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Use of Nonwoven Polypropylene Covers in Early Crop Potato Culture

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1. Introduction

In view of the high prices obtained for new potatoes, their production is more profitable than other ways of potato usage. Early potato production is associated with considerable risk producers have to take due to high yield variability over years and rapid price decrease as a result of increased supply. The success of potato production for an early crop is dependent to the higher extent on the weather conditions in the initial period of plants vegetation, especially temperature (Nishibe et al., 1989; Sale, 1979). Too low soil temperature retards the emergence and inhibits the initial plant growth. High income obtained from early potato production is possible under conditions assuring early tuber setting and rapid gain of tuber yield, and its marketing when the price is highest. In case of early potato production, its location in regions where vegetation begin early is of high importance. In the regions with delayed vegetation, the crop of new potatoes can be forced by applying perforated polyethylene film or nonwoven polypropylene covers directly on the planted field. The favourable microclimate under the cover faciliates the emergence and futher plant growth and development in the period with less favourable weather conditions for early potatoes (Hamouz et al., 2006; Jenkins & Gillison, 1995; Michaud et al., 1990; Wadas & Kosterna, 2007a). The earlier plant emergence resulted in a more extensive ground cover during early growth and the higher leaf area index (LAI). The growth duration and leaf area determine the amount of solar radiation intercepted by the canopy and influences on the extent of photosynthesis, evaporation, transpiration and final dry matter yield (Gordon et al., 1997; Nelson & Jenkins, 1990). In Europe the covers that were most frequently used in the early crop potato culture were those of perforated polyethylene film (Friessleben, 1984; Hamouz & Rybáček, 1988; Jenkins & Gillison, 1995; Lang, 1984). Widespread availability on the market of nonwoven polypropylene and extensive promotion of these covers have resulted in a frequently reduced perforated polyethylene film with nonwoven polypropylene in the field cultivation of earlies. Polypropylene covers were introduced into agriculture on a large scale in the 1990s. Globally, they are commonly known under the name of nonwoven fabrics (Cholakov & Nacheva, 2009). This material is light, water permeable, transparent and airy. The weight of 1 m^2 of nonwoven polypropylene fabric is about 2.5 times lower than the weight of perforated polyethylene film, therefore, the covering does not cause any hinder for plant developing.

2. Field microclimate under the polypropylene cover

The environmental factor which restricts early potato planting to the highest extent is soil temperature (Nishibe et al., 1989; Sale, 1979). Presprouting seed-potatoes can be planted when soil temperature at the depth of 5-10 cm is maintained at the level of 5-6°C for several subsequent days. Earlier planting into insufficiently heated soil is risky, since even short but excessive over-cooling of young plants strongly weakens their further growth and delays obtaining marketable yield.The unfavourable effect of low temperatures in the early period of potato growth can be reduced by applying nonwoven polypropylene cover. The study carried out in the Czech Republic, Germany and Poland showed that soil temperature at a depth of 5 cm under nonwoven polypropylene was higher by 1-2°C, and at the depth of 10 cm by 2-3°C than the temperature of uncovered soil, while the air temperature at the ground was higher by 2.0°C (Demmler 1998; Hamouz et al., 2006; Lutomirska & Szutkowska, 1999; Prośba-Białczyk & Mydlarski, 1998; Wadas & Kosterna, 2007a). Soil temperature under nonwoven polypropylene was on average 1-2°C lower than under perforated polyethylene film. The difference in temperatures in afternoon hours reached even 5°C (Figure 1). In Bulgaria, soil temperature at the depth of 5 cm under nonwoven polypropylene at 8.00 a.m. was higher by 0.4-2.4°C, and at 2 p.m. on sunny days, even by 4.6°C (Cholakov & Nacheva, 2009). Higher soil temperature, as well as isolation by means of the nonwoven polypropylene cover from a relative drop in air temperature at night creates a more favourable microclimate for plant growth. According to Bizer (1997) and Dvořák et al. (2004), nonwoven polypropylene cover creates a favourable microclimate for potato emergence and growth, even when the temperature at the ground drops to -7°C. Soil temperature at the depth of 10 cm was by then almost 3°C higher (and above 0°C) in comparison to the uncovered field.

