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GROWTH AND YIELD OF 'HAMBURG' PARSLEY UNDER NO-TILLAGE CULTIVATION USING WHITE MUSTARD AS A COVER CROP

Andrzej Borowy
University of Life Sciences in Lublin

Abstract. No-tillage cultivation using cover crops is an important part of sustainable horticulture, however there are only few date on this subject related to 'Hamburg' parsley. In two years` field experiment no-tillage cultivation using white mustard as a cover crop did not affect germination of 'Hamburg' parsley cv. Alba but further growth of no-tilled plants was slower. Yield of no-tilled plants with leaves was lower and the share of leaves in this yield was higher. Roots of no-tilled parsley were shorter and of lower weight, their yield was also lower but their health status was better. No-tillage did not have a negative effect on content of total nitrogen, phosphorus, potassium, calcium and magnesium in parsley leaves. No-tilled roots contained dry matter, total sugars and essential oils more and the content of L-ascorbic acid and of monosaccharides did not depend on cultivation method. No-tilled soil covered with mustard mulch was more moist, less porous and of higher bulk density. Mustard mulch controlled annual weeds in interrows well but it did not control weeds germinating in rows where parsley was seeded. Control of wintering and winter hard weeds was dependent on biomass produced by mustard plants.

Key words: soil properties, weeds, macronutrients, sugars, essential oils

INTRODUCTION

No-tillage cultivation using cover crops is an important element of sustainable horticulture [Lal 2008]. No-tillage offers several benefits: prevention of erosion, up to 80% of fuel conservation, enhancement of soil organic matter, preservation of soil structure and soil fauna, soil moisture conservation, improved soil aeration and infiltration [Pimentel et al. 1995, Baker et al. 1996], and cover crops intensify and broaden these beneficial effects [Masiunas 1998, Hartwig and Ammon 2002]. On dusty soils with unstable structure, the effect of conventional tillage on soil density and porosity is little and of short duration in comparison to no-tillage using cover crop [Borowy et al. 2000, Kono-

Corresponding author: Andrzej Borowy, Department of Horticultural Seed Production and Nursery, University of Life Sciences in Lublin, ul. St. Leszczyńskiego 58, 20-068 Lublin, Poland; e-mail: andrzej.borowy@up.lublin.pl

piński et al. 2001, 2002]. Roots of cover crop loose the soil and at the same time they tie soil particles improving its structure [Stirzaker and White 1995, Hartwig and Ammon 2002]. Mulch formed from aerial parts of cover crop covers the soil protecting it from water evaporation and increasing soil humidity [Borowy et. al. 2000, Konopiński et al. 2001, 2002]. Under no-tillage, yielding of vegetables is more variable then under conventional cultivation [Hoyt et. al. 1994, Borowy and Jelonkiewicz 2000a]. Moreover no-tilled soil covered with mulch gets warm slowly in the spring and this is unfavourable for vegetables cultivation in natural conditions of Poland [Jelonkiewicz and Borowy 2009].

Several plant species can be used in Poland as cover crops in cultivation of vegetables [Borowy and Jelonkiewicz 2000a, Kołota and Adamczewska-Sowińska 2003] and among them is white mustard, appreciated for a long time in Europe's temperate climate [Vaughn and Hemingway 1959, Sawicka and Kotiuk 2007]. Brassica species contain high amounts of glucosinolates and their degradation products inhibit germination and growth of weeds [Oleszek 1994, Boydston and Al-Khatib 2006, Mikuła and Borowy 2007, Piętka et al. 2010]. Moreover Brassica species can suppress nematodes [Nowakowski et al. 1996a, Nowakowski and Szymczak-Nowak 1998, 2003, Szymczak-Nowak and Nowakowski 2002], diseases [Charron and Sams 1999] and insects [Williams et al. 1993] infesting the crop. The growth and the yield of annual Brassica species depends on water supply and thermal conditions during vegetation period and the yielding of white mustard was less variable in comparison to other species studied by Toboła and Muśnicki [1999].

White mustard cultivated in Poland as an intercrop uptakes considerable amounts of mineral nutrients from the soil protecting them from leaching and producing a big quantity of biomass [Nowakowski et al. 1996b, Nowakowski and Kostka-Gościniak 1997, Nowakowski and Szymczak-Nowak 1998, 2003, Szczebiot and Ojczyk 2002, Szymczak-Nowak and Nowakowski 2002, Kisielewska and Harasimowicz-Herman 2008, Błażewicz-Woźniak and Wach 2012]. These nutrients will return to the soil after decaying of biomass [Szczebiot and Ojczyk 2002, Harasimowicz-Hermann and Hermann 2006, Błażewicz-Woźniak and Wach 2012] but all this complicates the fertilization of main crop [Hoyt et al. 1994]. Moreover no-tillage and cover crops can affect the uptake of nutrients by cultivated plant and finally also its yield and chemical composition [Borowy and Jelonkiewicz 2000b, Jelonkiewicz and Borowy 2009].

No-tillage cultivation using cover crops did not affect the germination of vegetables cultivated in Poland but their further growth was often slower and finally the yield was lower [Borowy et al. 2000a, Borowy and Jelonkiewicz 2000b, Mikuła and Borowy 2007, Jelonkiewicz and Borowy 2009]. 'Hamburg' parsley is a root vegetable popular in Poland [Adamczewska-Sowińska 2000, Gruszecki 2007a, 2007b, 2010] however the knowledge on its response to no-tillage cultivation using cover crop is very scanty. In three years` experiment carried out by Błażewicz-Woźniak [2003, 2005], white mustard, spring vetch, tansy phacelia and oat used as cover crops did not affect the length, diameter and coefficient of slenderness of `Hamburg` parsley roots. Under no-tillage the roots were more slender, more cylindrical and significantly shorter in comparison to conventional cultivation. They had also smaller diameter, however this difference was not significant. Total yield of roots harvested on no-tilled plots was significantly lower in every year of study and marketable yield was significantly lower in two out of three years. Parsley produced the lowest yield of roots on plots covered with mustard mulch.

