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The effect of biodegradable nonwovens in butterhead lettuce cultivation for early harvest

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ABSTRACT

Field experiments using ‘melt-blown’ biodegradable nonwovens were carried out on the ‘Melodion’ butterhead lettuce (*Lactuca sativa* var. *capitata* L.) cultivar for early harvest. All biodegradable nonwovens were manufactured in the Institute of Biopolymers and Chemical Fibres and POLMATEX CENARO in Łódź, Poland. Lettuce seeds were sown into boxes in a greenhouse at the beginning of March, and transplants were planted into the field at the beginning of April. Biodegradable nonwovens – aromatic polyester IBWCH 75 g m^{-2}, polybutylene succinate Bionolle 100 g m^{-2} and standard polypropylene PP Agro 20 g m^{-2} – were stretched over the lettuce in the field. The covers were kept on until 4-5 days before harvest. Plots without covers were defined as the control. Ascorbic acid, soluble sugar, dry matter, nitrates, chlorophyll a, chlorophyll b and carotenoid contents were recorded in the leaves. All biodegradable nonwovens showed a positive effect on yielding in comparison to the control in 2009. In the second year of the experiment, there were no significant differences between covers with regard to the yield. Dry matter and soluble sugar content in both years of the experiment was diversified. Nonwovens used as covers in 2009 significantly increased the content of nitrates in comparison to the control. In the second year, the highest level of nitrates was demonstrated in the control object. It is worth underlining that the maximum allowed limit of nitrate content in lettuce (4000 mg kg f.w.) was not exceed. The kind of cover had no significant effect on the level of chlorophyll a in 2009 or chlorophyll b and carotenoids in 2009 and 2010 in the lettuce.

Key words: direct cover, *Lactuca sativa* var. *capitata*, soil temperature, yield

INTRODUCTION

Various argo-technical methods in vegetable production may influence growth and plant development or change the content of chemical compounds inside the plants’ tissues. Soil mulching, using direct covers made from different materials and using low tunnels stretched above plants are amongst these methods (Lamont 1993, 1994). Introducing covers for soil and plants into agriculture allows vegetable growers to obtain higher, better quality yields; it affects the microclimate around the plant by modifying the radiation budget of the surface and decreasing the soil water loss. Many authors also emphasise the pro-ecological aspects of mulching, not only because of the positive effect on microclimate, but also because of the limiting use of herbicides (Benoit and Ceustermans 1992, Jenni et al. 1998), preventing soil erosion from wind and water and leaching of fertilisers, especially on light, sandy

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soils, and the development of plant diseases coming from the soil (Farias-Larios et al. 1994, Borosic et. al. 1998). These favourable conditions influence plants to develop without any physiological disorders and promote faster growth and earlier harvest (Cerne 1994, Rumpel 1994, Moreno and Moreno 2008). The main negative consequence of the use of polymer materials in agriculture is related to handling the plastic waste and the environmental impact. Pieces of polyethylene films and polypropylene nonwovens after harvest are left on the field and in the soil for many years, emitting harmful substances with the associated negative consequences to the environment and hindering soil cultivation (Picuno and Scarascia-Mugnozza 1994).

The ecological and economical problems related to recycling polymer wastes has resulted in the development of the strategy of producing agricultural materials from renewable sources, which degrade quickly without any harmful influence to the natural environment. The biodegradation of such materials is possible thanks to the presence of microorganisms such as bacteria, fungi and algae, whose enzymes cause the mineralisation of biodegradable polymer to carbon dioxide and/or methane, water and biomass (Chandra and Rustgi 1998). If oxygen is present, the biotic degradation that occurs is aerobic degradation and carbon dioxide is produced. If there is no oxygen available, the biotic degradation is anaerobic degradation, and methane is produced instead of carbon dioxide. Under some circumstances, both gases are produced (Kyrikou and Briassoulis 2007). After converting the polymers into simple chemical compounds, mineralisation occurs. Mineralisation is complete when all of the biodegradable materials or biomass is consumed and all of the carbon in it is converted to carbon dioxide. Complete mineralisation represents the rendering of all chemical elements into natural biogeochemical cycles (Stevens 2002). That biological recycling of biodegradable polymers is an important way of reducing plastic waste in the environment (Nanda et al. 2007).

There are many new polymers subjected to biodegradation on the world market, and the development of a new generation of thermoplastic polymers allows the production of not only films but also fibres and nonwovens. Therefore, in the last few years, interest has grown in biodegradable materials that can be used as mulches and direct covers in vegetable crop production. In many countries, investigations with the use of bio- and photo-degradable materials are being carried out and confirm their positive effect on yielding and the natural environment. Field tests on the use of biodegradable starch films were made in the production of tomatoes. The research showed that biodegradable mulches protected from weeds during the entire production period (Martin-Closas et al. 2008). Tests have been carried in many countries to determine the effect of biopolymers used as direct covers and low tunnel covers in the production of watermelon (Briassoulis 2006), strawberries (Scarascia-Mugnozza et al. 2006) and also as mulch in tomato cultivation (Moreno and Moreno 2008).

