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THE IMPACT OF BIODEGRADABLE NONWOVEN FABRIC COVERS ON THE YIELD AND QUALITY OF OVERWINTERING ONIONS

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Abstract. Field cultivation of vegetables in Poland is strictly related to weather conditions. Low temperatures occurring from November to March limit vegetable cultivation in the field. However protecting plants with row covers can prevent losses from untimely frosts and freezes and provide a means to modify the environment around the plant, favorably resulting in more rapid growth, earlier maturity, and possibly increased yields. Experiments were carried out in 2008–2010 at the experimental field of the Agricultural University of Kraków (N 50º4', W 19º50') in order to determine the impact of flat covers made from biodegradable nonwovens produced by the Institute of Biopolymers and Chemical Fibres and CENARO in Łódź. Seeds of frost-resistant 'Glacier' cultivar of onion were sown in the end of August, and after a significant drop in temperature occurred in the second half of November plants was covered with biodegradable nonwovens such as: Bionolle 59 g m^{-2} and 100 g m^{-2} and IBWCH 50 g m^{-2} and 75 g m^{-2}, as well as standard nonwoven polypropylene PP 50 g m^{-2}. A plot that remained uncovered throughout the winter served as the control. The covers were kept until spring and were removed one (2009) and two months (2010) before harvest. During harvest, measurements of plant height and marketable yield were taken. In the laboratory harvested onions were estimated for ascorbic acid, dry matter, soluble sugar and nitrates content. The investigations showed that covering onion with biodegradable nonwoven material had a positive impact on yield in the first year of the experiment. There were no significant differences in the yield quantity in the second year. Contents of the analysed organic compounds showed no regular patterns in both years of the experiment. In 2009, the vitamin C, dry matter and nitrate contents were higher than in 2010. In the second year of the study, the control onions had the most soluble sugars.

Key words: field cultivation, onion, flat covering

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INTRODUCTION

The introduction of polymeric materials in agriculture in the form of plant coverings and mulches has allowed growers to obtain higher and earlier yields and reduces the impact of changing weather conditions on plants. It also allows to reduce the use of herbicides and a more efficient use of water, which is very important during times of water scarcity. Plants grow better, their growth is faster and without physiological defects, and yielding occurs earlier [Moreno and Moreno 2008]. However, the polymer coverings commonly used for mulching and direct covers make an impact on the environment. Their decomposition occurs under the influence of UV radiation, which leads to the tearing of the polymer chains [Nijskens et al. 1990], but it is a long process. It is estimated that it takes about 300 years for low-density polyethylene film (ldPE) with a thickness of 60 μm to completely decompose [Kyrikou and Briassoulis 2007]. After cultivation, pieces of polyethylene film or polypropylene nonwoven fabric remain in the soil for a long time. A majority of this material is left in the fields or burnt, emitting polluting substances [Scarascia-Mugnozza et al. 2006]. Every year, thousands of tonnes of this waste end up in landfills, while remains of the film stay behind for years, making soil tillage more difficult [Siwek 2011].

Traditional polyethylene films and polypropylene nonwoven materials used in horticulture can be successfully replaced with materials made from biopolymers. The technical development of new generation biodegradable thermoplastic polymers such as aliphatic polyesters, aromatic polyesters, polycarbonates and polyacrylates allows their use for the production of not only films but also fibres and nonwoven materials. These kinds of films and nonwoven materials can be used for the direct covering of plants, mulching of the soil around the plants and the production of flowerpots. There has been much research into the use of biodegradable covers for crops, which has confirmed the beneficial effects of such materials on yield and on the environment. Investigations with the use of biodegradable covers in cultivation of lettuce for early harvest demonstrated the positive effect on yielding and its quality [Siwek at al. 2011]. Similar results were obtained by Siwek et al. [2009] with leek cultivation – usage of biodegradable flat covers increased marketable yield by 29%. However, as showed by Piróg [2009] covering plants not always increase yields. In his investigation yield harvested from covered and uncovered cucumber was on the same level.