The aim of this study was to evaluate the effect of no-tillage cultivation using white mustard as a cover crop on growth and yield of 'Hamburg' parsley as well as on physical soil properties and weed infestation.

MATERIAL AND METHODS

The field experiment was carried out in the Felin Experimental Farm (215 m above sea level, 51°14' N latitude, 22°38' W longitude) on podzolic soil developed from dusty medium loam containing 1.8% of organic matter and with pH of 6.6. The experiment was repeated two times in 2009–2010 and 2010–2011. On August 12th of the year proceeding cultivation of vegetables, 38.4 m^2 (6 × 6,4 m) of the experimental field was fertilized with 80 kg $N \cdot ha^{-1}$ ammonium nitrate, 22 kg $P \cdot ha^{-1}$ super–phosphate and 83 kg $K \cdot ha^{-1}$ potassium chloride. Than the field was tilled with rotary cultivator and seeded with 30 $kg \cdot ha^{-1}$ white mustard (*Sinapis alba* L.) 'Bardena' seeds. The seeds were sown in the rows using a hand seeder retaining 12 cm distance between rows. At the end of October an average height of mustard stand was determined and the plants growing on 1 m^2 were dug up 25 cm deep, their roots were cut of and washed with water and fresh weight of roots and shoots were determined. Afterwards the air-dry weight of these plant parts was measured and the content of total nitrogen (distillation method), phosphorus (colorimetric method), potassium (flame photometry), calcium (flame photometry) and magnesium (atomic absorption spectrometry) in air-dry mustard plants was determined in the Regional Chemical-Agricultural Station in Lublin. The adjoining 115.2 m^2 of the field was ploughed 20 cm deep in November and in the middle of April of the following year it was fertilized with the same quantities of phosphorus and potassium fertilizers as the field with white mustard and then cultivated with rotary cultivator 15 cm deep. In the case of nitrogen fertilization (ammonium nitrate), 70 kg $N \cdot ha^{-1}$ was mixed with upper soil layer before seed sowing and 70 kg $N \cdot ha^{-1}$ was applied as a top dressing on May 27th. No-tilled plots covered with mustard mulch were fertilized with 70 kg $N \cdot ha^{-1}$ one week after seed sowing and again with 70 $kg \cdot ha^{-1}$ on May 27th.

On April 16–18th the dry, standing mustard stems were rolled with the aim to form a mulch layer on the surface of no tilled plots. On April 17th 2010 and on April 19th 2011 the seeds of 'Hamburg' parsley (*Petroselinum crispum* (Mill.) Nyman ex A.W. Hill var. *tuberosum* (Bernh.) Mart. Crov.) `Alba` 6 $kg \cdot ha^{-1}$ were sown by hand on plots consisting of 4 rows 6 m long and 40 cm distance between the rows. The area of one plot was 9.6 m^{-2} and there were four plots in each treatment. Three weeks later the number and the fresh weight of weeds growing on 0.4 m^2 area obtained by fourfold randomly placing of 0.25 × 0.4 m frame in interrows of each plot were determined. At that time the weeds were in cotyledon or first true leaf stage. Then the plots were weeded by hand and the number of emerged parsley seedlings in 1 m of each row was counted. Additional hand weedings were conducted et the end of May and three weeks later. On June 20th, July 20th and August 20th the length of the longest leaf of twenty randomly chosen plants growing in each row was measured. Every year in the beginning of the second decade of May and July and in the beginning of the third decade of September three soil samples from 0–20 cm and 20–40 cm layers of each treatment were taken using 100 cm^{-3} cylinders with the aim to determine soil moisture, density and porosity. The samples were weighed, dried in 105°C during 24 hours and then weighed again. In the beginning of August, samples of fully developed parsley leaves were taken and then the content of total nitrogen, phosphorus, potassium, calcium and magnesium in air-dry leaves was determined in the Regional Chemical-Agricultural Station in Lublin using the methods mentioned above in relation to white mustard.

On September 22–25th parsley was dug up and then the weight of the whole plants with leaves was measured. Afterwards the leaves were cut of and parsley roots were sorted into three grades: with the diameter < 20 mm, 20–30 mm, and bigger then 30 mm. The parsley roots with the 20–30 mm and > 30 mm diameter were divided into healthy ones and with disease symptoms. Moreover the length and the weight of 20 roots chosen randomly from the grade with the diameter bigger than 30 mm were measured. Than the samples of healthy roots with about 30 mm diameter were taken with the aim to determine the content of dry matter (oven dry method), total sugars and monosaccharides (Schoorl-Luff's method), vitamin C (method described by J.H. Roe) and essential oils (using Deryng's apparatus) in the roots. All analysis were carried out in the Laboratory of the Department of Vegetable Crops and Medicinal Plants, University of Life Sciences in Lublin.

Obtained results were studied by analysis of variance and significance of differences was determined using Tukey's test at 0.05 probability level.

