ECOLOGICAL CHEMISTRY AND ENGINEERING A

Vol. 17, No. 12 2010

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EFFECT OF SHADING WITH VARIOUS COLOURED FILMS ON THE YIELD AND QUALITY OF CELERY AND BUTTERHEAD LETTUCE

WPŁYW CIENIOWANIA FOLIĄ O RÓŻNYM ZABARWIENIU NA PLON I JAKOŚĆ SELERÓW NACIOWYCH ORAZ SAŁATY MASŁOWEJ

Abstract: In 2005–2007 at the University of Agriculture in Krakow field experiments with shading with polyethylene films were carried out on medium-early celery 'Tango' cultivar and butterhead lettuce 'Melodion' cultivar.

Shadings with transparent, white and black films made from original and recycled materials were fixed on low tunnel structures on 7 days before harvesting lettuce (from 23.05.2005. and 23.05.2006, respectively) and on 10–12 days before harvesting celery (from 29.06.2005, 1.07.2006 and 25.06.2007, respectively). The best elongation growth of celery was shown under white film which also slightly increased the yield of celery stalks. In relation to yielding of celery in 2005 best effect was obtained under white film, in the next year under transparent and white film and in the last year of the experiment the yield was even in all objects with small advantage under white film. Shading lettuce with transparent film for 7 days before harvest increased the yield and soluble sugars content in plants. With the decrease of PAR permeability through films dry matter, soluble sugars and ascorbic acid content decreased in celery and lettuce. No differences were shown in the growth, quality and yield of celery and lettuce grown under films made from original and recycled materials.

Keywords: butterhead lettuce, celery, shading, polyethylene films, yield, quality

The use of shadings in vegetable production is connected with limitation of light that reaches plants. Films and non-wovens in various colours or double layers of these materials used as covers in low tunnels structures decrease permeability for PAR (*Photosynthetically Active Radiation*) by 10–70 %. Different radiation and thermal conditions under tested tunnels in sweet pepper cultivation resulted in growth decrease

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and differences in plant foliage [1]. Light access can be also limited by using additional layers of chalk and milk solutions on the tunnels' surface. Covering tunnels with extra layer of ethylene vinyl acetate film (EVA) decreased PAR transmission by 5 % and with polypropylene textile (PP) by 8 % [2]. Losses of light reaching 60 % were shown when cover made from polyester was stretched over plants [3]. In vegetable production deficit of light usually leads to yield decrease [2, 4, 5]. Initial experiments conducted in 2004 with shading celery shown that light limitation caused by black film clearly decrease dry matter and assimilation dyes content in plants [5].

The main objective of the study was to determine the effect of shading celery and butterhead lettuce with different solar permeability films on vegetative growth, marketable yield and some factors of yield quality.

Material and methods

All polyethylene films of original and recycled materials were manufactured by 'Jagapol' Film Manufacturing Facility in Krakow with the use of blow molding technology. Original films were made of Basell Orlen Polyolefins material and recycled films of high quality material originating from waste products supplied by Gumiplast company. As colouring agents white (Schulman 8160) and black (Polibatch black 1850) dyes were used.

Field experiments were conducted at Experimental Station of University of Agriculture in Krakow (Mydlniki) in 2005–2007. Trials were carried out on brown soil. After harvesting barley, field was first fertilized with phosphorus and potassium according to soil analyses and then ploughed. In the autumn of each year (2004, 2005 and 2006), the field was fertilized with 35 Mg · ha^{-1} manure, 100 kg P_2O_5 · ha^{-1} (triple superphosphate) and 200 kg K_2O · ha^{-1} (potassium chloride). In the spring, prior to planting, the field was fertilized with nitrogen, in doses of 50, 75 and 50 kg N · ha^{-1} (nitro-chalk). After the planting, only celeries were subjected to fertilization with ammonium nitrate in the dose 20 kg N · m^{-2}, following that 0.1 % lime saltpetre (2 dm^3 · m^{-2}) were used.

The work concerned a very early 'Melodion' cv. butterhead lettuce and medium-early celery 'Tango' cv. of intensively green leaves. Experiments with lettuce were carried in 2005 and 2006, with celery additionally in 2007 (due to difficulties with the interpretation of two-year results).