Materials made from biodegradable polymers were first introduced to the markets in the 1980s [Vroman and Tighzert 2009], and since then there has been a vast development of materials for the needs of agriculture. For example, in Italy alone the use of biodegradable materials for agriculture has increased from 116.000 tonnes/year in 1977 to 250.000 tonnes/year in 1993 [Dilara and Briassoulis 2000].

Growing onions from seeds allows for the early summer harvest of vegetables in the spring of the following year. Although the risks associated with overwintering onions in the field due to the possibility of young plants freezing. Directly covering onion with nonwoven materials immediately before the advent of cold weather improves its winter hardiness. This procedure is effective in protecting against the freezing of onion and is highly cost effective [Wanga et al. 2005]. However, the plants cannot be covered too early in autumn nor left covered too long in the spring, because this causes significant deterioration in the appearance and health of bulbs and stems.

Keeping onion crops under direct cover during winter months leads to an early harvest and accelerates the availability of the vegetables on the market by about 6 to 10 weeks compared to the spring sowing, and by about four to six weeks compared to the spring cultivation of onions. It is estimated that about 1.000–1.700 acres of onions are currently grown in Poland using this method [Adamicki 2005]. Early onions with green chives like these are more appealing, and also have a higher biological value than onions from long-term storage.

The aim of this study was to determine the effect of covers made from biodegradable nonwoven materials on overwintering onion plants and the resulting early spring crop and its quality.

MATERIALS AND METHODS

Experiments were carried out in 2008–2010 at the experimental field of the Agricultural University of Kraków (N 50º4', W 19º50') in order to determine the impact of the direct winter use of melt-blown biodegradable nonwoven fabric covers made by the Institute of Biopolymers and Chemical Fibres and CENARO in Łódź. For the study, the 'Glacier' cultivar of onion from the BejoZaden company was selected, which is meant for winter cultivation, and should be grown as early as possible in the spring in order to avoid vernalisation. The following materials were chosen for direct covering: biodegradable nonwoven natural-coloured IBWCh 50 g m^{-2} and IBWCh 75 g m^{-2}, Bionolle 59 g m^{-2} and 100 g m^{-2}, as well as a nonwoven polypropylene with a weight of 50 gm^{-2}. Seeds of frost-resistant winter onion cultivar 'Glacier' were sown on 21.08.2008 and 17.08.2009 with, a spacing of 30 × 3 cm (99 plants per 1 m^{-2}). Experimental fields were established in randomised blocks with four replications. The soil pH was slightly acid with electrical conductivity amounted < 2 mS $cm^{-}1$. Total mineral nitrogen ($N\text{-}NH_4$ + $N\text{-}NO_3$) was high > 150 mg dm^{-3}. The soil also characterized with high content of assimilable phosphorus (> 50 mg P dm^{-3}), average content of potassium (150–200 mg K) and high concentration of magnesium (> 120 mg dm^{-3}). After a significant drop in temperature, the plants were covered with mentioned covering materials (on 21.11.08 and 11.12.09, respectively). Plot that remained uncovered throughout the winter served as the control. The covers were kept until spring – 06.04.2009 and 30.03.2010, respectively. A single harvest was performed on 14.05.2009 and 01.06.2010. Throughout the experiment, hourly soil temperature measurements were performed at a depth of 10 cm using HOBO 8 CROP – ONSET meteorological sensors from the moment the crops were covered until the removal of the covers.

After harvesting, the onion diameter, length and number of leaves, number of plants with inflorescence shoots as well as marketable and total yield weight were measured. The quality assessment took into account the ascorbic acid, dry matter, soluble sugar and nitrate contents. The dry matter content was determined using the oven-dry method, total sugars using the colorimetric method, L-ascorbic acid using the Tillmans method, and nitrates using potentiometry. The results were statistically analysed at a significance level of p = 0.05 using the Newmann-Keuls test in the Statistica 9 program.