RESULTS

The emergence of mustard started one week after seeding and lasted several days. Precipitations occurring in the beginning of August in 2009 were conducive to good and uniform emergence of mustard which covered all surface of plots leaving no place for weeds. In 2010 the emergence of mustard was much worse because of the drought at the time of seed sowing. The weeds germinated in the places uncovered by mustard plants and among them were wintering and winter hard weed species. In this group the dominating weeds were annual bluegrass (*Poa annua* (L.)) and common chickweed (*Stellaria media* (L.) Vill.) and the less numerous weeds were Canadian horseweed (*Conyza canadensis* (L.) Cronquist), common chamomile (*Matricaria chamomilla* L.) henbit deadnettle (*Lamium amplexicaule* (L.)), shepherd's purse (*Capsella bursa-pastoris* (L.) Med.) and gray field speedwell (*Veronica polita* Fr.). Mustard plants grew fast and attained full flowering stage at the end of October. At this time an average height of mustard stand was 96 cm in 2009 and 93 cm in 2010 and the fresh and the air-dry weight of mustard plants growing on 1 m^2 was 4320.9 g and 642.1 g in 2009 and 3415.0 g and 561.0 g in 2010, respectively (tab. 1). The biomass produced by these plants contained 140.2 g of total nitrogen, 29.0 g of phosphorus, 201.5 g of potassium, 113.1 g of calcium and 10.9 g of magnesium (tab. 1). The shoots of white mustard contained total nitrogen, potassium, calcium and magnesium significantly more and phosphorus significantly less then the roots. Content of all studied macronutrients depended signifi-

Table 1. Fresh and air-dry weight of white mustard plants ($g \cdot m^{-2}$) and uptake of macronutrients by plants in 2009 and 2010 ($kg \cdot ha^{-1}$)

Parts of plant	Fresh weight			Air-dry weight			Total N			P			K			Ca			Mg		
	2009	2010	mean	2009	2010	mean	2009	2010	mean	2009	2010	mean	2009	2010	mean	2009	2010	mean	2009	2010	mean
Shoots	4010.0	3130.0	3570.0	580.2	496.0	538.1	134.0	133.4	133.7	26.7	24.8	25.8	177.5	195.9	186.7	108.5	111.1	109.8	10.4	9.9	10.2
Roots	310.9	285.0	298.0	61.9	65.0	63.5	5.8	7.2	6.5	2.7	3.6	3.2	10.5	18.1	14.3	3.4	3.2	3.3	0.6	0.8	0.7
Totally	4320.9	3415.0	3868.0	642.1	561.0	601.6	139.8	140.6	140.2	29.4	28.4	29.0	188.0	214.0	201.5	111.9	114.3	113.1	11.0	10.7	10.9

Table 2. Content of macronutrients in shoots and roots of white mustard in 2009 and 2010 (% of air-dry weight)

Parts of plant	Total N			P			K			Ca			Mg		
	2009	2010	mean	2009	2010	mean	2009	2010	mean	2009	2010	mean	2009	2010	mean
Shoots	2.31	2.69	2.50	0.46	0.50	0.48	3.06	3.95	3.51	1.87	2.24	2.06	0.18	0.20	0.19
Roots	0.93	1.10	1.02	0.44	0.56	0.50	1.69	2.78	2.24	0.55	0.49	0.52	0.10	0.13	0.12
Mean	1.62	1.90	1.76	0.45	0.53	0.49	2.38	3.37	2.88	1.21	1.37	1.29	0.14	0.17	0.16
$LSD_{0.05}$ Parts of plant (A)			0.086			0.021			0.065			0.034			0.008
Years (B)			0.053			0.043			0.087			0.012			0.003
A × B			n.s.			n.s.			0.169			0.065			n.s.

cantly on the year of study and in the case of potassium and calcium also on the interaction between the study year and the part of plant (tab. 2).

Mustard plants were killed by frost in the middle of November. Their leaves were decomposed during the winter and next year in the spring only lignified stems were standing on no-tilled plots. After rolling, the stems formed 1.5–3.0 cm thick mulch which covered 85–100% of soil surface in 2009 and 60–80% in 2010. With the time the mulch underwent slow decomposition and at the end of cultivation period it covered 90% of soil surface in 2010 and 25% in 2011. Mulch reduced significantly the number of weeds growing on no tilled plots three weeks after seed sowing (tab. 3). However their fresh weight was significantly higher (tab. 3) as a result of intensive growth of wintering and winter hard weeds in the spring, and especially of annual bluegrass and common chickweed. Some of them attained flowering stage in the second half of April. This was visible especially in 2011 when covering of soil surface by mulch was low and the wintering weeds had more place to grow. Mulch did not cover the rows in which parsley was seeded and where the weeds germinated in great number. In this situation, it

Table 3. Number and fresh weight of weeds growing on 1 m^2 under traditional and no-tillage cultivation three weeks after parsley sowing

Weed species	Conventional cultivation			No-tillage cultivation		
	2010	2011	mean	2010	2011	mean
Amaranthus retroflexus L.	33	41	37	2	0	1
Capsella bursa-pastoris (L.) Med.	53	43	48	3	11	7
Chenopodium album L.	169	139	154	6	7	7
Conyza canadensis (L.) Cronquist	2	0	1	3	4	4
Echinochloa crus-galli (L.) P.B.	49	56	53	4	3	4
Galinsoga parviflora Cav.	16	22	19	4	3	4
Galinsoga quadriradiata Ruiz et Pav.	11	7	9	3	6	5
Lamium amplexicaule L.	2	0	1	3	6	5
Matricaria chamomilla L.	4	3	4	2	4	3
Myosurus minimus L.	0	0	0	0	2	1
Plantago major L.	0	1	1	0	4	2
Poa annua L.	5	3	4	3	41	22
Polygonum aviculare L.	0	0	0	0	3	2
Stellaria media (L.) Vill.	3	2	3	3	28	16
Taraxacum offcinale Web.	1	0	1	1	2	2
Urtica urens L.	7	4	6	1	1	1
Veronica polita Fr.	5	3	4	1	13	7
Vicia villosa Roth.	0	1	1	0	0	0
Total number of weeds	360	325	343	39	138	89
Fresh weight of weeds	68.4	41.4	54.9	236.3	732.6	484.5

