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Effect of mulching with film of different colours made from original and recycled polyethylene on the yield of butterhead lettuce and celery

Piotr Siwek[1], Andrzej Kalisz[1], Renata Wojciechowska[2]

[1]Department of Vegetable Crops
[2]Department of Plant Physiology
Agricultural University in Kraków
29 Listopada 54, 31-425 Kraków, Poland
e-mail: psiwek@ogr.ar.krakow.pl

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ABSTRACT

The experiment carried out in 2005 and 2006 at the Experimental Station at Mydlniki by Krakow concerned the effect of mulching films of different colours made from original and recycled materials on microclimatic conditions and subsequent yield of 'Melodion' butter lettuce and 'Tango' celery. The objects of the experiment were polyethylene transparent, white and black films, made from original and recycled materials. Plants cultivated without mulching were the control. In lettuce cultivation on transparent mulch the temperature was by 2.4°C higher and in the case of celery by 1.7°C than the temperature of non-mulched soil. Under white and black film, the difference of temperature did not exceed 1.0°C. As far as the means from the two years are concerned, black mulches had most positive effect on the yield of both vegetables, followed by white and transparent films.

INTRODUCTION

Mulching is considered an agrotechnical procedure which can significantly modify microclimate around plants. Black films, commonly used for this purpose, reduce weeding, limit evaporation and increase soil temperature. Transparent films have greater effect on soil temperature as compared to white and other light-reflecting films (Decoteau et al. 1990). Furthermore, film and fabric mulches decrease the degree of soil kneading, keeping it in good structure throughout the whole vegetation period (Siwek 2002). Mulching also increases vegetable yield. The comparison of black and transparent films used in zuccini cultivation demonstrated higher effect of transparent film (Tuli and Yesilsoy 1997). However, mulching with transparent or black film did not have any effect on the yield of paprika (Hyun-Suk et al. 1999). On the other hand, Negreiros et al. (2005) found that yellow, brown, black and silver films had a positive, though balanced effect on the yield of melon.

One of the reasons to initiate the present study was a limited number of publications on the effectiveness of mulching in leaf vegetable cultivation. The aim of the study was to evaluate the effect of polyethylene film of different colours made from original and recycled materials on environmental conditions and yield of butter lettuce and celery.

MATERIAL AND METHODS

The experiment was carried out in 2005 and 2006 in the Experimental Station at Mydlniki by Krakow. It concerned a very early 'Melodion' butter lettuce and medium-early 'Tango' celery of intensively green leaves. Lettuce seeds were sown into greenhouse on 2 March in both years of the experiment. Transplants were planted on 7 April 2005 and 11 April 2006 respectively. Celery seeds were sown on 4 February 2005 and 6 February 2006, transplants were planted on 20 April and 19 April respectively. Transplants of both species were planted into the field in 30 × 25 cm distance. Experimental fields, each of the area of 3 m^2 (40 plants), were established in randomised blocks with four replications. The experiment concerned mulches of low density polyethylene films which differed in respect to the material they were made from and their colour: 1) non-mulched (the control), 2) transparent from original material; 3) transparent from recycled material; 4) white from original material; 5) white from recycled material; 6) black from original material; 7) black from recycled material. Original films were made of Basell Orlen Polyolefins material and recycled films of high quality material originating from waste products. As colouring agents white (Schulman 8160) and black (Polybatch black 1850) dyes were used.

Lettuce was harvested only once in each year, namely on 23 May 2005 and on 26 May 2006, and celery on 6 and 13 July respectively. In both years of the experiment manure (35 t ha^{-1}), triple superphosphate (150 kg P_2O_5 ha^{-1}) and potash salt (200 kg K_2O ha^{-1}) were used in autumn. In spring, before planting, the field was fertilized with 50 kg N ha^{-1} in 2005 and 75 kg N ha^{-1} in 2006 (nitrochalk). After the planting, only celeries were subjected to fertilization with ammonium nitrate (25 g N m^{-2}), following that 0.1% solution of lime saltpetre (20 dm^3 m^{-2}) was used.

