Effect of perforated foil and polypropylene fibre covers on growth of early potato cultivars

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ABSTRACT

This paper presents the results of a three-year research on the effect of perforated polyethylene foil and polypropylene fibre covers on the growth of early potato cultivars at various lengths of plant covering period (2 and 3 weeks after plant emergence). Plants grown under covers were higher, produced higher mass of above-ground parts, and were characterised by a smaller value of leaf weight ratio (LWR) and leaf area ratio (LAR) compared with the cultivation without covering. In the case of plant covering for 2 weeks after emergence the mass of leaves at the time of cover removal was on average almost 2 times higher and the mass of stems over 2.5 times higher than in the cultivation without covering; the values of LWR and LAR were however smaller by 0.094 and 0.137 m^2/kg, respectively. At the 3-week period of plant covering the differences in the mass of above-ground parts were a little smaller than at 2-week period of plant covering, and LWR and LAR were 1.4 times and 2.3 times higher, respectively. The research showed a significant effect of type of cover used on plant growth. When perforated foil was used, plants were higher and produced more mass of above-ground parts compared with polypropylene fibre usage. The most favourable effect of perforated foil covering was observed in the year with the lowest air temperature in May; 2 weeks after plant emergence, the use of perforated foil resulted in the mass of leaves and stems 1.5 times and 2.2 times as high as with the polypropylene fibre, respectively. The differences were lower when plants were covered for 3 weeks. The use of polypropylene fibre resulted in higher LWR and LAR by 0.060 and 0.276 m^2/kg, respectively, after 2 weeks from plant emergence, and by 0.072 and 0.328 m^2/kg after 3 weeks from plant emergence.

Keywords: early potato; perforated polyethylene foil; polypropylene fibre; height of plants; mass of leaves; mass of stems; leaf weight ratio (LWR); leaf area ratio (LAR)

The success of potato cultivation for an early crop depends to a higher degree on weather conditions in the initial period of plant vegetation. Soil temperature is the most limiting environmental factor for the early planting of potato (Sale 1979, Nishibe et al. 1989). Too low soil temperature not only retards the date of planting, but also slows down the emergence and inhibits the initial plant growth. This results in longer growth of above-ground plant parts and in delayed tuber setting. Favourable microclimatic conditions at the beginning of plant vegetation may be provided by the use of covers directly on the planted field. The use of cover facilitates the emergence and further crop growth and development in the period when weather conditions are less favourable for early potatoes (Hamouz and Rybáček 1988, Michaud et al. 1990, Rekowska et al. 1999, Hamouz et al. 2006, Wadas and Kosterna 2007a, b). The effect of cover application depends on the length of plant covering period. Plant covers left too long after the emergence reduce the amount of solar radiation received by a plant and may limit the development of assimilation leaf area (Jenkins 1993, Gimenez et al. 2002).

This paper presents the results of the three-year research on the effect of perforated polyethylene foil and polypropylene fibre covering on the growth of early potato cultivars at various lengths of plant covering period.

MATERIAL AND METHODS

The effect of cover type (perforated polyethylene foil, polypropylene fibre) and the date of its removal (2 and 3 weeks after plant emergence) on the growth of early potato cultivars Aksamitka and

