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Original article

Evaluation of degradable nonwoven covers on the growth and yield of overwintering leeks

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Summary

Studies were conducted during 2011–2013 in a central European climate aimed at comparing the effects of different degradable nonwovens: 50 g m^{-2} polylactide (PLA) nonwoven, 50 g m^{-2} polypropylene (PP photod.) nonwoven with 0.1% iron stearate, used as floating row covers, on the microclimate and yield of overwintering leeks. For comparison, standard PP nonwovens (50 g m^{-2}) and non-covered plants were used. Radiometric tests showed that the solar radiation reflectance and absorbance of the photodegradable nonwoven was the lowest compared to other materials, but transmittance of the PP photod. was the highest. During 2012–2013 season, degradable covers provided the plants significantly higher soil temperatures than in the open field. Marketable yield of leeks grown in the open field was significantly lower (by 100%) after overwintering in comparison to plants covered with all nonwovens. No negative effect of degradable materials on leek yield was observed when compared to conventional PP fleece. In conclusion, both degradable films, which are environmentally friendly, were suitable as direct covers and may be a good alternative to oil based PP fleece.

Keywords

Allium porrum, degradable polymers, photodegradation, polylactide, row covers

Significance of this study

What is already known on this subject?

- In the recent years, degradable polymers have raised interest due to the need for preservation of the environment. Biopolymer materials were widely tested in horticulture as soil mulches, but evaluation of their usefulness as floating row covers in plant production should be also examined.

What are the new findings?

- We show that novel degradable films are suitable as direct covers in the leek production being a good alternative to oil based, non-degradable materials.

What is the expected impact on horticulture?

- Implementation of the eco-friendly materials to horticultural production will decrease plastic wastes and globally entail financial savings.

Introduction

An increasing number of studies on degradable polymers used in agriculture suggest increasing attention to protection of the environment (Vox et al., 2005; Schettini et al., 2007; Riggi et al., 2011; Briassoulis et al., 2013; Sartore et al., 2013; Picuno, 2014; Sartore et al., 2016). Oil based polymers, largely used in horticulture, become plastic waste at the end of their lifetime, which is problematic for disposal and recycling processes (Kyrikou and Briassoulis, 2007; Kasirajan and Ngouajio, 2012; Briassoulis et al., 2013; Picuno, 2014; Scarascia-Mugnozza et al., 2016). A solution to this problem can be the introduction in agriculture of films produced with biodegradable materials (Scarascia-Mugnozza et al., 2006). Indeed, degradable polymers are better for the environment, not leaving any harmful residues. Additional consideration for the use of degradables over oil based polymers is the effects on growth and yield of crops covered with such materials as well as on climatic parameters (air and soil temperature, humidity, solar radiation, etc.) (Kapanen et al., 2008; Scarascia-Mugnozza et al., 2011). Comparison of growth- and yield-enhancing effects of biopolymers to standard non-degradable materials should be useful to deepen the sustainability of agricultural activities (Siwek et al., 2013b). Although numerous studies have described the results of direct row covering with the use of non-degradable polypropylene (PP) nonwovens on the soil and horticultural plants (Olle and Bender, 2010), research on degradable floating covers is relatively sparse in this case. It is possible that environment-friendly row covers made from degradable materials fulfill successfully the functions of standard, non-degradable polypropylene nonwovens.

Some studies reported an increase in soil temperatures under degradable covers in comparison to open field conditions. Siwek et al. (2013a) noted higher soil temperatures (by about 1°C) under Bionolle (fibrous material made of polybutylene succinate PBS, 59 g m^{-2}, Polmatex-Cenaro, Poland) in relation to the open field in production of overwintering leeks in central European climate. The same increase in soil temperatures was observed for overwintering onions and for lettuce in early spring production, both covered with Bionolle (PBS, 100 g m^{-2}, Polmatex-Cenaro, Poland) and IBWCH (biodegradable aliphatic-aromatic polyester, 75 g m^{-2}, Polmatex-Cenaro, Poland) in relation to non-covered controls (Siwek et al., 2012, 2013b). The authors compared also thermal properties of degradable covers to oil based nonwoven, which showed no significant differences. Degradable row covers should provide sufficient plant growth enhancement by raising not only soil temperatures but also air temperatures, as has been found for oil based polymer materials (Olle and Bender, 2010); however, to our best knowledge, there are no detailed reports on the effects of direct covers made from biopolymers on air temperature

in plant environments. Nonwovens, as mechanical barriers, greatly affect the spectral properties of the solar radiation received by the plants. Siwek et al. (2012) reported transmittance in the range 400–600 nm of the degradable Bionolle (100 g m^{-2}) and IBWCH (75 g m^{-2}) covers of 67.6 and 59.7%, respectively, while transmittance of oil based PP nonwoven (50 g m^{-2}) was equal to 71.0% (Siwek, 2002).