Films used for mulching were analyzed in respect to spectral transmission, reflection and absorption of radiation within the range of 400-1100 nm, using LI-1800-12-S (LI-COR, USA) integration sphere with standard light source, in accordance with the world standard. Soil temperature was recorded using HOBO 8 (Onset Corp.) during the vegetation of both species. Results were processed statistically with Newmann-Keuls test, using STATISTICA program at a significance level of $p = 0.05$.

RESULTS AND DISCUSSION

Modification of environmental conditions through mulching largely depends on optical parameters of the film used for mulching. Within PAR and 700-1100 nm ranges (Table 1), transmission was highest in the case of transparent films – on average 87.2% (recycled) and 86.4% (original). In the case of white films, differences within particular ranges amounted to 17.4 and 17.0%. This fact probably resulted from fuller dyeing into white of the original material during the manufacturing process. Black films did not transmit light in either of the ranges but strongly absorbed it (94.8% and 94.6%). In the case of other films absorption of radiation remained on the level below 10%. Strong reflection characterized both types of white film, but in the case of the original film it was by 15.6 and 15.2% higher. As far as transparent films were concerned, reflection remained on the level of ca. 8-9% and in the case of black films it amounted to 5% on average. While the results of measurements of the same parameters obtained by Siwek and Kunicki (1998), were similar for original polyethylene films, reflexivity values of white film were higher and transmission much lower, due to film thickness and the degree of its dyeing.

In butter lettuce cultivation regardless of the type of mulch used, soil temperature was higher than that of non-mulched soil. In 2006 soil warmed better, having positive effect on yield (Table 2, Fig. 1). Similar tendency occurred in celery cultivation, however differences in temperature in particular years were slight (Table 2, Fig. 2). As far as the effect of film colour on temperature is concerned, in the case of butter lettuce cultivated on transparent film it was higher by 2.4°C and in the case of celery by 1.7°C. Under white film the difference amounted to 1.0°C and 0.3°C respectively and under black film to 0.5°C in both

cultivations. The effect of the type of material the film was made from on soil temperature, regardless of its colour, was insignificant. In butter lettuce cultivation it was higher by 0.5°C under film made from recycled material and in celery cultivation it remained on the same level. It is worth noting that temperature was higher in the case of lettuce cultivated on white film made from recycled material due to higher sunlight transmission (Table 1).

Table 1. Transmittance, absorbtance and reflectance of applied mulches in the range 400-700 nm (PAR) and 700-1100 nm (%)

Kind of mulch	Transmittance		Absorptance		Reflectance	
	400-700	700-1100	400-700	700-1100	400-700	700-1100
Transparent original	86.9	86.0	4.3	6.0	8.8	8.0
Transparent recycled	87.5	86.8	3.9	5.3	8.6	7.9
White original	38.4	51.0	10.1	9.6	51.2	39.4
White recycled	55.8	68.0	8.6	7.8	35.6	24.2
Black original	0.4	0.9	94.8	94.3	4.8	4.8
Black recycled	0.0	0.0	94.9	95.0	5.1	5.0

Table 2. Average soil temperature at the depth 10 cm in lettuce (May) and celery (June) cultivation with different kind of polyethylene mulch (^{o}C)

Kind of mulch	14-24 May 2005	14-24 May 2006	Mean for years	1-25 June 2005	1-25 June 2006	Mean for years
Without mulch	11.1	13.1	12.1	16.5	16.4	16.4
Transparent original	14.8	14.7	14.7	18.3	17.8	18.0
Transparent recycled	14.2	15.3	14.7	18.0	18.5	18.2
White original	12.8	13.1	12.9	17.1	16.9	17.0
White recycled	13.2	14.5	13.8	16.2	16.7	16.4
Black original	11.5	13.6	12.5	16.6	17.3	16.9
Black recycled	12.5	13.9	13.2	17.1	16.7	16.9

