Effect of perforated foil and polypropylene fibre covers on assimilation leaf area 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 covering at various lengths of plant cover period (2 and 3 weeks after plant emergence) on the assimilation leaf area of early potato cultivars. In the case of plant covering for 2 weeks after emergence the assimilation leaf area and leaf area index (LAI) at the moment of cover removal were on average 2 times higher than in the cultivation without covering; at the 3-week period of plant covering they were almost 1.7 times higher. A higher favourable effect of covering was obtained in the year with the lowest air temperature in May. The use of the covers at that time increased the assimilation leaf area and LAI 2.5 times and 3 times, respectively. The research showed no significant effect of the type of cover used on the assimilation leaf area and LAI; however, the specific leaf area (SLA) was higher with the use of polypropylene fibre.

Keywords: early potato; perforated polyethylene foil; polypropylene fibre; assimilation leaf area; leaf area index (LAI); specific leaf area (SLA)

The potato tuber yield depends to a higher degree on the rate and duration of the tuber growth. The use of covers directly on the planted field enables to enhance the harvest of early potato tubers and to reduce the variability of the yield in the years (Jenkins and Gillison 1995, Demmler 1998, Dvořák et al. 2004, Jabłońska-Ceglarek and Wadas 2005, Hamouz et al. 2006). The favourable microclimate under the cover facilitates the emergence and further growth and vegetation development in the period with less favourable weather conditions for early potatoes (Michaud et al. 1990, Jenkins and Gillison 1995, Prośba-Białczyk and Mydlarski 1998, Hamouz et al. 2006, Wadas and Kosterna 2007). The earlier plant emergence resulted in a more extensive ground cover during early growth and the higher leaf area index (LAI) in May and June (Nelson and Jenkins 1990). 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). Yield forming effect of cover use depends on the length of plants covering period (Reust 1980, Jenkins and Gillison 1995). Plant covering left too long after the emergence may limit the development of assimilation leaf area (Lutomirska and Szutkowska 1999).

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

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 assimilation leaf area of early potato cultivars Aksamitka and Cykada were investigated. The experiment was carried out in the years 2002–2004 in the middle-eastern part of Poland 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. The field experiment was established in the splitblock method with a control object without covering in three replications. In the successive years the 8week seed potatoes presprouted in the temperature 12–15°C were

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

Years	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

planted on 9, 16 and 13 April, 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. The materials used in the experiment were the perforated polyethylene foil with 100 holes per 1 m^2 and the polypropylene fibre Pegas Agro 17UV. The covers were spread on the ground immediately after planting. In relation to the year and the cultivar, the full plant emergence under the 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 the perforated foil rather than under the polypropylene fibre caused earlier plant emergence by 1–2 days (Wadas and Kosterna 2007). The covers were removed 2 or 3 weeks after the plant emergence. Immediately after the removal, the assimilation leaf area, leaf area index (LAI) and specific leaf area (SLA) were determined. The measurements were made on four successive plants per plot. The assimilation leaf area was measured by the weight method (Roztropowicz 1999).

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 three-year period of 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 did not have an effect on early plant growth. In contrast, the year 2004 was very cold and it had the highest amount of precipitation.