The aim of the presented study was to evaluate the effect of direct covering of butterhead lettuce as a typical crop for forced spring cultivation with two biodegradable nonwovens on soil conditions and yielding in early spring. Butterhead lettuce was the tested species because of its short period of vegetation and resistance to spring cold.

MATERIAL AND METHODS

The study was carried out in 2009-2010 at the Experimental Station of the University of Agriculture in Krakow, Poland and using 'Melodion' butterhead lettuce (*Lactuca sativa* var. *capitata* L.) grown in the spring season and using biodegradable nonwovens (melt-blown type) for direct covering manufactured by the Institute of Biopolymers and Chemical Fibres and CENARO in Łódź, Poland.

Two transparent biodegradable nonwovens – aromatic polyester IBWCH 75 g m^{-2} and polybutylene succinate Bionolle 100 g m^{-2} – and additionally a conventional polypropylene nonwoven PP 20 g m^{-2} were used in the experiment.

Butterhead lettuce seeds were sown both years in a greenhouse at the beginning of March. The seedlings were planted in a spacing of 30 × 25 cm on 6 April 2009 and 8 April 2010, respectively. The fertilisation with nitrogen carried out before planting with ammonium nitrate was dependent on the content in the soil (70 and 80 kg N ha, respectively). The experimental plots were randomly arranged in blocks of four replications (each with an area of 3 m^2, 40 plants). Direct covers were stretched over the plants right after planting and removed 4-5 days before harvest took place on 15 May 2009 and 26 May 2010, respectively. Plants cultivated without covers were the control.

The marketable yield was estimated during harvest. 20 heads of lettuce from each combination were collected for laboratory analyses. To evaluate the biological value of the lettuce, we took measurements of ascorbic acid using the method described by Tillmans (Pinta 1977), dry weight (using drying method in 92-95^{o}C), soluble sugars (using the anthrone method), nitrate content (with the use of ion-selective electrodes connected to an ionometer), and the content of chlorophyll a and b and carotenoids were determined (Lichtenthaler and Wellburn 1983). All data were subjected to an analysis of variance with the use of the Statistica program and the Neumann-Keuls test was used to estimate the significance of differences at $p = 0.05$.

The covers used in the experiment were subjected to spectral analysis. The analyses were made in respect to spectral transmission, absorption and reflection of radiation within the range of 400-1100 nm using a LI 1800-12-S integration sphere with standard light source (Czarnowski 1994).

RESULTS AND DISCUSSION

Modification of the environmental conditions by covers depended largely on the optical parameters of the nonwovens used. The radial properties of covers, especially transmission, absorption and reflection of radiation within the range of PAR and infrared, had the highest influence on light conditions (Siwek and Libik 1999). In the presented experiment (Tab. 1), a higher PAR transmission was determined for biodegradable nonwoven Bionolle 100 g m^{-2} (67.6%) than nonwoven IBWCH 75 g m^{-2} (59.7%). On the other hand, absorption and reflection of radiation was higher when nonwoven IBWCH 75 g m^{-2} was used in comparison to nonwoven Bionolle 100 g m^{-2}. Comparing these results with the results obtained by Siwek (2002), we determined that the reflection of biodegradable nonwovens applied in this experiment was higher by half than the reflection of polypropylene nonwoven PP 20 g m^{-2} (17.4%) within the same range of radiation. However, biodegradable nonwovens transmitted only 17% less light than polypropylene nonwoven PP (81%). Nonwoven PP 20 g m^{-2} used in the present experiment was of the same quality and the radiometric results were obtained with the use of the same method.

The investigations carried with the use of direct covers in vegetable cultivation showed that the thermal conditions were more stable under covers than on uncovered soil. Libik and Siwek (1994) noted that the use of polypropylene nonwoven PP 17 g m^{-2} did not cause the overheating of watermelon plants during the day in the summer months and protected them from cold at night. The results obtained in the presented experiment confirm the fact that the influence of nonwovens on soil temperature is strictly connected with the kind of material used. In butterhead lettuce cultivation, the soil temperature was higher than that of the uncovered object regardless of the type of cover used (Tab. 2). In the first year of the experiment, the mean temperature under covers was higher by 0.7°C, and in the second by 3.1°C. Biodegradable nonwoven IBWCH 75 g m^{-2} showed better thermal insulation conditions, similar to polypropylene nonwoven PP 20 g m^{-2}, when compared with nonwoven Bionolle 100 g m^{-2}. The minimum temperature in this case was 1.0 and 1.3°C higher, in 2009 and 2010, respectively. The maximum temperature differed less, but in 2010 it was 5.0°C lower under the Bionolle as compared to IBWCH 75 g m^{-2}. The fast