The microclimate influenced by the covers interacts strongly with the growth and development of plants, and, consequently, affects the yield and chemical composition of crops (Olle and Bender, 2010; Kalisz et al., 2014). Higher yields of vegetables covered with non-degradable PP nonwoven were reported for lettuce (Słodkowski and Rekowska, 2004; Rekika et al., 2009); Chinese cabbage (Kalisz et al., 2014); broccoli and white cabbage (Słodkowski and Rekowska, 2004); sweet pepper (Michalik, 2010); and some *Allium* plants, including garlic (Rekowska and Skupień, 2007) and leek (Adamczewska-Sowińska and Kołota, 1998; Kołota and Adamczewska-Sowińska, 2007). Beneficial effects of degradable covers on the yield was also observed inter alia with overwintering leeks grown under 59 g m^{-2} Bionolle (Siwek et al., 2013a) and cucumbers grown under 75 g m^{-2} IBWCH and 54 g m^{-2} nonwoven polylactic acid (PLA) (Zawiska and Siwek, 2014). Regarding the chemical composition of plants, oil based nonwoven covers alter the content of pigments, L-ascorbic acid, sugars and dry weight in relation to plants grown in the open field (Olle and Bender, 2010). Degradable floating covers also affect the chemical composition of plants (Siwek et al., 2012, 2013b). As reported by Siwek et al. (2013a), leeks covered with Bionolle (59 and 100 g m^{-2}) had a higher dry weight content than non-covered control plants. Soluble sugar concentration was also higher than that in controls, but only in the case of 59 g m^{-2} Bionolle, while the highest increase in L-ascorbic acid level was observed for plants covered with 100 g m^{-2} Bionolle. Some contradictory results observed in particular experimental years (Siwek et al., 2013b) indicate the need for further research in this area.

Leek is a valuable species, expanding the assortment of field vegetable crops produced in Poland. Its production area accounts for 4,000–5,000 ha, which is 2.3–2.9% of the total agricultural area in the country. The total leek area in the European Union (EU) in 2015 was 26,000 ha (Eurostat, 2016). Poland is the second largest producer of leeks in the EU after France (5,110 ha) but before Belgium (4,000 ha), Spain (2,880 ha), the Netherlands (2,780 ha) and Germany (2,350 ha). Late leek cultivars are great winter-hardy plants that can withstand temperatures of up to -15°C and can remain in the field well into winter in central European climate. However, severe frosts in conjunction with the lack of snow cover may reduce marketable yield of leeks by 50–70% (Kołota and Adamczewska-Sowińska, 2007). Winter hardiness of leeks may be enhanced by direct covering (Adamczewska-Sowińska and Kołota, 2001). Thus, the goal of the present study was to assess the impact of degradable row covers on the yield and chemical composition of the leek plants in winter production in comparison to oil based PP nonwoven and to the plants grown in the open field.

Materials and methods

Plant material and experimental design

The experiment was conducted during the years 2011–2013 at the Vegetable Experimental Station of the University of Agriculture in Kraków, southern Poland (50°04'N, 19°51'E). The climate of the region is humid continental (Dfb) according to Köppen's classification. The soil type was a Fluvic Cambisol. The bare-root transplants of leeks with 0.5-cm thick pseudostems were produced in nursery beds. The planting dates of winter leeks (cultivar Kenton) were 8 July 2011 and 26 June 2012 in 75 × 15 cm spacing and at a 13–15 cm depth. Plants were ridged three times. The experimental design was randomized complete block design with three replications; each treatment consisted of 80 plants. All cultivation practices (irrigation, plant protection, weed control, fertilisation) were adapted to production guidelines recommended for leeks. Plants were covered with polymer materials on 23 November 2011 and 28 November 2012. Covers remained on the plants until harvest time. Harvest was conducted on 18 April 2012 and 24 April 2013, respectively, after overwintering of the plants in the field.

