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EFFECT OF DIFFERENT MULCHES ON THE THERMAL SOIL CONDITIONS AND ON THE YIELD OF SWEET PEPPER IN THE OPEN FIELD

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A b s t r a c t. During the three-year study, the suitability of several mulches (tree bark, sawdust of pine-trees, black polyethylene, perforated black polyethylene and nonwoven) for cultivation of sweet pepper in the open field was evaluated. On the basis of daily measurements (at 8 a.m. and at 2 p.m.) of soil temperature, sums of the soil temperature during the pepper vegetation period (June-September) were calculated and compared for the tested mulches and bare soil.

A positive effect of the mulches on the soil temperature was shown. The highest increase in temperature (at 8 a.m. and at 2 p.m.) were noted underneath the synthetic mulches (black polyethylene) while the organic mulches favourably affected the increase of the soil temperature in the morning. Statistically significant effect of mulching the soil with synthetic materials on the sweet pepper yield was shown.The highest mean marketable fruit yield was obtained from the plots mulched with perforated black polyethylene (4.1 kg/m^2), with black polyethylene (3.9 kg/m^2) and with nonwoven (3.7 kg/m^2), compared to the bare soil (3.3 kg/m^2) and to the soil mulched with bark (3.2 kg/m^2) and with pine-trees sawdust (3.0 kg/m^2).

K e y w o r d s: mulches, thermal soil conditions, sweet pepper, fruit yield

INTRODUCTION

Sweet pepper *(Capsicum annuum* L.) is a thermophilous vegetable of high environment requirements. In our climatic conditions, temperature of the air and of the soil surrounding the root system are important conditions deciding about the yield of this species in the open field. A significant improvement of the environmental conditions can be achieved through soil mulching, which is advantageous to the temperature and moisture of the soil and which also limits weed intensity [1-5,7,9,11-13].

This study was conducted to evaluate the effects of soil mulching with different materials on soil temperature and on sweet pepper yield in the open field.

MATERIALS AND METHODS

The experiment was carried out in the years 1992-1994 in Krasnystaw (Chełm voivodeship) on soils derived from loess and loess-like formations, containing 2.0-2.7 % of humus in a surface 0-20 cm thick layer. The material of investigation was sweet pepper cultivar Mira (breeded at the Horticultural Plant Breeding Station Igołomina). Two different types of mulches were used:

- organic (tree bark and pine-trees sawdust)
- synthetic (black polyethylene, perforated black polyethylene and nonwoven).

Bare soil was control object. Black polyethylene (0.03 mm), perforated black polyethylene (100 perforates per m^2) and black nonwoven 'Covertan' were used for mulching. In every year preceding the experiment, bark and sawdust were composted and enriched with nitrogen (N-2 g/dcm^3). The synthetic mulches were laid before transplanting pepper,

whereas bark and sawdust were laid (10 cm thick layer) directly after planting.

In the autumn, manure was applied in a dose of 30 t/ha in the field where pepper was cultivated. Mineral fertilization was applied on the basis of chemical analysis of the soil. The content of nutrients was brought to the level N-200, P-90, K-130 kg/ha. Top dressing was applied to pepper leaves as follows: twice Agrosol NMgFe (1 % solution) and twice lime saltpetre (1 % solution).

Transplants were prepared in a greenhouse of the Agricultural Experimental Station in Lublin-Felin, according to generally accepted principles for this vegetable. The plants were transplanted in the ground from the 1st to the 5th of June with a spacing of 40x50 cm. The experiment was set according to the method of randomized blocks, in four replicates. Each replicate included 20 plants, the area of the field was 4 m^2 (2.5x1.6 m). Data on the pepper cultivation are given in Table 1.

