https://doi.org/10.17221/61/2017-HORTSCI

The effect of cover crops on the yield of carrot (*Daucus carota* L.) in ploughless and conventional tillage

Marzena Błażewicz-Woźniak[1]*, *Dariusz Wach*[1], *Elżbieta Patkowska*[2], *Mirosław Konopiński*[1]

[1]*Department of Cultivation and Fertilization of Plants,* [2]*Department of Plant Protection, University of Life Sciences in Lublin, Lublin, Poland*

**Corresponding author: wozniak@up.lublin.pl*

Citation: Błażewicz-Woźniak B., Wach D., Patkowska E., Konopiński M. (2019): The effect of cover crops on the yield of carrot (*Daucus carota* L.) in ploughless and conventional tillage. Hort. Sci. (Prague), 46: 57–64.

Abstract: The experimental design included seven cover crop species and six kinds of soil tillage in the field cultivation of carrot. The use of cover crops had a positive impact on the yield of marketable roots of carrot in comparison with the cultivation without the cover crops. A significant increase of marketable yield was noted after phacelia, buckwheat, mustard and sunflower. The flat ploughless tillage significantly reduced the marketable yield of roots in comparison with traditional ploughing. The largest marketable yield of roots was obtained from cultivation on ridges after mixing the biomass of buckwheat or phacelia or mustard with the soil, and the smallest, after reduced spring tillage using aggregate without cover crops. The largest marketable yield in flat ploughless tillage was obtained when using grubber before winter, and the biomass of phacelia was mixed with soil. Growing carrot on the ridges had a positive influence on increasing the share of the marketable yield of roots in comparison with other variants of cultivation including the conventional tillage. The all cover crops with the exception of spring vetch significantly increased the share of marketable roots in the yield compared with cultivation without cover crops. The largest percentage of the marketable yield was noted after use of phacelia.

Keywords: *Secale*; *Avena*; *Fagopyrum*; *Helianthus*; *Phacelia*

The progressing degradation of the natural environment requires the need to resign from the commonly used mechanisms of increasing the yield of plants. Sustainable agriculture became the alternative, in which an important role plays the conservation tillage of the soil and the use of catch crops (Lithourgidis et al. 2011). The catch crop biomass is mixed with soil or remains on the surface, forming a living or frozen protective layer (Dumanski et al. 2006). Catch crops not only protect the soil from water and wind erosion, but also promote the biological activity of the soil (Patkowska, Błażewicz-Woźniak 2014; Patkowska et al. 2015, 2016), they prevent the loss of minerals through capturing them and making them available to the subsequent plants (Kęsik, Błażewicz-Woźniak 2008). They are a rich source of mineral components and improve the balance of organic matter in the soil (Gaskell, Smith 2007; Błażewicz-Woźniak, Wach 2012; Domagała-Świątkiewicz, Gąstoł 2013). The catch crops improve biodiversity, reduce the occurrence of diseases and pests of cultivated plants, they reduce weed infestation (Stokłosa et al. 2008; Błażewicz-Woźniak, Konopiński 2009, 2011; Lithourgidis et al. 2011, Błażewicz-Woźniak et al. 2015a, 2016). The use of cover crops has a beneficial effect on the soil structure, increasing the supply of water in the soil, and improving many physical and chemical properties of

Supported by the Ministry of Higher Education of Poland, Project No. N N310 210837 210837.