$LSD_{0.05}$	Cult. meth. (A)	Years (B)	A × B
Number of weeds	125.3	n.s.	n.s.
Weight of weeds	179.6	231.4	452.8

Table 4. Effect of cultivation method on soil moisture at the 0–20 and 20–40 cm depth in 2010–2011, %

Cultivation method	Soil layer	2010				2011				Mean for the years			
		I*	II*	III*	mean	I*	II*	III*	mean	I*	II*	III*	mean
Conventional	0–20	16.21	13.84	14.73	14.93	15.92	20.76	17.30	17.99	16.07	17.30	16.02	16.46
	20–40	16.63	13.53	14.06	14.74	15.90	17.58	15.19	16.22	16.27	15.56	14.63	15.49
	0–40	16.42	13.69	14.40	14.84	15.91	19.17	16.25	17.11	16.17	16.43	15.33	15.98
No-tillage	0–20	25.63	24.16	18.07	22.62	27.11	27.26	17.85	24.07	26.37	25.71	17.96	23.35
	20–40	23.84	23.01	17.96	21.60	20.71	26.91	17.64	21.75	22.78	24.96	17.80	21.85
	0–40	24.74	23.59	18.02	22.11	23.91	27.09	17.75	22.91	24.33	25.34	17.89	22.52
Mean	0–20	20.92	19.0	16.40	18.78	21.51	24.01	17.58	21.03	21.22	21.51	16.99	19.91
	20–40	20.24	18.27	16.01	18.17	18.31	22.25	16.42	18.99	19.28	20.26	16.22	18.59
	0–40	20.58	18.64	16.21	18.48	19.91	23.13	17.00	20.01	20.25	20.89	16.61	19.25

LSD $_{0.05}$	I* May 11–12th	II* July 11th		III* September 21–23rd
Cult. meth. (A)	1.05	A × B 2.88	B × D 3.69	A × C × D 9.44
Years (B)	1.05	A × C 2.88	C × D 3.69	B × C × D n.s.
Depth (C)	1.05	A × D 3.69	A × B × C 5.91	A × B × C × D n.s.
Term (D)	1.56	B × C n.s.	A × B × D 9.44	

Table 5. Effect of cultivation method on soil bulk density at the 0–20 and 20–40 cm depth in 2010–2011, g·cm^{-3}

Cultivation method	Soil layer	2010				2011				Mean for the years			Mean
		I*	II*	III*	mean	I*	II*	III*	mean	I*	II*	III*	
Conventional	0–20	1.39	1.45	1.52	1.45	1.35	1.42	1.54	1.44	1.37	1.44	1.53	1.45
	20–40	1.53	1.55	1.54	1.54	1.41	1.42	1.55	1.46	1.47	1.49	1.55	1.50
	0–40	1.47	1.50	1.50	1.49	1.38	1.42	1.55	1.45	1.43	1.46	1.53	1.47
No-tillage	0–20	1.49	1.46	1.55	1.50	1.66	1.43	1.46	1.51	1.58	1.45	1.51	1.51
	20–40	1.55	1.52	1.52	1.53	1.68	1.74	1.59	1.67	1.62	1.63	1.56	1.60
	0–40	1.52	1.49	1.54	1.52	1.67	1.59	1.53	1.59	1.60	1.54	1.54	1.56
Mean	0–20	1.44	1.46	1.54	1.48	1.51	1.43	1.50	1.48	1.48	1.45	1.52	1.48
	20–40	1.54	1.53	1.53	1.54	1.54	1.58	1.57	1.56	1.54	1.56	1.55	1.55
	0–40	1.49	1.50	1.54	1.51	1.52	1.50	1.54	1.52	1.51	1.50	1.54	1.52

LSD $_{0.05}$ — I* May 11–12th; II* July 11th; III* September 21–23rd

Cult. meth. (A)	0.06	A × B	0.11	B × D	n.s.	B × C × D	n.s.
Years (B)	n.s.	A × C	0.11	C × D	n.s.	A × B × C × D	n.s.
Depth (C)	0.06	A × D	0.16	A × B × C	0.18		
Term (D)	n.s.	B × C	n.s.	A × B × D	0.26		
				A × C × D	0.26		

Table 6. Effect of cultivation method on soil total porosity of the 0–20 and 20–40 cm depth in 2010–2011, %