Table 1. Calendar of sweet pepper cultivation in the years 1992-1994

Cultivation stage	Date		
	1992	1993	1994
Sowing	13.03	15.03	14.03
Sprouting	27.03	31.03	29.03
Planting of seedlings	06.04	08.04	05.04
Bedding out of plants	02.06	05.06	01.06
First fruit harvest	06.08	14.08	04.08
End of vegetation	05.10	09.10	10.10

The temperature was measured every day at 8 a.m. and 2 p.m. between the 1st of June and the 30th of September using the thermometer PT-217, electrodes of which were immovably installed at 10 cm soil depth. On the basis of the measurement results, sums of soil temperatures (at 8 a.m. and 2 p.m.) for a period of pepper vegetation (June-September) on 5 different mulches and on bare soil were calculated and compared. Every day at 11.30 a.m., PAR (Photosynthetically Active Radiation) was measured 50 cm above the bare soil using the fitfotometer FF-01. Pepper fruit (cultivar Mira) were harvested at a technical maturity stage, separately for each replicate. A total fruit yield, a marketable fruit yield and an early fruit yield (marketable fruit yield from the 1st and the 2nd harvests) and also the number of total and marketable fruit were calculated.

After the research, the results of the yield of sweet pepper cultivated on the soil mulched with different materials and on the unmulched soil were statistically elaborated according to single classification system for orthogonal data by means of the method of variance analysis. The significance of the differences was evaluated by means of the method of T-Tukey's confidence intervals at 5 % confidence level.

RESULTS

Sums of the mean twenty-four-hour air temperature for a pepper vegetation period indicate that the most favourable thermal conditions were in 1992 (2189 °C) and in 1994 (2173 °C), whereas the year 1993 was definitely cooler (1843 °C) and less favourable to the pepper yield (Fig. 1). Thermal conditions of the soil correlated strictly with the temperature of the air. The investigated mulches had a favourable effect on the soil temperature. In the morning (8 a.m.) the soil temperature underneath all the mulches was higher than on the bare soil. The most significant effect of the mulches on the increase of the soil temperature in the morning was noticed in 1993, when the weather conditions were less favourable.

In the afternoon (2 p.m.), the mulches affected the soil temperature differently. Temperatures underneath the organic mulches were lower than in the bare soil. Tree bark and

sawdust of pine-trees created an isolation barrier from the sun rays and prevented the soil from heating. A high increase in temperature was noted under the black polyethylene mulch in the years 1992 and 1993, and under non-woven only in 1993. During the drought of 1994 (Fig. 2) the soil temperature under the synthetic mulches in the afternoon was also lower than that of the unmulched soil. With very high air temperatures for our climate, it indicates that the synthetic mulches can also prevent from overheating of the soil.

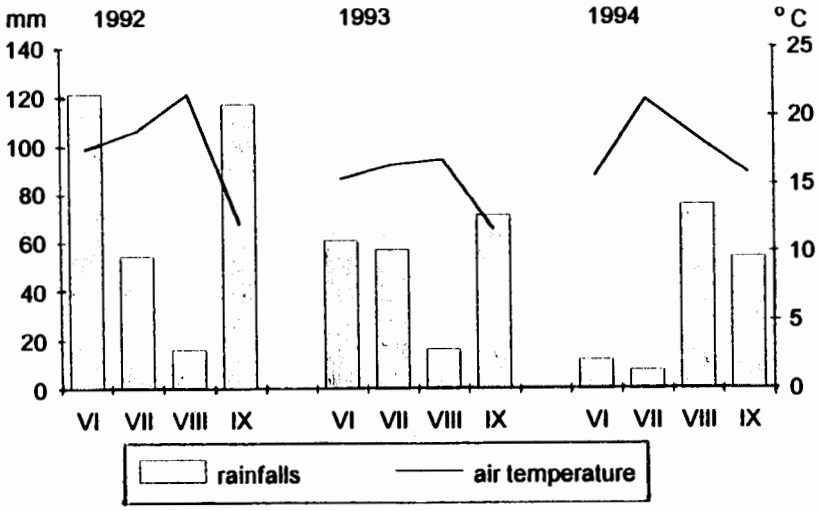

Fig. 1. Rainfalls and mean twenty-four-hour air temperature during the vegetation period of sweet pepper.

