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GROWTH AND YIELD OF STAKE TOMATO UNDER NO-TILLAGE CULTIVATION USING HAIRY VETCH AS A LIVING MULCH

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Abstract. No-tillage cultivation with living mulch offers several benefits related to environmental protection and fulfills requirements of sustainable agriculture very well, however there are only few reports on vegetable cultivation using this method and referring to natural conditions of Poland. In three years field experiment stake tomatoes cv. Malinowy Ożarowski grown on no-tilled plots covered with wintering hairy vetch as a living mulch produced significantly lower total and marketable yield in comparison to conventional cultivation. Yield of fruits infested with potato blight was also significantly lower but their share in total yield was much higher. Content of carotenoids, monosaccharides and total sugars in fruits harvested under conventional cultivation was significantly higher and content of dry matter was significantly lower in comparison to no-tillage and content of vitamin C was independent of cultivation method. At time of full fruiting, leaves of tomatoes grown on plots covered with mulch contained more nitrogen, phosphorus and potassium and content of calcium and magnesium did not depend of cultivation method. Method of cultivation did not affect root-taking of potted tomato transplants but then tomatoes grown on plots covered with living mulch were dominated by hairy vetch and grew much slower till third decade of July when majority of vetch plants decayed. Growth of tomatoes in vetch mulch was much more differentiated during whole vegetation period. Living and then dry vetch mulch covered soil surface almost entirely and suppressed annual weeds well. Average decade temperature at 5 cm and 10 cm depth of conventionally cultivated soil was usually higher and soil moisture in 0–40 cm layer was significantly lower than those of soil covered with mulch. Cultivation method did not affect soil total porosity nor bulk density. At time of tomato planting, fresh and air-dry weight of hairy vetch was 39.7 $t \cdot ha^{-1}$ and 6.5 $t \cdot ha^{-1}$ on an average respectively and it contained 180 kg N, 43 kg P, 209 kg K, 51 kg Ca and 12 kg Mg. Studied cultivation method offered several benefits related to environmental protection but was more management intensive and variable than conventional tillage.

Key words: soil properties, weeds, macroelements, sugars, vitamins

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INTRODUCTION

In sustainable agriculture natural resource management should be conducted in the way securing persistent covering of needs of present and future generations [Lal 2008]. Soil is a very important natural resource and therefore all kinds of activities increasing soil fertility and protecting soil from degradation are appreciated in this agricultural system [Sainju and Singh 1997]. One of them is no-tillage cultivation using living mulches [Pimentel et al. 1995]. Shoots of plants grown as living mulch cover the surface of soil and protect it from wind and water erosion [Leary and DeFrank 2000, Hartwig and Ammon 2002]. Their residues promote development of soil microorganisms and contribute to increase of soil organic matter content [Jabłoński et al. 1996, Poniedziałek and Stokowska 1999, Hartwig and Ammon 2002]. Their roots loose the soil and tie the soil particles and at the same time they uptake mineral nutrients protecting them from leaching [Sainju and Singh 1997, Hartwig and Ammon 2002]. The plant grown as a living mulch uptakes mineral nutrients altering their availability for the main crop and therefore its fertilization is in this system more difficult than in conventional cultivation [Hoyt et al. 1994]. These nutrients will return to the soil in the biomass produced by living mulch after its decaying [Leary and DeFrank 2000]. Reduced tillage and living mulches increase the earthworm biomass [Hartwig and Ammon 2002] as well as the number of arthropods and among them also the number of beneficial insects living in the field [Bugg 1992, Teasdale et al. 2004, Prasifka et al. 2006].

On dusty soils characterized by unstable structure, the effect of conventional tillage on soil density and porosity is little and short-lived in comparison to no-tillage cultivation [Borowy et. al. 2000, Konopiński et. al. 2001, 2002]. Living mulches shade the soil surface and lower its temperature [Teasdale et al. 1993, Teasdale and Abdul-Baki 1995, Nieróbca 2005]. Moreover, in the spring no tilled soil gets warm slowly [Jabłoński et al. 1996] and this can influence the growth of warm weather vegetables [Maletta and Janes 1987, Borowy and Jelonkiewicz 2000, Jelonkiewicz and Borowy 2000, Borowy and Komosa 2003, Jelonkiewicz and Borowy 2009]. No-tillage and living mulches affect soil properties and this can influence the uptake of nutrients by cultivated plant and finally also its chemical composition [Knavel et al. 1977, Mullins et al. 1980, Knavel and Herron 1981, Tindall et al. 1990, Jelonkiewicz and Borowy 2009]. In the experiment carried out by Tindall et al. [1990], the root zone temperature affected significantly the uptake of all studied mineral elements except for boron, iron and molybdenum. Living mulches reduce weed and sometimes also disease and pest infestation [Teasdale and Daughtry 1993, Masiunas et al. 1997, Poniedziałek and Stokowska 1999, Teasdale et al. 2004, Hoffman and Regnier 2006]. However, after decaying they can intercept wind blown seeds produced by some weed species [Masiunas et al. 1997, Jelonkiewicz and Borowy 2005].

In temperate climate it is useful to sow a winter-hardy living mulch in late summer to protect the soil in autumn and in winter when it is most exposed to erosion [Wyland et al. 1996, Sainju and Singh 1997]. Next year in the spring, the living mulch resumes vegetation and the field covered with this mulch can be used for no-tillage cultivation of some vegetables. Suitable for this purpose are toll growing vegetables cultivated from transplants with long vegetation period [Kołota and Adamczewska-Sowińska 2003], for example stake tomatoes. In tomato cultivation it is important to choose a proper species as a living mulch in regard to its competitive ability [Adamczewska-Sowińska and Kołota 2002]. Managing competition between living mulch and the cash crop is a major concern for farmers and living mulches characterized by an intensive growth should be suppressed [Leary and DeFrank 2000].

Among living mulches especially valuable are those fixing nitrogen, e. g. hairy vetch [Masiunas 1998, Hartwig and Ammon 2002]. In the studies conducted by Nelson et al. [1991], the hairy vetch was one of the most promising legumes for use as a cover crop in vegetables cultivation. In the experiment carried out by Decker et al. [1994], the biomass yield of hairy vetch cultivated as a cover crop ranged from 2.9 to 5.1 $t \cdot ha^{-1}$ and it supplied from 109 to 206 kg $N \cdot ha^{-1}$. Hairy vetch contains several allelochemicals inhibiting germination of weed seeds [Bradow and Connick 1990] and is well suited for use as a winter cover crop to suppress weeds in temperate cropping systems [Teasdale and Daughtry 1993, Brandsaeter and Netland 1999, Hoffman and Regnier 2006]. In the studies conducted by Teasdale and Daughtry [1993], the soil moisture was greater under both live and desiccated hairy vetch compared to bare soil during droughty periods. According to Kotliński [2001], hairy vetch is a good winter-hardy cover crop for use in vegetable production in Poland. In the experiment conducted in Maryland, USA by Abdul-Baki and Teasdale [1993], stake tomatoes grown from transplants on no-tilled plots covered with hairy vetch mulch produced higher yield than those grown under black polyethylene, paper, or no mulch in conventional system. Leaves of determinate tomato cultivars grown in hairy vetch mulch [Abdul-Baki et al. 1996] or in mixed hairy vetch – rye mulch [Kotliński and Abdul-Baki 2000] were significantly less infested by potato blight. Tomato is one of the most important vegetables cultivated in Poland [Skąpski and Borowy 2000]. The aim of this study was to evaluate the growth and the yield of stake tomato under no-tillage cultivation using hairy vetch as a winter-hardy living mulch in southeastern Poland.

