. Na początku wegetacji na redlinach rosło mniej chwastów niż w uprawie płaskiej. Gatunek rośliny uprawnej nie wpłynął na liczebność zachwaszczenia pierwotnego natomiast oddziaływał na zachwaszczenie wtórne. Najmniej chwastów oznaczono w zachwaszczeniu wtórnym cykorii, której dobrze rozwinięte rozety liściowe skutecznie wyeliminowały chwasty.

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