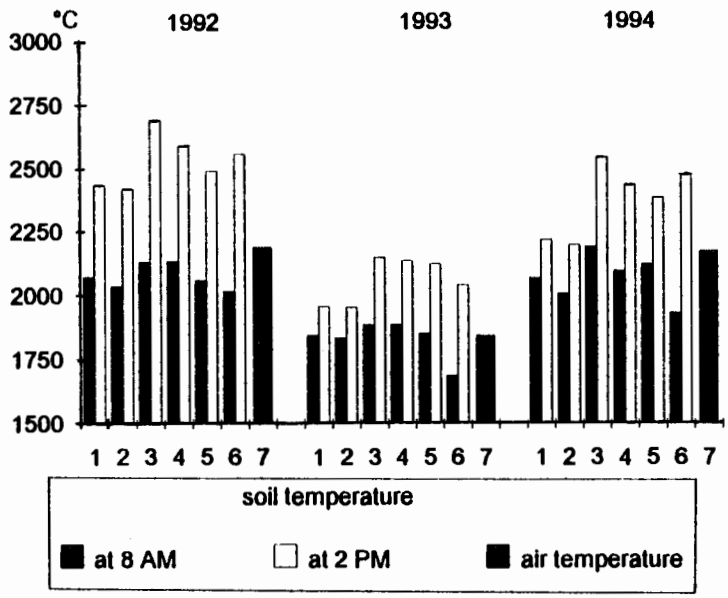

Fig. 2. Sums of mean twenty-four-hour air temperature and of soil temperatures measured at 8 a.m. and at 2 p.m. underneath different mulches: 1-bark, 2-sawdust, 3-black polyethylene, 4-black perforated polyethylene, 5-nonwoven, 6-bare soil and 7-air.

Table 2. Effects of soil mulching on the total and marketable yield of sweet pepper fruit

	Total yield (kg/m^2)				Marketable yield (kg/m^2)				Share of marketable yield in total yield (%)			
Mulch treatment	1992	1993	1994	Mean	1992	1993	1994	Mean	1992	1993	1994	Mean
Bark	5.848	2.485	2.253	3.529	5.195	2.364	1.976	3.178	88.8	95.1	87.7	90.1
Sawdust	6.145	2.315	1.683	3.381	5.168	2.193	1.524	2.962	84.1	94.7	90.6	87.6
Black polyethylene	7.478	3.425	3.636	4.846	5.562	3.207	2.973	3.914	74.3	93.6	81.8	80.8
Black perforated polyethylene	7.075	3.540	3.839	4.818	5.653	3.338	3.324	4.105	79.9	94.3	86.6	85.2
Nonwoven	7.069	2.720	3.695	4.495	5.677	2.493	3.053	3.741	80.3	91.6	82.6	83.2
Bare soil	5.893	2.703	2.978	3.858	4.799	2.550	2.581	3.310	81.4	94.3	86.7	85.8
Mean	6.585	2.865	3.014	4.155	5.342	2.691	2.572	3.353	81.1	93.9	85.3	85.3
LSD 0.05												
Years (a)				0.6533				0.5991				
Mulch treatment (b)	1.1436	0.3296	1.0132	1.0682	1.1041	0.3245	0.8495	0.9796				
ab				2.0156				1.8483				

Table 3. Effects of soil mulching on early marketable yield of sweet pepper fruit

	Early yield (kg/m^2)				Share of early yield in marketable yield (%)			
	1992	1993	1994	Mean	1992	1993	1994	Mean
Bark	1.467	0.414	0.166	0.682	28.2	17.5	8.4	21.5
Sawdust	1.591	0.472	0.156	0.740	30.8	21.5	10.2	25.0
Black polyethylene	1.711	0.627	0.396	0.911	30.8	19.6	13.3	23.3
Black perforated polyethylene	1.894	0.705	0.461	1.020	33.5	21.1	13.9	24.8
Nonwoven	2.038	0.644	0.481	1.054	35.9	25.8	15.8	28.2
Bare soil	1.283	0.341	0.308	0.644	26.7	13.4	11.9	19.5
Mean	1.664	0.534	0.328	0.842	31.1	19.8	12.8	23.8
LSD 0.05								
Years (a)				0.1385				
Mulch treatment (b)	0.2630	0.0700	0.2135	0.2350				
ab				0.3384				