RESULTS AND DISCUSSION

The microclimate surrounding the plants changed dramatically under the influence of direct covering. As shown by Libik and Siwek [1994] and Salinas and Pearson [1994], the thermal conditions under the covers depend on the type of material. In this experiment, the soil temperature during the onion plant covering was low, and its average did not exceed 3°C (tab. 1). In both years, it was lowest for the uncovered soil. The highest average daily temperature was recorded under the IBWCH 75 g m^{-2} film, both during the first and second year of the study. The differences were greater in the second year of the experiment, and compared to the control were 2.3°C higher for the daily average, 2.8°C for the daily maximum and 2.9°C for the daily minimum. In the first year, these differences were within 0.2–0.5°C. During winter cracking and leaking of covers were observed, but despite this their beneficial effects persisted and reflected in the yield. The IBWCH 75 g m^{-2} biodegradable film was decidedly more durable – the covers remained completely on the plants until their removal at the beginning of spring.

Table 1. The soil temperature at a depth of 10 cm during the cultivation of the 'Glacier' onion cultivar in 2008/9 and 2009/10, during the covering period (°C)

Type of material used as flat cover	Daily average		Maximum		Minimum	
	2008/9	2009/10	2008/9	2009/10	2008/9	2009/10
IBWCh 75 g m^{-2}	1.0	0.3	1.7	1.0	0.4	-0.2
Bionolle 100 g m^{-2}	0.9	-1.5	1.3	-0.5	0.6	-2.2
Agrotextile 50 g m^{-2}	1.2	–	1.8	–	0.8	–
Control	0.7	-2.6	1.2	-1.8	0.3	-3.1

The estimation of onion overwintering showed that better effect was obtained in 2009 year (tab. 2). In that year over 80% of plants grown under flat cover made from biodegradable non-woven Bionolle 59 g m^{-2} and agrotextile overwintered well, which resulted in high yields. In that year of the study less than half plants from control object overwintered. Low air temperatures occurred in 2010 year caused that the effect of flat covers was limited. Only less than half plants from all plots overwintered and best results were obtained when plants were covered with nonwoven Bionolle 59 g m^{-2}.

Covering onions during first year of the study (2008/2009) resulted in intense plant growth compared to the controls (tab 3). Plants grown under the cover of IBWCh 50 g m^{-2} had the thickest neck (1.8 cm) and the largest diameter of the bulbs (4.4 cm). Irrespective of the type of material used, the covering of onion during the 2009/2010 winter did not significantly affect the elongation growth of the plants. In the second year of the experiment, plants covered with biodegradable Bionolle 100 g m^{-2} and IBWCh 50 g m^{-2}

as well as the control were characterised by the tall height of the plants and the length of their leaves. In addition, plants that were covered with these two materials produced the bulbs with the largest diameters.

Table 2. Estimation of overwintering effect of flat covers in onion cv. 'Glacier' cultivation

Type of material used as flat cover	Number of plants per m^{-2} after winter	
	2009	2010
Agrotextile 50 g m^{-2}	71 a	31 a
Bionolle 59 g m^{-2}	80 b	42 a
Bionolle 100 g m^{-2}	45 a	35 a
IBWCh 50 g m^{-2}	42 a	36 a
IBWCh 75 g m^{-2}	36 a	36 a
Control	44 a	39 a

for p = 0.05 (Newmann-Keuls test), significant differences are marked with different letters

Table 3. Growth rate indicators of 'Glacier' cv. overwintering onion plants grown under biodegradable nonwoven fabric covers during harvest (cm)

Type of material used as flat cover	Plant height		Leaf length		Neck thickness		Bulbs diameter	
	2009	2010	2009	2010	2009	2010	2009	2010
Agrotextile 50 g m^{-2}	64.4 b	48.1 ab	54.0 b	45.3 ab	1.6 a	1.2 a	3.7 a	3.6 bc
Bionolle 59 g m^{-2}	62.1 b	44.4 a	45.7 a	40.3 a	1.7 a	1.3 ab	3.8 a	3.0 a
Bionolle 100 g m^{-2}	60.5 b	55.3 c	51.4 b	50.8 c	1.6 a	1.5 c	4,3 b	4.4 d
IBWCh 50 g m^{-2}	60.0 b	50.2 bc	47.3 a	45.9 bc	1.8 b	1.4 bc	4.4 b	3.8 cd
IBWCh 75 g m^{-2}	64.1 b	48.3 ab	52.2 b	44.4 ab	1.6 a	1.4 c	3.9 a	3.4 b
Control	55.2 a	50.0 bc	44.7 a	46.4 bc	1.5 a	1.5 c	3.6 a	3.3 ab