MATERIAL AND METHODS

The field experiment was conducted in the Felin Experimental Farm (215 m above see level, 51^{o} 14' N latitude, 22^{o} 38' W longitude) on podzolic soil developed from dusty medium loam containing 1.7% of organic matter and with pH of 6.5. It was repeated three times in the years 2006–2007, 2007–2008 and 2008–2009. On August 12–14th of the year proceeding cultivation of tomato, 30 m^2 (5 × 6 m) of the experimental field was fertilized with 20 kg $N \cdot ha^{-1}$ ammonium nitrate, 65 kg $P \cdot ha^{-1}$ super – phosphate and 210 kg $K \cdot ha^{-1}$ potassium salt. Than the field was tilled with rotary cultivator and seeded with 70 kg hairy vetch (*Vicia villosa* L.) $seeds \cdot ha^{-1}$. The adjoining 30 m^2 of the field was ploughed 20 cm deep in November and in the middle of May of the following year it was fertilized with the same quantities of mineral fertilizers as the field with hairy vetch and then cultivated with rotary cultivator 15 cm deep.

On May 17–19th six weeks old, potted transplants of tomato (*Lycopersicon esculentum* L.) cv. 'Malinowy Ożarowski' having 7 developed leaves were planted on four plots marked on both parts of the experimental field. On one 2.0 × 2.4 m plot (harvest area) 6 tomato plants were planted by hand in two rows with 1.0 m distance between rows and 0.8 m between plants in the row. The distance was bigger then recommended in tomato field growing with the purpose to have better possibilities for observation of hairy vetch growth and then of its mulch decomposition. One plot was considered as one replication. The factor studied in the experiment was the method of cultivation which considered in two following levels: as conventional cultivation and as no-tillage with living mulch.

One day before tomatoes planting, hairy vetch plants growing on 1 m^2 were dug up and then the roots were cut off, washed with water, dried and fresh weight of roots and shoots were determined. Then the air-dry weight of hairy vetch roots and shoots were measured and the content of total nitrogen (distillation method), phosphorus (colorimetric method), potassium (flame photometry), calcium (flame photometry) and magnesium (atomic absorption spectrometry) in dry vetch plants was determined in the Regional Chemical-Agricultural Station in Lublin. The growth and the development of hairy vetch were observed and the percentage of soil cover by vetch plants in the beginning and then by dry vetch mulch were evaluated during vegetation period.

In the years 2007 and 2008 immediately after transplants planting, electronic sensors recording soil temperature at 5 cm and 10 cm depth every hour were installed in the places not shaded by tomatoes on one plot cultivated traditionally and on one plot covered with living mulch.

Four weeks after planting, tomatoes grown on conventionally cultivated and on no-tilled plots were top dressed with 30 $kgN·ha^{-1}$ and 50 $kgN·ha^{-1}$ ammonium nitrate, respectively. In this time the stakes were inserted near the plants and than the tomato stems were tied up to the stakes and pruned to one main stem which was topped in the beginning of the second decade of August. Up to this time the stem length of all tomato plants was measured every week. Moreover, the diameter of stem base was measured every week started from the beginning of June till second decade of September. Every year the infestation of tomatoes by potato blight (*Phytophthora infestans*) was observed and in the middle of September the percentage of tomato leaves infested by this disease was evaluated visually.

Every year in the days of June 15–18th, when majority of weeds attained seed and first true leaves stage, weed flora as well as number and fresh weight of weeds growing on 0.4 m^2 area obtained by fourfold randomly placing of 25 cm x 40 cm frame were determined on each plot and then the plots were weeded. Weeds emerging later were removed soon after emergence.

Every year in the days of June 1–4th, July 13–16th, and August 29–31st three soil samples from the 0–20 cm and 20–40 cm layers of each treatment were taken using 100 cm^{-3} cylinders. Then the samples were weighed, dried in 105°C during 24 hours and then weighed again. Obtained results were used for calculation of soil moisture, density and porosity.

The fruits were harvested once a week starting on July 10–12th and ending on September 10–13th. At harvest they were segregated as marketable (fruit diameter > 3.5 cm), non marketable and diseased and then the diameter and the fresh weight of each marketable fruit were measured. During last harvest the unripe fruits were also harvested. Moreover at the time of full fruiting (beginning of August), the content of dry matter (oven dry method), monosaccharides, total sugars (Schoorl-Luff's method), and carotenoids (Mac Kinney's method) in marketable fruits was determined. The analysis were carried out in the Laboratory of the Department of Vegetable Crops and Medicinal Plants, University of Life Sciences in Lublin. At the same time the samples of tomato leaves (first developed leaf on shoot top) were taken and then the content of total nitrogen, phosphorus, potassium, calcium and magnesium in the leaves was determined in Regional Chemical-Agricultural Station in Lublin using mentioned above methods.

Average monthly air temperatures and monthly sums of rainfalls noted in a meteorological station situated in the Felin Experimental Farm are presented in table 1.

Table 1. Average monthly air temperatures and monthly sums of rainfalls in Felin Experimental Farm in 2007–2009
Tabela 1. Średnie miesięczne temperatury powietrza i miesięczne sumy opadów w Gospodarstwie Doświadczalnym Felin w latach 2007–2009

Month Miesiąc	Temperature, °C Temperatura, °C			Rainfalls, mm Opady, mm		
	2007	2008	2009	2007	2008	2009
May Maj	14.9	12.8	13.6	80.5	101.6	71.1
June Czerwiec	18.1	17.7	16.4	87.8	25.9	125.5
July Lipiec	19.1	18.3	19.9	87.0	77.1	57.1
August Sierpień	18.4	19.3	19.0	37.6	55.0	54.7
September Wrzesień	12.9	12.6	13.0	129.8	102.2	50.1
Average Średnia	16.7	16.1	16.4	-	-	-
Sum Suma	-	-	-	422.7	361.8	358.5

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

RESULTS

The emergence of hairy vetch started 10 days after sowing and continued two weeks. At the beginning, the plants grew slowly attaining 5–10 cm height and covering 5–10% of soil surface before frost came. In this time following wintering and winter hard weeds emerged: shepherd's purse (*Capsella bursa-pastoris* (L.)) Med., henbit (*Lamium amplexicaule* (L.)), common chickweed (*Stellaria media* (L.) Vill.) and annual bluegrass (*Poa annua* (L.)). Intensive growth of hairy vetch begun next year in the spring. At the time of tomato transplants planting in the middle of May, intertwined vetch shoots formed dense stand about 50 cm high covering wintering weeds and soil surface entirely. Hairy vetch dominated over about 20 cm high tomatoes (fig. 1) which commenced their growth in the field. In this time in dependence on the year, the fresh and the air-dry weight of vetch shoots ranged from 2766 to 4768 g·m^{-2} and from 495,1 to 734,3 g·m^{-2} and the fresh and air-dry weight of vetch roots ranged from 140 to 233 g·m^{-2} and from 25.8 to 36.8 g·m^{-2} respectively. The fresh and the air-dry weight of