Depending on the soil mulching, significant differences in the sweet pepper yield in the open field were noticed (Tables 2 and 3). The highest mean total and marketable fruit yield was obtained from the plants grown in the soil mulched with black polyethylene, perforated black polyethylene and with nonwoven. On the soil mulched with tree bark and sawdust, the mean total and marketable yield was lower than that of the bare soil. The amount of fruit (Fig. 3) and the contribution of the marketable yield in the total one (Table 2) indicate that the quality of the yield was better on the organic mulches, compared to the bare soil and the soil mulched with synthetic materials. During the droughts of 1992 and 1994, much more unmarketable fruit with symptoms of blossom-end rot were obtained from the plants mulched with polyethylene and nonwoven, compared to the plots mulched with

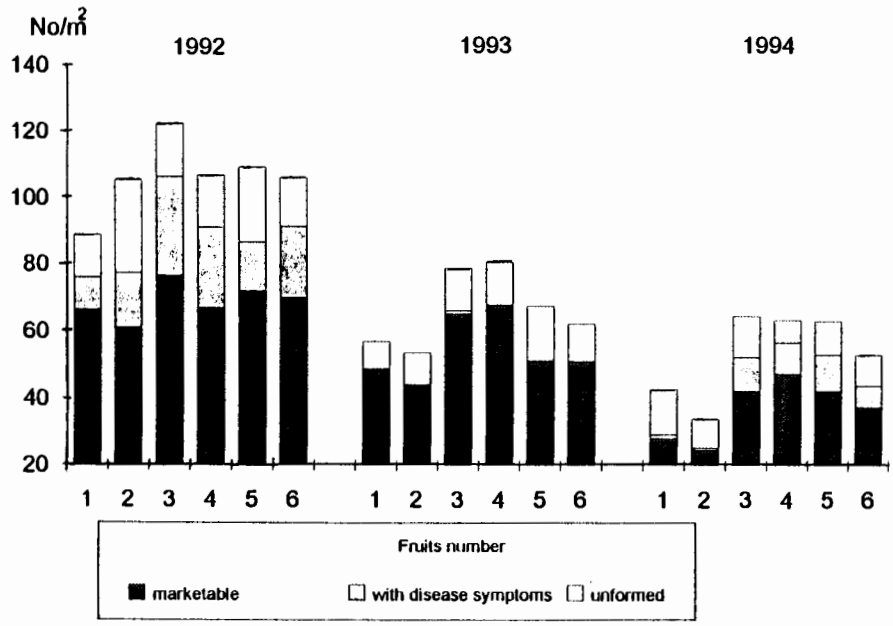

Fig. 3. Effects of soil mulching on the number of sweet pepper fruit (No./m^2). Denotations 1-6 as in Fig. 2.

organic materials. In the year 1993, when the amount of rainfall in the period from June to September was definitely higher (Fig. 1) than that of the hot summers of 1992 and 1994, the symptoms of this disease were not observed. A minimal amount of fruit with symptoms of blossom-end rot was only obtained from the plants grown on the soil mulched with black polyethylene.

conditions (June to August) and of a high amount of rainfall in July and August. Comparison of average decade values of PAR (at 11.30 a.m.) indicates also that the conditions for photosynthesis were extremely favourable (Fig. 4). The highest PAR values were observed in June (298-315 W/m^2) and slightly lower values were observed in July (234-265 W/m^2) and in August (224-270 W/m^2). In