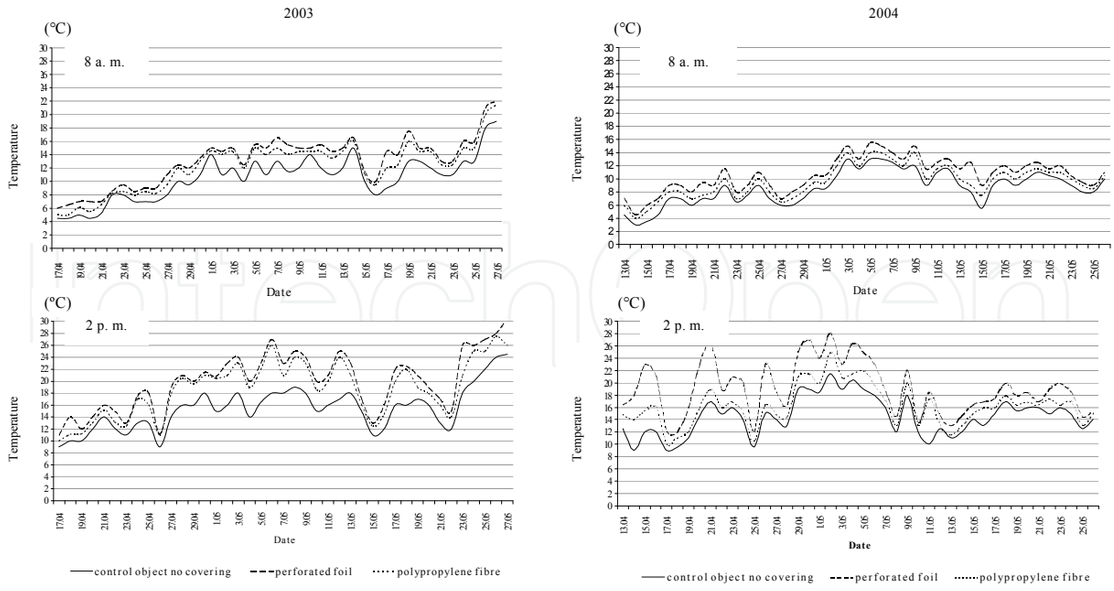

Fig. 1. Soil temperature at depth of 10 cm [°C] depending on the kind of cover at 8^{00} a.m. and 2^{00} p.m. in 2003 – 2004 (Wadas & Kosterna, 2007a)

3. Growth and development of plants

Profitable yield of new potatoes after 60 days from planting can already be obtained when the period between planting and plant emergence lasts 15-21 days, from plant emergence to the end of tuber seeting – 19-24 days, and the period of yield accumulation lasts a minimum 20 days (Kubiak & Gaziński, 1996). The period from planting to plant emergence is reduced along with an increase in soil temperature (Bizer, 1994). The application of nonwoven polypropylene cover enables earlier potato planting, forcing plant emergence and in the case of unfavourable thermal conditions, protects emerging plants against ground frosts. Presprouting seed-potatoes can be planted in the field when the soil warms up to 5-6°C. With the use of nonwoven polypropylene cover, planting can be started when soil temperature at the depth of 10 cm is about 3-4°C (Bizer, 1994; Lutomirska, 2006). Studies carried out in the Czech Republic, Poland, Bulgaria and Croatia showed that an increase in soil temperature as a result of applying nonwoven polypropylene cover in early crop potato culture shortened the period between planting to plant emergence by 2-8 days and forcing growth and development of plants in the later period (Table 1). Yearly variation of those differences are explained by environmental factors. The application of covering results in higher forcing of individual plant development phases in years with less favourable meteorological conditions during the initial period of potato growth. A higher increase of soil temperature under perforated polyethylene film, on average by 1-2°C as compared to nonwoven polypropylene, resulted in earlier occurrence of successive plant development phases by only 1-2 days (Ban et al. 2011; Cholakov & Nacheva, 2009; Hamouz et al., 2006; Lutomirska, 1995; Prośba-Białczyk & Mydlarski, 1998; Wadas & Kosterna, 2007a). Plants growing under nonwoven polypropylene were more uniform in size, higher, and developed a larger mass of aboveground parts as compared to cultivation without covering (Cholakov & Nacheva, 2009; Rekowska & Orłowski., 2000; Wadas & Kosterna 2007b; Wadas et al., 2009). Earlier plant development as a result of covering allow for the higher solar radiation interception and rapid enlargement of assimilation leaf area. A higher value of the leaf area index (LAI) has a favourable effect on the growth of tubers during the vegetation period, as well as on the final yield (Firman & Allen, 1989; Zrůst & Cepl, 1991; Zrůst et al. 1999). Forcing plant emergence as a result of applying covers results in more extensive ground cover by leaves only during early potato growth. Later, there were smaller differences as leaf senescence began under the cover sooner (Nelson & Jenkins, 1990). In the agro-meteorological conditions of east-central Poland, at the time of cover removal, the plants covered for two weeks after emergence were on average 9.4 cm higher, and after a 3-week