Lettuce seeds were sown into greenhouse on 2 March both years of the experiment. Transplants were planted on 7 April 2005 and 11 April 2006, respectively. Lettuce was harvested each year on 30 May. Celery seeds were sown on 4 February 2005, 5 February 2006 and 6 February 2007. Transplants with 4 leaves were planted on 17, 19 and 20 April and the harvest was carried out on 5, 11 and 13 July, respectively. Transplants of both species were planted into the field in 30 × 25 cm distance. Experimental plots, each of 3 m^2 (40 plants) were established in randomized blocks with four replications.

Shadings (0.1 mm thick and 2.4 m width) were fixed on the tunnel structure of 1.5 (width) × 1 m (height) × 10 m (length) and to assure air circulation in tunnels film

reached only to 30 cm above soil surface. Lettuce was shading a week before harvest (23 May 2005 and 25 May 2006, respectively) and celery 10–12 days before harvest (29 June 2005, 1 July 2006 and 25 June 2007, respectively).

Treatments were made by various kinds of films used in shading:

1. control (without film),
2. transparent film from original material,
3. transparent film from recycled material,
4. white film from original material,
5. white film from recycled material,
6. black film from original material,
7. black film from recycled material.

Yield was determined in the area of 1 m^2 based on four replications including standards for celery: PN-R-75512 and butter lettuce PN-R-7522.

In order to determine dry matter content, samples of plant material were dried at 92–95 ^oC, total sugars were determined using antrone reagent method and L-ascorbic acid with Tillman's method. Results were processed statistically with Newmann-Keuls test, using STATISTICA program at a significance level of $p = 0.05$.

Results and discussion

As shown earlier [5], the transmittance of radiation through PE film differed considerably. The laboratory measurements indicated that the transmittance of radiation within the ranges of λ = 400–700 nm and χ = 700–1100 nm differed depending on the tested cover. The highest transmittance was through transparent film: 87.1 % and 86.2 % in the above ranges, respectively. White film had very low transmission within these ranges (21.2 % and 33.6 %, respectively) and black film did not let the radiation at all [5].

The measurements of morphological parameters of plants showed a significant effect of shadings on the vegetative growth of celery. Shading in final cultivation stage caused that celery grown under white film, in all three years of the experiment, were higher than other ones (Table 1). Plants grown under black film – where access of light was very low – were not much higher than control plants. Similar dependence was demonstrated with the length of the stalks. No differences in number of leaves were observed. No statistically important differences were shown in the growth of celery cultivated under films made from recycled and original materials.

In relation to yielding in 2005 best effect was obtained under white film, in the next year under transparent and white film and in the last year of the experiment the yield was even in all objects with small advantage under white film (Table 2). Mean values indicated that increase of marketable yield was obtained when shading with white and transparent films were used. It was shown that black film decreased growth and yield, which was smaller than the yield obtained from the control. No differences were shown in the yield of celery cultivated under films made from recycled and original materials.

In sweet pepper production coloured non-woven limited solar radiation considerably and reduced soil temperature which resulted in differences in vegetative growth, poorer

Table 1

The effect of kind of plastic film used for shadings on the growth of celery in 2005–2007

Kind of plastic film	2005			2006			2007			Mean 2005–2007		
	Height of plant [cm]	Length of stalk [cm]	Number of stalks per plant	Height of plant [cm]	Length of stalk [cm]	Number of stalks per plant	Height of plant [cm]	Length of stalk [cm]	Number of stalks per plant	Height of plant [cm]	Length of stalk [cm]	Number of stalks per plant
Control (without film)	51.4 aA [2]	25.5 bA	10.0 abA	41.2 aA	17.5 aA	10.4 a	47.4 aA	25.3 abA	9.8 aA	46.7	22.8	10.0
Transparent original	58.3 cd	27.3 bc	9.5 a	53.5 c	22.4 b	12.3 b	50.5 a	24.8 ab	10.5 a	54.1	24.8	10.8
Transparent recycled	56.2 bc	26.6 bc	9.5 a	52.3 c	21.7 b	12.4 b	46.6 a	26.0 ab	9.8 a	51.7	24.8	10.6
Mea for transparent	57.2 B	26.9 B	9.5 A	52.9 C	22.0 B	12.3 B	48.5 A	25.4 B	10.2 A	52.9	24.8	10.7
White original	58.3 cd	28.1 c	9.6 a	58.0 d	21.7 b	12.4 b	55.2 b	26.8 b	10.5 a	57.2	25.5	10.8
White recycled	60.2 d	27.8 bc	10.1ab	54.2 c	23.0 b	12.7 b	55.4 b	26.2 ab	10.0 a	56.6	25.7	10.9
Mean for white	59.2 B	27.9 B	9.8 AB	56.1 D	22.3 B	12.5 B	55.3 B	26.5 B	10.2 A	56.9	25.6	10.8
Black original	49.7 a	23.1 a	10.3 b	46.6 b	18.6 a	11.7 ab	47.4 a	23.7 a	10.2 a	47.9	21.8	10.7
Black recycled	54.9 b	25.9 bc	10.3 b	46.5 b	18.0 a	12.5 b	48.0 a	23.4 a	10.5 a	49.8	22.4	11.1
Mean for black	52.3 A	24.5 A	10.3 B	46.5 B	18.3 A	12.1 B	47.7 A	23.6 A	10.4 A	48.8	22.1	10.9
Original [1]	55.4 X	26.2 X	9.8 X	52.7 X	20.9 X	12.1 X	50.1 X	25.2 X	10.3 X	52.7	24.1	10.7
Recycled [1]	57.1 X	26.8 X	10.0 X	51.0 X	20.9 X	12.5 X	49.4 X	25.2 X	10.1 X	52.5	24.3	10.9