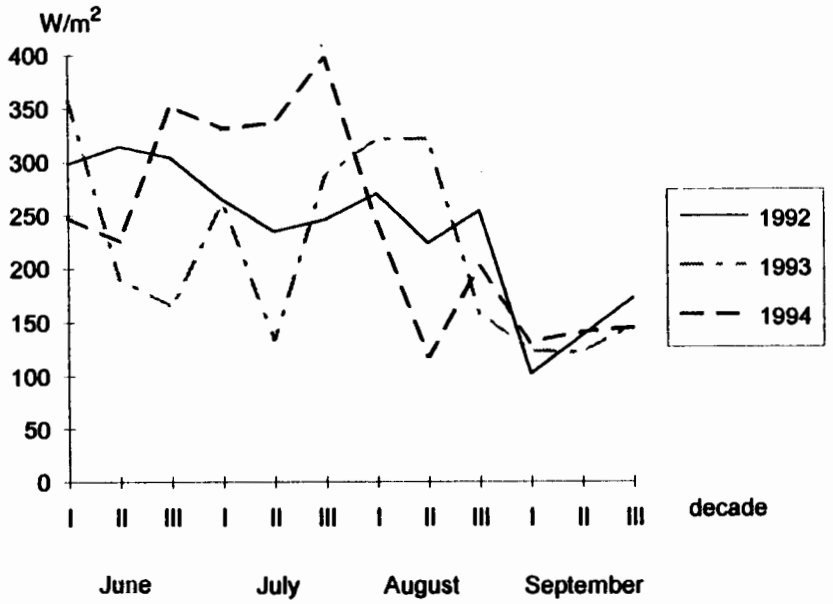

Fig. 4. Mean decade values of PAR (measured at 11.30 a.m.) during vegetation period of sweet pepper.

Soil mulching had a very positive effect on an early time of pepper yield in the field (Table 3). The highest mean marketable yield from the 1st and the 2nd harvests was obtained from the plots mulched with nonwoven (28.2 % of the total marketable yield), with sawdust (25.0 %) and with perforated black polyethylene (24.8 %), compared to that from the bare soil (19.5 %).

The analysis of the quantity of the total and marketable yield of pepper (cultivar Mira) points to two significant differences between the yields of the particular research years. A very high yield was obtained in the year 1992 which was especially favourable to thermophilous plants because of the excellent thermal

1993 and 1994, big oscillations in the range of PAR values were observed - particularly in July of 1993 and in August of 1994. In 1994, the pepper yield was retarded by the drought which lasted from the middle of June till the end of July. The weather permitting conditions significantly affected an early time of the pepper yield cultivated in the field in 1992, when the mean early yield made up over 30 % of the total marketable fruit yield.

It was also shown that the weather conditions and soil mulching had a distinct effect on a number of fruit obtained from 1 m^2 (Fig. 3). The lowest amount of fruit was collected in the hot and dry year 1994, when mass shedding of flowers and fruit sets and also fruit

falling were observed. The lowest amount of fruit was obtained from the plots mulched with tree bark and sawdust, where the surface temperature of the mulches had reached over 50 °C on hot days. Regarding very short plants of Mira cultivar, it was a factor intensifying the phenomena of shedding flowers and fruit sets.

DISCUSSION

The conducted research indicated a positive effect of mulching on the thermal conditions of soil. The highest temperature in the morning and in the afternoon was noted underneath the synthetic mulches. Similar results were also achieved by others [2,4,6,7,9,10,13]. The most favourable thermal conditions were created by mulching with black polyethylene. Many others [2-8,11,12] applied polyethylenes of different colours as mulches, too. Ashworth and Harrison [2] and Kossowski and Hortyńska [9] observed the highest increase in the temperature of the soil mulched with colourless polyethylene, while Decoteau *et al.* [4] observed the same on the soil mulched with black and red polyethylenes. Under the conditions of the Lublin region, the organic mulches prevented from overheating the soil in the afternoon. Aiyelaagbe and Fawusi [1], Ashworth and Harrison [2] and Roberts and Anderson [12] achieved similar results. It was noted during the drought of 1994 that the synthetic mulches can prevent from overheating of the soil, even at very high air temperatures. The research conducted in a hot climate by Roberts and Anderson [13] showed that only organic mulches (straw) and shading the plants could prevent from the increase in the soil temperature while the soil mulched with black polyethylene underwent the most heating.

The best results were achieved from the plots mulched with black polyethylene, under the conditions of the Lublin region. Others achieved similarly positive results [6,7,9-11]. According to some of them [8-10], the increase in yield was reflected in a bigger amount of fruit per one plant, has also been proven by this research.

Several studies [5-7,11] showed that the highest pepper fruit yield was obtained from cultivation on the soil mulched with polyethylenes of a reflective nature which increases a PAR value and improves the conditions for photosynthesis. It was also shown in these studies that the highest fruit yield was obtained in 1992 when the highest and relatively constant PAR values were noted.