Table 1. Transmittance, absorbance and reflectance of covers made from biodegradable nonwovens in the range of 400-700 nm (PAR) (%)

Kind of cover	Transmittance	Absorbance	Reflectance
Biodegradable nonwoven Bionolle 100 g m^{-2}	67.6	0.6	31.8
Biodegradable nonwoven IBWCH 75 g m^{-2}	59.7	2.8	37.5

Table 2. Average soil temperature (°C) at the depth of 10 cm in butterhead lettuce cultivation with different kinds of biodegradable covers in the period: 6 April-10 May 2009 and 8 April-20 May 2010

Kind of cover	Mean		Minimum		Maximum	
	2009	2010	2009	2010	2009	2010
Polypropylene nonwoven PP 20 g m^{-2}	15.1	12.5	11.1	9.2	20.2	16.9
Biodegradable nonwoven Bionolle 100 g m^{-2}	14.7	10.4	11.0	7.9	19.0	13.3
Biodegradable nonwoven IBWCH 75 g m^{-2}	15.1	13.1	12.0	9.2	18.6	18.3
Control	14.3	8.9	9.1	4.5	20.8	15.1

Table 3. The effect of kind of nonwoven used as covers on marketable yield of 'Melodion' butterhead lettuce in two years of the study (kg m^{-2})

Kind of cover	2009	2010
Polypropylene nonwoven PP 20 g m^{-2}	4.72 b*	2.13 a
Biodegradable nonwoven Bionolle 100 g m^{-2}	5.05 b	1.98 a
Biodegradable nonwoven IBWCH 75 g m^{-2}	4.78 b	2.43 a
Control	3.47 a	2.50 a

*Values marked with the same letters do not differ significantly at $p = 0.05$

breaking of biodegradable nonwoven could be the reason for the differences observed.

In the presented experiment, similar results were obtained to those demonstrated by Wescott et al. (1991) and Libik and Siwek (1994) – that higher yield was obtained from plants grown under direct covers. In the first year of the experiment (2009), the marketable yield, obtained from treatments where covers were used, was about 40% higher that the yield obtained from the control (Tab. 3). In the second year of the experiment, the yield of covered lettuce was on a similar level in all treatments (about 13% less than the control, but not statistically proven). This opposite trend could be connected with generally lower temperatures and more cloudy days in 2010. On the basis of scientific reports confirming the positive effect of direct covers on the yield of watermelon and lettuce (Libik and Siwek 1994), pepper (Rumpel 1994), tomatoes (Martin-Closas et al. 2008), the differences between the years were characterised by a high variability.

The results obtained in the present experiment show that using nonwovens as direct covers in lettuce cultivation affected the dry weight, soluble sugar and nitrate content in plant tissues. In 2009, a slightly higher content of soluble sugars was found in plants covered with Bionolle 100 g m^{-2}. During the second year of the experiment, the differences were insignificant except the lettuce with IBWCH 75 g m^{-2} had lower soluble sugar content. In 2009, the highest content of dry weight was demonstrated in plants covered with IBWCH 75 g m^{-2}, whereas the lowest was found in plants covered with Bionolle 100 g m^{-2} (Tab. 4). In the next year, the dependence was opposite. The nonwovens demonstrated an influence on the content of nitrates in comparison to the control. In the first year of the experiment, the lowest content of nitrates was demonstrated in the control. Opposite results appeared during the second year. The generally low content of nitrates in 2010 might be attributed to the low amount of light that reached the plants. It is worth mentioning that in all of the experimental treatments, nitrate content did not exceed the level of 4000 mg NO_3^- per kg of fresh weight, i.e. the limit determined by the European Union for lettuce harvested from 1 April to 30 September.

The results presented in Table 5 indicate that in both years of the experiment the contents of chlorophyll a, chlorophyll b and carotenoids in 2009 did not depend significantly on the type of cover used. In the next season, a larger amount of chlorophyll a occurred in the control. This result confirms the influence of unfavourable weather, especially the light conditions that spring. Because of the lower level of photosynthetically active radiation, less activity in the photosynthetic system of plants covered with standard PP and biodegradable nonwovens could be expected.