Degradable materials

The degradable PLA row cover (50 g m^{-2}) was made from commercially available 6251D polylactide (Nature Works LLC, Minnetonka, USA) dedicated for spun-bonded technology. Photodegradable nonwoven fleece (50 g m^{-2}) was formed from Moplen HP462 polypropylene (Basell Orlen Polyolefins, Płock, Poland) supplemented with an iron stearate photodegradation activator used at a concentration of 0.1%. Degradable nonwovens were formed on a laboratory line built by the Polmatex-Cenaro, Central Research and Development Centre of Textile Machines in Łódź (Poland). Characteristics of PLA and photodegradable polymers were presented by Gross and Kalra (2002); Kyrikou and Briassoulis (2007); Sulak et al. (2012); and Puchalski et al. (2015). Other treatments in the present experiment were non-degradable PP nonwovens (50 g m^{-2}) and non-covered controls. Some morphological and mechanical properties of nonwovens used in the experiment are presented in Table 1.

Spectral properties

Nonwoven materials were laboratory tested for solar radiation reflectance (R), absorbance (A) and transmittance (T) using an LI-1800-12S external integrating sphere with an LI-1800 portable spectroradiometer, equipped with PC-1800 software, and an LI-1800-10 quartz fibre optic probe (LI-COR, Lincoln, USA). The source of radiation was a

Table 1. Morphological and mechanical parameters of tested nonwovens.

Nonwovens	Mass per unit area (g m^{-2})	Thickness (mm)	Elongation at break (%)		Stress at break (N)		Fibre diameter (µm)
			MD	TD	MD	TD	
PP	46.8	0.32	71.2	75.7	113.0	70.0	15.8
PLA	50.6	0.33	3.8	4.0	25.5	13.7	11.5
PP photod.	51.9	0.36	17.1	17.6	61.6	38.2	13.5

MD: machine directions ; TD: transverse directions.

spectral halogen lamp of 3,200 K. Spectral properties of the nonwovens were tested in two radiation ranges: 700–1,100 (near-infrared, NIR) and 400–700 nm (photosynthetically active radiation, PAR) with wavelength sample intervals of 2 nm. Reflectance and transmittance were determined by direct measurements, while absorbance was calculated from the formula: A = 100 - (R + T).

Air and soil temperatures

Air temperatures were obtained from the Institute of Meteorology and Water Management, Kraków, Poland (50°08'N, 19°80'E).

Throughout the experiment, hourly soil temperature measurements were performed at a depth of 10 cm using HOBO U12-001 autonomous sensors (Onset Computer Corp., Bourne, USA). Sensors were placed in the central part of each treatment. Daily soil temperatures were calculated, and data were then presented as average values of daily mean, maximum and minimum temperatures for the whole covered period. Soil temperature fluctuated more during the 2011–2012 season; thus, the warm and cold days (2 January 2012 and 4 February 2012, respectively) were chosen for presenting the comparison of the course of temperature (hour interval) under different covers on such days.

Plant measurements and yield

Leeks were harvested at commercial fresh market maturity in the second half of April, after overwintering. The quality of yield was assessed according to the United Nations Economic Commission for Europe commercial quality standards for leeks (UNECE FFV-21, 2012). During harvest, plants were measured for length, diameter and weight of the blanched part. Leaves of all harvested plants were then trimmed and weighed. Marketable yield consisted of blanched parts of leek pseudostems of diameter > 2 cm.

Laboratory analysis of plant material

Dry weight was determined by drying the plant samples at 92–95°C, after which the weights of the dried and fresh samples were measured using an electronic analytical balance Sartorius A120S (Sartorius AG, Göttingen, Germany). The soluble sugars were determined by the anthrone method (Yemm and Willis, 1954). The plant material was mixed with 80% ethanol, and the absorbance was measured at 625 nm with a Helios Beta spectrophotometer (Thermo Fisher Scientific Inc., Waltham, USA). The L-ascorbic acid content was determined by the Tillman's titration method (Krełowska-Kułas, 1993). Plant material (50 g) was mixed with 200 cm^3 acetic acid. The extract was then titrated with Tillman's reagent (2,6-dichlorophenolindophenol) after another 30 min.