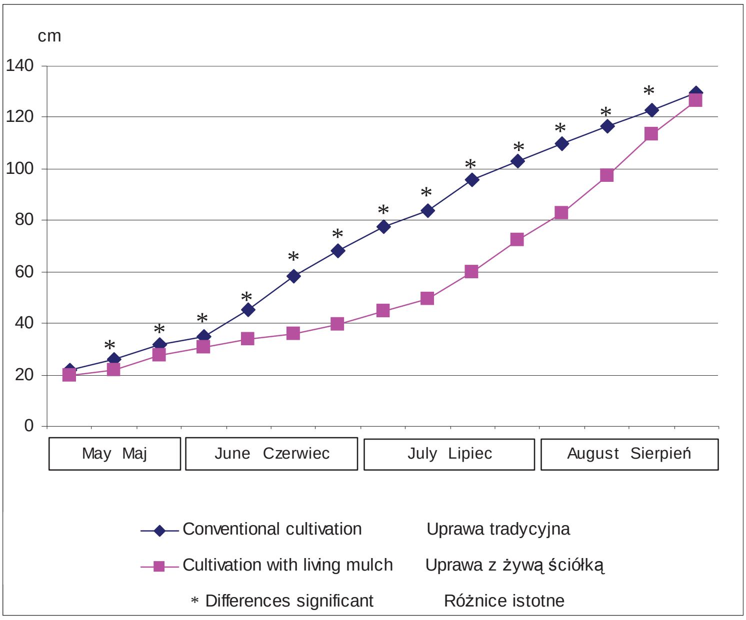

Fig. 1. Effect of cultivation method on length of tomato stem (mean for 2007–2009)
Rys. 1. Wpływ metody uprawy na długość łodygi pomidora (średnio dla lat 2007–2009)

hairy vetch plants were significantly different in the study years (tab. 2). The air dry shoots and roots of hairy vetch contained 2.78% and 2.36% of total nitrogen, 0.51% and 0.59% of phosphorus, 3.34% and 2.37% of potassium, 0.84% and 0.47% of calcium and 0.18% and 0.15% of magnesium on an average respectively (tab. 3). In the middle of May the vetch plants growing on 1 m^{-2} accumulated 18.0 g of nitrogen, 4.3 g of phosphorus, 20.9 g of potassium, 5.1 g of calcium and 1.2 g of magnesium on an average (tab. 4). In this time the shoots of vetch grew fast entwining tomato plants and it was necessary to rake them aside. Hairy vetch commenced flowering at the end of May and attained full flowering stage in the first half of June. In this time its stand was about 80 cm high. The top dressing with ammonium nitrate effected in the middle of June stimulated also the growth of hairy vetch which stopped after setting of pods at the end of June. In the beginning of July, ripening of pods and then progressive decaying of plants commenced. In the first days of August the dried vetch shoots formed 2–3 cm thick mulch which covered soil surface entirely and decomposed slowly. At the end of cultivation period the mulch covered about 90% of soil surface and numerous seeds produced earlier by vetch plants emerged. Many insects and arachnids lived in the living and then in the dry vetch mulch while only very few were present on uncovered, crusted surface of soil on conventionally cultivated plots.

Table 2. Fresh and air-dry weight of hairy vetch shoots and roots in the middle of May in 2007–2009
Tabela 2. Świeża i powietrznie sucha masa pędów i korzeni wyki kosmatej w połowie maja w latach 2007–2009

Plant's part Część rośliny	Fresh weight, g·m^{-2} Świeża masa, g·m^{-2}				Air-dry weight – Powietrznie sucha masa							
					% of fresh weight % świeżej masy				g·m^{-2}			
	2007	2008	2009	mean średnio	2007	2008	2009	mean średnio	2007	2008	2009	mean średnio
Shoots Pędy	4768.0	2766.0	3831.0	3788.0	15.4	17.9	16.3	16.5	734.3	495.1	624.5	618.0
Roots Korzenie	233.0	140.0	185.0	186.0	15.8	18.4	17.1	17.0	36.8	25.8	31.6	31.4
Totally Razem	5001.0	2906.0	4016.0	3974.0	15.6	18.2	16.7	16.8	771.1	520.9	656.1	649.4
$LSD_{0.05}$ – $NIR_{0,05}$												
Shoots – Pędy				795.4				1.7				106.7
Roots – Korzenie				41.9				1.9				5.1

The average decade temperature of the conventionally tilled soil measured at the 5 cm and 10 cm depth were usually higher than those of no-tilled soil covered with hairy vetch mulch (tab. 5). This effect was especially visible at the 10 cm depth in the beginning of cultivation. In the second decade of May 2008, the average temperature of conventionally cultivated soil at the 5 cm depth was 5,0^{o}C higher and at the 10 cm depth it was 5,7^{o}C higher than the temperature of no-tilled soil covered with living mulch. In succeeding weeks these differences decreased gradually and sometimes disappeared. At the end of tomato cultivation, the average temperature of no-tilled soil covered with dry vetch mulch was in some decades higher than the temperature of conventionally cultivated soil. Under conventional cultivation the decade temperature amplitudes measured at the 5 cm and 10 cm depth were usually higher than under no-tillage. The decade temperature amplitudes of the conventionally tilled soil measured at the 5 cm depth were always higher and of the no-tilled soil were usually higher than those at the 10 cm depth.

The moisture of no-tilled soil covered with hairy vetch was at the 0–40 cm depth significantly higher than on conventionally tilled plots. This effect was dependent on the year of study as well as on the term and on the depth of measurement. It was especially distinct in the 0–20 cm layer during dry periods of summer (tab. 6). Method of cultivation did not affect significantly the soil total porosity nor the soil bulk density (tab. 7

and 8). During soil samples taking, numerous channels created by earthworms were observed in the no-tilled soil covered with hairy vetch while only very few channels were visible in the conventionally tilled soil. Moreover during dry weather the soil surface on plots covered with mulch stayed uncrusted while a hard crust formed on the soil surface of conventionally cultivated plots.

On conventionally cultivated plots, the emergence of weeds started 8–10 days after planting of tomato transplants. In the years 2007, 2008 and 2009 four weeks after tomato planting, 463, 786 and 624 weeds belonging to 16, 13 and 18 species grew on 1 m^2 of conventionally cultivated plot and their fresh weight was 432 g, 641 g and 553 g respectively. Dominating species were: annual bluegrass, barnyard grass (*Echinochloa crus-galli* (L.) Beauv.), common chickweed, hairy galinsoga (*Galinsoga quadriradiata* (Ruiz et Pav.)), henbit, marsh cudweed (*Gnaphalium uliginosum* L.), lambsquarters (*Chenopodium album* (L.)), redroot pigweed (*Amaranthus retroflexus* (L.)), shepherd's purse, and smallflower galinsoga (*Galinsoga parviflora* (Cav.)). In this time there were no weeds growing on plots covered with hairy vetch. Single weeds, among others dandelion (*Taraxacum officinale* (L.)) seedlings, appeared on these plots in the second half of vegetation period, after partial decaying of vetch mulch. Few weeds emerged also in the places where tomato transplants were planted.

Method of cultivation did not affect the root-taking of tomato transplants but then tomatoes cultivated on plots covered with living mulch grew much slower than those cultivated conventionally. Two weeks after plantation, their stem diameter was 6.0 mm and 6.7 mm, and at the end of cultivation it was 16.4 mm and 19.3 mm on an average respectively, with the differences being significant during whole vegetation period (fig. 2). At planting, the mean length of stem of tomato transplants was 20.9 cm and one week later it was 26.0 cm on plots cultivated conventionally and 22.1 cm on plots covered with living mulch. These differences increased up to the third decade of July when majority of vetch plants decayed. Then the stems of tomatoes cultivated on plots covered with dry vetch mulch started to grow faster and at the time of topping they almost attained the height of those cultivated conventionally (fig. 2). Moreover, during first weeks after plantation the leaves of tomatoes grown on plots covered with living mulch had a lighter green colour suggesting deficiency of nitrogen and during whole vegetation period the growth of tomato plants was in this treatment much more differentiated.