https://doi.org/10.17221/61/2017-HORTSCI

the soil (Zhang et al. 2007; Mulumba, Lal 2008; Kęsik, Błażewicz-Woźniak 2010a, b; Błażewicz-Woźniak, Konopiński 2009, 2013). Cover crops left in the form of mulch have a positive effect on soil moisture, increase infiltration, and regulate temperature (Hoffbeck 2008). The introduction of plant biomass into the soil stabilizes its structure (Bronick, Lal 2005; Lipiec et al. 2006; Dexter, Czyż 2011). In the world agriculture and especially in organic farming, the concept of ploughing using a mouldboard plough is becoming less and less popular. However, in Poland ploughing, it is still considered the traditional or conventional cultivation method of soil. The disadvantages of ploughing apart from high energy input include, among others, the destruction of the natural protective layer of the soil, the reduction of the population of geobiont, over-drying of topsoil, impaired nutrient cycling, too rapid decomposition of organic matter as well as too deep placement of organic fertilizers. Ploughing is conducive to water and wind erosion (Czyż, Dexter 2008; Dexter, Czyż 2011). The problem of creating optimum conditions for the yielding of root vegetables such as carrots is of particular importance in the case of crusting-prone soils, with an unstable structure (Błażewicz-Woźniak 2004). Considering these aspects, the method of tillage is a very important aspect as well as the choice of the best possible cover crops and taking into account the specific climate and soil features of the habitat.

The aim of the study was to determine the effects of different cover crop plant species and the method and time of mixing their biomass with the soil on the yield of carrots. It was assumed that the biomass of catch crops, mixed with the top layer of soil before winter or in the spring, will protect the soil from the destructive effects of external factors and at the same time will improve the soil properties, compensating for the reduction of tillage and giving up ploughing.

MATERIAL AND METHODS

The field experiment was carried out in 2009–2012 at the Exp. St. Felin belonging to 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 cultivation, are susceptible to rain thickening easily, and easy-crusting during drought periods. Before cover crops sowing, the soil contained 1.06–1.15% of humus in 0–20 cm layer and was characterized by slightly acidic reaction (pH in KCl 5.76–5.90). Soil fertility in available phosphorus, potassium, and magnesium was: P – 146.8; K – 111.5; Mg – 102.9 mg/kg soil. The experiment was set up by means of completely randomized blocks in 4 replications. The area of a single plot was 33 m^2. The experimental design included following factors: I. Cover crop species: spring rye (*Secale cereale* L.), common oat (*Avena sativa* L.), common vetch (*Vicia sativa* L.), white mustard (*Sinapis alba* L.), lacy phacelia (*Phacelia tanacetifolia* Benth.), buckwheat (*Fagopyrum esculentum* Moench), and fodder sunflower (*Helianthus annuus* L.); II. Tillage: 1. Traditional plough cultivation with a set of pre-winter measures (pre-winter ploughing 25–30 cm using mouldboard plough – Oz) and cultivation with aggregate in spring (cultivator + harrow + string roller) (Aw); 2. Sowing the cover crops, stubble grubber cultivator use before winter, cultivation aggregate in spring, forming the ridges in spring (Gz + Aw + Rw); 3. Sowing the cover crops, subsoiling tillage, cultivation aggregate in spring (cultivator + harrow + string roller) (GLz + Aw); 4. Sowing the cover crops, stubble grubber cultivator use before winter, cultivation aggregate in spring (Gz + Aw); 5. Sowing the cover crops, stubble grubber cultivator use in spring (NTz + Gw); 6. Sowing the cover crops, cultivation aggregate in spring (NTz + Aw). Cultivation without cover crops was the control. Sowing the cover crops was performed after the harvest of pre-crop, i.e. winter wheat. Directly after wheat harvesting, the disking was made and then ploughing to the depth of about 15 cm with subsequent harrowing. Every year, the cover crops were sown on the same date, i.e. on August 1. Before winter, the grown mass of cover crops was mixed with top soil or left on the soil surface as a mulch, according to the experimental scheme. Mineral fertilization was applied in the spring in the following amounts of NPK: 150 : 50 : 160 kg/ha. Phosphorus in the form of triple superphosphate and potassium in the form of potassium salt was brought as a whole prior to sowing, while nitrogen in the form of ammonium nitrate in 2 equal doses: ½ before sowing and ½ as a top dressing. The experimental plant was carrot (*Daucus carota* L.) Flakkee 2 cv. that was sown every

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Table 1. Mean monthly air temperatures and amount of precipitation in ES Felin in years 2010–2012