Country	Number of days	Reported by
Czech Republic	4-8	Hamouz et al., 2006
Poland	4-5	Lutomirska, 1995
	3-6	Prośba-Białczyk & Mydlarski, 1998; Wadas & Kosterna, 2007a
Bulgaria	2-7	Cholakov & Nacheva, 2009
Croatia	6	Ban et al., 2011

Table 1. Forcing of potato plant emergence as a result of nonwoven polypropylene covering

period of plant covering by 11.7 cm higher in comparison to plants cultivated without any covering, while the assimilation leaf area was 2 and 1.6 times higher, respectively. With the application of perforated polyethylene film, the plants were higher by 4.5 cm, on average, after 2 weeks from emergence, and by 7 cm after 3 weeks from emergence, in comparison to plants covered by nonwoven polypropylene fabric (Table 2). The type of cover applied had a smaller effect on the size of assimilation leaf area (Wadas & Kosterna 2007b; Wadas et al., 2009). The effect of covering on the assimilation leaf area depends to a high degree on meteorological conditions. In years with more favourable thermal conditions for early crop potato culture, leaving the covering (especially perforated film) for too long over plants after emergence can hinder the development of the assimilation leaf area, while in the lower temperature the effect is more favourable (Lutomirska & Szutkowska, 1999). When nonwoven polypropylene is removed too long after plant emergence, the transmision of photoactive radiation through this cover varied from 85 to 65%, depending on dust accumulation on the cover and water vapour condensation on the inner surface of the cover (Gimenez et al., 2002). A change of conditions in the initial period of plant growth as a result of applying nonwoven polypropylene cover could advance new potato harvest by up to 2-3 weeks, as compared to cultivation without plant covering (Bizer, 1994; Hamouz et al., 2005, as cited in Jaša, 1994; Sawicka & Pszczółkowski, 2002).

Specification		No covering	Nonwoven polypropylene	Perforated polyethylene film
Height of plants (cm)	2 weeks after plant emergence	17.7	27.1	31.6
	3 weeks after plant emergence	22.0	33.7	40.7
Weight of leaves per plant (g)	2 weeks after plant emergence	31	57	62
	3 weeks after plant emergence	52	77	90
Weight of stems per plant (g)	2 weeks after plant emergence	20	47	62
	3 weeks after plant emergence	33	71	109
Assimilatiom leaf area (cm^2)	2 weeks after plant emergence	918	1867	1916
	3 weeks after plant emergence	1632	2665	2896
Leaf area index	2 weeks after plant emergence	0.49	0.99	1.02
	3 weeks after plant emergence	0.87	1.42	1.48

Table 2. Effect of nonwoven polypropylene and perforated polyethylene film covering on growth of early potato cultivars (Wadas & Kosterna, 2007b; Wadas et al., 2009)

4. Tuber yield

The use of nonwoven polypropylene cover makes possible to start harvesting early, to increase the yield of new potatoes and to reduce yield variability in successive years, in comparison to cultivation without plant covering. The production effect of applying cover reflected in an increase in the tuber yield depends, to a high degree, on soil and climatic conditions and on the potato harvesting date (Table 3).