At the beginning of August the leaves of tomatoes cultivated on plots covered with mulch contained more nitrogen, phosphorus and potassium and the content of calcium and magnesium was independent of the cultivation method. The content of all above mentioned macroelements depended significantly of the study year and the content of nitrogen, potassium and magnesium depended also of the interaction between the cultivation method and the year of study (tab. 9).

Every year the main disease infesting tomatoes was potato blight which appeared on the oldest leaves of conventionally cultivated plants at the end of July and then spread gradually on all plants till end of vegetation. In September, about 60% of leaves of conventionally cultivated plants were infested by potato blight in comparison to 25% under no-tillage. The yield of diseased fruits was also significantly higher under conventional cultivation but its share in the total yield was slightly lower than under no-tillage (tab. 10).

Table 3. Percentage of macroelements in air-dry shoots and roots of hairy vetch in the middle of May in 2007–2009
Tabela 3. Zawartość makroskładników w powietrznie suchej masie korzeni i pędów wyki kosmatej w połowie maja w latach 2007–2009, % p.s.m.

Plant's part Część rośliny	Nitrogen – Azot				Phosphorus – Fosfor				Potassium – Potas				Calcium – Wapń				Magnesium – Magnez			
	2007	2008	2009	mean średnio	2007	2008	2009	mean średnio	2007	2008	2009	mean średnio	2007	2008	2009	mean średnio	2007	2008	2009	mean średnio
Shoots Pędy	2.98	2.63	2.72	2.78	0.50	0.53	0.51	0.51	2.72	3.80	3.51	3.34	0.72	1.14	0.65	0.84	0.18	0.16	0.20	0.18
Roots Korzenie	2.40	2.39	2.29	2.36	0.59	0.60	0.57	0.59	1.88	2.76	2.46	2.37	0.25	0.91	0.26	0.47	0.14	0.15	0.16	0.15
Mean Średnio	2.69	2.51	2.51	2.57	0.55	0.57	0.54	0.55	2.30	3.28	2.99	2.86	0.49	1.03	0.46	0.66	0.16	0.16	0.18	0.17
$LSD_{0.05}$ – $NIR_{0,05}$																				
Shoots – Pędy				0.12				0.02				0.09				0.08				0.02
Roots – Korzenie				0.03				0.03				0.06				0.02				0.02

Table 4. Content of macroelements in hairy vetch plants in the middle of May in 2007–2009, $g \cdot m^{-2}$
Tabele 4. Zawartość makroskładników w roślinach wyki kosmatej w połowie maja w latach 2007–2009, $g \cdot m^{-2}$

Plant's part Część rośliny	Nitrogen – Azot				Phosphorus – Fosfor				Potassium – Potas				Calcium – Wapń				Magnesium – Magnez			
	2007	2008	2009	mean średnio	2007	2008	2009	mean średnio	2007	2008	2009	mean średnio	2007	2008	2009	mean średnio	2007	2008	2009	mean średnio
Shoots Pędy	21.9	13.0	17.0	17.3	3.7	2.6	3.2	4.1	20.0	18.8	21.9	20.2	5.3	5.6	4.1	5.0	1.3	0.8	1.3	1.1
Roots Korzenie	0.9	0.6	0.7	0.7	0.2	0.2	0.2	0.2	0.7	0.7	0.8	0.7	0.1	0.2	0.1	0.1	0.1	0.1	0.1	0.1
Totally Razem	22.8	13.6	17.7	18.0	3.9	2.8	3.4	4.3	20.7	19.5	22.7	20.9	5.4	5.8	4.2	5.1	1.4	0.9	1.4	1.2
$LSD_{0.05}$ – $NIR_{0,05}$																				
Shoots – Pędy				3.4				0.5				1.7				0.4				0.1
Roots – Korzenie				0.1				n.s. n.i.				0.1				0.1				n.s. n.i.

Table 5. Mean, minimal and maximum decade soil temperatures at 5 cm and 10 cm depth dependence on cultivation method in May–September 2007–2008 (°C)

Tabela 5. Średnia, minimalna i maksymalna dekadowa temperatura gleby na głębokości 5 cm i 10 cm w miesiącach maj-wrzesień w latach 2007 i 2008 w zależności od metody uprawy (°C)

Month Miesiąc	Decade Dekada	2007												2008											
		conventional cultivation uprawa tradycyjna						cultivation with living mulch uprawa z żywą ściółką						conventional cultivation uprawa tradycyjna						cultivation with living mulch uprawa z żywą ściółką					
		5 cm			10 cm			5 cm			10 cm			5 cm			10 cm			5 cm			10 cm		
		1*	2*	3*	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
Maj May	II	18.1	12.9	27.1	18.0	12.8	24.2	17.0	12.4	25.5	16.4	12.3	23.1	20.3	13.7	31.3	21.1	12.9	27.7	15.3	12.8	18.1	15.4	12.6	17.8
	III	20.9	15.6	30.7	20.8	15.2	29.5	19.8	14.5	28.7	19.2	13.3	26.9	19.9	13.7	31.5	20.2	12.9	27.9	17.0	14.1	19.4	16.9	13.9	19.2
June Czerwiec	I	18.9	14.5	28.3	19.1	14.1	26.7	18.6	14.1	27.1	17.9	14.5	24.8	19.5	13.3	29.5	20.1	12.6	26.7	16.6	14.5	19.4	16.5	14.5	19.3
	II	21.1	15.5	28.3	21.2	15.2	27.5	20.3	16.8	24.0	19.9	16.4	22.9	21.4	15.2	30.7	21.9	14.9	28.3	17.8	15.2	19.8	17.7	14.9	19.4
	III	18.3	13.6	26.0	18.4	13.3	23.6	18.3	15.6	22.1	18.1	15.6	21.3	19.7	14.1	31.9	20.1	13.7	29.1	18.7	15.2	23.2	18.5	14.9	22.5
July Lipiec	I	17.8	12.8	28.3	17.9	12.6	26.3	17.3	14.9	20.6	17.0	14.5	20.2	19.1	13.7	32.3	19.7	13.3	26.3	18.3	15.6	22.1	18.2	15.2	21.0
	II	21.1	13.9	30.7	21.0	13.7	29.1	19.3	15.2	23.6	18.8	15.3	22.9	22.3	17.1	34.9	23.2	15.2	28.3	19.5	17.1	22.5	19.6	16.8	21.7
	III	20.7	13.6	29.1	20.7	13.3	27.5	19.8	14.5	23.6	19.5	14.9	22.9	19.9	14.9	32.3	20.2	12.9	26.3	18.7	15.6	21.7	18.5	15.3	21.3
August Sierpień	I	19.7	13.9	28.3	19.8	13.7	24.8	19.5	14.9	25.9	19.1	14.9	24.4	21.4	15.6	34.9	21.8	13.7	28.7	19.9	16.8	24.4	19.7	16.5	24.0
	II	20.5	15.2	30.7	20.5	15.0	28.7	20.3	16.8	26.0	19.9	16.8	24.8	16.5	11.8	26.3	16.5	9.8	22.5	16.7	13.3	20.2	16.5	13.0	19.8
	III	20.9	12.9	31.1	20.8	13.3	27.5	19.5	13.7	25.2	19.2	14.1	24.0	19.2	13.3	29.5	19.9	12.2	24.0	18.5	14.9	21.7	18.6	14.7	21.5
September Wrzesień	I	15.5	12.4	21.3	15.6	12.6	20.2	15.2	12.6	18.7	15.0	12.2	18.3	14.0	8.6	23.6	13.6	7.0	20.2	15.0	11.0	20.2	14.7	10.8	20.0
	II	14.7	12.2	19.0	14.9	12.6	18.7	14.8	12.6	18.3	14.5	12.6	18.3	16.5	14.5	22.1	16.9	14.9	21.7	16.8	14.5	22.1	16.7	14.5	22.0
Mean Średnio		19.1	13.8	27.6	19.1	13.7	25.7	18.4	14.5	23.8	18.0	14.4	22.7	19.3	14.2	30.1	19.7	13.4	26.0	17.6	14.9	21.2	17.7	14.5	20.9