RESULTS AND DISCUSSION

The assimilation leaf area depended to a higher degree on the weather conditions. More favourable conditions for an early growth of leaf area 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 the covers in the potato cultivation for early crop significantly affected the size of assimilation leaf area. In the moment of cover removal, the assimilation leaf area of plants covered for 2 weeks after emergence was on average 2 times higher, and after 3 weeks of plant covering it was 1.7 times higher than in the control object without covering (Tables 2 and 3). The course of early potato leaf area development depends more strongly on the air temperature than on the environment and genotype. Earlier plant development as a result of covering allows for the higher solar radiation interception and quick enlargement of assimilation leaf area (Firman and Allen 1989, Nishibe et al. 1989, Van Delden et al. 2000, Gimenez et al. 2002), which was confirmed in the present study. The effect of covering on the assimilation leaf area depended to a higher degree on the weather conditions. The highest enlargement of assimilation leaf area as a result of covering was obtained in 2004, with the lowest mean air temperature in May. In this year, the assimilation leaf area of plant covered for 2 weeks after emergence was 2.5 times higher in the moment of cover removal; after the 3-week period of plant covering the area was almost 3 times higher than in the control object without covering. In the years with more favourable temperature conditions for potato cultivation on early crop, the effect of covering was lower (Tables 2 and 3). The study carried out in the central part of Poland showed that in higher temperature covers (especially of perforated foil) left over the plant after emergence can hinder the development of assimilation leaf area, while in the lower temperature the effect is more favourable (Lutomirska and Szutkowska 1999). When the perforated foil was removed too long after the emergence, the amount of solar radiation which incidents on plant was reduced by 20–40%, but the transmission of photoactive radiation through polypropylene cover varied from 85 to 65%, depending on dust accumulation on the cover and water vapour condensation on the inner surface of the cover (Jenkins 1993, Gimenez et al. 2002). The reduction of the incoming photoactive radiation under cover is compensated by the enlargement of leaf area development, due to the more favourable temperature.

Table 2. Assimilation leaf area after 2 weeks from plant emergence (m^2)

Cultivar	Years	Control object, no covering	Type of cover		Mean for covers
			perforated foil	polypropylene fibre	
Aksamitka	2002	0.0998	0.1953	0.2198	0.2076
	2003	0.1026	0.1680	0.1973	0.1827
	2004	0.0603	0.1532	0.1100	0.1316
	mean	0.0876	0.1722	0.1757	0.1739
Cykada	2002	0.1141	0.1811	0.2493	0.2152
	2003	0.1025	0.1868	0.1735	0.1802
	2004	0.0714	0.2652	0.1700	0.2176
	mean	0.0960	0.2110	0.1976	0.2043
Mean for years	2002	0.1070	0.1882	0.2346	0.2114
	2003	0.1025	0.1774	0.1854	0.1814
	2004	0.0658	0.2092	0.1400	0.1746
Mean		0.0918	0.1916	0.1867	0.1891

LSD (P = 0.05) for: years = 0.0314, comparison of the control object with the rest (contrast) = 0.0217, cultivars = 0.0156, years × cultivar = 0.0269, type of cover = n.s., years × type of cover = 0.0562

The research showed significant differences between the assimilation leaf area of the Aksamitka and Cykada cultivars. In the case of covering the plant for 2 weeks after emergence, the assimilation leaf area of Cykada in the moment of cover removal was higher on average by 0.0230 m^2, covering the plant for 3 weeks after emergence resulted in the area higher by 0.0323 m^2 than those of Aksamitka

Table 3. Assimilation leaf area after 3 weeks from plant emergence (m^2)

Cultivar	Years	Control object, no covering	Type of cover		Mean for covers
			perforated foil	polypropylene fibre	
Aksamitka	2002	0.1787	0.2605	0.2560	0.2582
	2003	0.2054	0.2587	0.2614	0.2601
	2004	0.0894	0.3088	0.1931	0.2510
	mean	0.1578	0.2760	0.2369	0.2564
Cykada	2002	0.1956	0.3402	0.3118	0.3260
	2003	0.2137	0.2630	0.3151	0.2890
	2004	0.0966	0.3061	0.2613	0.2837
	mean	0.1686	0.3031	0.2961	0.2996
Mean for years	2002	0.1872	0.3003	0.2839	0.2921
	2003	0.2095	0.2609	0.2882	0.2746
	2004	0.0930	0.3075	0.2272	0.2673
Mean		0.1632	0.2896	0.2665	0.2780

LSD (P = 0.05) for: years = 0.0324, comparison of the control object with the rest (contrast) = 0.0224, years × contrast = 0.0370, cultivars = 0.0286, type of cover = n.s.