Country	Increase in tuber yield (t ha^{-1})	Reported by
Czech Republic	1.01-15.66	Hamouz et al., 2006, 2007
Poland	4.0-5.40	Prośba-Białczyk & Mydlarski, 1998
	2.87-9.97	Pszczółkowski & Sawicka, 1999
	6.36-10.04	Rekowska et al., 1999
	1.19-11.80	Wadas et al., 2001, 2008
Bulgaria	1.91-14.31	Cholakov & Nacheva, 2009
Croatia	1.85	Ban et al., 2011

Table 3. Effect of nonwoven polypropylene covering on marketable tuber yield of early potato

In conditions of east-central Poland (the Siedlce Region), covering the crop with nonwoven polypropylene resulted in an increase in marketable tuber yield after 60 days from planting very early cultivars of potato on average by 4.63 t ha^{-1} (33%), while after 75 days from planting, the average yield increase was 3.72 t ha^{-1} (13%) (Wadas et al., 2001). A similar increase in the early tuber yield of potato was obtained in the central part of Poland (Lutomirska, 1995). In later study carried out in east-central Poland, after 60 days from planting, the marketable tuber yield of early potato cultivars in cultivation with the use of nonwoven polypropylene was higher on average by 5.82 t ha^{-1} (81%) (Wadas et al., 2008). In the Lublin Region, the average tuber yield increase as a result of nonwoven polypropylene covering amounted to 7.34 t ha^{-1} (71.7%) after 60 days from planting, and 5.51 t ha^{-1} (22.5%) at harvest date two weeks later (Pszczółkowski & Sawicka, 1999). In conditions of north-western Poland (the Szczecin Region), plant covering with nonwoven polypropylene resulted in increased marketable tuber yield after 55 days from planting on average by 9.84 t ha^{-1} (52%), and after 65 days from planting - by 7.52 t ha^{-1} (27%) (Rekowska et al., 1999). On the other hand, in south-western Poland (the Wrocław Region), where thermal conditions in spring are more favourable for production of early potatoes, plant covering with nonwoven polypropylene increased marketable tuber yield after about 60 days from planting very early potato cultivars on average by 4.5 t ha^{-1} (74%), and when the harvest was carried out two weeks later, the difference in tuber yield amounted to 4.7 t ha^{-1} (30%) (Prośba-Białczyk & Mydlarski, 1998). In the central part of the Czech Republic, plant covering with nonwoven polypropylene brought about an increase of marketable tuber yield on average by 6.28 t ha^{-1} (50%) after 60 days from planting, and by 5.38 t ha^{-1} (22%) when the harvest was carried out one week later (Hamouz et al., 2006, 2007), while in Croatia, the increase in tuber yield was 1.85 t ha^{-1} (12%) (Ban et al., 2011). In Bulgaria, where the practice of growing cultures using nonwoven polypropylene covers is almost unknown, the increase in early potato yield as a result of using the cover amounted, on average, to 8.98 t ha^{-1} (32%) after 60 days from plant emergence, and 6.21 t ha^{-1} (16%) after 75 days from