	Year	Month						
		Apr	May	June	July	Aug	Sept	Oct
Temperature (°C)	2010	9.4	14.5	18.0	21.6	20.2	12.5	5.6
	2011	10.2	14.3	18.6	18.4	18.8	15.2	8.0
	2012	9.5	15.0	17.3	21.4	19.2	15.0	8.0
	Mean 1951–2005	7.4	13.0	16.2	17.8	17.1	12.6	7.8
Precipitation (mm)	2010	24.5	156.7	65.6	101.0	132.8	119.0	11.2
	2011	29.9	42.2	67.8	189.0	65.3	5.4	28.5
	2012	34.0	56.3	62.8	52.3	37.6	35.5	88.8
	Mean 1951–2005	40.2	57.7	65.7	83.5	68.6	51.6	40.1

year on April 26th in rows (at 50 cm spacing). The sowing rate was 2.61 kg/ha. The pre-sowing seeds were stained in Marshal 250 DS (carbosulfan) at the quantity of 70 g/kg seeds. For carrot growing, following chemical agents were used: after sowing (in April) – dispersed Afalon 450 SC (linuron) at the dose of 1.8 l/ha; in June – Dursban 480 EC (chloropyriphos) at the dose of 1.5 l/ha; in August – spraying with fungicide Amistar 250 SC (azoxystrobin) at the dose of 0.8 l/ha. The weather conditions during the vegetation period of carrot in years 2010–2012 are shown in Table 1. At the time of harvest (first decade of October), the marketable yield of carrot roots (EKG/ONZ FFV-10), total yield and yield of small (diameter < 20 mm) and misshapen roots and leaf yield were determined. Achieved results were statistically processed using variance analysis (ANOVA). The difference significance was determined by means of the Tukey's test at $P = 0.05$.

RESULTS AND DISCUSSION

The marketable yield of carrot roots ranged from 9.8 to 87.9 t/ha (Table 2). The highest yield was collected in 2010 (an average of 51.5 t/ha) and the lowest in 2012 (23.6 t/ha). The use of cover crops had a positive impact on the yield of marketable roots compared with the cultivation without cover crops. A significant increase of marketable yield was noted after phacelia (45.3 t/ha), buckwheat (43.2 t/ha), mustard (41.8 t/ha) and sunflower (40.0 t/ha) cover crops. The positive impact of these cover crops was recorded in all the years of research. Similar results after applying of phacelia mulch were obtained in the cultivation of parsley. Oat and phacelia mulches created the best conditions, whereas mustard mulch created the worst environment for parsley yielding (Błażewicz-Woźniak 2005). In the studies of PŁAZA et al. (2009) of the non-legume plants in stubble catch crops biomass of phacelia had the highest content of macronutrients. The smallest yield of marketable roots in 2010 was harvested after catch crops of rye and oats, and in the years 2011 and 2012 in addition to cultivation without catch crops, a weak effect was also obtained after the application of vetch. Franchini et al. (2004) found a large uptake and accumulation of phosphorus by *Vicia sativa*. In contrast, mulch made out of common vetch distinguished a better after-effect on the total yield of carrot roots in comparison to spring rye mulch. The share of the marketable roots yield of carrots in total was bigger in all conservation tillage variants in after-effect than after conventional tillage without plant mulches (Kęsik, Błażewicz-Woźniak 2009).

The flat ploughless tillage significantly reduced the marketable yield of carrot roots in comparison with traditional plough cultivation. The smallest crop was collected after limiting the tillage to using the aggregate in spring (NTz + Aw) – an average of 32.2 t/ha, or stubble grubber cultivator use in spring (NTz + Gw) – 33.9 t/ha, and the largest in the cultivation on ridges (Gz + Aw + Rw) – an average of 59.3 t/ha and it was higher also from the one collected from conventional cultivation. Desisting from spring-tillage and sowing seeds in non-cultivated soil significantly decreased the total yield of parsley roots comparing to conventional tillage. However it did not affect the yield of marketable roots (Błażewicz-Woźniak 2005). Analysing the interaction of experience factors, the highest yield of marketable roots was obtained from the cultivation of carrots on ridges after mixing the soil with buckwheat biomass (an average of 64.7 t/ha) or tansy