Cultivation method	Soil layer	2010				2011				Mean for the years			
		I*	II*	III*	mean	I*	II*	III*	mean	I*	II*	III*	mean
	0–20	47.81	44.96	39.87	44.21	47.88	45.05	40.61	44.51	47.85	45.01	40.24	44.37
Conventional	20–40	45.83	45.06	39.96	43.62	46.12	45.50	40.47	44.03	45.98	45.28	40.22	43.83
	0–40	46.82	45.01	39.92	43.92	47.00	45.28	40.54	44.27	46.91	45.15	40.23	44.10
	0–20	43.72	44.56	43.02	43.77	36.08	44.89	43.27	41.41	39.90	44.73	43.15	42.59
No-tillage	20–40	41.31	41.94	41.06	41.44	36.60	33.23	39.06	36.30	38.96	37.59	40.06	38.87
	0–40	42.52	43.25	42.04	42.60	36.34	39.06	41.17	38.86	39.43	41.16	41.61	40.73
	0–20	45.77	44.76	41.45	43.99	41.98	44.97	41.94	42.96	43.88	44.87	41.70	43.48
Mean	20–40	43.57	43.50	40.51	42.53	41.36	39.37	39.77	40.17	42.47	41.44	40.14	41.35
	0–40	44.67	44.13	40.98	43.26	41.67	42.17	40.85	41.56	43.17	43.15	40.92	42.41

$LSD_{0.05}$	I* May 11–12th	II* July 11th		III* September 21–23rd	
Cult. meth. (A)	1.69	A × B 3.44	B × C 3.44	A × B × C	n.s.
Years (B)	1.69	A × C 3.44	B × D n.s.	A × B × D	n.s.
Depth (C)	1.69	A × D 7.46	C × D n.s.	A × C × D	n.s.
Term (D)	2.05			A × B × C × D	n.s.

Table 7. Effect of cultivation method on parsley germination (no·m row^{-1}) and lenght of parsley leaves (cm) measured triple during vegetation period

Cultivation method	No. of seedlings			Lenght of leaves											
	2010	2011	mean	2010				2011				Mean			
				June 20th	July 20th	August 20th	mean	June 20th	July 20th	August 20th	mean	June 20th	July 20th	August 20th	mean
Conventional	183	198	191	5.73	12.17	26.84	14.91	6.29	14.55	29.72	16.85	6.01	13.36	28.28	15.88
No-tillage	186	210	198	3.51	8.22	22.37	11.37	3.49	7.73	21.23	10.81	3.50	7.98	21.80	11.09
Mean	185	204	195	4.62	10.20	24.61	13.14	4.89	11.14	25.47	13.83	4.76	10.67	25.04	13.49
$LSD_{0.05}$															
Cult. meth. (A)			n.s.												1.473
Years (B)			n.s.												n.s.
A × B			n.s.												n.s.

Table 8. Percentage of macronutrients in air – dry parsley leaves in dependence on cultivation method in 2010–2011. % of air-dry weight

Cultivation method	N – total			P			K			Ca			Mg		
	2010	2011	mean	2010	2011	mean	2010	2011	mean	2010	2011	mean	2010	2011	mean
Conventional	2.53	2.86	2.70	0.41	0.33	0.37	3.61	3.47	3.54	1.76	1.95	1.86	0.23	0.18	0.21
No – tillage	2.91	3.29	3.10	0.44	0.32	0.38	3.94	3.70	3.82	1.68	2.08	1.88	0.19	0.20	0.20
Mean	2.72	3.08	2.90	0.43	0.33	0.38	3.78	3.59	3.68	1.72	2.02	1.87	0.21	0.19	0.20
$LSD_{0.05}$															
Cult. meth. (A)			0.14			n.s.			0.10			n.s.			n.s.
Years (B)			0.11			0.04			0.12			0.27			n.s.
A × B			0.36			n.s.			0.23			n.s.			n.s.

was necessary to weed the rows by hand three times up to June 20th. The effect of mulch on weed infestation was visible especially in the first months of parsley cultivation. With the time the area of soil surface covered with mulch decreased and the area covered with with parsley leaves increased. The leaves covered the soil surface completely in the beginning of second decade of July and stopped germination of weeds. Later only tall growing weed species, e.g. barnyard grass (*Echinochloa crus-galli* (L.) P.B.), hairy galinsoga (*Galinsoga quadriradiata* (Ruiz et Pav.)), lambsquarters (*Chenopodium album* (L.)), redroot pigweed (*Amaranthus retroflexus* (L.)) and smallflower galinsoga (*Galinsoga parviflora* (Cav.)) appeared sporadically among parsley plants.

Moisture of no-tilled soil covered with mustard mulch was significantly higher in both years (tab. 4) and its bulk density was significantly higher in 2011 only (tab. 5). Total porosity of no-tilled soil was lower, with the difference being significant only in the second year of study (tab. 6).

Germination of parsley on no-tilled and conventionally cultivated plots begun two weeks after seed sowing at the same time on no-tilled and conventionally cultivated plots and the number of emerged parsley seedlings was independent on cultivation method in both years of study. However the further growth of parsley plants was better under conventional cultivation. In both years the length of parsley leaves measured in June, July and in August was in this treatment significantly higher (tab. 7).

Table 9. Effect of cultivation method on length (cm) and weight (g) of parsley root in 2010–2011

Cultivation method	Length			Weight		
	2010	2011	mean	2010	2011	mean
Conventional	17.9	19.1	18.5	41.7	43.8	42.8
No-tillage	16.1	16.7	16.4	37.4	39.3	38.4
Mean	17.0	17.9	17.5	39.6	41.6	40.6
$LSD_{0.05}$						
Cult. meth. (A)			1.9			4.3
Years (B)			n.s.			n.s.
A × B			n.s.			n.s.

Table 10. Effect of cultivation method on yield of parsley plants with leaves in 2010–2011 ($kg \cdot m^{-2}$)

Cultivation method	2010	2011	Mean
Conventional	4.30	5.05	4.68
No-tillage	2.68	2.95	2.82
Mean	3.49	4.00	3.75
$LSD_{0.05}$			
Cult. meth. (A)			0.48
Years (B)			0.48
A × B			n.s.