plant emergence (Cholakov & Nacheva, 2009). The study carried out in Poland, Germany and in eastern Canada (Quebéc) showed a higher favourable effect of covering with nonwoven polypropylene as compared to perforated polyethylene film in early crop potato culture. The application of nonwoven polypropylene made it possible to obtain a similar or even higher marketable tuber yield after 60 days from planting (Bizer, 1994; Demmler, 1998; Lutomirska, 1995; Michaud et al., 1990; Pszczółkowski & Sawicka, 2003; Rekowska & Orłowski 2000). Only in a year with a very cold spring, when the application of perforated polyethylene film obtained, in east-central Poland, a higher marketable tuber yield of early cultivars after 60 days from planting, on average by 4.18 t ha^{-1} (32%), while in years with warmer springs and at later harvesting date, yields obtained with application of perforated polyethylene film or nonwoven polypropylene were similar (Wadas et al. 2007). According to Bizer (1994), in years with dry springs, nonwoven polypropylene proves to be better covering, particularly on light soils, since a water shortage is likely to occur under perforated film. Cover use has the greatest effect on the potato tuber yield at very early harvest date, but when harvest is delayed, the effect of covering, reflecting in an increase in the new potato tuber yield in comparison to the cultivation without covering, is reduced. The study carried out in the central part of Czech Republic showed an increase in tuber yield as a result of applying covers in the period before the end of June, while along with the delay of the harvest date, the difference in the tuber yield in cultivation with and without covering was reduced, to reach an insignificant level by the end of June (Hamouz et al., 2004, 2005). The effect of applying nonwoven polypropylene cover in early crop potato culture depends to a high degree on meteorological conditions during the period of plant vegetation (Hamouz et al., 2004, 2006; Jabłońska-Ceglarek & Wadas, 2005; Lutomirska, 1995, 2006; Wadas et al., 2001, 2008). A higher increase of tuber yield as a result of applying the cover is obtained in years with less favourable thermal conditions in the initial period of potato growth. In east-central Poland in years with very cold springs, covering the crops with nonwoven polypropylene made it possible to obtain, after 60 days from planting, up to four times higher marketable tuber yield than in cultivation without covering (Jabłońska-Ceglarek & Wadas, 2005; Wadas et al., 2008). In the Czech Republic, potato cultivation under nonwoven polypropylene in the year with an exceptionally cold spring resulted in even six times higher marketable tuber yield after 60 days from planting (Dvořák et al., 2004; Hamouz et al., 2004, 2005). The application of covers assures to a high yield of potato tubers at an early harvest date, provided that the covers are removed at the proper time (Dvořák et al., 2007; Lutomirska & Szutkowska, 1999; Reust, 1980). Leaving the cover over the plants for too long after emergence can hinder development of assimilation leaf area and reduce the number of setting tubers. In conditions of east-central Poland, the length of plant covering period (two or three weeks after emergence) did not have any significant effect on the tuber yield after 60 days from planting, while for the harvest date delayed by two weeks, the yield was higher when the covers were removed two weeks after plant emergence (Wadas et al., 2008). The date of removing perforated polyethylene film had a greater effect on tuber yield than the date of removing nonwoven polypropylene, especially in years with warmer springs. The application of nonwoven polypropylene cover in the early crop potato culture assures not only a higher tuber yield, but also contributes to improvement of its structure by increasing the productivity of marketable tuber fractions, and simultaneously increasing share of large tubers in the yield, with diameters above 50 mm (Ban et al., 2011; Prośba-Białczyk & Mydlarski, 1998; Pszczółkowski & Sawicka, 2003; Rekowska et al., 1999; Wadas et al., 2001, 2008).

5. Tuber quality

A change in conditions for the initial growth and development of potato plants by applying nonwoven polypropylene or perforated polyethylene film cover affects not only the volume of the tuber yield, but also the chemical composition of tubers. Forcing of plant growth as a result of using covers results in an increase in dry matter and starch content in tubers. While applying nonwoven polypropylene, the dry matter content in tubers was higher by 0.69-2.17%, and starch by 0.45-1.46% than in cultivation without plant covering (Dvořák et al., 2006, 2008; Hamouz et al., 2006; Jabłońska-Ceglarek & Wadas, 2005; Wadas et al., 2003, 2004, 2006). A greater beneficial effect of applying covers in the form of an increase of dry matter content in tubers is found for early harvest date and in years with high air temperatures and abundant sunshine. According to other authors, the application of nonwoven polypropylene or perforated polyethylene film covers created less favourable conditions for accumulation of dry matter in tubers of very early potato cultivars (Prośba-Białczyk & Mydlarski, 1998; Sawicka & Pszczółkowski, 2005). Changed conditions for initial growth and development of potato plants as a result of applying the covers resulted in an increase in content of total sugars, reducing sugars and saccharose in tubers (Sawicka & Pszczółkowski, 2005). The study did not show any effect of applying nonwoven polypropylene in early crop potato culture on protein accumulation in tubers. On the other hand, a tendency was observed towards an increase in the ascorbic acid (vitamin C) concentration and a decrease in the concentration of carotenoids and polyphenols (Dvořák et al., 2006, 2008; Jabłońska-Ceglarek & Wadas, 2005; Lachman et al., 2003; Wadas et al., 2003, 2004, 2006). This method of potato cultivation resulted in a lower content of ascorbic acid in tubers as compared to cultivation without plant covering (Prośba-Białczyk & Mydlarski, 1998). Plant growth forcing as a result of nonwoven polypropylene covering contributes to an improvement of the tuber quality by reducing the concentration of nitrates, aspecially for the early harvesting date. In this method of potato cultivation, the content of nitrates was lower by 29-239 mg $N0_3$ in 1 kg of fresh weight of tubers (Dvořák et al., 2006; Lachman et al., 2003; Wadas et al., 2005). Covering the plants with nonwoven polypropylene also created very favourable conditions for accumulation of phosphorus and potassium in tubers (Wadas et al., 2007, 2008). The application of covers in early crop potato culture should be also considered in the aspect of plant health. Higher soil moisture under the cover can contribute to an increased occurrence of tubers infected with *Streptomyces scabies* and *Rhizoctonia solani* and to a faster rate of *Phytophthora infestans* spreading (Pszczółkowski & Sawicka, 1998).