Cykada was investigated. The experiment was carried out at the Agricultural Experimental Station of University of Podlasie in Siedlce, in the years 2002–2004. The Experimental Station is situated in the middle-eastern part of Poland, where thermal conditions are less favourable for potato cultivation for early harvest. The field experiment was established in the splitblock method with a control object without covering, in three replications, on a light soil, characterized by mean to very high content of available phosphorus, low to mean content of potassium, mean to high content of magnesium, and pH 6.1–6.7. In three successive years seed potatoes, presprouted for 8 weeks at the temperature of 12–15°C, were planted on 9, 16 and 13 April, respectively, with row spacing of 0.30 m and 0.625 m between rows. The average length of sprouts at the time of planting amounted to 15–20 mm. The plots were four rows wide and 6 m long. Materials used in the experiment were perforated polyethylene foil with 100 holes of diameter 0.01 m per 1 m^2 and polypropylene fibre Pegas Agro 17UV. The covers were spread on the ground immediately after planting. Depending on the year and the cultivar, full plant emergence under covers was observed after 22–24 days from planting, and in the control object without covering 2–6 days later. A higher increase in the soil temperature, on average by 1–2°C, under perforated foil rather than under polypropylene fibre caused earlier plant emergence by 1–2 days (Wadas and Kosterna 2007a). The covers were removed 2 or 3 weeks after plant emergence. Immediately after the removal, the height of plants, mass of leaves, mass of stems, leaf weight ratio (LWR) and leaf area ratio (LAR) were determined. The measurements were made on four successive plants per plot. LWR and LAR were defined as a ratio of mass of leaves/mass of the whole plant and a ratio of assimilation leaf area/mass of the whole plant, respectively (Pietkiewicz 1985).

The results of the experiment were analysed statistically by means of analysis of variance. The analysis of the results was conducted using the orthogonal contrast to compare the control object without covering with the remaining objects. The significance of differences was verified using the Tukey's test at $P = 0.05$.

In the threeyear period of the study, the most favourable weather conditions for potato cultivation for the early crop were in 2002 (Table 1). In 2003, a very cold first half of April with temporary snow did not allow the early potato planting, however, a considerable warming at the end of the month favoured an early plant emergence. The drought in the first decade of May had no effect on early plant growth. In contrast, the year 2004 was very cold and it received the highest amount of precipitation. The second half of April and the beginning of May were quite warm but in the second decade of May the weather got cooler and remained such till the end of the month. The lower temperature after emergence retarded plant growth.

RESULTS AND DISCUSSION

The growth of plants depended to a higher degree on the weather conditions. More favourable conditions for quick growth of potato plants were in 2002 and 2003, with a higher air temperature in May, than in the cold year 2004 (Tables 2 and 3). The use of covers in potato cultivation for early crop significantly affected the growth of plants. The plants grown under covers are more uniform and higher (Hamouz and Rybáček 1988, Rekowska et al. 1999), which was confirmed in the present discussed study. At the time of cover removal, the plants covered for 2 weeks after emergence were on average by 0.116 m higher, and after 3-week period of plant covering by 0.152 m higher than in the control object without covering (Tables 2 and 3). In the study carried out by Rekowska et al. (1999) in the northwestern part of Poland, the plants grown under covers were on average by 0.064 m higher.

The research showed a significant difference between the height of the plants of Aksamitka and Cykada cultivars. In the case of plant covering for 2 weeks after emergence, the plants of Cykada were on average by 0.057 m higher, and with covering for 3 weeks after emergence by 0.030 m higher than those of Aksamitka cultivar (Tables 2 and 3). The highest differences between the studied cultivars in the initial period of plant growth were found in

Table 1. Mean air temperature and precipitation sums in the vegetation period of potato

Year	Temperature (°C)		Precipitation (mm)	
	April	May	April	May
2002	9.0	17.0	12.9	51.3
2003	7.1	15.6	13.6	37.2
2004	8.0	11.7	35.9	97.0
Mean 1981–2000	8.1	11.2	49.6	48.2

Table 2. Height of plants after 2 weeks from emergence (m)

Cultivar	Year	Control object, no covering	Type of cover		Mean for covers
			perforated foil	polypropylene fibre	
Aksamitka	2002	0.224	0.318	0.307	0.312
	2003	0.168	0.252	0.247	0.250
	2004	0.114	0.231	0.171	0.201
	mean	0.169	0.267	0.241	0.254
Cykada	2002	0.235	0.353	0.345	0.349
	2003	0.184	0.379	0.318	0.348
	2004	0.138	0.360	0.237	0.298
	mean	0.186	0.364	0.300	0.332
Mean for years	2002	0.230	0.336	0.326	0.331
	2003	0.176	0.316	0.282	0.299
	2004	0.126	0.295	0.204	0.250
	mean	0.177	0.316	0.271	0.293