Table 11. Effect of cultivation method on quality and structure of yield of parsley roots in 2010–2011 ($kg \cdot m^{-2}$)

Cultivation method	Total				Root diameter											
					> 30 mm				20–30 mm				< 20 mm			
	2010	2011	mean	%*	2010	2011	mean	% total yield	2010	2011	mean	% total yield	2010	2011	mean	% total yield
Conventional	2.25	2.74	2.50	53.4	1.47	1.69	1.58	63.2	0.64	0.90	0.77	30.8	0.14	0.15	0.15	6.0
No-tillage	1.42	1.33	1.38	48.9	0.75	0.83	0.79	57.3	0.55	0.36	0.46	33.3	0.12	0.14	0.13	9.2
Mean	1.78	2.04	1.91	50.1	1.11	1.26	1.19	60.3	0.60	0.63	0.62	32.1	0.13	0.15	0.14	7.6
$LSD_{0.05}$																
Cult. meth. (A)			0.25				0.22				0.06				n.s.	
Years (B)			0.25				n.s.				n.s.				n.s.	
A × B			n.s.				n.s.				n.s.				n.s.	

* Share of total root yield in the yield of plants with leaves (%)

Table 12. Effect of cultivation method on yield of healthy and diseased parsley roots in dependence on root diameter and year of cultivation ($kg \cdot m^{-2}$)

Cultivation method	Root diameter																				
	> 30 mm							20–30 mm							< 20 mm						
	healthy			diseased				healthy			diseased				healthy			diseased			
	2010	2011	mean	2010	2011	mean $kg \cdot m^{-2}$	mean % *	2010	2011	mean	2010	2011	mean $kg \cdot m^{-2}$	mean % **	2010	2011	mean	2010	2011	mean $kg \cdot m^{-2}$	mean % ***
Conventional	0.99	1.07	1.03	0.48	0.62	0.55	34.8	0.48	0.68	0.58	0.16	0.22	0.19	24.7	0.11	0.10	0.11	0.03	0.05	0.04	36.4
No-tillage	0.67	0.73	0.70	0.08	0.10	0.09	11.4	0.49	0.14	0.40	0.06	0.05	0.06	12.6	0.10	0.12	0.11	0.02	0.02	0.02	15.4
Mean	0.83	0.9	0.87	0.28	0.36	0.32	23.1	0.49	0.41	0.49	0.11	0.14	0.13	18.7	0.11	0.11	0.11	0.03	0.04	0.03	25.9
$LSD_{0.05}$																					
Cult. meth. (A)			0.14			0.08				n.s.			0.03				n.s.			0.01	
Years (B)			n.s.			n.s.				0.06			n.s.				n.s.			n.s.	
A × B			n.s.			n.s.				n.s.			n.s.				n.s.			n.s.	

* % of total > 30 mm root yield
** % of total 20–30 mm root yield
*** % of total < 20 mm root yield

Table 13. Effect of cultivation method on content of dry matter. L-ascorbic acid. monosaccharides. total sugars and essential oils in parsley roots in 2010–2011

Cultivation method	Dry matter %			L-ascorbic acid mg·100 g f. m.			Monosaccharides % f. m.			Total sugars % f. m.			Essential oils % f. m.		
	2010	2011	mean	2010	2011	mean	2010	2011	mean	2010	2011	mean	2010	2011	mean
Conventional	17.7	19.8	18.8	33.9	18.3	26.1	0.57	0.27	0.42	4.26	1.29	2.78	0.011	0.015	0.013
No-tillage	20.1	21.3	20.7	32.5	22.7	27.6	0.54	0.31	0.43	5.02	2.96	3.99	0.014	0.020	0.017
Mean	18.9	20.6	19.8	33.2	20.5	26.9	0.56	0.29	0.43	4.64	2.13	3.39	0.013	0.018	0.015
$LSD_{0.05}$															
Cult. meth. (A)			1.5			n.s.			n.s.			0.23			0.002
Years (B)			1.5			3.2			0.08			0.23			0.002
A × B			n.s.			n.s.			n.s.			n.s.			n.s.

At the time of full vegetation, the leaves of conventionally cultivated parsley contained lower amounts of potassium and total nitrogen while the content of other studied macronutrients did not depend on cultivation method. Content of total nitrogen, phosphorus, potassium and calcium depended significantly on the year of study and in the case of total nitrogen and potassium also on the interaction between the year of study and the cultivation method. Content of magnesium was not dependent on studied factors (tab. 8).

Cultivation method had a significant effect on the length and the weight of parsley roots measured directly after harvest. The roots harvested on no-tilled plots were much shorter and lighter from those cultivated conventionally (tab. 9).

In both study years, the yield of parsley plants with leaves harvested on no-tilled plots was significantly lower (tab. 10). Moreover the share of roots in this yield was 48.9% in comparison to 53.4% under conventional cultivation (tab. 11). The total yield of roots, the yield of roots with diameter > 30 mm and the yield of roots with diameter of 20–30 mm harvested on no-tilled plots were significantly lower in comparison to these yields obtained under conventional cultivation. Only the yield of roots with the diameter < 20 mm did not depend on cultivation method (tab. 11). Under no-tillage cultivation, the share of roots with diameter > 30 mm in total yield was smaller and the share of roots with diameter of 20–30 mm was slightly bigger than under conventional cultivation (11).