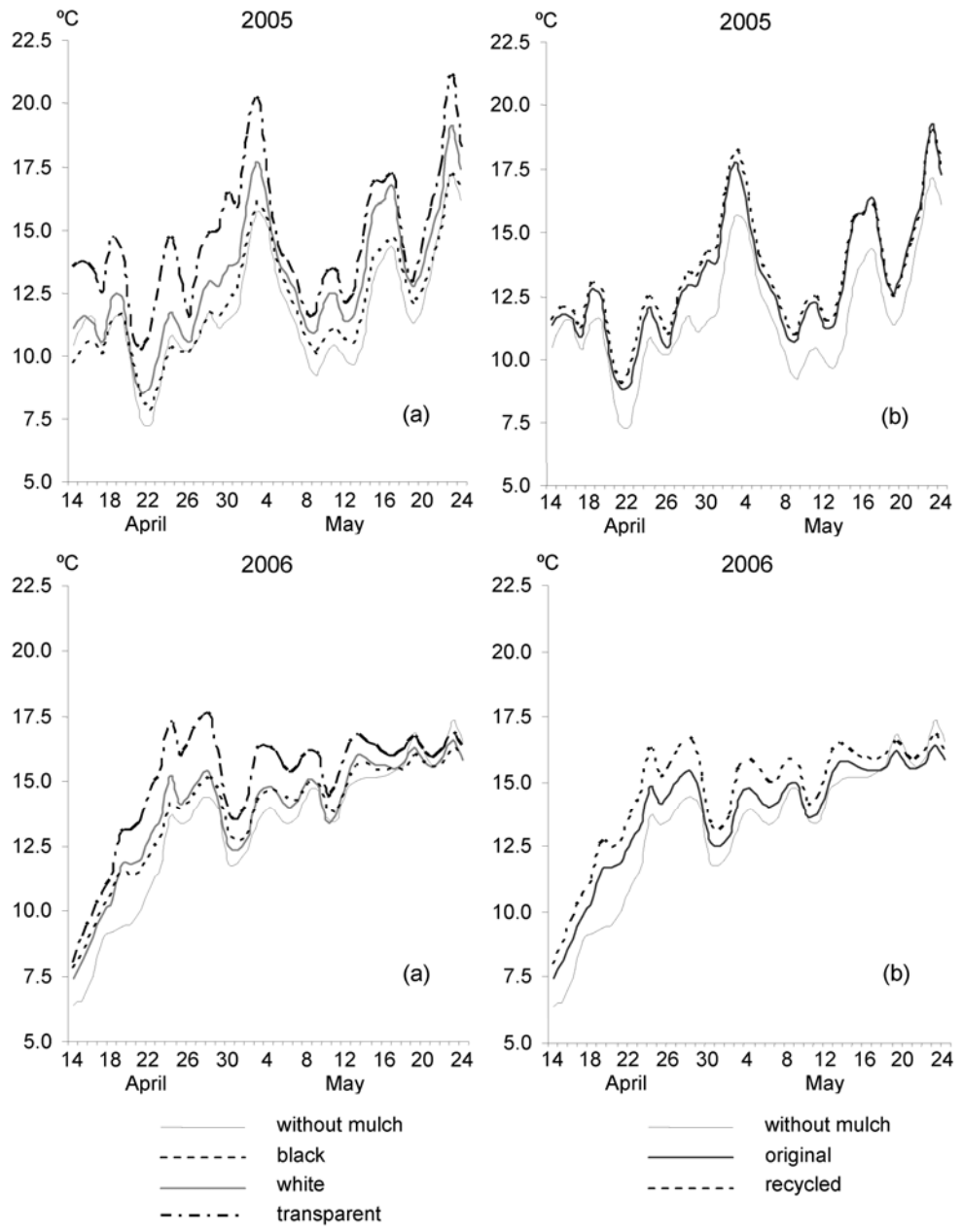

Fig. 1. The effect of kind of mulch film on soil temperature (at the depth 10 cm) in the lettuce cultivation: (a) colour, (b) kind of material