LSD (P = 0.05) for: years = 0.024, comparison of the control object with the rest (contrast) = 0.017, cultivars = 0.014, years × cultivar = 0.024, contrast × cultivar = 0.020, type of cover = 0.025, years × type of cover = 0.043

2004, with the lowest air temperature and simultaneously the highest rainfall in May. With 2-week covering, the plants of Cykada, more tolerant to wet conditions, were on average by 0.073 m higher than Aksamitka at the time of cover removal. The use of covers had more favourable effects on the initial growth of Cykada. After 2 weeks from plant emergence, the plants of Cykada grown under covers were on average by 0.146 m higher in comparison with the control object without covering. The difference in the height of Aksamitka plants amounted to 0.085 m.

Table 3. Height of plants after 3 weeks from emergence (m)

Cultivar	Year	Control object, no covering	Type of cover		Mean for covers
			perforated foil	polypropylene fibre	
Aksamitka	2002	0.243	0.390	0.355	0.372
	2003	0.248	0.412	0.392	0.402
	2004	0.136	0.338	0.242	0.290
	mean	0.209	0.380	0.330	0.355
Cykada	2002	0.258	0.404	0.381	0.392
	2003	0.288	0.483	0.398	0.440
	2004	0.148	0.416	0.252	0.334
	mean	0.231	0.434	0.344	0.389
Mean for years	2002	0.250	0.397	0.368	0.382
	2003	0.268	0.448	0.395	0.421
	2004	0.142	0.377	0.248	0.312
	mean	0.220	0.407	0.337	0.372

LSD (P = 0.05) for: years = 0.038, comparison of the control object with the rest (contrast) = 0.026, cultivars = 0.014, type of cover = 0.034, years × type of cover = 0.058

The height of plants depended on the type of covers (Tables 2 and 3). The use of perforated foil resulted in a higher potato plant growth rate than the use of polypropylene fibre. Plant covering with perforated foil resulted in plants that were on average by 0.045 m higher after 2 weeks from emergence and by 0.070 m higher after 3 weeks from emergence. The most favourable effect of perforated foil use on plant growth was observed in 2004, with the lowest mean air temperature in May. When perforated foil was used, the plants were on average by 0.091 m higher after 2 weeks from emergence, and by 0.129 m higher after 3 weeks from emergence compared with polypropylene fibre. In the study carried out by other authors, when perforated foil was applied, plants were on average by 0.027 m higher than when polypropylene fibre was used (Rekowska et al. 1999).

Plants grown under covers produce higher mass of above-ground part (Hamouz and Rybáček 1988), which was confirmed in the present study. At the time of cover removal, the mass of leaves of plants covered for 2 weeks after emergence was, on average, by almost twice as high, and after a 3-week period of plant covering it was 1.6 times as high as in the control object without covering; however, the mass of stems was over 2.5 times as high, independently of the date of cover removal (Tables 4–7). The effect of covering on the mass of leaves depended to a higher degree on the weather conditions. The highest increase in the mass of leaves as a result of covering was obtained in 2004, with the lowest mean air temperature in May. In this year, the mass of leaves of plants covered for 3 weeks after emergence was 2.5 times as high at the time of cover removal as in the control object without covering.

The research showed significant differences between the mass of leaves and stems of the Aksamitka and Cykada cultivars (Tables 4–7). In the case of plant covering for 2 weeks after emergence, the leaf mass of Cykada at the time of cover removal was on average by 0.012 kg (26%) higher and the mass of stems by 0.014 kg (40%) higher than the respective values of Aksamitka. The highest difference between the studied cultivars was found in 2004, with the lowest air temperature and simultaneously the highest rainfall in May. The leaf mass of Cykada, more tolerant to wet conditions, was on average 1.7 times as high, and the mass of stems 2.2 times as high as Aksamitka at the time of cover removal. The mass of leaves of Cykada plants covered for 3 weeks after emergence was on average by 0.007 kg (11%) higher, the mass of stems being similar. The use of covers caused a higher increase in the mass of above-ground parts of Cykada cultivar.