Table 4. Leaf area index (LAI) after 2 weeks from plant emergence

Cultivar	Years	Control object, no covering	Type of cover		Mean for covers
			perforated foil	polypropylene fibre	
Aksamitka	2002	0.53	1.04	1.17	1.11
	2003	0.55	0.89	1.05	0.97
	2004	0.32	0.82	0.59	0.70
	mean	0.45	0.92	0.94	0.93
Cykada	2002	0.61	0.97	1.33	1.15
	2003	0.55	1.00	0.92	0.96
	2004	0.38	1.41	0.91	1.16
	mean	0.51	1.12	1.05	1.09
Mean for years	2002	0.57	1.00	1.25	1.13
	2003	0.55	0.94	0.99	0.97
	2004	0.35	1.12	0.75	0.93
Mean		0.49	1.02	0.99	1.01

LSD ($P = 0.05$) for: years = 0.17, comparison of the control object with the rest (contrast) = 0.11, cultivars = 0.08, years × cultivar = 0.14, type of cover = n.s., years × type of cover = 0.30

cultivar (Tables 2 and 3). The highest difference between the studied cultivars in the first period of plant growth was showed in 2004, with the lowest air temperature and simultaneously the highest rainfall in May. With 2-week covering of the plant, the assimilation leaf area of Cykada, more tolerant to the wet conditions, was 1.5 times higher than the Aksamitka in the moment of cover removal.

The present study has not shown a significant effect of the type of cover used on the size of as-

Table 5. Leaf area index (LAI) after 3 weeks from plant emergence

Cultivar	Years	Control object, no covering	Type of cover		Mean for covers
			perforated foil	polypropylene fibre	
Aksamitka	2002	0.95	1.39	1.36	1.38
	2003	1.10	1.38	1.39	1.39
	2004	0.48	1.65	1.03	1.34
	mean	0.84	1.47	1.26	1.37
Cykada	2002	1.04	1.81	1.66	1.74
	2003	1.14	1.40	1.68	1.54
	2004	0.52	1.63	1.39	1.51
	mean	0.90	1.62	1.58	1.60
Mean for years	2002	1.00	1.60	1.51	1.56
	2003	1.12	1,39	1.54	1.46
	2004	0.50	1.64	1.21	1.42
Mean		0.87	1.54	1.42	1.48

LSD ($P = 0.05$) for: years = 0.17, comparison of the control object with the rest (contrast) = 0.12, years × contrast = 0.20, cultivars = 0.15, type of cover = n.s.

Table 6. Specific leaf area (SLA) after 2 weeks from plant emergence (m^2/kg fw)

Cultivar	Years	Control object, no covering	Type of cover		Mean for covers
			perforated foil	polypropylene fibre	
Aksamitka	2002	2.6983	3.0350	3.2550	3.1450
	2003	3.4313	3.6293	3.9013	3.7653
	2004	2.7883	3.1600	3.2917	3.2258
	mean	2.9727	3.2748	3.4827	3.3787
Cykada	2002	2.5960	2.8743	2.8900	2.8823
	2003	3.4160	3.3823	3.6370	3.5095
	2004	2.8567	2.8177	2.9380	2.8778
	mean	2.9562	3.0248	3.1550	3.0899
Mean for years	2002	2.6472	2.9547	3.0730	3.0137
	2003	3.4237	3.5058	3.7690	3.6374
	2004	2.8225	2.9888	3.1150	3.0518
Mean		2.9644	3.1498	3.3190	3.2343

LSD (P = 0.05) for: years = 0.1818, comparison of the control object with the rest (contrast) = 0.1256, cultivars = 0.0949, contrast × cultivar = 0.1367, type of cover = 0.1638

similation leaf area (Tables 2 and 3). Only in 2004, with the cold spring, the use of the perforated foil resulted in 1.5 times higher assimilation leaf area 2 weeks after the plant emergence than the polypropylene fibre.