Explanation as in table 2

In their study, Rekowska and Słodkowski [2005], Siwek and Libik [2005], Michalik [2010], Rekowska [2010], Sałata [2011] showed that the use of direct covers in the cultivation of vegetables would accelerate and increase yields. In the presented experiment, covering onions in 2009 with 50 g m^{-2} polypropylene nonwoven as well as biodegradable polymer Bionolle 59 g m^{-2} increased yield by 33% in comparision to the control (tab. 4). Orłowski et al. [2005] also showed similar relationship; they achieved over a 11% higher yields for butterhead lettuce grown under polypropylene cover than the uncovered control. Wanga [2005] determined that covers not only increased the yield of overwinter onion, but also prevented loses resulted from low temperatures and frost. In 2010 slightly higher marketable yield of onion was obtained from the control as compared with those that were covered. But these were not statistically significant differences.

In both years, the onions collected from the control had the highest dry matter content, as well as vitamin C in 2010 (tab. 5). Siwek [2002] did not show significant differences in dry matter content between cucumbers grown under covers and without covers. Similar results were obtained by Błażewicz-Woźniak [2010] in the cultivation of fennel with the use of direct covers. The amount of soluble sugars was highest in plants grown under protective covers made of agrotextile PP 50 g m^{-2}, IBWCh 50 g m^{-2} as well as the uncovered control in 2009. The control onions contained the most sugars in the second year of the experiment. The highest nitrate content in 2009 was collected from plants covered with biodegradable nonwoven Bionolle 59 g m^{-2} and the IBWCh 75 g m^{-2} and from those covered with the IBWCh 50 g m^{-2} biodegradable nonwoven in the second year. The experiment showed that in 2009 the vitamin C, dry matter and nitrate levels were higher than in 2010.

Table 4. Yield of 'Glacier' overwintering onion grown under cover of biodegradable nonwoven materials

Type of material used as flat cover	Marketable yield (kg m^{-2})			Plant with shoot (pc. m^{-2})	
	2009	2010	mean	2009	2010
Agrotextile 50 g m^{-2}	5.32 b	1.05 a	3,18	29 d	–
Bionolle 59 g m^{-2}	5.32 b	1.26 a	3,29	18 c	–
Bionolle 100 g m^{-2}	4.53 ab	1.29 a	2,91	14 bc	–
IBWCh 50 g m^{-2}	3.51 a	1.31 a	2,41	8 ab	–
IBWCh 75 g m^{-2}	4.66 ab	1.20 a	2,93	16 bc	–
Control	3.58 a	1.65 a	2,61	5 a	-
Mean	4,48 B	1,29 A	2,88	15	–

Explanation as in table 2

Table 5. The content of selected components in 'Glacier' cv. overwintering onion grown under flat cover of biodegradable nonwoven materials

Type of material used as flat cover	Vitamin C (mg 100 g^{-1} f. m.)		Dry weight (%)		Soluble sugars (% f. m.)		Nitrates (mg NO_3 kg^{-1} f.m.)	
	2009	2010	2009	2010	2009	2010	2009	2010
Agrotextile 50 g m^{-2}	15.33 ab	13.23 c	11.43 b	10.18 b	7.30 ab	6.67 a	86.2 b	48.2 c
Bionolle 59 g m^{-2}	15.10 ab	11.20 a	11.27 a	10.67 bc	7.05 a	6.74 a	92.8 c	43.1 b
Bionolle 100 g m^{-2}	15.76 ab	12.76 bc	11.30 a	10.67 bc	6.95 a	6.89 ab	76.8 a	38.3 a
IBWCh 50 g m^{-2}	14.40 a	11.60 ab	11.27 a	9.55 a	7.43 b	6.46 a	76.1 a	63.4 e
IBWCh 75 g m^{-2}	16.86 b	10.76 a	11.35 ab	10.29 b	6.97 a	6.61 a	92.2 c	50.0 d
Control	16.00 ab	13.46 c	11.78 c	10.97 c	7.17 ab	7.22 b	84.0 b	43.3 b

