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THE EFFECT OF BLACK POLYETHYLENE MULCH ON YIELD OF FIELD-GROWN CUCUMBER

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Abstract. Cucumber is one of the most popular vegetables in Poland. This vegetable species is characterised by high requirements in terms of soil temperature and moisture. The utilization of polyethylene mulch in combination with drip irrigation has played a major role in the increases in production of cucumber. The benefits associated with the use of this cultivation method include earlier and higher yields, reduced soil evaporation, reduced weed populations, reduced fertilizer leaching, greater water use efficiency, reduced soil compaction, control of certain pests, and cleaner harvested product. In years 2002, 2003 and 2005 experiments were conducted to study the impact of soil mulching with black polyethylene on Akord F_1 cucumber yields. Plants were cultivated on sandy loam soil using irrigation and fertigation applied with the assistance of drip lines. No significant differences were observed in levels of total and marketable yields of fruits as well as in dry matter and total carbohydrate contents in fruits obtained from plants cultivated in mulched and unmulched soils. Irrigation efficiency, on the soil mulched with black polyethylene was higher than on the soil without mulching.

Key words: *Cucumis sativus* L., fruit yield, dry matter, sugar content, irrigation efficiency

INTRODUCTION

Polyethylene mulch has been used in vegetable production for enhancement of earliness in yield, weed control, reduction of nutrient loss by leaching, and favorable soil temperature and moisture [Bhella and Kwolek 1984, Sweeney et al. 1987, Bhella 1988]. Soil water does not escape from under polyethylene mulch. Plant growth on mulch is often at least twice that on bare soil. The resulting larger plants will require more water, so mulching is not a substitute for irrigation. Water supply to plants cultivated under plastic is possible only by drip irrigation. Polyethylene mulch and drip

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irrigation will increase cost of production. These costs should be offset by increased income due to earlier harvests, better quality fruit and higher yields. Kaniszewski [1997], has shown the highest yield of cucumber from transplant when black polyethylene mulching and drip irrigation were applied. Drip irrigation is also a very good solution for combining fertilisation with irrigation, or, in other words, fertigation. By employing fertigation, it is possible to adjust doses and times of fertiliser application to the actual requirements of plants, thus increasing yields, decreasing fertiliser consumption and limiting unfavourable effects of environmental factors on plants [Hartz and Hochmuth 1996]. Polyethylene mulching, in combination with drip irrigation and frequent injection of nutrients, can be used in the irrigation system (fertigation) to enhance water and nutrient use efficiency [Bowen and Frey 2002].The beneficial influence of drip irrigation and fertigation on the yield and quality of cucumbers cultivated in the field was reported by Güler and Ibrikci [2002].

The aim of the investigation was to evaluate the effect of mulching with black polyethylene by drip irrigation and fertigation on the yield and fruit quality of field-grown cucumber.

MATERIALS AND METHODS

The research was carried out in years 2002, 2003 and 2005. The experiment was set up in a random block system, in four replicates, with one factor having two distinctive levels: black polyethylene-mulched and bare (unmulched) soil. Plants were irrigated and fertigated by Aqua-traxx drip lines made by Toro, with drippers spaced at a distance of 20 cm and a capacity of 0.57 $dm^3 \cdot h^{-1}$.

The investigations were carried out on a sandy loam soil. The pH of the soil was 6–6.5. Rye was the forecrop for cucumber. In the second half of April, ploughing was carried out to a depth of approx. 20 cm. Cucumber plants of cv. Akord F_1 were grown from two-week-old transplants, planted in the field at a spacing of 120 × 15 cm in the last ten days of May. The area of each experimental plot was 10.8 m^2 (3,6 × 3 m). One-week before planting, black polyethylene mulch (0.6 m wide by 0.15 mm thick) and drip lines were laid.

Plant irrigation was conducted on the basis of the water potential in the soil. The measurements of the potential were taken by means of automatic RA tensiometers produced by Irrometer, which allowed irrigation to start when the value of the water potential in the soil was equal to or less than -20 kPa. The tensiometers were placed in the soil along the rows of plants, with their ceramic tips at a depth of 15–20 cm. A single water dose amounted to 10 mm.