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Table 2. Effect of cover crops and tillage on the yield of marketable roots of carrot (t/ha) in the years 2010-2012

Tillage (C)	Marketable yield of roots (t/ha)									$LSD_{0.05}$
	Cover crops (B)									
	control	rye	oat	vetch	mustard	phacelia	buckwheat	sunflower	mean	
2010										
Oz + Aw	43.7	47.9	45.9	50.9	41.7	46.6	55.4	35.8	46.0	
Gz + Aw + Rw	68.6	61.2	75.8	81.3	87.9	85.6	76.6	73.8	76.3	B 5.80
GLz + Aw	49.8	37.2	45.2	53.7	42.4	61.6	53.2	54.0	49.6	
Gz + Aw	46.4	41.0	30.1	39.7	46.8	63.0	44.2	46.0	44.7	C 4.72
NTz + Gw	43.4	37.6	36.1	43.4	52.0	63.0	78.3	43.7	49.7	
NTz + Aw	36.7	36.7	29.2	34.7	50.4	57.9	47.8	46.9	42.5	B × C
Mean	48.1	43.6	43.7	50.6	53.5	62.9	59.3	50.0	51.5	16.71
2011										
Oz + Aw	44.9	48.8	49.1	49.7	56.6	56.2	53.9	49.0	51.0	
Gz + Aw + Rw	66.6	71.8	61.7	62.6	66.1	66.1	76.1	69.2	67.5	B 4.96
GLz + Aw	35.7	54.7	43.4	31.8	48.7	44.4	42.1	44.4	43.2	
Gz + Aw	35.8	39.8	42.9	37.3	40.6	43.0	42.3	35.9	39.7	C 4.04
NTz + Gw	37.7	37.3	40.8	32.2	38.9	29.7	30.9	42.3	36.2	
NTz + Aw	32.0	36.2	43.4	36.0	38.8	43.7	40.0	27.8	37.2	B × C
Mean	42.1	48.1	46.9	41.6	48.3	47.2	47.6	44.8	45.8	14.31
2012										
Oz + Aw	23.3	25.8	22.9	27.6	24.4	24.3	26.1	30.0	25.6	
Gz + Aw + Rw	38.7	28.7	26.3	34.2	32.7	35.0	41.3	34.6	33.9	B 3.99
GLz + Aw	12.6	18.4	26.8	16.6	25.6	21.8	16.9	22.9	20.2	
Gz + Aw	28.4	32.4	29.0	26.9	26.9	28.1	32.4	30.9	29.4	C 3.25
NTz + Gw	11.1	22.8	14.1	12.7	18.3	22.2	9.8	14.2	15.7	
NTz + Aw	13.0	23.8	18.8	13.2	13.9	22.9	10.6	18.1	16.8	B × C
Mean	21.2	25.3	23.0	21.9	23.6	25.7	22.9	25.1	23.6	11.51
Mean for 2010–2012										
Oz + Aw	37.3	40.8	39.3	42.7	40.9	42.4	45.1	38.3	40.8	B 2.82
Gz + Aw+Rw	57.9	53.9	54.6	59.4	62.2	62.2	64.7	59.2	59.3	
GLz + Aw	32.7	36.8	38.5	34.0	38.9	42.6	37.4	40.4	37.7	C 2.29
Gz + Aw	36.9	37.7	34.0	34.6	38.1	44.7	39.7	37.6	37.9	
NTz + Gw	30.7	32.6	30.3	29.4	36.4	38.3	39.7	33.4	33.9	B × C
NTz + Aw	27.2	32.2	30.5	28.0	34.4	41.5	32.8	30.9	32.2	8.08
Mean	37.1	39.0	37.9	38.0	41.8	45.3	43.2	40.0	40.3	D 1.33