The yields of all assortments of parsley roots harvested on no-tilled plots and the share of diseased roots in these yields were much lower in comparison to conventional cultivation. Under no-tillage, the diseased roots with the diameter > 30 mm, 20–30 mm and < 20 mm made 11.4%, 12.6% and 15.4% of all roots respectively in comparison to 34.8%, 24.7% and 36.4% under conventional cultivation (tab. 12).

Parsley roots harvested on no-tilled plots contained dry matter, total sugars and essential oils significantly more and the content of L-ascorbic acid and of monosaccharides did not depend on method of cultivation. Content of all components depended significantly on the year of study (tab. 13).

DISSCUSSION

The results obtained in the experiment confirm the opinion that white mustard is a valuable, seeded at a low sowing rate and fast growing intercrop producing big quantity of biomass [Nowakowski and Szymczak-Nowak 1998, Sawicka and Kotiuk 2007], suitable for late summer seeding as a cover crop in vegetables cultivation in Poland [Borowy and Jelonkiewicz 2000a, Kołota and Adamczewska-Sowińska 2003]. It is killed by frost what eliminates the need of desiccants use and makes it useful for organic production. The quantity of biomass produced by white mustard depended on weather conditions at the time of its germination and this confirms the results obtained by Nowakowski et al. [1996b], Mikuła and Borowy [2007], Kisielewska and Harasimowicz-Hermann [2008]. In spite of this, white mustard is much less sensitive to hydrothermic conditions than several other species of brassicas family [Muśnicki et al. 1997, Toboła and Muśnicki 1999]. The biomass produced by white mustard 'Bardena' plants seeded in the first half of August was similar and often higher than those stated in experiments conducted by Nowakowski et al. [1996b], Nowakowski and Szymczak-Nowak [1998, 2003], Mikuła and Borowy [2007], Kisielewska and Harasimowicz-Herman [2008], because the quality of soil as well as the seeding rate were in these studies higher than in majority of above cited works.

The plants of white mustard 'Bardena' growing on 1 ha area accumulated 140.2 kg of total nitrogen, 29.0 kg of phosphorus, 201.5 kg of potassium, 113.1 kg of calcium and 10.9 kg of magnesium on an average. Quantity of accumulated macronutrients in mustard plants was comparable to their content in 20–30 tons of manure [Nurzyński 2003]. These quantities were higher than those obtained by Kisielewska and Harasimowicz-Hermann [2008] because of the higher yield of biomass produced by mustard plants in this experiment. Similar accumulation of nitrogen, phosphorus and potassium by plants of five mustard cultivars stated Nowakowski et al. [1996a].

Mustard plants and then mustard mulch protected the soil against wind, rain and weeds all year round. The degree of weed control varied according to mustard residue biomass and weed species and this agrees with the statement of Teasdale et al. [2004]. Mustard mulch was decomposed slowly and stayed on soil surface till parsley harvest what confirms the results of Mikuła and Borowy [2006] however its role in controlling of weeds was important especially in the first half of vegetation period because later the parsley leaves covered the surface of plots thoroughly and stopped germination of weeds. The mulch did not control the weeds germinating in the rows. Moreover wintering and winter hard weeds made a problem in the second year of study in which mustard produced a small quantity of biomass. According to Teasdale et al. [2004] cover crops can contribute to weed control in reduced-tillage systems but herbicides or other weed control tactics are required for achieving optimum weed control and crop yield.

Higher humidity of no-tilled soil covered with mulch stated in this experiment agrees with the results obtained by Borowy et al. [2000a] and Konopiński et al. [2001, 2002]. In the spring no-tilled soil looses water slower and moreover the mulch protects against evaporation of soil water during whole vegetation period [Baker et al. 1996]. Humidity of the upper 0–20 cm soil layer was more variable because it was exposed to direct effect of rain, wind and sun. After rain, humidity of this soil layer was higher and after period of drought it was lower than that of 20–40 cm soil layer. Soil in the experiment was dusty, susceptible to crusting, contained little organic matter, had an unstable structure and therefore the effect of cultivation method on total soil porosity and bulk density was visible especially in the first half of cultivation period and significant in one study year only. This agrees with the results obtained by Borowy et al. [2000a] and Konopiński et al. [2001, 2002] in the same natural conditions. Roots of cover crop as well as insects and earthworms living in no-tilled soil improve its structure replacing to some degree the soil tillage [Stirzaker and White 1995, Hartwig and Ammon 2002].

Method of cultivation did not affect the term of germination nor the number of parsley emerged seedlings. Similarly Błażewicz-Woźniak [2003] did not state an influence of no-tillage cultivation with white mustard as a cover crop on density of parsley plants in three years` study. At the time of parsley seeding, no-tilled soil was more humid and compact and this was conducive to seed germination but further growth of parsley plants was slower under no-tillage. Similarly red beet, white cabbage, determinate tomato [Borowy et al. 1998], snap bean [Borowy and Jelonkiewicz 2000b] and cucumber

[Jelonkiewicz and Borowy 2009] grew slower under no-tillage cultivation with rye as a cover crop. 'Hamburg' parsley is a root vegetable which should be cultivated on soils of very good structure and tilled with great care [Adamczewska-Sowińska 2000]. In the experiment the bulk density of no-tilled soil was higher and its porosity was lower and this could make the growth of parsley roots more difficult. Moreover the temperature of no-tilled soil covered with mulch is lower [Borowy et al. 2000a] and this could also influence negatively the growth of parsley plants.