Statistical analyses

Statistical analyses were carried out by one-way ANOVA using the STATISTICA version 12 software package (StatSoft Inc., Tulsa, USA), followed by post hoc comparisons conducted with Duncan's multiple range test to determine homogeneous groups at $p < 0.05$. Differences in soil temperature between experimental treatments were tested using Kruskal-Wallis median test and Mann-Whitney U tests for the pairwise comparisons at a significance level of 0.05.

Results and discussion

Row cover materials affect the amount and quality of solar radiation that reaches plants (Friend and Decoteau, 1990; Gimenez et al., 2002). In the present experiment, the solar radiation reflectance and absorbance of the photodegradable PP cover were the lowest in both radiation ranges (PAR and NIR) compared to other materials (Table 2). Biodegradable cover made with polylactide (PLA) had the highest solar radiation reflectance and absorbance in the PAR and NIR ranges. The most important parameter is transmittance, which directly affects climatic parameters under cover. Plants grown under photodegradable nonwovens received more solar radiation in comparison to other tested materials, as PP photod. transmits around 75% of radiation. On the other hand, PLA based nonwovens had the lowest transmittance: differences in comparison to PP photod. reached 33.5% and 30.1% in the PAR and NIR ranges, respectively, while they reached 13.3% and 15.3%, respectively, in comparison to conventional PP material. Several studies reported an alteration in the plant solar radiation environment under floating row covers (Gimenez et al., 2002; Siwek, 2002), including biodegradable nonwoven fleeces (Siwek et al., 2012; Zawiska and Siwek, 2014). These alterations are associated with the type and structure of the materials, their

Table 2. Spectral properties of nonwovens used for covering of the plants – reflectance, absorbance and transmittance (%).

Nonwoven type	Reflectance		Absorbance		Transmittance	
	400-700 nm	700-1,100 nm	400-700 nm	700-1,100 nm	400-700 nm	700- 1,100 nm
PP	31.5 ± 1.54	30.7 ± 1.54	13.5 ± 0.83	9.4 ± 0.83	55.0 ± 6.19	59.9 ± 6.19
PLA	35.8 ± 3.33	40.2 ± 3.33	22.5 ± 1.73	15.2 ± 1.73	41.7 ± 2.72	44.6 ± 2.72
PP photod.	24.3 ± 1.54	24.9 ± 1.54	0.5 ± 0.31	0.4 ± 0.31	75.2 ± 6.22	74.7 ± 6.22

PP: standard polypropylene nonwoven (50 g m^{-2}); PLA: polylactide nonwoven (50 g m^{-2}); PP photod.: polypropylene nonwoven with an iron stearate photodegradation activator (50 g m^{-2}); ± SD: standard deviation, $n = 4$.

Table 3. Mean air temperature (°C) in the vegetation period of leeks.

Season	December			January			February			March			April		
	Tavg	Tmax	Tmin	Tavg	Tmax	Tmin	Tavg	Tmax	Tmin	Tavg	Tmax	Tmin	Tavg	Tmax	Tmin
2011–2012	1.7	5.3	-2.6	-1.3	1.6	-4.4	-6.8	-2.6	-11.7	4.5	10.4	-1.7	9.8	16.2	3.2
2012–2013	-2.8	0.8	-6.7	-2.4	0.0	-4.9	-0.5	1.9	-3.1	-0.9	2.9	-4.6	8.9	14.6	2.9

Tavg: mean temperature; Tmax: maximum temperature; Tmin: minimum temperature.

Table 4. Average soil temperature during overwintering of leeks under various row covers (1 December – 15 April).

Season	Treatment	Mean temperature (°C)	Maximum temperature (°C)	Minimum temperature (°C)
2011–2012	PP	4.3 a	5.6 a	3.2 a
	PLA	4.4 a	5.6 a	3.3 a
	PP photod.	4.3 a	5.6 a	3.1 a
	Control	4.0 a	5.5 a	2.7 a
2012–2013	PP	1.4 a	2.2 a	0.7 a
	PLA	2.1 b	2.8 b	1.5 b
	PP photod.	2.0 b	2.7 b	1.3 b
	Control	1.4 a	2.2 a	0.7 a

Mean values within a column, separately for the season, followed by different letters are significantly different at $p < 0.05$ according to the Kruskal-Wallis and Mann-Whitney U tests, $n = 544$ (2011–2012) or $n = 540$ (2012–2013). PP: standard polypropylene nonwoven (50 g m^{-2}); PLA: polylactide nonwoven (50 g m^{-2}); PP photod.: polypropylene nonwoven with an iron stearate photodegradation activator (50 g m^{-2}); Control: non-covered plots.

thickness, method of water condensation on the inner side and material age.