Mineral components of the soil were supplemented to the following levels (in $mg \cdot dm^{-3}$): N – 120, P – 80, K – 220. The mineral content of the soil before fertilisation is presented in table 1. Before planting, the full dose of phosphorus, 75% of the dose of potassium, and 50% of the dose of nitrogen were applied. In 2003 and 2005, the phosphorus content in the soil was high, therefore fertilisation with phosphorus was not applied. The remaining parts of nitrogen and potassium were applied by fertigation. Plants were fertigated using a fertiliser solution delivered by another drip line which was laid out on the opposite side in relation to the line intended for irrigation. Both irrigation and fertigation drip lines were placed on the surface. Fertigation started when cucumber plants had produced three proper leaves and it was applied four times at weekly intervals. The nitrogen dose to be delivered via fertiliser solution was divided into four equal parts, and the potassium dose was divided into two equal parts that were used together with the third and the fourth parts of the nitrogen dose. Fertigation was carried out irrespective of the water potential in the soil. A single dose of a fertiliser solution was 10 mm.

Table 1. The mineral element content ($mg \cdot dm^{-3}$) in the soil before fertilization
Tabela 1. Zawartość składników mineralnych ($mg \cdot dm^{-3}$) w glebie przed nawożeniem

Year – Rok	$N\text{-}NO_3^-$	P	K	Ca	Mg
2002	7	33	70	480	38
2003	1	114	110	470	52
2005	11	153	150	796	77

The protection of plants against weeds, diseases and pests was conducted according to the current recommendations.

In the irrigation system used in the experiment, water meters made by Metron had been installed with the aim of measuring the amount of water used for watering cucumber plants. Using the data comparing yield and water consumption, the efficiency of irrigation was calculated, or, in other words, fruit yield obtained as a result of application of 1 mm of water.

Throughout the research period, harvests of cucumber fruit were conducted three times a week, from the beginning of July to the beginning of September. All the fruits whose length exceeded 6 cm were harvested. During harvest, the sizes of the total and marketable yields were determined. All the harvested fruits constituted the total yield. The marketable yield included, in accordance with the Polish standard PN-85/R-75359, healthy fruits of a regular shape, without disease symptoms, no mechanical damage and no evidence of damage caused by pests or plant protection products. Marketable fruits were graded according to the above-mentioned standard into the following three classes: pickling grade: 6–10 cm long with a diameter of 2.5–4.5 cm, pickling grade: 9–15 cm long with a diameter of 4.5–5.5 cm, and salad cucumbers with a length of 12–20 cm.

After four weeks of harvesting, dry matter content and total carbohydrates in cucumber fruits were determined. For this purpose, a sample of 0.5 kg of fruits was taken from each plot. The dry matter content was determined using the gravimetric method after drying at the temperature of 105°C, and the total carbohydrate content – with the Lane-Eynon method.

The results obtained were analysed statistically. An analysis of variance was carried out, and the significance of differences between the investigated features were determined using Newman-Keuls test at a significance level of $\alpha = 0.05$. The significance of the influence of the years and black polyethylene mulch on fruit quality was determined with the use of F test.

RESULTS AND DISCUSSION

The performed synthesis from three years of investigations revealed that the size of total and marketable yields was affected only by years, while the dry matter content in cucumber fruits was impacted by this factor to a lesser extent (tab. 2). On the other hand, soil mulching as well as the interaction of years and soil mulching failed to exert noticeable effect on the level of total and marketable yield and the content of dry matter in cucumber fruits. In addition, years, mulching and the interaction between them also failed to exert a significant impact on the total sugar content in cucumber fruits.

Table 2. Analysis of significance of years and black polyethylene mulch on total and marketable yields as well as on dry matter and total carbohydrates content in cucumber fruit
Tabela 2. Analiza istotności wpływu lat oraz ściółkowania gleby czarną folią na wielkość plonu ogólnego i handlowego, zawartość suchej masy i cukrów ogółem w owocach ogórka

Variance source Źródło zmienności	F			
	Total yield Plon ogólny	Marketable yield Plon handlowy	Dry matter content in fruit Zawartość suchej masy w owocach	Total carbohydrates content in fruit Zawartość cukrów ogółem w owocach
Year Rok	48.83*	39.50*	4.01*	0.18
Mulching Ściółkowanie	1.42	0.98	0.73	2.05
Interaction: year × mulch Interakcja: rok × ściółkowanie	0.25	0.22	1.89	0.01