The present study showed a significant effect of the type of cover used on the mass of above-

Table 4. Mass of leaves per plant after 2 weeks from plant emergence (kg fw)

Cultivar	Year	Control object, no covering	Type of cover		Mean for covers
			perforated foil	polypropylene fibre	
Aksamitka	2002	0.037	0.064	0.068	0.066
	2003	0.030	0.047	0.050	0.048
	2004	0.022	0.048	0.033	0.041
	mean	0.030	0.053	0.050	0.052
Cykada	2002	0.044	0.063	0.087	0.075
	2003	0.030	0.055	0.048	0.051
	2004	0.025	0.094	0.058	0.076
	mean	0.03319	0.071	0.064	0.067
Mean for years	2002	0.04083	0.064	0.077	0.070
	2003	0.030	0.051	0.049	0.050
	2004	0.023	0.071	0.045	0.058
	mean	0.031	0.062	0.057	0.060

LSD (P = 0.05) for: years = 0.013, comparison of the control object with the rest (contrast) = 0.009, cultivars = 0.006, years × cultivar = 0.010, contrast × cultivar = 0.008, type of cover = NS (not significant), years × type of cover = 0.015

Table 5. Mass of leaves per plant after 3 weeks from plant emergence (kg fw)

Cultivar	Year	Control object, no covering	Type of cover		Mean for covers
			perforated foil	polypropylene fibre	
Aksamitka	2002	0.061	0.089	0.081	0.085
	2003	0.058	0.076	0.064	0.070
	2004	0.032	0.097	0.067	0.082
	mean	0.050	0.087	0.071	0.079
Cykada	2002	0.060	0.097	0.084	0.091
	2003	0.066	0.079	0.083	0.081
	2004	0.034	0.105	0.082	0.093
	mean	0.053	0.094	0.083	0.088
Mean for years	2002	0.060	0.093	0.083	0.088
	2003	0.062	0.078	0.074	0.076
	2004	0.033	0.101	0.074	0.088
	mean	0.052	0.090	0.077	0.084

LSD (P = 0.05) for: years = NS (not significant), comparison of the control object with the rest (contrast) = 0.010, years × contrast = 0.016, cultivars = 0.006, type of cover = 0.011

ground plant parts, especially in the year with cold spring (Tables 4–7). A higher soil and air temperature under perforated foil causes quicker plant growth than polypropylene fibre. In 2004, with lowest air temperature in April and May, the use of perforated foil resulted in 1.5 times higher mass of leaves and 2.2 times higher mass of stems 2 weeks after the plant emergence compared to polypropylene fibre. The differences were lower when plants were covered for 3 weeks. The study

Table 6. Mass of stems per plant after 2 weeks from plant emergence (kg fw)

Cultivar	Year	Control object, no covering	Type of cover		Mean for covers
			perforated foil	polypropylene fibre	
Aksamitka	2002	0.031	0.080	0.062	0.071
	2003	0.015	0.035	0.034	0.035
	2004	0.009	0.035	0.021	0.028
	mean	0.018	0.050	0.039	0.044
Cykada	2002	0.036	0.080	0.091	0.085
	2003	0.014	0.052	0.034	0.044
	2004	0.014	0.092	0.038	0.064
	mean	0.022	0.075	0.054	0.064
Mean for years	2002	0.034	0.080	0.078	0.078
	2003	0.014	0.044	0.034	0.039
	2004	0.012	0.063	0.029	0.046
	mean	0.020	0.062	0.047	0.054