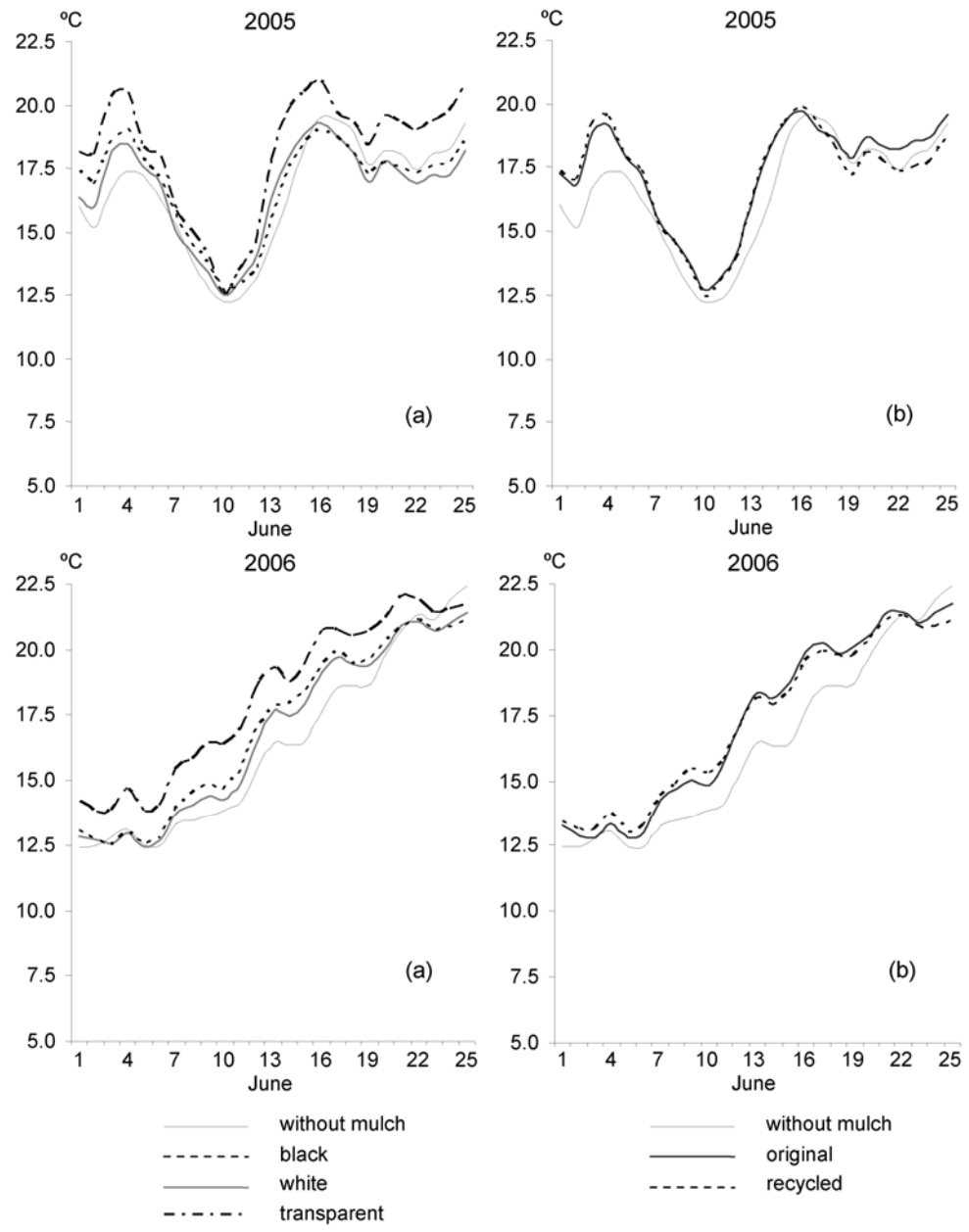

Fig. 2. The effect of kind of mulch film on soil temperature (at the depth 10 cm) in the celery cultivation: (a) colour, (b) kind of material