* differences significant at α = 0.05
różnice istotne przy α = 0,.05

In all years of investigations, higher total and marketable yields were recorded from plants cultivated on soil mulched with black polyethylene than from plants growing on unmulched soil (figs. 1, 2), although differences in yield levels were small, of 0.4–10% order, and were not statistically significant. Nevertheless, higher cucumber yields from plants cultivated in soil mulched with black polyethylene in comparison with yields from plants cultivated in soil without mulching were reported, among others, by: Libik [1976], Dobromilska et al. [1995], Ruppel and Makswitat [1996], Siwek and Kunicki [1998], Lorenzo et al. [2001], Siwek [2002] as well as Ibarra-Jimenez et al. [2008]. According to Lipiński and Lipińska [1984], favourable effects of mulching with black polyethylene on cucumber yields were apparent in the case of early sowing. When plants were sown later, their response to mulching was much weaker. Kaniszewski [1997] showed that black polyethylene mulching combined with drip irrigation increased marketable cucumber yield grown from transplants but had either no impact or even reduced yields of cucumbers cultivated from sowing. Other vegetables responded in different ways to soil mulching. Diaz-Perez [2009] reported that when broccoli was cultivated in soil mulched with black polyethylene, in some years it responded well to such treatment, while in others, no differences in yields were observed between plants grown in mulched and unmulched soils. Yields of muskmelon cultivated in mulched soil were significantly higher in comparison with plants grown in unmulched soil [Ibarra et al. 2001], whereas yields of drip-irrigated cabbage cultivated in soil covered with black polyethylene were by about 5% higher when compared with cabbage which was also drip-irrigated but grown in unmulched soil [Tiwari et al. 2003].

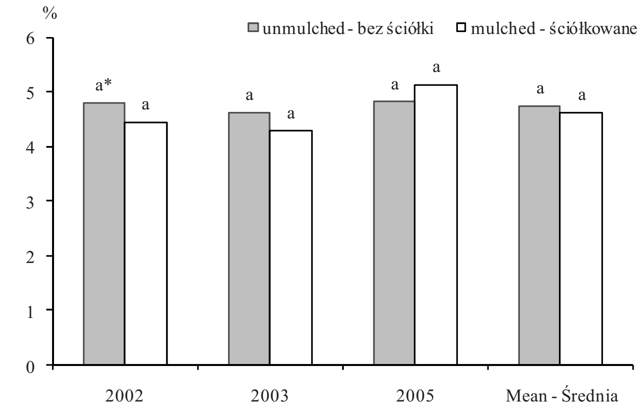
* Means followed by the same letter, in each year, are not significantly different at $\alpha = 0.05$
Średnie oznaczone tymi samymi literami, w poszczególnych latach, nie różnią się istotnie przy $\alpha = 0,05$

Fig. 1. Effect of black polyethylene mulch on total cucumber yield
Ryc. 1. Wpływ ściółkowania gleby czarną folią na wielkość plonu ogólnego ogórka

* see fig. 1 – patrz ryc. 1

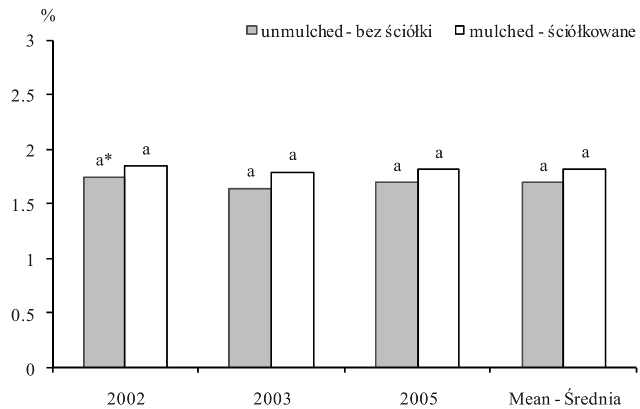
Fig. 2. Effect of black polyethylene mulch on cucumber marketable yield
Ryc. 2. Wpływ ściółkowania gleby czarną folią na wielkość plonu handlowego ogórka

In all years of experiments, no significant impact of soil mulching on the content of dry matter and total sugars in cucumber fruits was recorded (figs. 3, 4), although fruits obtained from plants cultivated in mulched soil were characterized by a slightly higher sugar concentration. In years 2002–2003, dry matter content was found higher in fruits obtained from plants grown in unmulched soil, whereas in 2005 – in cucumber plants cultivated in mulched soil.