Monthly averages for air temperature are presented in Table 3. The winter of the 2011–2012 season was characterised by more dynamic changes in air temperature; the highest difference between maximum and minimum temperatures was found in February, equal to 9.1°C. In all other winter months of this season, calculated values were higher than those in 2012–2013.

Both environment-friendly materials (PLA and PP photod.) provided the plants significantly higher soil temperatures compared to the open field and oil based PP nonwoven during the 2012–2013 season (Table 4). This increase was observed especially in the minimum temperature range, which was twice higher than that in the control and PP nonwoven treatments. However, average soil temperature under all tested polymers and in the open field did not differ significantly in the season 2011–2012.

The patterns of daily changes in soil temperature during warm and cold days during the winter months of 2012 are presented in Figure 1. Almost the same course of soil temperatures was observed in covered plots and in the open field on a warm day. On a cold day, all direct covers (non-degradable and degradable ones) provided much higher soil temperatures (by about 2°C, on average) compared to the open field.

Nonwoven covers are known to increase soil temperature in the plant environment (Olle and Bender, 2010), but thermal conditions of the soil depend on the type of material used (Siwek et al., 2013b). Nonwovens are manufactured with different weights and structures; thickness; and air permeability; thus, heat convection may be different (Qashou, 2009). In the present experiment, row covers affected soil temperature, but thermal conditions were also influenced by climatic variables. During the 2011–2012 season, all nonwovens, including degradable ones, only slightly increased soil temperature in comparison to the open field, with small differentiation among them, while in the years 2012–2013, average temperatures under commercial PP nonwoven and in the open field were statistically comparable and signifi-

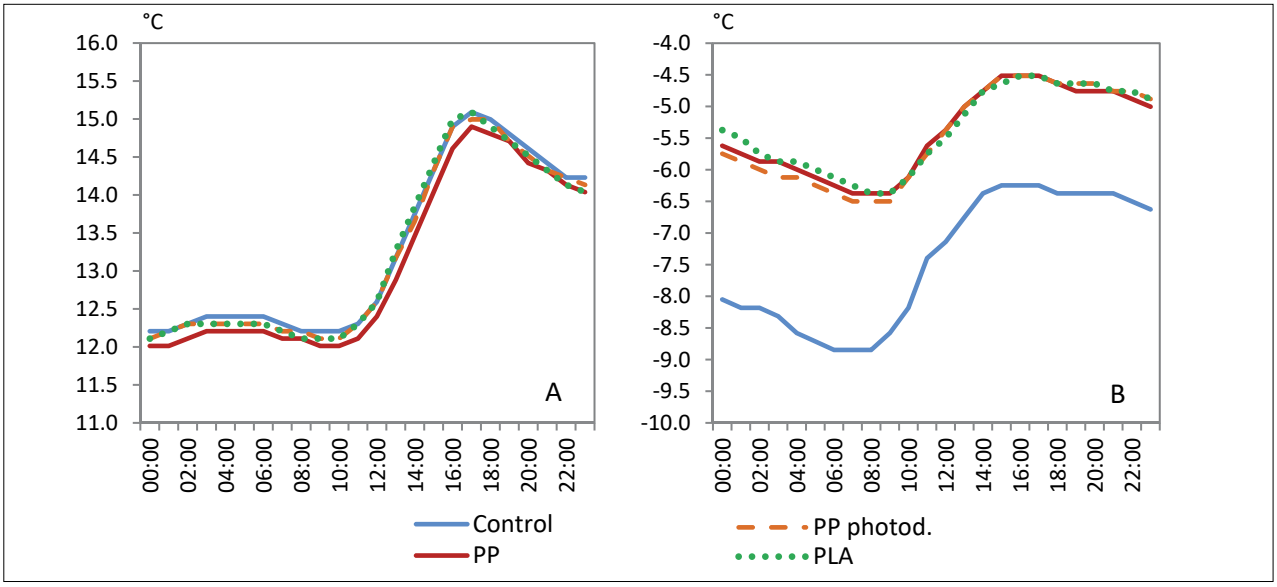


Figure 1. Daily course of temperature in the soil during the most warm (A) and cold (B) day (2 January and 4 February 2012, respectively), depending on the type of covering materials. Treatments: PP: standard polypropylene nonwoven (50 g m^{-2}); PLA: polylactide nonwoven (50 g m^{-2}); PP photod.: polypropylene nonwoven with an iron stearate photodegradation activator (50 g m^{-2}); Control: non-covered plots.