New biodegradable nonwovens will appear in practice in the near future. Their main advantages are the features comparable with nonwovens used

Table 4. The effect of the kind of cover on dry weight, soluble sugar and nitrate content in 'Melodion' butterhead lettuce in two years of the study

Kind of cover	Dry matter (%)		Soluble sugars (%)		Nitrates NO_3^- (mg kg^{-1} f.w.)	
	2009	2010	2009	2010	2009	2010
Polypropylene nonwoven PP 20 g m^{-2}	5.50 b*	5.95 b	1.10 a	1.35 b	1528 b	627 c
Biodegradable nonwoven Bionolle 100 g m^{-2}	5.26 a	6.11 c	1.23 b	1.46 b	1591 c	250 a
Biodegradable nonwoven IBWCH 75 g m^{-2}	5.94 c	5.50 a	1.11 a	0.98 a	1815 d	456 b
Control	5.56 b	5.98 b	1.10 a	1.49 b	1392 a	940 d

*Explanations: see Table 3

Table 5. The effect of the kind of cover on chlorophyll a, chlorophyll b and carotenoid content in the 'Melodion' butterhead lettuce cultivar in two years of the study

Kind of cover	Chlorophyll a (mg g^{-1} f.w.)		Chlorophyll b (mg g^{-1} f.w.)		Carotenoides (mg g^{-1} f.w.)	
	2009	2010	2009	2010	2009	2010
Polypropylene nonwoven PP 20 g m^{-2}	0.603 a*	0.332 a	0.302 a	0.194 a	0.144 a	0.192 a
Biodegradable nonwoven Bionolle 100 g m^{-2}	0.567 a	0.382 a	0.316 a	0.213 a	0.119 a	0.214 a
Biodegradable nonwoven IBWCH 75 g m^{-2}	0.592 a	0.391 a	0.288 a	0.201 a	0.144 a	0.205 a
Control	0.507 a	0.433 b	0.254 a	0.203 a	0.125 a	0.202 a

*Explanations: see Table 3

in horticulture and the possibility of biodegradation in the soil and composting. However, their popularisation will still need financial support from the government and corporate bodies.

CONCLUSIONS

1. The positive effect of biodegradable nonwovens used as direct covers depended on the growing season. The yield of butterhead lettuce was higher in 2009. Due to a rainy and colder season in 2010, the yield was significantly smaller, without the effect of covering.
2. Dry matter, soluble sugars and nitrates in butterhead lettuce varied in the consecutive years, which confirms a significant impact of microclimate on plant growth.
3. Biodegradable and non-degradable direct covers reduced chlorophyll a content only in the unfavourable 2010 season. The covering did not influence chlorophyll b and carotenoid contents in lettuce leaves.

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ZASTOSOWANIE WŁÓKNIN BIODEGRADOWALNYCH W UPRAWIE SAŁATY NA ZBIÓR WCZESNY

Streszczenie: Przeprowadzono doświadczenia z sałatą masłową odmiany ‘Melodion’, wykorzystując do okrywania bezpośredniego włókniny biodegradowalne typu ‘melt-blown’ wykonane przez Instytut Biopolimerów i Włókien Chemicznych oraz POLMATEX CENARO w Łodzi, Polska. Do zabiegu osłaniania zastosowano: włókniny biodegradowalne o barwie naturalnej: IBWCH 75 g m^{-2} i Bionolle 100 g m^{-2} oraz agrowłókninę polipropylenową 20 g m^{-2}. Sałatę wysiano w obu latach na początku marca do skrzynek wysiewnych w szklarni i z początkiem kwietnia wysadzono w pole po 40 roślin na poletko, w czterech powtórzeniach. Osłony bezpośrednie z włóknin założono po sadzeniu, a zdjęto na kilka dni przed zbiorem. Jako kontrolę przyjęto poletka nieosłonięte. W ocenie jakości sałaty uwzględniono zawartość kwasu askorbinowego, suchej masy, cukrów rozpuszczalnych, azotanów, chlorofilu a, chlorofilu b i karetonoidów. Zabieg osłaniania roślin sałaty włókninami biodegradowalnymi wyraźnie wpłynął na wzrost plonu w porównaniu z kontrolą tylko w 2009 roku. W drugim roku doświadczeń nie stwierdzono wyraźnego wpływu zastosowania osłon na wysokość plonu sałaty. Zawartość suchej masy w obydwu latach doświadczeń była bardzo zróżnicowana. Włókniny biodegradowalne zastosowane jako osłony w 2009 roku wpłynęły istotnie na wzrost zawartości azotanów w główkach sałaty masłowej w porównaniu z kontrolą. W drugim roku najwięcej azotanów (przy ogólnie znacznie mniejszym poziomie) wykazały rośliny kontrolne. Należy zaznaczyć, że norma maksymalnej dopuszczalnej zawartości azotanów dla sałaty masłowej wynosząca 4000 mg kg^{-1} ś.m. nie została przekroczona. Zawartość chlorofilu a, chlorofilu b i karotenoidów w główkach sałaty masłowej wykazała brak jednoznacznej zależności od zastosowanych osłon.

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