Content of macronutrients (except magnesium) in the leaves determined at the time of full parsley vegetation was dependent mainly on the year of study, while in a less degree on the cultivation method and in the case of nitrogen and potassium also on the interaction between these factors. These results agree partly with those obtained by Borowy and Jelonkiewicz [2000b] and Jelonkiewicz and Borowy [2009] in the same natural conditions, however additional studies are necessary to define more precisely the effect of no-tillage cultivation using cover crops on content of macronutrients in cash plants.

Every year the parsley grew slower under no-tillage cultivation and finally it produced lower yield of plants with leaves and in this yield the share of leaves was slightly higher than under conventional cultivation. The roots formed by these plants were shorter and of smaller weight. Their total yield as well as the yield of roots of 20–30 mm and of > 30 mm in diameter were also lower. These results agree with those obtained by Błażewicz-Woźniak [2003, 2005]. Several other vegetables like cucumber, red beets, snap beans, tomatoes, white cabbage produced also lower yield under no-tillage cultivation with cover crop in Poland [Borowy et al. 1998, Borowy and Jelonkiewicz 2000b, Jelonkiewicz and Borowy 2009]. However in this experiment, the roots harvested on no-tilled plots were more healthy than those cultivated conventionally. Similarly Patkowska and Konopiński [2011] found a beneficial effect of three cover crops on the health state of salsify roots.

No-tillage cultivation using white mustard as a cover crop did not have a negative effect on content of several components in parsley roots. The content of dry matter was significantly higher and this is consistent with the results obtained by Borowy et al. [1998]. Quantity and quality of parsley yields harvested on plots cultivated conventionally were similar to the yields obtained by Gruszecki [2007a, 2007b] in the same growing conditions.

CONCLUSIONS

1. White mustard seeded at the rate of 30 kg·ha^{-1} was useful as a not winter hard cover crop in no-tillage cultivation of 'Hamburg' parsley. Its shoots covered soil surface in the autumn of the year proceeding parsley cultivation and then in the next year dry mustard stems covered soil till harvest of parsley at the end of September. Quantity of biomass produced by mustard plants and degree of soil covering by mustard depended on the amount of rainfall occurring at the time of mustard seeds sowing.

2. No-tilled soil covered with white mustard mulch was more moist, less porous and of higher bulk density in comparison to conventionally tilled soil during the period of parsley cultivation.

3. Mustard mulch controlled annual weeds in interrows well in the period from sowing of parsley seeds at the end of second decade of April till soil surface covering by parsley leaves at the beginning of second decade of July. Poor emergence of mustard fovoured the growth of wintering and winter hard weeds which were difficult to control in the spring of the following year. The mulch did not control weeds in the rows where parsley was seeded.

4. No-tillage cultivation with white mustard as a cover crop did not affect germination of parsley but further growth of no-tilled parsley plants was slower during whole cultivation period.

5. No-tillage cultivation with white mustard as a cover crop did not have a negative effect on content of total nitrogen, phosphorus, potassium, calcium and magnesium in the leaves measured in the time of full vegetation of parsley plants.

6. Yield of no-tilled parsley plants with leaves was lower and the share of leaves in this yield was higher. Roots of no-tilled plants were shorter and of lower weight. Yield of roots produced by these plants was lower but their health status was better.

7. Parsley roots harvested under no-tillage cultivation contained dry matter, total sugars and essential oils more and the content of L-ascorbic acid and of monosaccharides did not depend on cultivation method.

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WZROST I PLONOWANIE PIETRUSZKI KORZENIOWEJ W UPRAWIE BEZORKOWEJ Z UŻYCIEM GORCZYCY BIAŁEJ JAKO ROŚLINY OKRYWOWEJ

Streszczenie. Uprawa bezorkowa z użyciem roślin okrywowych jest ważnym elementem ogrodnictwa zrównoważonego, lecz jak dotąd niewiele informacji z tego zakresu odnosi się do pietruszki korzeniowej. W dwuletnim doświadczeniu polowym, uprawa bezorkowa z użyciem gorczycy białej jako rośliny okrywowej nie miała wpływu na wschody pietruszki korzeniowej 'Alba', natomiast dalszy wzrost roślin uprawianych tą metodą był wolniejszy. W uprawie bezorkowej plon całkowity roślin pietruszki z liśćmi był mniejszy, a udział liści w tym plonie był większy w porównaniu z plonem zebranym w uprawie tradycyjnej. Rośliny uprawiane metodą bezorkową miały korzenie krótsze i o mniejszej masie. Wytworzony przez nie plon korzeni był również mniejszy, ale charakteryzował się lepszą zdrowotnością. Uprawa bezorkowa nie miała ujemnego wpływu na zawartość azotu całkowitego, fosforu, potasu, wapnia i magnezu w liściach pietruszki. Korzenie uprawiane tą metodą zawierały więcej suchej masy, cukrów ogółem i olejków eterycznych, zaś zawartość kwasu L-askorbinowego i cukrów prostych była niezależna od metody uprawy. Gleba nieuprawiana i okryta mulczem wytworzonym przez gorczycę białą była bardziej wilgotna, mniej porowata i miała większą gęstość objętościową. Mulcz chronił skutecznie międzyrzędzia przed wzrostem chwastów rocznych, natomiast nie miał wpływu na ich wschody w rzędach, w których były posiane nasiona pietruszki. Wpływ mulczu na chwasty trwałe był uzależniony od masy wytworzonej przez rośliny gorczycy.

Słowa kluczowe: właściwości gleby, chwasty, makroskładniki, cukry, olejki eteryczne

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