Table 5. Biometrical parameters of leek as influenced by tested nonwovens in the year 2012.

Treatment	Length of white pseudostem (cm)	Diameter of white pseudostem (cm)	Weight of white pseudostem (g)	Weight of the leaves (g)
PP	15.3 b	2.6 b	87 b	95 bc
PLA	13.3 b	2.5 b	97 bc	94 bc
PP photod.	20.1 c	2.4 b	107 c	110 c
Control	10.1 a	2.0 a	51 a	43 a

Mean values within a column, separately for the year, followed by different letters are significantly different at $p < 0.05$ according to the Duncan test, $n = 4$. Treatments: PP: standard polypropylene nonwoven (50 g m^{-2}); PLA: polylactide nonwoven (50 g m^{-2}); PP photod.: polypropylene nonwoven with an iron stearate photodegradation activator (50 g m^{-2}); Control: non-covered plots.

cantly lower than those under degradable polymers (Table 4). However, in more severe thermal conditions, during the coldest day, all tested nonwovens protected well the plants against lower temperatures (Figure 1).

All measured biometric parameters of covered leeks were higher than those of control plants (Table 5). Non-covered plants had the lowest length of bleached pseudostems, while nonwovens increased bleached pseudostem length, with most occurring in the case of photodegradable nonwoven (by 10 cm, on average). There was no significant difference in pseudostem diameter of the leeks covered with degradable and non-degradable materials, while control plants had the lowest diameter. Control leeks also formed pseudostems of the lowest weight, while bleached parts of plants covered with nonwovens were significantly heavier. Leeks covered with photodegradable nonwoven gave heavier pseudostems than plants grown under non-degradable PP nonwoven. There were no significant differences in weight of the leaves among covered plants, while control leeks formed leaves of the lowest weight. All polymer covers caused an increase in leek growth, with the photodegradable PP material being best in this respect. As observed by Siwek et al. (2013a), the bleached part of overwintering leeks grown under Bionolle degradable covers (59 and 100 g m^{-2}) was generally similar to that of non-covered controls, but its averaged length was greater. Siwek et al. (2013b) reported better growth of overwintering onions covered with nonwovens in comparison to controls (open field), with some significant differences between degradable and non-degradable polymers.

Table 6. Yield (kg m^{-2}) of leek as influenced by tested nonwovens in the years 2012–2013.

Treatment	2012	2013
PP	1.75 b	2.06 b
PLA	2.00 b	2.20 b
PP photod.	2.15 b	2.04 b
Control	1.02 a	1.40 a

Mean values within a column followed by different letters are significantly different at $p < 0.05$ according to the Duncan test, $n = 4$. Treatments: PP: standard polypropylene nonwoven (50 g m^{-2}); PLA: polylactide nonwoven (50 g m^{-2}); PP photod.: polypropylene nonwoven with an iron stearate photodegradation activator (50 g m^{-2}); Control: non-covered plots.

Marketable yield of leeks left without any cover during winter was significantly lower (by 100%) in comparison to plants covered with non-degradable and degradable nonwovens (Table 6). Covering the plants with nonwovens can increase the marketable yield of overwintering crops by several tens of per cent in comparison to open field cultivation (Shijun and Lijuan, 2001; Rekowska and Skupień, 2009). No effect of degradable materials on leek yield was observed when compared to standard PP fabric. This is a good indication that tested environment-friendly materials do not negatively influence plant yield. Siwek et al. (2013b) showed for winter onions that newly manufactured and prototype biodegradable materials (59 and 100 g m^{-2} Bionolle, 50 and 75 g m^{-2} IBWCH) could affect plant yield in different ways (they may increase or decrease the yield, depending on the material and the climatic conditions) in comparison to standard PP nonwovens.