1* – Mean – Średnia
2* – Minimal – Minimalna
3* – Maximum – Maksymalna

Table 6. Effect of cultivation method on soil moisture at the 0–20 cm and 20–40 cm depth in 2007–2009, %
Tabela 6. Wpływ metody uprawy na wilgotność gleby w warstwie 0–20 cm i 20–40 cm w latach 2007–2009, %

Cultivation method Metoda uprawy	Soil layer Warstwa gleby	2007				2008				2009				Mean for the years Średnio dla lat			
		I*	II*	III*	mean średnio	i*	ii*	iii*	mean średnio	i*	ii*	iii*	mean średnio	i*	ii*	iii*	mean średnio
Conventional Tradycyjna	0–20	16.3	12.8	12.8	14.0	20.2	18.7	12.7	17.2	19.5	12.8	12.6	15.0	18.7	14.8	12.7	15.4
	20–40	15.7	13.9	13.4	14.3	23.1	19.1	14.9	19.0	20.9	13.9	13.6	16.1	19.9	15.6	14.0	16.5
	0–40	16.0	13.4	13.1	14.2	21.7	18.9	13.8	18.1	20.2	13.4	13.1	15.6	19.3	15.2	13.4	16.0
With living mulch Z żywą ściółką	0–20	16.2	14.8	16.8	15.9	20.5	18.3	16.9	18.6	19.2	14.7	16.5	16.8	18.6	15.9	16.7	17.1
	20–40	17.2	15.0	16.7	16.3	19.3	16.3	15.7	17.1	20.4	15.1	15.6	17.0	19.0	15.5	16.0	16.8
	0–40	16.7	14.9	16.8	16.1	19.9	17.3	16.3	17.8	19.8	14.9	16.1	16.9	18.8	15.7	16.4	17.0
Mean Średnio	0–20	16.3	13.8	14.8	15.0	20.4	18.5	14.8	17.9	19.4	13.8	14.6	15.9	18.7	15.4	14.7	16.3
	20–40	16.5	14.5	15.1	15.3	21.2	17.7	15.3	18.1	20.7	14.5	14.6	16.6	19.5	15.6	15.0	16.7
	0–40	16.4	14.2	15.0	15.2	20.8	18.1	15.1	18.0	20.1	14.2	14.6	16.3	19.1	15.5	14.9	16.5

$LSD_{0.05}$ – $NIR_{0,05}$	I* June 1–4th – 1–4 czerwca	II* July 13–16th – 13–16 lipca	III* August 29–31st – 29–31 sierpnia
Cult. meth. – Met. upr. (A)	0.9	A × B 2.9	A × B × C n.s. – n.i.
Years – Lata (B)	1.3	A × C 2.9	A × B × D n.s. – n.i.
Term – Termin (C)	1.3	A × D 1.7	A × B × C × D n.s. – n.i.
Depth – Głębokość (D)	n.s – n.i.	B × C 5.1	
		B × D 2.9	
		C × D 2.9	

Table 7. Effect of cultivation method on soil total porosity at the 0–20 and 20–40 cm depth in 2007–2009, %
Tabela 7. Wpływ metody uprawy na porowatość ogólną gleby w warstwie 0–20 cm i 20–40 cm w latach 2007–2009, %

Cultivation method Metoda uprawy	Soil layer Warstwa gleby	2007				2008				2009				Mean for the years Średnio dla lat			
		I*	II*	III*	mean średnio	i*	ii*	iii*	mean średnio	i*	ii*	iii*	mean średnio	i*	II*	III*	mean średnio
Conventional Tradycyjna	0–20	38.8	36.0	35.3	36.7	47.8	46.4	44.4	46.1	42.9	42.3	40.5	41.9	43.2	41.6	40.0	41.6
	20–40	34.3	33.3	32.7	33.4	40.7	38.9	36.3	38.6	37.1	36.2	38.1	37.1	37.4	36.1	35.7	36.4
	0–40	36.6	34.7	34.0	35.1	44.3	42.7	40.2	42.4	40.0	39.3	39.4	39.6	40.3	38.9	37.9	39.0
With living mulch Z żywą ściółką	0–20	35.0	36.8	37.1	36.3	44.8	43.2	44.8	44.3	38.9	38.5	40.1	39.2	39.6	39.5	40.7	39.9
	20–40	34.5	38.8	40.5	37.9	38.3	41.3	36.6	38.7	37.1	37.2	37.5	37.3	36.6	39.1	38.2	38.0
	0–40	34.8	37.8	38.8	37.1	41.6	42.3	40.7	41.5	38.0	37.9	38.8	38.2	38.1	39.3	39.4	38.9
Mean Średnio	0–20	36.9	36.4	36.2	36.5	46.3	44.8	44.5	45.2	40.9	40.4	40.3	40.5	41.4	40.5	40.3	40.7
	20–40	34.4	36.1	36.6	35.7	39.5	40.1	36.5	38.7	37.1	36.7	37.8	37.2	37.0	37.6	37.0	37.2
	0–40	35.7	36.3	36.4	36.1	42.9	42.5	40.5	42.0	39.0	38.6	39.1	38.9	39.2	39.1	38.7	39.0

$LSD_{0.05}$ – $NIR_{0,05}$	I* June 1–4th – 1–4 czerwca	II* July 13–16th – 13–16 lipca	III* August 29–31st – 29–31 sierpnia
Cult. meth. – Met. upr. (A)	n.s. – n.i.	A × B n.s. – n.i.	C × D n.s. – n.i.
Years – Lata (B)	3.1	A × C n.s. – n.i.	A × B × C n.s. – n.i.
Term – Termin (C)	n.s – n.i.	A × D n.s. – n.i.	A × B × D n.s. – n.i.
Depth – Głębokość (D)	1.6	B × C 6.3	A × B × C × D n.s. – n.i.
		B × D 5.7	

Table 8. Effect of cultivation method on soil bulk density at the 0–20 cm and 20–40 cm depth in 2007–2009, $g \cdot cm^{-3}$

Tabela 8. Wpływ metody uprawy na ciężar objętościowy gleby w warstwie 0–20 cm i 20–40 cm w latach 2007–2009, $g \cdot cm^{-3}$

Cultivation method Metoda uprawy	Soil layer Warstwa gleby	2007				2008				2009				Mean for the years Średnio dla lat			
		I*	II*	III*	mean średnio	i*	ii*	iii*	mean średnio	i*	ii*	iii*	mean średnio	i*	ii*	iii*	mean średnio
Conventional Tradycyjna	0–20	1.60	1.62	1.66	1.68	1.35	1.37	1.39	1.37	1.48	1.53	1.57	1.53	1.48	1.51	1.54	1.51
	20–40	1.64	1.67	1.70	1.67	1.55	1.62	1.66	1.61	1.53	1.57	1.64	1.58	1.57	1.62	1.67	1.62
	0–40	1.62	1.65	1.68	1.65	1.45	1.50	1.53	1.49	1.51	1.55	1.61	1.56	1.53	1.57	1.61	1.57
With living mulch Z żywą ściółką	0–20	1.64	1.62	1.63	1.63	1.53	1.50	1.43	1.49	1.54	1.52	1.50	1.52	1.57	1.55	1.52	1.55
	20–40	1.65	1.66	1.64	1.65	1.61	1.53	1.65	1.60	1.56	1.55	1.53	1.55	1.61	1.58	1.61	1.60
	0–40	1.65	1.64	1.63	1.64	1.57	1.52	1.54	1.54	1.55	1.54	1.52	1.54	1.59	1.57	1.56	1.57
Mean Średnio	0–20	1.62	1.62	1.65	1.63	1.44	1.44	1.41	1.43	1.55	1.56	1.59	1.57	1.54	1.54	1.55	1.54
	20–40	1.65	1.67	1.67	1.66	1.58	1.58	1.66	1.61	1.53	1.55	1.57	1.55	1.59	1.60	1.63	1.61
	0–40	1.64	1.65	1.66	1.65	1.51	1.51	1.54	1.52	1.54	1.56	1.58	1.56	1.57	1.57	1.59	1.58