Microclimatic conditions had effect on the yield of both leafy vegetables. The marketable yield of lettuce heads cultivated on mulch in 2005 was significantly higher than in the control (Table 3). Neither the colour of the film used as mulch

Table 3. The effect of kind of plastic film used for soil mulching on marketable yield of lettuce in two years of the study

	Yield (kg m^{-2})		
Kind of plastic film	2005	2006	Mean for years
Control (without film)	2.36 a A[2]	3.57 a A	2.96
Transparent original	3.37 b	4.52 abc	3.94
Transparent recycling	3.66 b	4.27 ab	3.96
Mean for transparent film	3.51 B	4.39 B	3.95
White original	3.02 b	4.80 bc	3.91
White recycling	3.33 b	5.41 c	4.37
Mean for white film	3.18 B	5.10 C	4.14
Black original	3.04 b	5.10 bc	4.07
Black recycling	3.26 b	5.07 bc	4.16
Mean for black film	3.15 B	5.08 C	4.11
Original film[1]	3.14 X	4.81 X	3.97
Recycling film[1]	3.41 X	4.92 X	4.16

[1] Mean for the kind of material
[2] Statistical analysis concerns each year separately; values designated with the same letters do not differ significantly; small letters concern interaction kind of material × color of film, capital letters – color of film, X,Y – kind of material

nor the type of material it was made from seemed to affect the yield. In 2006 the yield was generally higher due to warmer spring. On transparent mulch it was closest to the yield of the control. A significantly higher yield was obtained on white and black films, particularly on white film made from recycled material (5.41 kg m^{-2}). In statistical analysis the effect of film colour, particularly black and white, was significant. Similarly to the preceding year, no significant differences were demonstrated in the yield depending on the type of material the film was made from. The comparison of the mean values from the two years of the experiment

shows the tendency of yield increase in effect of mulching with all film types, in particular films of white and black colour. In comparison with the control, the difference amounted to 33.4% (transparent film), 39.9% (white) and 38.8% (black) respectively. Positive effect of transparent film on lettuce yield is related to direct radiation transmission and better soil warming as compared to black and white films (Siwek and Kunicki 1998). Therefore in this case, a slightly better yield was obtained in 2005 when spring was cooler. In 2006 considerable competition for nutrients and water between lettuce and weeds under transparent film might have resulted in a lower yield.

Mulching is not always expected to bring about soil temperature increase. It was demonstrated (Andrade Jr. et al. 2005) that in warmer climates organic mulch (e.g. hay, rice hull) and black film have similar effects on lettuce yield. Differences in thermal and light conditions also affected marketable yield of celery, which consisted of the yields of stalks and blades (Table 4). The yield obtained in 2005 was higher than the one obtained in the second year of the experiment, mostly due to favourable weather conditions, particularly in the final vegetation phase. However, in both years of the experiment the marketable yield obtained with the use of mulches was significantly higher. In 2005 highest yield was obtained from treatments mulched with black film (the mean for this colour amounts to 11.61 kg m^{-2}), followed by white and transparent films. The same tendency concerned yields of stalks and leaf blades. In 2006 the yield of celery was comparable in respect to particular film types and colours. Only in the case of mulching with white film made from recycled material the obtained yield of 7.68 kg m^{-2} was significantly higher than the control. The comparison of the means from two years demonstrated that black films had most possitive effect on yielding. They were followed by white and transparent films. As compared with the control, the yield was higher by 52.7%, 42.4% and 30.8% respectively. The effect of the material the film was made from was not statistically proved. In the work of Siwek (2002), who compared several types and colours of mulches in second crop cultivation of celery, highest yield was obtained in the case of black polyethylene film. In the 3-year experiment the yield was higher by 85.4% than the control. Besides higher yield, in result of soil covering with transparent film and whole plant covering with low tunnels, Jenni et al. (2006) noted a significant decrease in premature inflorescence shood formation. Based on the available literature and the obtained results it can be said that the effectiveness of mulching depends to the largest degree on climate and weather conditions prevailing in a given year. In the geographic latitude of Poland, the selection of optimum film colour depends on summer temperatures. In hot summers black and white films are better for field cultivation of vegetables, whereas in cool summers transparent films should be selected. This is the result of the intensity of soil temperature increase under transparent film and weed growth under mulch as well as their competition with cultivated vegetables.