There was no clear effect of covering with nonwovens (both degradable and non-degradable) on the chemical composition of leek plants (Table 7). During the spring of

Table 7. Content of dry weight, soluble sugars and L-ascorbic acid in leek as influenced by tested nonwovens in the years 2012–2013.

Year	Treatment	Dry weight (g 100 g^{-1} FW)	Soluble sugars (g 100 g^{-1} FW)	L-ascorbic acid (mg 100 g^{-1} FW)
2012	PP	11.94 b	4.82 b	17.10 b
	PLA	11.17 b	4.07 b	21.20 b
	PP photod.	9.08 a	3.35 a	13.90 a
	Control	11.30 b	3.90 b	18.00 b
2013	PP	8.85 a	3.41 b	23.40 b
	PLA	11.85 b	4.85 c	21.50 a
	PP photod.	10.43 b	3.97 b	24.90 b
	Control	9.28 a	3.01 a	22.00 a

Mean values within a column, separately for the year, followed by different letters are significantly different at $p < 0.05$ according to the Duncan test, $n = 4$. Treatments: PP: standard polypropylene nonwoven (50 g m^{-2}); PLA: polylactide nonwoven (50 g m^{-2}); PP photod.: polypropylene nonwoven with an iron stearate photodegradation activator (50 g m^{-2}); Control: non-covered plots.

2012, leeks covered with photodegradable nonwovens had the lowest content of dry weight, soluble sugars and L-ascorbic acid in comparison to other treatments. During 2013, the lowest content of these constituents was found in control plants together with leeks grown under standard nonwovens (in the case of dry weight) and, in the case of L-ascorbic acid, under PLA. The highest content of soluble sugars in 2013 was found in plants covered with PLA nonwovens. Direct covers, through modification of the plant environment, affect plant metabolism and content of several chemical constituents. According to Olle and Bender (2010), accumulation of pigments, vitamin C, dry weight and sugar in vegetable crops covered with non-degradable PP nonwovens is usually lower in comparison to non-covered plants. A decrease in the amount of dry weight and vitamin C in covered spring garlic in comparison to plants grown in the open field also was found by Rekowska and Skupień (2007). On the other hand, winter garlic grown under covers showed higher dry weight content in bulbs, total sugar in leaves but simultaneously less amount of L-ascorbic acid (Rekowska and Skupień, 2009). Alterations in the chemical composition of the plants covered with environment-friendly materials may be observed as was noted by Siwek et al. (2013a) for leeks grown under Bionolle (59 and 100 g m^{-2}) with rather no consistent response to the treatments. In the present experiment, lack of clear effects of direct covers (both degradable and non-degradable) on the plants probably was due to an influence of weather conditions. Probably, climatic diversification in experimental years had stronger effects on the chemical composition of the leeks than the covers themselves.

Degradable polymer materials continue to be developed and may play a larger role in agricultural production in the future. Such materials must maintain suitable mechanical and physical properties during crop production and then degrading at the intended time and conditions. In this research, tested films made by a polylactide and polypropylene with an iron stearate photodegradation activator had rather similar lifetime and functionality to commercial polypropylene nonwoven throughout the crop cycle. However, the photodegradable PP nonwoven showed some cracks in the structure after a season and had to be replaced with a new nonwoven while polylactide nonwoven showed no cracks and was still suitable for use in subsequent crop production cycle.

Conclusions

Alternative methods for the avoidance of plastic wastes in agriculture include the use of degradable polymers. These materials do not contaminate the environment and disposal could be accomplished by incorporating them into soil, instead of removing them from the field. This study demonstrated that environment-friendly covers (degradable polylactide nonwoven and polypropylene nonwoven with 0.1% iron stearate activator) tested on overwintering leeks may be considered suitable for agricultural applications. Spectral properties of nonwovens differ quite much, which resulted in their specific effects on air/soil temperature – degradable covers may increase soil temperature in comparison to open field conditions or even polypropylene nonwoven. The results proved that leek yield was positively influenced by the degradable materials, comparable to polypropylene nonwoven. The influence of degradable direct covers on the chemical composition of leeks, wintered in the field, was however unclear. In summary, both tested degradable films were suitable as direct covers in the production of overwintering leeks and may be a good alternative to oil based, non-degradable materials.

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