6. Cost effectiveness of the production

The application of nonwoven polypropylene cover in potato production requires higher inputs incurred related not only to the purchase of nonwoven polypropylene, but also to labour input for its spreading and removing, as well as for harvesting the crops (Prośba-Białczyk et al., 1997; Pszczółkowski et al., 2000/2001; Wadas, 2003; Wadas et al., 2003, 2006; Wadas & Sawicki, 2009). Increasing production inputs is effective when the value of the tuber yield increase obtained as a result of plant covering is higher than the costs incurred. German studies showed that for the cost of purchasing nonwoven polypropylene

amounting to 2000 DM per 1 ha, when the cover is used 2-2.5 times, yearly costs ranged from 800 and 1000 DM per 1 ha, while for the cost of purchasing perforated polyethylene film amounting to 1400 DM per 1 ha, and using the cover 1.5-2 times, yearly costs ranged from 700 to 1050 DM. Therefore, yearly costs of using both covers were similar (Demmler, 1998). The amount of actually incurred costs depends, first of all, on how many times the nonwoven polypropylene cover is reused. The reuse rate of nonwoven polypropylene depends on its mechanical damage, sun radiation and degree of contamination. In the Czech Republic, at the cost of purchasing nonwoven polypropylene amounting to 1000-1200 EURO per 1 ha, its two-time application proved cost-effective for farmers (Hamouz & Dvořák 2004). In Poland, the cost of purchasing nonwoven polypropylene calculated for three seasons of its use amounted to PLN 5200-6300 per 1 ha (Prośba-Białczyk et al., 1997; Wadas, 2003). In south-western Poland, the production cost of early potatoes under nonwoven polypropylene was higher, depending on the year, between 85-92% as compared to cultivation without the cover, and the cost of nonwoven polypropylene accounted for 37-41% of incurred costs (Prośba-Białczyk et al., 1997). Such method of producing early potatoes in east-central Poland required incurring costs which were higher by 47-89%, and the cost of purchasing the nonwoven polypropylene accounted for 24-40% of direct costs. Due to a higher price, the direct costs of producing early potatoes under nonwoven polypropylene were higher by 18-25% than under perforated polyethylene film (Wadas, 2003; Wadas et al., 2003, 2006; Wadas & Sawicki, 2005, 2009). While assessing the cost-effectiveness of early potato production under nonwoven polypropylene cover, it is not only the sum of incurred costs which is important, but also unit costs, which provide information about the level of selling price which will balance the costs incurred. In south-western Poland, the costs of producing 1 kg of tubers under nonwoven polypropylene were 1.3-1.5 times higher, and in a year with very favourable conditions for early crop potato culture, it was almost the same as in the cultivation without covering. In the agro-meteorological conditions of east-central Poland, covering the crop with nonwoven polypropylene increased unit costs of production by 1.2 to 2.1 times. Unit costs of production were lower than in cultivation without covering only in the year with unfavourable thermal conditions for early crop potato culture, due to high yields obtained in cultivation under nonwoven polypropylene. Unit costs of production under nonwoven polypropylene were 1.3 to 1.6 times higher compared with perforated polyethylene film. Only in one year which was very favourable for early crop potato culture were they almost the same to that of applying perforated polyethylene film. It is more efficient to increase imputs for early potato production by applying nonwoven polypropylene in less favourable thermal conditions during the initial period of potato growth. In such a case, a significant yield increase in cultivation under covers balances the costs incurred and makes it possible to obtain a higher direct surplus from production than without covering (Table 4).

The cost-effectiveness of early potatoes production under nonwoven polypropylene cover depends on the income-to-costs ratio. Applying the nonwoven polypropylene in the early crop potato culture ensures high cost-effectiveness of production in years with cold springs. In conditions favouring rapid growth of potatoes, production costs of 1 kg tubers under cover are higher, which makes production less profitable in comparison to cultivation without plant covering.