Table 4. The effect of kind of plastic film used for soil mulching on the marketable yield of celery (kg m^{-2}) in two years of the study

Kind of plastic film	2005			2006			Mean for marketable yield
	Yield of stalks	Yield of blades	Marketable yield	Yield of stalks	Yield of blades	Marketable yield	
Control	4.92 a A[3]	2.10 a A	7.02 a A	3.40 a A	1.85 a A	5.25 a A	6.13
Transp.[1] original	6.84 b	2.82 bc	9.66 bc	4.33 ab	2.62 ab	6.95 ab	8.30
Transp. recycling	5.75 ab	2.55 ab	8.30 ab	4.43 ab	2.74 ab	7.17 ab	7.73
Mean for transp.	6.30 B	2.69 B	8.98 B	4.38 B	2.68 B	7.06 B	8.02
White original	6.82 bc	2.91 bc	9.73 bc	4.25 ab	2.79 ab	7.05 ab	8.39
White recycling	7.57 cd	2.90 bc	10.47 cd	4.69 b	2.99 b	7.68 b	9.07
Mean for white	7.19 C	2.91 BC	10.10 C	4.47 B	2.89 B	7.36 B	8.73
Black original	8.22 d	3.04 bc	11.26 cd	4.37 ab	2.76 ab	7.13 ab	9.19
Black recycling	8.56 d	3.41 c	11.97 d	4.36 ab	2.73 ab	7.09 ab	9.53
Mean for black	8.39 D	3.22 C	11.61 D	4.36 B	2.74 B	7.11 B	9.36
Original[2]	7.29 X	2.92 X	10.22 X	4.31 X	2.72 X	7.04 X	8.63
Recycling[2]	7.29 X	2.95 X	10.25 X	4.49 X	2.82 X	7.31 X	8.78

[1] Transparent film
[2, 3] see explanation in Table 3

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WPŁYW ŚCIÓŁKOWANIA FOLIĄ POLIETYLENOWĄ O RÓŻNYM ZABARWIENIU WYKONANĄ Z SUROWCA ORYGINALNEGO I RECYKLINGOWEGO NA MIKROKLIMAT I PLONOWANIE SAŁATY MASŁOWEJ I SELERA NACIOWEGO

Streszczenie: W latach 2005 i 2006 w Stacji Doświadczalnej w Mydlnikach koło Krakowa przeprowadzono doświadczenia dotyczące wpływu zabarwienia folii do ściółkowania i rodzaju surowca z którego została wykonana na warunki mikroklimatu oraz plon sałaty 'Melodion' i selera naciowego 'Tango'. Obiekty doświadczenia stanowiły ściółki z folii polietylenowej: bezbarwna oryginalna; bezbarwna recyklingowa; biała oryginalna; biała recyklingowa; czarna oryginalna; czarna recyklingowa. Obiektem kontrolnym były rośliny uprawiane bez ściółkowania. W uprawie sałaty na ściółce bezbarwnej temperatura była wyższa o 2,4^{o}C, a selera o 1,7^{o}C od temperatury gleby nieosłoniętej. Pod folią białą i czarną różnica nie przekraczała 1,0^{o}C. W zestawieniu średnich dwuletnich najbardziej korzystny wpływ na plonowanie obu warzyw miały ściółki czarne, następnie białe i bezbarwne.

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