The assimilation leaf area and the type of foliage made the architecture of lowland meadows, which in main measure decides about the effectiveness of solar radiation interception. The effect of the examined factors on the leaf area index (LAI) is

Table 7. Specific leaf area (SLA) after 3 weeks from plant emergence (m^2/kg fw)

Cultivar	Years	Control object, no covering	Type of cover		Mean for covers
			perforated foil	polypropylene fibre	
Aksamitka	2002	3.0233	2.9443	3.1900	3.0672
	2003	3.5807	3.6247	4.0807	3.8527
	2004	2.8410	3.1753	2.8617	3.0185
	mean	3.1483	3.2481	3.3774	3.3128
Cykada	2002	3.3383	3.5057	3.6940	3.5997
	2003	3.2280	3.3253	3.7880	3.5568
	2004	2.7870	2.9740	3.1970	3.0853
	mean	3.1178	3.2683	3.5600	3,4139
Mean for years	2002	3.1808	3.2250	3.4420	3.3334
	2003	3.4043	3.4750	3.3950	3.7048
	2004	2.8140	3.0747	3.0290	3.0519
Mean		3.1330	3.2582	3.4690	3.3634

LSD (P = 0.05) for: years = 0.4593, comparison of the control object with the rest (contrast) = n.s., cultivars = n.s., years × cultivar = 0.3191, type of cover = n.s.

the same as on the assimilation leaf area. The enlargement of leaf area as a result of covering results in more extensive ground cover during the early potato growth (Tables 4 and 5). The higher LAI value affected favourably the growth of tubers during vegetation and even the final tuber yield (Zrůst and Čepl 1991, Zrůst et al. 1999). In the study carried out by Rykaczewska (2004) the LAI of very early potato cultivars achieved the highest values; they amounted to 2.3–2.5 in the end of flowering (about 18 June). The LAI lower than 3 (presumed to be the optimum) was probably caused by the rainfall shortage hampering the plant growth. In the present study, when covering the plants for 2 weeks after emergence, the LAI of early potato varieties amounted to 1.01 in the moment of cover removal (about 20 May), in after three-weeks of covering it amounted to 1.48 (Tables 4 and 5). According to Nelson and Jenkins (1990) the force of plant emergence as a result of covering resulted in more extensive ground cover only during early potato growth (May to early June). Later, there were smaller differences as leaf senescence began under the cover sooner. The relationship between the rate of tuber yield and the LAI value is rather diverse, since potatoes are very sensitive to weather changes during vegetation reacting by falling or growing new leaves. The LAI value depends not only on the cultivar and phase of plant development but also, unlike to leaf area ratio (LAR) and specific leaf area (SLA), can be modified by fertilization, irrigation and other factors (Gordon et al. 1997, Zrůst et al. 1999).

The LAR and SLA, which describe the growth of plant, are genetic features of cultivar, but their values can be modified by weather conditions (Zrůst et al. 1999). The highest SLA value was in 2003, which was a warm and moderately moist year (Tables 6 and 7). The change of conditions in the first period of potato growth as a result of covering had a significant effect on SLA. The early foliar expansion is associated with a strong increase in SLA (Van Delden et al. 2000), which was confirmed in the discussed study. In the case of covering the plants for 2 weeks after emergence, the SLA was higher on average by 0.2679 m^2/kg in the moment of cover removal; 3-week covering resulted in values higher by 0.2304 m^2/kg than the control object without covering (Tables 6 and 7).

After 2 weeks of plant emergence the average values of SLA of Aksamitka cultivar were higher by 0.1981 m^2/kg than Cykada. The use of covers caused a higher increase in SLA of Aksamitka cultivar. Later, the SLA value of the studied cultivars was modified by weather conditions. In 2002, with the highest mean air temperature and the lowest total rainfall in the first and second decades of May, the SLA of Cykada cultivar, more tolerant to the wet conditions, was higher on average by 0.4600 m^2/kg than that of Aksamitka (Tables 6 and 7).

The present study showed a significant effect of the type of cover used on SLA. The use of the polypropylene fibre contributed to higher SLA on average by 0.1692 m^2/kg after 2 weeks from plant emergence and by 0.2108 m^2/kg after 3 weeks from plant emergence compared to the use of perforated foil. The higher SLA and similar LAI value after using perforated foil under polypropylene fibre indicated a larger production of thinner leaves.

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