Explanation as in table 2

The biodegradable nonwoven materials used as covers were characterised by different mechanical strengths. The Bionolle 100 g m^{-2} was less durable than IBWCh 75 g m^{-2}. The Bionolle 100 g m^{-2} covers began to crack already a few days after their application. After the disappearance of snow in the spring, leaves began to grow and break through the material. The result was pieces of the material remaining on the soil around the plants as mulch. However the positive effect of flat covers was kept.

CONCLUSIONS

1. The undertaken experiment has shown the possibility of using biodegradable nonwoven materials as direct covers during winter onion cultivation.
2. The winter hardiness of plants was improved through the use of nonvowen materials; the plants that were covered had fewer fros-demage leaves.
3. Biodegradable nonwoven materials IBWCh 50 g m^{-2} and IBWCh 75 g m^{-2} had the most beneficial impact on the overwintering and yield of onion, although yield quality indicators were mixed.

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WPŁYW OSŁON Z WŁÓKNINY BIODEGRADOWALNEJ NA PLON I JAKOŚĆ CEBULI ZIMUJĄCEJ

Streszczenie. Polowa uprawa warzyw jest w Polsce uzależniona od warunków atmosferycznych. Niskie temperatury panujące od listopada do marca ograniczają uprawę roślin w polu w tym okresie, jednak wprowadzenie zabiegu osłaniania bezpośredniego umożliwia uprawę niektórych, odpornych na niskie temperatury odmian warzyw. Dzięki temu zabiegowi rośliny zimują w polu i na wiosnę kolejnego roku szybko wznawiają wegetację. Ponadto prawidłowo użyte płaskie osłony powodują przyspieszenie we wzroście wielu gatunków roślin oraz zwiększają plony. Doświadczenia wykonano w latach 2008–2010 na polu doświadczalnym Uniwersytetu Rolniczego w Krakowie, wykorzystując do okrywania bezpośredniego na zimę włókniny biodegradowalne typu melt-blown wykonane przez Instytut Biopolimerów i Włókien Chemicznych i CENARO w Łodzi. Cebulę mrozoodpornej odmiany 'Glacier' wysiano w drugiej dekadzie sierpnia, a w drugiej połowie listopada całe rośliny przykryto włókninami biodegradowalnymi Bionolle 59 g m^{-2} i 100 g m^{-2} oraz IBWCH 50 g m^{-2} i 75 g m^{-2} , a także standardową włókniną polipropylenową o masie powierzchniowej 50 g m^{-2}. Jako kontrolę przyjęto poletka nieosłonięte przez zimę. Osłony utrzymywano do wiosny i zdjęto 40 (2009) oraz 60 (2010) dni przed zbiorem. Podczas zbioru wykonano pomiary fitometryczne roślin cebuli oraz oznaczano wielkość plonu handlowego. W ocenie jakości plonu uwzględniono zawartość kwasu askorbinowego, suchej masy, cukrów rozpuszczalnych i jonów azotanowych. Stwierdzono, że osłanianie cebuli włókninami biodegradowalnymi w pierwszym roku doświadczeń wpłynęło korzystnie na plonowanie. W drugim roku nie wykazano istotnych różnic w wielkości plonu. Zawartości analizowanych składników organicznych nie wykazały regularnych prawidłowości w obydwu latach doświadczeń. W 2009 r. poziom witaminy C, suchej masy i azotanów był większy niż w roku 2010. W drugim roku doświadczeń najwięcej cukrów rozpuszczalnych było w cebulach pochodzących z obiektu kontrolnego.

Słowa kluczowe: uprawa ozima, cebula, płaskie osłony

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