Oz – pre-winter ploughing with 25–30 cm depth; Aw – cultivation with soil aggregate (10–15 cm depth) in spring; Gz – pre-winter tillage with use of stubble grubber cultivator (25 cm depth); Gw – tillage with use of stubble grubber cultivator (25 cm depth) in spring; GLz – pre-winter cultivation with use of subsoiler (30 cm depth); Rw – forming ridges in spring; B – cover crop; C – tillage; D – year

mustard (62.2 t/ha) and the lowest in combination NTz + Aw + Aw without cover crop (27.2 t/ha). In the flat ploughless cultivation the highest marketable yield was obtained when phacelia biomass was mixed with the soil before winter using Gruber (an average of 44.7 t/ha). The cultivation on ridges, spring ploughing and catch crops: common vetch, tansy phacelia and oats, had a significant influence on the increase of marketable salsify roots yield (Konopiński et al. 2013).

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Table 3. Effect of cover crops and tillage on the total yield, yield of small and misshapen roots of carrot (t/ha) and percentage of marketable yield in total yield of roots (%) (average for 2010–2012)

Tillage (C)	Cover crops (B)									$LSD_{0.05}$
	control	rye	oat	vetch	mustard	phacelia	buckwheat	sunflower	mean	
Total yield of roots (t/ha)										
Oz + Aw	53.0	54.4	50.7	53.9	50.9	54.8	53.1	50.1	52.6	
Gz + Aw + Rw	71.7	66.6	67.6	72.2	75.4	77.8	77.3	71.9	72.6	B 2.63
GLz + Aw	52.6	50.9	51.6	50.2	50.4	55.5	51.9	54.1	52.1	
Gz + Aw	50.3	48.2	44.6	48.3	50.3	57.6	53.5	49.4	50.3	C 2.14
NTz + Gw	48.0	48.2	45.7	44.1	48.9	55.1	56.2	47.9	49.3	
NTz + Aw	45.0	47.6	45.5	45.9	51.0	58.6	52.1	47.3	49.1	B × C
Mean	53.4	52.7	51.0	52.4	54.5	59.9	57.3	53.5	54.3	7.54
Yield of small roots (t/ha)										
Oz + Aw	1.6	2.4	2.6	2.3	2.5	2.6	2.0	2.0	2.2	
Gz + Aw + Rw	5.8	4.6	4.2	5.0	4.7	5.7	5.7	5.9	5.2	B 0.77
GLz + Aw	4.0	3.7	2.1	3.1	2.0	1.6	1.1	2.4	2.5	
Gz + Aw	2.1	3.3	3.1	1.8	1.5	1.4	0.8	1.4	1.9	C 0.62
NTz + Gw	2.7	3.7	2.6	2.7	1.9	2.6	2.1	2.1	2.5	
NTz + Aw	1.9	3.5	2.5	1.4	2.3	1.6	1.4	1.2	2.0	B × C
Mean	3.0	3.5	2.8	2.7	2.5	2.6	2.2	2.5	2.7	2.20
Yield of misshapen roots (t/ha)										
Oz + Aw	14.1	11.2	8.9	9.0	7.6	9.8	6.0	9.9	9.6	
Gz + Aw + Rw	8.0	8.1	8.9	7.9	8.5	9.9	7.0	6.9	8.1	B 1.98
GLz + Aw	15.9	10.4	11.0	13.1	9.6	11.3	13.3	11.3	12.0	
Gz + Aw	11.3	7.2	7.4	11.8	10.7	11.5	13.0	10.4	10.4	C 1.61
NTz + Gw	14.5	12.0	12.9	12.0	10.6	14.2	14.4	12.4	12.9	
NTz + Aw	15.8	11.9	12.5	16.6	14.3	15.5	17.9	15.2	15.0	B × C
Mean	13.3	10.1	10.3	11.7	10.2	12.0	11.9	11.0	11.3	5.66
Percentage of marketable yield in total yield of roots (%)										
Oz + Aw	69.4	74.4	76.4	79.1	79.6	77.1	85.2	75.9	77.1	
Gz + Aw + Rw	81.3	79.9	80.0	82.8	82.5	80.6	84.0	82.4	81.7	B 3.80
GLz + Aw	58.5	70.0	74.1	64.4	77.0	74.2	69.0	72.9	70.0	
Gz + Aw	72.8	78.4	76.1	72.2	76.4	77.3	74.2	77.0	75.6	C 3.09
NTz + Gw	60.7	67.0	63.7	63.1	72.0	66.7	61.0	66.3	65.1	
NTz + Aw	58.7	67.3	65.3	58.3	63.4	68.8	58.4	63.1	62.9	B × C
Mean	66.9	72.8	72.6	70.0	75.2	74.1	72.0	72.9	72.1	10.87