In this study it was noticed that the organic mulches did not have a positive effect on the pepper yield. Goyal *et al.* [6,7] achieved similar results, while Aiyelaagbe and Fawusi [1] in Nigeria obtained a higher pepper yield from the soil mulched with organic materials than from bare soil. Also, Roberts and Anderson [12] noticed that during two years, a higher pepper yield was obtained through application of straw mulch, compared to black polyethylene mulching.

Under the conditions of the Lublin region, it was shown that soil mulching affects an early time of pepper yield in the field. Similar results were achieved by Van Derwerken and Wilcox [14], who also noticed that irrigation and mulching of the soil with polyethylene effectively limits appearance of blossom-end rot of fruits. In this study, a lower intensity of this disease was observed on the plots mulched with organic materials.

In our climate, the early time and the quantity of the pepper yield are determined by a choice of a proper cultivar and by the weather permitting conditions [3,9]. Big differences in the yields between the years 1992 and 1994 prove that observation. Others [6,11,12] also showed that, even in a warm climate, the weather conditions of a particular year affect changes in the sweet pepper yield in the open field.

CONCLUSIONS

1. Soil mulching with different materials had a positive effect on the soil temperature.
   - The organic mulches (tree bark and pine-trees sawdust) favourably affected the increase in the soil temperature in the

morning while in the afternoon, they prevented from heating the soil.
- Application of the synthetic mulches (black polyethylene, perforated black polyethylene and nonwoven) significantly improved the thermal conditions of the soil in the morning and in the afternoon.
- At very high air temperatures in the year 1994, the synthetic mulches prevented also from overheating of the soil in the afternoon.

2. The soil mulching with synthetic materials had a positive effect on the sweet pepper yield. The highest mean marketable fruit yield was obtained from the plants cultivated on the soil mulched with perforated black polyethylene (4.1 kg/m^2), with black polyethylene (3.9 kg/m^2) and with nonwoven (3.7 kg/m^2), compared to the bare soil (3.3 kg/m^2) and to the soil mulched with bark (3.2 kg/m^2) and with pine-trees sawdust (3.0 kg/m^2).
3. In the year 1992, because of particularly favourable weather conditions to thermophilous plants, a very high mean marketable yield of pepper fruit was obtained (5.3 kg/m^2), compared to the year 1993 (2.7 kg/m^2) and the year 1994 (2.6 kg/m^2).
4. The soil mulching had a positive effect on the early time of the sweet pepper yield in the field cultivation.

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WPŁYW RÓŻNYCH ŚCIÓŁEK NA WARUNKI TERMICZNE GLEBY I PLONOWANIE PAPRYKI SŁODKIEJ W POLU

W trzyletnich badaniach oceniono przydatność kilku ściółek (kora, trociny drzew iglastych, folia czarna, folia czarna perforowana, włóknina) do uprawy papryki slodkiej w otwartym polu. Na podstawie codziennych pomiarów (godz. 8^{oo} i 14^{oo}) temperatury gleby obliczono i porównano dla badanych ściółek i gleby nieokrytej sumy temperatur gleby w okresie wegetacji papryki (czerwiec- wrzesień).

Wykazano pozytywny wpływ ściółek na temperaturę gleby. Największy wzrost temperatury (godz. 8^{oo} i 14^{oo}) notowano pod ściółkami syntetycznymi (czarną folią). Ściółki organiczne oddziaływały korzystnie na wzrost temperatury gleby w godzinach porannych. Stwierdzono statystycznie istotny wpływ ściółkowania gleby materiałami syntetycznymi na plonowanie papryki slodkiej. Najwyższy średni plon handlowy owoców uzyskano z obiektów na glebie okrytej czarną folią perforowaną (4.1 kg/m^2), czarną folią (3.9 kg/m^2) oraz włókniną (3.7 kg/m^2) w porównaniu do gleby nieokrytej (3.3 kg/m^2), kory (3.2 kg/m^2) i trocin (3.0 kg/m^2).

S ł o w a k l u c z o w e: mulcze, warunki termiczne gleby, słodka papryka, plon.