LSD (P = 0.05) for: years = 0.012, comparison of the control object with the rest (contrast) = 0.008, cultivars = 0.005, years × cultivar = 0.009, contrast × cultivar = 0.007, type of cover = 0.009, years × type of cover = 0.016, years × cultivar × type of covers = 0.018

Table 7. Mass of stems per plant after 3 weeks from plant emergence (kg fw)

Cultivar	Year	Control object, no covering	Type of cover		Mean for covers
			perforated foil	polypropylene fibre	
Aksamitka	2002	0.048	0.129	0.096	0.112
	2003	0.043	0.112	0.073	0.093
	2004	0.010	0.088	0.044	0.066
	mean	0.034	0.110	0.071	0.090
Cykada	2002	0.035	0.107	0.069	0.088
	2003	0.049	0.105	0.084	0.094
	2004	0.014	0.111	0.061	0.086
	mean	0.033	0.108	0.071	0.089
Mean for years	2002	0.041	0.118	0.083	0.100
	2003	0.046	0.109	0.078	0.094
	2004	0.012	0.099	0.053	0.076
	mean	0.033	0.109	0.071	0.090

LSD (P = 0.05) for: years = 0.016, comparison of the control object with the rest (contrast) = 0.011, cultivars = NS (not significant), years × cultivar = 0.016, type of cover = 0.018

carried out by Rekowska et al. (1999) did not show a significant effect of the type of cover used on the diameter of leaf rosette.

The growth of individual plants is described by the leaf weight ratio (LWR) and leaf area ratio (LAR). These ratios are a genetic feature of a cultivar and phase of plant development, but their values can be modified by weather conditions (Zrůst et al. 1999, Rykaczewska 2004). The lowest LWR and LAR values were recorded in 2002, with

Table 8. Leaf weight ratio (LWR) after 2 weeks from plant emergence

Cultivar	Year	Control object, no covering	Type of cover		Mean for covers
			perforated foil	polypropylene fibre	
Aksamitka	2002	0.548	0.454	0.520	0.487
	2003	0.677	0.567	0.592	0.560
	2004	0.703	0.578	0.627	0.602
	mean	0.643	0.533	0.580	0.556
Cykada	2002	0.549	0.442	0.490	0.465
	2003	0.679	0.511	0.580	0.543
	2004	0.641	0.507	0.610	0.558
	mean	0.622	0.487	0.560	0.522
Mean for years	2002	0.548	0.448	0.500	0.476
	2003	0.678	0.539	0.580	0.562
	2004	0.672	0.542	0.620	0.580
	mean	0.633	0.510	0.570	0.539

LSD (P = 0.05) for: years = 0.042, comparison of the control object with the rest (contrast) = 0.029, cultivars = 0.019, type of cover = 0.031

Table 9. Leaf weight ratio (LWR) after 3 weeks from plant emergence

Cultivar	Year	Control object, no covering	Type of cover		Mean for covers
			perforated foil	polypropylene fibre	
Aksamitka	2002	0.563	0.411	0.469	0.440
	2003	0.570	0.406	0.467	0.436
	2004	0.763	0.526	0.600	0.563
	mean	0.632	0.448	0.512	0.480
Cykada	2002	0.637	0.479	0.560	0.518
	2003	0.584	0.431	0.500	0.464
	2004	0.706	0.497	0.580	0.536
	mean	0.642	0.469	0.540	0.506
Mean for years	2002	0.600	0.445	0.510	0.479
	2003	0.577	0.418	0.480	0.450
	2004	0.734	0.512	0.590	0.550
	mean	0.637	0.458	0.530	0.493