*designations as in Table 2

The total yield of carrot roots, depending on the experimental factors ranged from 26.4 to 106.2 t/ha. Regardless of the year of research the highest yields were collected after phacelia (an average of 59.9 t/ha) and buckwheat cover crops (57.3 t/ha) and the lowest after oats (51.0 t/ha), though the other catch crops had not significantly affected the total yield of carrot roots compared with the cultivation without catch crops (53.4 t/ha) (Table 3). Regardless of the cover crops the highest total yield of roots were collected from cultivation on ridges (72.6 t/ha) and it was significantly greater than those from the conventional tillage (52.6 t/ha). Growing on ridges creates better conditions for the growth of roots due to decreased soil compaction and increases its porosity (Konopiński et al. 2001). Reducing tillage to the pre-winter or spring use of the stubble grubber cultivator or aggregate had an adverse effect on the to-

https://doi.org/10.17221/61/2017-HORTSCI

tal yield of carrot roots. The highest total yield of carrot roots average from three years was collected from a combination of cultivation on ridges using phacelia (77.8 t/ha) or buckwheat cover crops (77.3 t/ha). The use of phacelia cover crops increases the total yield of roots in ploughless tillage, so that it was comparable or even slightly higher than after pre-winter traditional plough. In the studies of Khatun and Farooque (2005) mulching the soil increased the total yield of carrot roots (20.2–21.6 t/ha) compared with the cultivation without mulch (15.6 t/ha). In the growing of parsley, the highest roots yield was achieved in the combination, where mulch from the oats, phacelia and vetch were mixed with soil using a plough. The use of white mustard as cover crops was unfavourable (Błażewicz-Woźniak 2004). The best total and marketable yields of radish were obtained in cultivation on ridges using grass mulch (Błażewicz-Woźniak 2009). The worst option was the cultivation on flat soil without mulch. In the studies of Konopiński and Błażewicz-Woźniak (2008) the biggest yields of chicory, scorzonera and salsify roots were collected from the cultivation on the ridges. The best total and marketable yield of chicory roots were received from the plots with vetch mulch, scorzonera from oat mulch and salsify from phacelia mulch.

The yield of small carrot roots, depending on the year of the study, amounted an average from 1.5 t/ha in 2012 to 3.8 t/ha in 2010. Most of the small roots were collected from the cultivation on ridges, which resulted in numerous emergences of carrots in this cultivation combination (Błażewicz-Woźniak et al. 2015b). Regardless of tillage, the highest yield of small roots was recorded after rye cover crops and the lowest after buckwheat. In the analysis of the interaction, the highest yield of small roots was obtained in the cultivation on ridges after sunflower cover crops (5.9 t/ha) and the lowest in combination Gz + Aw + buckwheat (0.8 t/ha).