$LSD_{0.05}$ – $NIR_{0,05}$
Cult. meth. – Met. upr. (A) n.s. – n.i.
Years – Lata (B) 0.08
Term – Termin (C) n.s – n.i.
Depth – Głębokość (D) 0.05

I* June 14th – 1–4 czerwca

II* July 13–16th – 13–16 lipca
A × B n.s. – n.i.
A × C n.s. – n.i.
A × D n.s. – n.i.
B × C 0.15
B × D 0.13

III* August 29–31st – 29–31 sierpnia
C × D n.s. – n.i.
A × B × C n.s. – n.i.
A × B × D n.s. – n.i.
A × B × C × D n.s. – n.i.

Table 9. Percentage of macroelements in air-dry tomato leaves in dependence on cultivation method in 2007–2009
Tabela 9. Zawartość makroelementów w powietrznie suchych liściach pomidora w zależności od metody uprawy w latach 2007–2009, % p.s.m.

Cultivation metod Metoda uprawy	Nitrogen – Azot				Phosphorus – Fosfor				Potassium – Potas				Calcium – Wapń				Magnesium – Magnez			
	2007	2008	2009	average średnio	2007	2008	2009	average średnio	2007	2008	2009	average średnio	2007	2008	2009	average średnio	2007	2008	2009	average średnio
Conventional Tradycyjna	3.88	2.62	3.98	3.49	0.31	0.48	0.44	0.41	3.36	3.60	4.40	3.79	4.52	4.76	3.76	4.35	0.38	0.28	0.32	0.33
With living mulch Z żywą ściółką	4.49	3.24	4.02	3.92	0.44	0.41	0.43	0.43	4.78	3.36	4.32	4.15	3.90	5.70	3.11	4.24	0.32	0.35	0.30	0.32
Average Średnio	4.19	2.93	4.00	3.71	0.38	0.45	0.44	0.42	4.07	3.48	4.36	3.97	4.21	5.23	3.44	4.29	0.35	0.32	0.31	0.33
$LSD_{0.05}$ – $NIR_{0,05}$																				
Cult. meth. – Met. upr. (A)				0.13				0.02				0.08				n.s. n.i.				n.s. n.i.
Years – Lata (B)				0.20				0.03				0.12				0.88				0.03
A × B				0.37				n.s. n.i.				0.21				n.s. n.i.				0.05

Table 10. Effect of cultivation method on yield of tomato fruits in 2007–2009, g·tomato plant^{-1}
Tabela 10. Wpływ metody uprawy na plon owoców pomidora w latach 2007–2009, g·roślina pomidora^{-1}

Fruits Owoce	Conventional cultivation Uprawa tradycyjna					Cultivation with living mulch Uprawa z żywą ściółką					Mean for years Średnio dla lat				
	2007	2008	2009	średnio	% total yield % plonu całk.	2007	2008	2009	średnio	% total yield % plonu całk.	2007	2008	2009	średnio	% total yield % plonu całk.
Ripe ϕ > 35 mm Dojrzałe ϕ > 35 mm	1440.2	1527.3	1495.3	1487.6	73.5	752.1	842.5	808.0	800.9	61.1	1096.1	1184.9	1151.7	1144.2	68.6
Ripe ϕ<35 mm Dojrzałe ϕ < 35 mm	103.9	105.3	113.4	104.5	5.2	78.4	110.2	108.7	99.1	7.6	91.2	107.8	111.1	103.3	6.2
Diseased Chore	240.6	305.8	284.6	277.0	13.7	202.2	220.5	189.2	203.9	15.5	221.4	263.2	236.9	240.5	14.4
Unripe Niedojrzałe	146.1	153.8	162.1	154.0	7.6	198.6	210.1	214.7	207.8	15.8	172.4	182.0	188.4	180.9	10.8
Total yield Plon całkowity	1930.8	2092.2	2055.4	2026.1	100.0	1231.3	1383.3	1320.6	1311.7	100.0	1581.1	1737.8	1688.0	1668.9	100.0

$LSD_{0.05}$ – $NIR_{0,05}$ Cult. meth.	Ripe – Dojrzałe ϕ > 35 mm	Ripe – Dojrzałe ϕ < 35 mm	Diseased – Chore	Unripe – Niedojrzałe	Total yield – Plon całkowity
Met. upr. (A)	106.2	n.s. – n.i.	19.4	10.4	112.3
Year – Rok (B)	142.6	12.7	28.7	15.8	150.6
A × B	n.s. – n.i.	26.4	n.s. – n.i	n.s. – n.i	n.s. – n.i.

Table 11. Effect of cultivation method on content of several components in tomato fruits
Tabela 11. Wpływ metody uprawy na zawartość kilku składników w owocach pomidora

Cultivation method Metoda uprawy	Dry matter, % Sucha masa, %				Monosaccharides, % Cukry proste, %				Total sugars, % Cukry ogółem, %				Carotenoids, mg·100 g^{-1} Karotenoidy, mg·100 g^{-1}				Vitamin C, mg·100 g^{-1} Witamina C, mg·100 g^{-1}			
	2007	2008	2009	mean średnio	2007	2008	2009	mean średnio	2007	2008	2009	mean średnio	2007	2008	2009	mean średnio	2007	2008	2009	mean średnio
Conventional Tradycyjna	5.8	6.0	5.3	5.7	4.1	3.1	3.9	3.7	4.4	3.8	4.3	4.2	10.6	8.5	9.9	9.7	22.8	21.7	18.1	20.9
With living mulch Z żywą ściółką	5.9	6.3	6.2	6.1	3.2	2.3	3.0	2.8	3.4	3.2	3.6	3.4	5.7	5.3	6.8	5.9	21.3	24.0	18.9	21.4
Mean Średnio	5.9	6.2	5.8	5.9	3.7	2.7	3.5	3.3	3.9	3.5	4.0	3.8	8.2	6.9	8.4	7.8	22.1	22.9	18.5	21.2
$LSD_{0.05}$ – $NIR_{0,05}$																				
Cult. meth. – Met. upr. (A)				0.2				0.7				0.5				0.3				n.s. n.i.
Year – Rok (B)				0.2				0.8				0.5				0.2				0.5
A × B				n.s. – n.i.				n.s. – n.i.				n.s. – n.i.				n.s. – n.i.				n.s. – n.i.