* see fig. 1 – patrz ryc. 1

Fig. 3. Effect of black polyethylene mulch on dry matter content in cucumber fruit
Ryc. 3. Wpływ ściółkowania gleby czarną folią na zawartość suchej masy w owocach ogórka



* see fig. 1 – patrz ryc. 1

Fig. 4. Effect of black polyethylene mulch on total carbohydrate content in cucumber fruit
Ryc. 4. Wpływ ściółkowania gleby czarną folią na zawartość cukrów ogółem w owocach ogórka

In all years of experiments, less water was used for the irrigation of cucumbers cultivated in soil mulched with black polyethylene than for the irrigation of cucumbers grown in unmulched soil (tab. 2). At the absence of significant differences in yields, it resulted in better irrigation effectiveness in mulched than in unmulched soil. Better drip irrigation efficiency of cucumber cultivated in soil mulched with black polyethylene than in unmulched soil at the absence of differences in yields was reported by Kaya et

Table 3. Amount of rainfall and irrigation as well as efficiency of irrigation of field-grown cucumber
Tabela 3. Suma opadów i nawadniania oraz efektywność nawadniania ogórka gruntowego

Specification Wyszczególnienie	Mulch Ściółka	2002	2003	2005	Mean Średnia
Rainfall sum in the period 21st May – 31st August (mm) Suma opadów atmosferycznych w okresie od 21 V do 31 VIII (mm)	-	170	184	150	168
Sum of irrigation in the period 21st May – 31st August (mm) Suma nawadniania w okresie od 21 V do 31 VIII (mm)	black polyethylene czarna folia	220	92	111	141
	unmulched bez ściółki	248	151	162	187
Irrigation efficiency ($t \cdot ha^{-1} \cdot mm^{-1}$) Efektywność nawadniania ($t \cdot ha^{-1} \cdot mm^{-1}$)	black polyethylene czarna folia	0.34	0.32	0.27	0.31
	unmulched bez ściółki	0.30	0.24	0.22	0.25

al. [2005]. On the other hand, Kirnak and Demirtas [2006] obtained both higher marketable fruit yields and better irrigation effectiveness for mulched than for unmulched soil.

CONCLUSIONS

1. Significant variability was observed in yields of cucumber fruits in individual years of investigations.
2. Soil mulching with black polyethylene did not exert a significant influence on levels of total and marketable yields of cucumber fruits as well as on the dry matter and total sugar contents in fruits.
3. Drip irrigation effectiveness of cucumber cultivated in the soil mulched with black polyethylene was higher than of cucumber grown in the unmulched soil.

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WPŁYW ŚCIÓŁKOWANIA GLEBY CZARNĄ FOLIĄ NA PLONOWANIE OGÓRKA GRUNTOWEGO

Streszczenie. Ogórek jest jednym z najbardziej popularnych warzyw w Polsce. Gatunek ten charakteryzuje się między innymi wysokimi wymaganiami w stosunku do temperatury i wilgotności gleby. Ściółkowanie gleby w połączeniu z nawadnianiem kroplowym może być dobrym rozwiązaniem dla spełnienia tych wymagań. Korzyści wynikające z takiego sposobu uprawy to: wcześniejszy i większy plon, zmniejszone parowanie gleby i wymywanie składników pokarmowych, a co za tym idzie – większa efektywność nawadniania i nawożenia, mniej chwastów na plantacji, mniejsze zbicie gleby, możliwość zmniejszenia stosowania pestycydów i czystsze produkty. W latach 2002, 2003 i 2005 przeprowadzono badania dotyczące wpływu ściółkowania gleby czarną folią polietylenową na plonowanie ogórka gruntowego odmiany Akord F_1. Rośliny były uprawiane na glebie piaszczysto-gliniastej, z zastosowaniem nawadniania i fertygacji, prowadzonych przy użyciu linii kroplujących. Nie stwierdzono istotnych różnic w wielkości plonu ogólnego i handlowego owoców oraz zawartości suchej masy i cukrów w owocach z roślin uprawianych na glebie ściółkowanej i bez ściółki. Efektywność nawadniania na glebie ściółkowanej czarną folią była większa niż na glebie nieściółkowanej.

Słowa kluczowe: *Cucumis sativus* L., plon owoców, sucha masa, zawartość cukrów, efektywność nawadniania

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