The most misshapen roots were collected after cultivation without cover crops (an average of 13.3 t/ha). Catch crops reduced the yield of misshapen roots, but the statistically confirmed influence of cover crops on this characteristic was observed after the application of rye (an average of 10.1 t/ha), mustard (10.2 t/ha), oats (10.3 t/ha) and sunflower (11.0 t/ha). Flat ploughless tillage, with the exception of pre-winter cultivation using Gruber (Gz + Aw) significantly increased the yield of misshapen roots compared with traditional ploughing. The smallest misshapen roots yield was collected in the cultivation on ridges (an average of 8.1 t/ha), and the largest after the spring cultivation using aggregate (15.0 t/ha). The application of mulches had no significant influence on the roots geometrical features of parsley, i.e. length, diameter, coefficient of slenderness. The shape of parsley roots was modified by the method of the tillage prior to sowing. The roots from the no-tillage objects were shorter but more slender, and their shape was more cylindrical (Błażewicz-Woźniak 2003). Increasing the share of large pores facilitating the good growth of storage roots in the conventionally cultivated soil compared with the no-tillage soil has been confirmed by many authors (Lipiec et al. 2006; Martinez et al. 2008; Fernandez-Ugalde et al. 2009).

In the yield structure of carrots, the marketable roots, depending on the year, accounted from 63.6% in 2012 to 79.5% in 2010. In all the years of research, cultivation on ridges had a positive impact on increasing the share of the marketable yield of roots (to an average of 81.7%) as compared to other variants including conventional tillage (Table 3). In flat ploughless cultivation the largest share of the marketable yield was obtained after pre-winter tillage using gruber (Gz + Aw) – 75.6%, and the smallest after the reduction of the tillage for the spring use of aggregate (NTz + Aw) – 62.9%. The percentage of commercial radish roots in the total yield was formed in the objects with cultivation on the ridges at using grass mulch (Błażewicz-Woźniak 2009). All catch crops with the exception of vetch significantly increased the share of commercial roots in the yield compared with the cultivation without catch crop (66.9%). The largest share of the marketable roots yield was recorded after phacelia cover crops (75.2%). Analysing the interaction of the experimental factors, regardless of the year of the study, the largest share of commercial roots in the yield were achieved when buckwheat biomass was mixed with soil using a pre-winter deep plough (85.2%) and in the combination of cultivation: Gz + Aw + Rw + buckwheat (84.0%), and the smallest after pre-winter cultivation using subsoiler without cover crops (58.5%).

Carrots, during three years of experiments, depending on the tillage combination created leaves, the yield of which ranged from 4.9 to 39.9 t/ha. The largest yield of leaves was obtained after catch crops of mustard, oat or vetch and the smallest in cultivation without catch crops (Table 4). The yield of leaves in a flat cultivation without ploughing was similar to the yield of that in the conventional tillage, while the

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Table 4. Effect of cover crops and tillage on the yield of carrot leaves (t/ha)

Tillage (C)	Cover crops (B)									$LSD_{0.05}$
	control	rye	oat	vetch	mustard	phacelia	buck-wheat	sunflower	mean	
	Yield of leaves (t/ha)									
Oz + Aw	13.4	14.7	16.8	17.1	15.1	15.9	15.0	15.4	15.4	
Gz + Aw + Rw	15.4	18.3	19.6	19.1	22.5	24.3	19.7	17.1	19.5	B 1.07
GLz + Aw	13.1	15.0	15.2	16.8	13.6	14.7	14.1	15.0	14.7	
Gz + Aw	13.2	13.7	14.7	13.8	15.4	16.0	12.9	14.7	14.3	C 0.87
NTz + Gw	13.1	14.1	15.5	16.1	15.8	17.4	15.6	15.7	15.4	
NTz + Aw	13.4	12.9	16.8	14.3	17.0	15.5	14.1	14.4	14.8	B × C
Mean	13.6	14.8	16.4	16.2	16.6	17.3	15.2	15.4	15.7	3.08

* designations as in Table 2

highest yield of leaves was obtained in the cultivation of carrots on ridges. By analysing the interaction of the experimental factors, the highest yield of leaves was obtained in the cultivation of carrots on ridges after phacelia cover crops (24.3 t/ha). The application of mulch had a favourable influence on the mass of radish leaves (Błażewicz-Woźniak 2009).

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Received for publication March 29, 2017
Accepted after corrections July 11, 2018