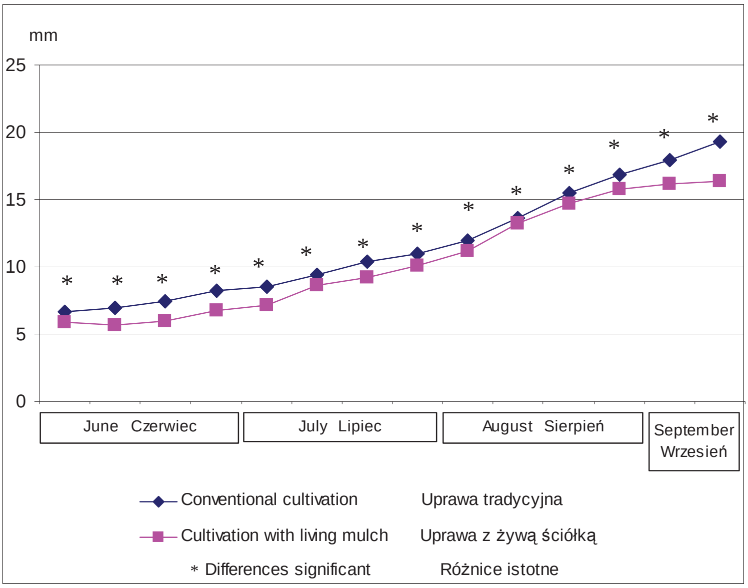

Fig. 2. Effect of cultivation method on diameter of tomato stem (mean for 2007–2009)
Rys. 2. Wpływ metody uprawy na średnicę łodygi pomidora (średnio dla lat 2007–2009)

Under conventional cultivation the total yield of tomato fruits as well as the yield of ripe fruits with diameter bigger then 35 mm and the yield of unripe fruits was significantly lower then under no-tillage cultivation with living mulch. Method of cultivation did not affect the yield of fruits with diameter smaller then 35 mm. The yields of all mentioned fruit assortments were significantly dependent of the year of study. Moreover, there was a significant effect of interaction between method of cultivation and year of study on the yield of fruits having diameter smaller then 35 mm. In the total yield of fruits harvested under conventional cultivation, the share of ripe fruits with diameter bigger then 35 mm was considerably higher and the share of unripe fruits was considerably lower in comparison to no-tillage cultivation (tab. 10).

The content of carotenoids, monosaccharides and total sugars in the fruits harvested under conventional cultivation was significantly higher and the content of dry matter was significantly lower in comparison to no-tillage cultivation. Method of cultivation did not affect the content of vitamin C in tomato fruits. The content of all mentioned components depended significantly on the year of study (tab. 11).

DISCUSSION

The tomatoes cultivated on no-tilled plots covered with hairy vetch mulch grew slower and produced lower yield of smaller fruits which ripened later than under conventional cultivation. The share of unripe fruits in total yield was in this treatment almost twice bigger. This could be caused by the lower soil temperature [Maletta and Janes 1987] as well as by the competition of hairy vetch plants during first half of cultivation period [Masiunas 1998] which delayed the growth and development of tomato plants. Similar results obtained Jelonkiewicz and Borowy [2000] and Borowy and Komosa [2003] in no-tillage cultivation of tomato determinate cultivar using rye (*Secale cereale* L.) as a cover crop. Tomato is a warm weather vegetable and temperature is the main factor determining its yield in field cultivation in temperate climate of Poland [Skąpski and Borowy 2000]. In the spring no-tilled soil gets warm slowly [Jabłoński et al. 1996] and moreover it is shaded by living mulch. In the experiment the temperature of no-tilled soil covered with hairy vetch was in May several degrees centigrade lower then under conventional cultivation and this agrees with the results obtained by Teasdale and Abdul-Baki [1995] and Nieróbca [2005]. Unfavourable effect of no-tillage and living mulch on soil temperature remained till August. However, at the end of summer the dry hairy vetch mulch protected the soil against loss of heat and in September the soil temperature was in this treatment sometimes higher than under conventional cultivation. This agrees with the results obtained by Borowy et al. [2000] in the same natural conditions in no-tillage studies using rye as a cover crop as well as with the results concerning temperature of soil covered with a lawn obtained by Nieróbca [2005]. Moreover hairy vetch decreased decade amplitude and extreme values of soil temperature what agrees with the results obtained by Ashworth and Harrison [1983], Teasdale and Mohler [1993], Teasdale and Abdul-Baki [1995] and Nieróbca [2005]. According to Teasdale and Abdul-Baki [1995], early root and shoot growth as well as height of early yield of tomato fruits depend on the number of hours at optimum temperatures for root growth during the first 4 weeks of cultivation.

The critical period of weed competition of tomatoes grown from transplants is about four weeks after their plantation in the field [Dobrzański 1999] and in the experiment this was the time of the most intensive growth of hairy vetch which dominated distinctly over just planted tomatoes. According to Leary and DeFrank [2000], the critical period of the main crop is the optimum time for suppression of the living mulch and therefore this problem could be probably solved by cutting hairy vetch before transplants plantation [Abdul-Baki and Teasdale 1993]. Tomatoes grown from transplants belong to the vegetables most resistant to weed competition [Dobrzański 1999] and therefore in this experiment the living mulch was not suppressed with the aim to study the relations occurring between hairy vetch and tomato plants during vegetation period. Growing longer, hairy vetch produces more biomass and after decaying forms more dense mulch what is beneficial for the soil [Sainju and Singh 1997] and the environment [Lal 2008]. In the experiment curried out by Abdul-Baki and Teasdale [1993], the yield of fruits produced by stake tomatoes under no-tillage cultivation using hairy vetch as a living mulch was higher than under conventional cultivation but in this experiment hairy vetch was cut before transplants plantation and moreover the air temperatures in Maryland are higher than in Poland. According to Masiunas [1998], hairy vetch will reduce early season growth of vegetables if not adequately controlled.

In the spring no-tilled soil loses the reserve of winter gathered water faster than cultivated soil [Jabłoński et al. 1996]. Moreover, wintering living mulch grows intensively in the spring and takes up much water what can cause several problems in plant cultivation during dry periods [Liebl et al. 1992, Jelonkiewicz and Borowy 2009]. However, the amount of rainfall occurring in the experiment in May was sufficient to keep the soil moist also on no-tilled plots covered with living mulch (tab. 1 and 6). After decaying, hairy vetch formed thick mulch which protected the soil against evaporative loss of water in the summer and finally the soil moisture was in this treatment significantly higher than on conventionally cultivated plots (tab. 6). This agrees with the results obtained by Ashworth and Harrison [1983] and by Teasdale and Daughtry [1993]. The experiment was established on dusty medium loam containing 1,7% of organic matter and characterized by an unstable structure and therefore the effect of cultivation on soil total porosity and on bulk density was insignificant and of short duration (tab. 7 and 8) and it seems that these soil parameters did not affect the growth of tomato plants which develop a deep and strong root system [Skąpski and Borowy 2000]. The roots of living mulch and the earthworms could contribute to loosening of the no-tilled soil [Jabłoński et al. 1996, Poniedziałek and Stokowska 1999, Leary and DeFrank 2000, Hartwig and Ammon 2002]. These results confirm those obtained earlier in the same natural conditions by Borowy et al. [2000] and Konopiński et al. [2001, 2002]. The shoots of hairy vetch covered soil surface and its roots tied soil particles from September of the year when vetch seeds was sown till September of the next year when tomatoes were harvested, and protected the soil against wind and water erosion [Leary and DeFrank 2000, Hartwig and Ammon 2002].

In the experiment, hairy vetch as a living and then as a dry mulch was very effective in reducing weed infestation and this agrees with the results obtained by Nelson et al. [1991], Teasdale [1993], Teasdale and Daughtry [1993] and Brandsaeter and Netland [1999]. Residues of hairy vetch contain alcohols, aldehydes, furans, and monoterpenes which inhibit germination of weed seeds [Bradow and Connick 1990]. Hairy vetch grew intensively in May and suppressed wintering weeds which germinated in the autumn of the previous year. However, in the second half of cultivation period the vetch mulch intercepted wind blown seeds produced by spring-flowering dandelion plants which grew in a big number around the field what confirms earlier observations made by Masiunas et al. [1997] and Jelonkiewicz and Borowy [2005] in regard to rye mulch.