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

Table 2

The effect of kind of plastic film used for shadings on the marketable yield of celery [kg · m^{-2}] in 2005–2007

Kind of film	2005			2006			2007			Mean for stalks + blades
	stalks	blades	stalks + blades	stalks	blades	stalks + blades	stalks	blades	stalks + blades	
Control (without film)	2.72 abA [2]	1.71aA	4.43 abA	3.41 abA	2.19 aA	5.60 aA	4.25 aA	2.36 aB	6.62 aA	5.55
Transparent original	2.31 a	1.64 a	3.95 a	4.61 b	2.54 a	7.15 a	4.29 a	2.14 a	6.44 a	5.85
Transparent recycled	2.86 ab	1.82 ab	4.68 b	4.02 ab	2.33 a	6.34 a	4.10 a	2.01 a	6.11 a	5.71
Mean for transparent	2.58 A	1.73 A	4..31 A	4.31 B	2.43 A	6.75 B	4.20 A	2.08 AB	6.27 A	5.78
White original	2.91 ab	1.90 b	4.81 b	4.12 ab	2.38 a	6.50 a	4.44 a	2.16 a	6.61 a	5.97
White recycled	3.60 b	1.79 ab	5.39 c	3.62 ab	2.38 a	6.00 a	4.84 a	2.23 a	7.08 a	6.16
Mean for white	3.25 B	1.85 B	5.10 B	3.87 AB	2.38 A	6.25 AB	4.64 A	2.20 AB	6.84 A	6.06
Black original	2.72 a	1.35 a	4.07 a	3.27 a	2.21 a	5.47 a	4.30 a	1.96 a	6.26 a	5.27
Black recycled	2.43 a	1.41 a	3.84 a	3.45 ab	2.08 a	5.53 a	4.30 a	1.96 a	6.26 a	5.21
Mean for black	2.57 A	1.38 A	3.95 A	3.36 A	2.14 A	5.50 A	4.30 A	1.96 A	6.26 A	5.23
Original [1]	2.65 X	1.63 X	4.28 X	4.00 X	2.38 X	6.37 X	4.34 X	2.09 X	6.44 X	5.70
Recycled [1]	2.96 X	1.67 X	4.64 X	3.70 X	2.26 X	5.96 X	4.41X	2.07 X	6.48 X	5.69

Explanation: as in Table 1.

foliage and losses flower and fruit sets. The microclimate conditions under tested covers affected the yield significantly. The early yield under tunnels covered with PE films was considerably higher than under non-woven tunnels. When air temperature was high plants grown under non-woven covers had better growing and yielding conditions. Here the radiation and thermal conditions were much better which resulted in better and higher yield [1]. Lower yield, delay in growth and development as a result of shading were obtained in cucumber [2], pepper [3] and tomato [4]. In presented experiment deficit of light under black film resulted in smaller plants and shorter stalks of celery than these obtained from transparent and white film (Table 2). The single plant weight decreased simultaneously with the decrease of PAR permeability through films. Plant weight and length of stalks were significantly higher under transparent and white film in comparison with control.