LSD (P = 0.05) for: years = 0.037, comparison of the control object with the rest (contrast) = 0.025, cultivars = 0.020, years × cultivar = 0.034, type of cover = 0.036

the highest mean air temperature and the lowest total rainfall in the first and second decade of May (Tables 8–11). Zrůst and Čepl (1991) showed a significant relation of potato tuber yield with LAR, especially for leaf type cultivars. The LAR value decreases almost linearly as plants develop. This is a result of a decreasing share of assimilation tissues in the whole plant mass. During ontogenesis the share of assimilation organs in the mass of the whole plant (LAR) decreases more quickly than specific leaf area (SLA). A temporary increase of the LAR value can result from a sud-

Table 10. Leaf area ratio (LAR) after 2 weeks from plant emergence (m^2/kg fw)

Cultivar	Year	Control object, no covering	Type of cover		Mean for covers
			perforated foil	polypropylene fibre	
Aksamitka	2002	1.476	1.366	1.693	1.530
	2003	2.326	2.054	2.312	2.183
	2004	1.962	1.825	2.061	1.943
	mean	1.921	1.748	2.022	1.885
Cykada	2002	1.426	1.270	1.410	1.339
	2003	2.321	1.737	2.100	1.918
	2004	1.834	1.429	1.790	1.608
	mean	1.860	1.479	1.770	1.622
Mean for years	2002	1.451	1.318	1.550	1.434
	2003	2.323	1.896	2.210	2.051
	2004	1.898	1.627	1.920	1.776
	mean	1.891	1.614	1.890	1.754

LSD (P = 0.05) for: years = 0.148, comparison of the control object with the rest (contrast) = 0.102, cultivars = 0.079, contrast × cultivar = 0.113, type of cover = 0.091

Table 11. Leaf area ratio (LAR) after 3 weeks from plant emergence (m^2/kg fw)

Cultivar	Year	Control object, no covering	Type of cover		Mean for covers
			perforated foil	polypropylene fibre	
Aksamitka	2002	1.705	1.207	1.501	1.354
	2003	2.041	1.374	1.904	1.639
	2004	2.166	1.688	1.716	1.702
	mean	1.971	1.423	1.707	1.565
Cykada	2002	2.119	1.680	2.050	1.867
	2003	1.881	1.431	1.880	1.656
	2004	1.962	1.512	1.830	1.673
	mean	1.987	1.541	1.920	1.732
Mean for years	2002	1.912	1.444	1.780	1.610
	2003	1.961	1.402	1.890	1.648
	2004	2.064	1.600	1.770	1.687
	mean	1.979	1.482	1.810	1.648

LSD (P = 0.05) for: years = NS (not significant), comparison of the control object with the rest (contrast) = 0.163, cultivars = 0.102, years × cultivar = 0.176, type of cover = 0.195

den improvement in environmental conditions, e.g. after a drought period or a period of frosts (Pietkiewicz 1985, Rykaczewska 2004). A change in the conditions in the initial period of potato growth as a result of covering had a significant effect on LWR and LAR. When plants were covered for 2 weeks after emergence, LWR was on average by 0.094 smaller at the time of cover removal; 3-week covering resulted in values by 0.144 smaller compared with the control object without covering; the LAR value was by 0.137 m^2/kg and 0.331 m^2/kg smaller, respectively (Tables 8–11).

After 2 weeks from plant emergence, the average values of LWR and LAR of Aksamitka cultivar were higher than the values obtained for Cykada. Later, the LWR and LAR values of the studied cultivars were modified by weather conditions. In 2002, with the highest mean air temperature and the lowest total rainfall in the first and second decade of May, the LWR and LAR of Cykada cultivar, more tolerant to wet conditions, were higher than those of Aksamitka (Tables 8–11).

The present study showed a significant effect of the type of cover used on LWR and LAR. The use of polypropylene fibre was associated with LWR that was on average by 0.060 and 0.072 higher after 2 and 3 weeks from plant emergence, respectively, compared with the use of perforated foil; the LAR value was by 0.276 m^2/kg and 0.328 m^2/kg higher, respectively (Tables 8–11). A higher LAR value associated with the use of polypropylene fibre indicates that more delicate and thinner leaves have been produced.

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