Specification	Nonwoven polypropylene			Perforated polyethylene film		
	Years with warm spring		Year with cold spring	Years with warm spring		Year with cold spring
	2002	2003	2004	2002	2003	2004
Increase in production costs (PLN ha^{-1})	4067.5	4032.2	4330.0	2229.1	2340.8	2665.3
Increase in tuber yield (t ha^{-1})	6.09	1.79	9.59	2.79	2.39	13.78
Value of additional tuber yield (PLN ha^{-1})	10953.0	3585.0	16311.5	5022.0	4780.0	23413.2
Marginal effectiveness	2.67	0.89	3.76	2.22	2.03	8.77

Table 4. Cost effectiveness of nonwoven polypropylene and perforated polyethylene film covers use in early potato production (Wadas & Sawicki, 2009)

7. Conclusions

Success in early crop potato culture depends to a high degrre on the soil and air temperature in the initial period of plant growth. Obtaining early yields from field production is possible in soil and climatic conditions which enable early planting and rapid plant growth. The unfavourable effect of low temperatures in the initial period of potato growth can be reduced by the application of nonwoven polypropylene cover directly on the planted field. With the use of covers, potato planting can be started when the soil temperature at the depth of 10 cm is about 3-4°C. The application of covers enables earlier potato planting, forcing plant emergence and the growth and development of plants in the later period, and consequently, results in earlier setting of tubers, rapid yield gain and reduction of the yield variability in any years. A change in conditions during the initial period of plant growth as a result of applying covers could advance new potato harvest by up to 2-3 weeks. Such a method of production requires higher input incurred, while the effect of applying covers, reflected in an increase in the tuber yield, to a high degree depends on soil and climatic conditions. An increase in production inputs by the application of nonwoven polypropylene cover is more effective in less favourable thermal conditions in the initial period of potato growth. A considerable tuber yield increase in cultivation under cover results in such a case in decrease of unit costs and consequently, the cost-effectiveness of production is higher than without covering. In conditions favouring rapid potato growth, the application of covers increases unit costs, which makes production less profitable as compared to cultivation without covering. The application of nonwoven polypropylene cover facilitates a significant increase in income from potato production at a very early harvest date. Along with a delay in harvesting, the effect of applying the cover, reflected in an increase in the tuber yield, decreases in comparison to cultivation without covering.

8. Acknowledgment

Krystyna Struk, Director of Agricultural Experimental Station in Zawady, is acknowledged for her valuable technical assistance during the field experiments and during harvest operations. The author would like to acknowledge the Reviewers and Editors for their valuable comments and suggestions for this paper.

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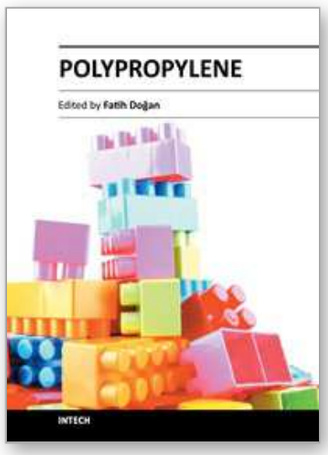

Polypropylene

Edited by Dr. Fatih Dogan

ISBN 978-953-51-0636-4
Hard cover, 500 pages
Publisher InTech
Published online 30, May, 2012
Published in print edition May, 2012

This book aims to bring together researchers and their papers on polypropylene, and to describe and illustrate the developmental stages polypropylene has gone through over the last 70 years. Besides, one can find papers not only on every application and practice of polypropylene but also on the latest polypropylene technologies. It is also intended in this compilation to present information on polypropylene in a medium readily accessible for any reader.

How to reference

In order to correctly reference this scholarly work, feel free to copy and paste the following:

Wanda Wadas (2012). Use of Nonwoven Polypropylene Covers in Early Crop Potato Culture, Polypropylene, Dr. Fatih Dogan (Ed.), ISBN: 978-953-51-0636-4, InTech, Available from: http://www.intechopen.com/books/polypropylene/use-of-polypropylene-covers-in-early-crop-potato-culture

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