Preharvest plant shading significantly modified some factors of biological value in stalks (Table 3). In the first two years of the experiment the highest content of ascorbic acid and dry matter was found in control plants, and in the last year of the experiment in the stalks grown under transparent film. Celery cultivated under transparent film had the highest content of soluble sugars in 2007 and in the year before. Shading with black film regardless of the material the film was made from, caused a significant decrease of ascorbic acid, dry matter and soluble sugars content.

Shading lettuce during 7 days before harvest with different coloured films demonstrated that yield depended on light permeability through shadings (Table 4). In 2005 great difference between yield obtained from control and from shading plants was observed. Because of the cool spring that year all shadings increased mast of plants. The highest marketable yield was obtained from stands shading with white and transparent film. Significantly higher was also yield from black film in comparison with the control. In the following year, similar tendencies were observed particularly in the case of transparent film. Significantly lower yield was obtained from lettuce grown under black film. Mean values from two years of the experiment show that the main cause for the obtained dependences is the inducting effect of light on lettuce's mass. Bad light conditions even for a short period of time can significantly decrease yield. The type of material the film was made from had no effect on yielding. Similar dependences were observed as far as the content of soluble sugars in butterhead lettuce is concerned. The highest content of soluble sugars was found in control and in plants grown under transparent film, the lowest in plants from black film. The content of ascorbic acid was changeable in each object only in 2005 small differences have been shown in plants grown under black and white films in relation to other treatments. This fact might have been connected with plants' reaction to light stress. The highest content of dry matter in 2005 was demonstrated in plants grown under transparent film and in the following year under white film and in non-covered plants. The kind of material shading films were made from had no significant effect on ascorbic acid and dry matter content in lettuce leaves. It was demonstrated that in the second year of the experiment the content of soluble sugars was slightly modified by the kind of materials from which films were made.

Table 3

The effect of kind of plastic film used for shading on ascorbic acid, soluble sugars, and dry matter content in celery stalks in 2005–2007

Kind of film	Ascorbic acid [mg · 100 g^{-1} f.m.]			Soluble sugars [mg · 100 g^{-1} f.m.]			Dry matter [%]		
	2005	2006	2007	2005	2006	2007	2005	2006	2007
Control (without film)	10.47 eC [2]	18.20 dD	13.10 dC	0.90 eD	1.37 bC	1.31 cdB	6.01 dC	9.50 dD	7.73 cC
Transparent original	9.10 d	12.63 bc	14.03 e	0.84 d	1.55 c	1.64 f	5.42 c	7.03 c	8.51 e
Transparent recycled	8.70 d	13.07 c	13.10 d	0.79 d	1.79 d	1.54 e	5.33 c	7.02 c	7.99 d
Mean for transparent	8.90 B	12.85 C	13.57 D	0.81 C	1.67 D	1.59 C	5.37 B	7.02 C	8.25 D
White original	8.00 c	10.10 a	11.00 c	0.69 c	0.97 a	1.37 d	4.61 b	5.16 a	6.81 b
White recycled	7.30 b	12.20 b	10.53 c	0.67 c	1.63 c	1.22 c	4.72 b	7.01 c	6.76 b
Mean for white	7.60 A	11.15 B	10.77 B	0.68 B	1.30 B	1.30 B	4.66 A	6.09 B	6.78 B
Black original	8.90 d	9.50 a	6.43 a	0.61 b	0.94 a	0.69 a	4.78 a	5.45 ab	5.30 a
Black recycled	6.23 a	9.90 a	7.37 b	0.49 a	0.94 a	0.79 b	4.93 a	5.89 b	5.32 a
Mean for black	7.56 A	9.70 A	6.90 A	0.55 A	0.94 A	0.74 A	4.52 A	5.67 A	5.31 A
Original [1]	8.67 Y	12.60 X	11.14 X	0.71 X	1.21 X	1.25 X	4.78 X	6.78 X	7.09 Y
Recycled [1]	7.41 X	13.34 Y	11.02 X	0.65 X	1.43 Y	1.22 X	4.93 X	7.35 Y	6.95 X

Explanation: as in Table 1.