The advantageous effect of hairy vetch on potato blight infestation of determinate tomato cultivars observed by Abdul-Baki et al. [1996] and Kotliński and Abdul-Baki [2000] was not so distinct in these studies in which an indeterminate tomato cultivar was cultivated. In this experiment the leaves of conventionally cultivated tomatoes were infested by potato blight much more but the share of diseased fruits in total yield was slightly lower in comparison to no-tillage.

Basing on the observations made during vegetation period it can be stated that the no-tillage and the mulch increased considerably the number and the diversity of insects and arachnids which lived on plots in this treatment and this agrees with the opinions of Bugg [1992] and Teasdale et al. [2004] as well as with the results obtained by Hooks and Johnson [2004] and Prasifka et al. [2006]. Bigger number of earthworms observed on no-tilled plots covered with hairy vetch agrees with the results obtained by Hartwig and Ammon [2002].

In the experiment at the time of tomato planting the fresh and the air-dry weight of hairy vetch was 39.74 $t \cdot ha^{-1}$ and 6.494 $t \cdot ha^{-1}$ on an average respectively (tab. 2) and it contained together 180 kg N, 43 kg P, 209 kg K, 51 kg Ca, and 12 kg Mg (tab. 4). The results illustrating air-dry weight and nitrogen content are similar to those obtained by Decker et al. [1994]. Final quantity of macroelements accumulated by vetch plants was higher because the plants grew till the beginning of July. The decomposition of vetch rest started at the end of this month and continued till the end of vegetation period. During this time the macroelements were released partially to the soil and this could contribute to the intensive growth of tomatoes observed in this treatment in August (fig. 1 and 2). The release of elements from decayed plant proceeds slowly [Wilson and Hargrove 1986] and therefore in the experiment the majority of elements released by hairy vetch residues was available for the succeeding crop cultivated on this stand in the next year. The weight of vetch plants depended of the sum of rainfalls occurring at the time of seeds sowing. The lower sum of rainfalls in August 2007 (tab. 1) was the cause of lower emergence and then of lower fresh and dry weight of vetch plants in May of the next year (tab. 2).

The content of macroelements in tomato leaves and the content of dry matter, sugars and vitamins in tomato fruits depended mainly of the year of study and then of the cultivation method and sometimes of the interaction between these two parameters (tab. 9 and 11). Every year the temperature of air and soil and the sum of rainfalls as well as the biomass of hairy vetch were different and this could influence the uptake of mineral nutrients by tomato plants and the production of organic components in tomato fruits. In the beginning of August the leaves of tomatoes cultivated on plots covered with mulch contained more nitrogen, phosphorus and potassium and this was the time of the most intensive vegetative growth of tomato plants in this treatment. These results are generally in accordance with those obtained by Knavel et al. [1977], Mullins et al. [1980], Knavel and Herron [1981], Borowy and Jelonkiewicz [2000], Jelonkiewicz and Borowy [2009].

The results obtained in the experiment confirm the opinion of Leary and DeFrank [2000] that living mulches offer several benefits related to environmental protection and that they are more management intensive and variable in comparison to conventional tillage [Masiunas et al. 1997].

CONCLUSSIONS

1. Average decade temperature at 5 cm depth and 10 cm depth of conventionally cultivated soil was usually higher and soil moisture in 0–40 cm layer was significantly lower then those of no-tilled soil covered with vetch mulch. Cultivation method did not affect soil total porosity nor bulk density.

2. Hairy vetch as a living and then as a dry mulch covered soil and suppressed annual weeds well during whole vegetation period. In the middle of May the fresh and the air-dry weight of vetch plants was 39,7 $t \cdot ha^{-1}$ and 6,5 $t \cdot ha^{-1}$ on an average respectively.

3. Tomatoes cultivated on no-tilled plots covered with vetch mulch grew slower and produced significantly lower total and marketable yield and the share of unripe and diseased fruits in total yield was in this treatment bigger than under conventional cultivation.

4. Fruits harvested from plants cultivated conventionally contained carotenoids, monosaccharides and total sugars significantly more and dry matter significantly less and content of vitamin C was independent of cultivation method.

5. In the beginning of August, leaves of tomatoes cultivated on no-tilled plots covered with vetch mulch contained significantly more nitrogen, phosphorus and potassium and content of calcium and magnesium was independent of cultivation method.

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WZROST I PLONOWANIE POMIDORA PALIKOWEGO W UPRAWIE BEZORKOWEJ Z UŻYCIEM WYKI KOSMATEJ JAKO ŻYWEJ ŚCIÓŁKI

Streszczenie. Uprawa bezorkowa z użyciem żywej ściółki oferuje wiele korzyści związanych z ochroną środowiska i wpisuje się bardzo dobrze w zasady rolnictwa zrównoważonego, lecz dotychczas niewiele jest informacji o uprawie tą metodą warzyw w warunkach przyrodniczych Polski. W trzyletnim doświadczeniu polowym wysoko rosnąca odmiana pomidora 'Malinowy Ożarowski', uprawiana przy palikach metodą bezorkową z użyciem wyki kosmatej jako żywej ściółki, wydała istotnie mniejszy plon owoców ogółem i owoców handlowych niż w uprawie tradycyjnej. Plon owoców porażonych zarazą ziemniaka był również istotnie mniejszy, ale jego udział w plonie ogółem był znacznie większy. Zawartość karotenoidów, cukrów prostych i cukrów ogółem w owocach zabranych w uprawie tradycyjnej była istotnie większa, a zawartość suchej masy istotnie mniejsza niż w uprawie bezorkowej. Metoda uprawy nie miała wpływu na zawartość wit. C. W pełni owocowania liście pomidorów rosnących na poletkach okrytych wyką zawierały więcej azotu, fosforu i potasu, natomiast zawartość wapnia i magnezu była niezależna od metody uprawy. Metoda uprawy nie miała wpływu na przyjmowanie się doniczkowanej rozsady, ale następnie pomidory rosnące poletkach okrytych żywą ściółką były zdominowane przez wykę i rosły znacznie wolniej do trzeciej dekady lipca, kiedy obumarła większość roślin wyki. Rośliny pomidora rosnące w ściółce charakteryzowały się wzrostem znacznie bardziej zróżnicowanym przez cały okres wegetacji. Żywa ściółka i następnie ściółka utworzona z zaschniętych roślin wyki okrywały powierzchnię gleby prawie całkowicie i skutecznie ograniczały wzrost chwastów rocznych. Średnia temperatura dekadowa gleby uprawianej metodą tradycyjną mierzona na głębokości 5 cm i 10 cm była najczęściej wyższa, a wilgotność gleby w warstwie 0–40 cm była istotnie niższa niż gleby okrytej ściółką. Metoda uprawy nie miała wpływu na porowatość ogólną ani na gęstość gleby. Świeża i sucha masa roślin wyki oznaczana w czasie sadzenia pomidorów wynosiła średnio 39,7 $t \cdot ha^{-1}$ i 6,5 $t \cdot ha^{-1}$ i zawierała 180 kg N, 43 kg P, 209 kg K, 51 kg Ca i 12 kg Mg. Badana metoda uprawy charakteryzowała się zaletami odnoszącymi się do ochrony środowiska, ale także większą uciążliwością w stosowaniu i zmiennością w oddziaływaniu na wzrost i plonowanie pomidora.

Słowa kluczowe: właściwości gleby, zachwaszczenie, makroelementy, cukry, witaminy

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