Table 4

The effect of kind of plastic film used for shading on the yield and content of some quality indices in lettuce leaves in 2005–2006

Kind of film	Yield [kg · m^{-2}]			Soluble sugars [%]		Ascorbic acid [mg · 100 g^{-1} f.m.]		Dry matter [%]	
	2005	2006	Mean	2005	2006	2005	2006	2005	2006
Control (without film)	2.35 aA[2]	5.13 abB	3.74	1.14 bB3	1.08 bC	25.70 dC	19.63 bcA	4.74 eB	5.38 cC
Transparent original	4.74 b	6.26 c	5.50	1.27 b	1.25 c	20.26 c	16.40 a	4.79 e	4.69 a
Transparent recycled	4.16 b	6.12 c	5.14	1.22 b	1.10 b	18.50 bc	21.00 c	5.23 f	5.08 b
Mean for transparent	4.45 C	6.19 C	5.32	1.24 B	1.17 D	19.38 C	18.68 A	5.01 C	4.87 A
White original	4.54 b	4.74 a	4.64	0.81 ab	1.07 b	15.33 a	20.07 bc	3.98 b	5.88 d
White recycled	4.27 b	5.73 bc	5.00	0.50 a	0.76 a	16.70 ab	19.60 bc	4.33 c	5.16 b
Mean for white	4.41 C	5.24 B	4.82	0.65 A	0.92 B	16.01 A	19.83 A	4.15 A	5.52 D
Black original	3.09 a	4.29 a	3.69	0.58 a	0.71 a	17.60 b	20.07 bc	3.75 a	5.10 b
Black recycled	3.07 a	4.72 a	3.89	0.85 ab	0.73 a	17.59 b	17.80 ab	4.52 d	5.34 c
Mean for black	3.08 B	4.50 A	3.79	0.71 A	0.72 A	17.59 B	18.25 A	4.13 A	5.22 B
Original [1]	3.68 X	5.11 X	4.39	0.89 X	1.03 Y	17.73 X	18.70 X	4.17 X	5.26 X
Recycled [1]	3.47 X	5.44 Y	4.45	0.86 X	0.92 X	17.59 X	19.50 X	4.69 X	5.24 X

Explanation: as in Table 1.

Conclusions

1. The best elongation growth of celery was shown under white film which also slightly increased the yield of celery stalks.

2. Shading lettuce with transparent film for 7 days before harvest increased the yield and soluble sugars content in plants.

3. In celery and in butterhead lettuce with the decrease of PAR permeability through films content of dry matter, soluble sugars and ascorbic acid in general also decreased.

4. No differences were shown in the growth, quality and yield of celery and lettuce grown under films made from original and recycled materials.

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WPŁYW CIENIOWANIA FOLIĄ O RÓŻNYM ZABARWIENIU NA PLON I JAKOŚĆ SELERÓW NACIOWYCH ORAZ SAŁATY MASŁOWEJ

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Abstrakt: W latach 2005–2007 wykonano w Uniwersytecie Rolniczym w Krakowie doświadczenia polowe z cieniowaniem folią polietylenową roślin selerów naciowych odm. ‘Tango’ i sałaty masłowej odm. ‘Melodion’. Cieniowanie folią bezbarwną, białą i czarną, wyprodukowaną z surowców oryginalnych i recyklingowych w przypadku sałaty wykonywano na tydzień przed zbiorem (odpowiednio od 23.05.2005 r. i 23.05.2006 r.), a w przypadku selerów 10–12 dni przed zbiorem (odpowiednio od 29.06.2005 r., 1.07.2006 r. i 25.06.2007 r.).

Wzrost elongacyjny selera naciowego był najsilniejszy pod folią białą, która powodowała także nieznaczne zwiększenie plonu ogonków liściowych. Pod względem plonowania w 2005 r. najlepszy wynik uzyskano pod folią białą, w kolejnym pod bezbarwną i białą, a w ostatnim plon był wyrównany we wszystkich obiektach, z niewielką przewagą obiektów, w których stosowano folię białą. Cieniowanie roślin sałaty bezbarwną folią na tydzień przed zbiorem spowodowało wzrost plonu oraz zawartości cukrów rozpuszczalnych. Wraz ze zmniejszaniem przepuszczalności folii dla promieniowania fotosyntetycznie czynnego, zawartość suchej masy, cukrów i kwasu askorbinowego w selerach i sałacie zmniejszała się. Rodzaj surowca stosowanego do produkcji folii nie miał wpływu na wzrost, plonowanie i jakość selerów i sałaty.

Słowa kluczowe: sałata masłowa, seler naciowy, cieniowanie, folia polietylenowa, plon, jakość