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INFLUENCE OF DIFFERENT ORGANIC MULCHES ON SOIL TEMPERATURE DURING PEPPER (*CAPSICUM ANNUUM* L.) CULTIVATION

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Abstract

The aim of the paper was to present the influence of different types of organic mulch on soil temperature during the cultivation of pepper. The experimental work was carried out in 2012-2013in the experimental field on University of Forestry – Sofia, with pepper cv. 'Sofiiskakapia'. For the purpose of the study were used different available materialsas organic mulches, which were waste products from organic agriculture:spent mushroom compost (SMC),barley straw (BS), grass windrow (GW), weeds. Mulched plots were compared with two control variants – hoed control plots, (HC) and non-hoed control plots (NHC).The mulching materials were spread manually in a 5-6 cm thick layer, after strengthen the seedlings of pepper. The soil temperature was recorded in 7 days, at a depth of 0, 5, 10 and 15 cm, by calculating the average daily temperature, from mulching to harvesting of production. Mulching materials affect soil temperature. Least variation in soil temperature was recorded at a mulch of straw with average temperature 19-22°C during the August, when the air temperature was highest. With the greatest variation in soil temperatures of mulching plots were two variants: with mulch of weeds and with mulch of grass windrow where the green waste materials, used for mulching, started to decompose slowly.

***Key words**: soil temperature, barley straw mulch, spent mushroom compost, grass windrow mulch, pepper.*

INTRODUCTION

The optimum temperature for cultivation of bell pepper is between 18 and 25 °C. Extremely high temperatures above 32–35°C, in combination with a low air humidity, cause falling off of the flowers and fruit sets and increase the percentage of non-standard deformed fruits. Root system develops better when soil temperature is between 18–22°C (Panayotov et all. 2006).

In the hot summer days high soil temperatures affect evaporation and soil moisture, and hence the growth and development of pepper (Van Donk et al., 2011). Temperature stress, which is obtained at high soil temperatures at uncovered soil (32 – 34°C) may be minimized by the use of the mulch. (Godawatte et al., 2011; Yordanova and Gerasimova, 2012). Mulching improves plant growth, increased yields and quality (Sharma and Sharma, 2003; Singh et al., 2007). The organic mulches which are recycled into the soil can reduce the cost of production and are useful for the environment (Roe et al., 1992).

One of the best materials for mulching is compost, especially for growing of intensive crops (Vogtman, 1990; Yordanova, 2008). Mulching with grass also has a positive effect on the quality and quantity of the yields in a number of crops (Dvořák et al., 2009; Sinkevičienė, et al., 2009). It degrades faster than other mulch materials, with 10 cm layer of grass windrow is more effective than the 5 cm layer (Jodaugienė et al., 2012). Grass windrow positively affect the activity of soil enzymes and biomass in the soil (Jodaugienė et al., 2010).

It has been found that the mulching with straw has a favorable effect on the growth of pepper (Roberts and Anderson, 1994; Mochiah et al., 2012). This is explained by the preserving and maintenance of the soil moisture, the maintenance of a moderate soil temperature and suppressing the growth of weeds. Use of green stalks of weeds as mulch material only ismentioned as a method applied in old gardening practices historically. This provoked the decision to explore the possibility of using green weed residues as mulch material and to determine the influence of different types of mulch on soil temperature and crop yields in the cultivation of pepper.

MATERIALS AND METHODS

The experiment was conducted in 2012-2013, in the experimental field of the University of Forestry – Sofia (42°7′ N, 23°43′E and 552 m altitude). The soil is fluvisol, slightly stony, slightly acidic. This area came under a continental climatic sub region, in a mountain climatic region.
The study was performed with bell pepper (*Capsicum annuum*), cv. 'Sofiiskakapia', with growing period lasted 116-120 days, with pre-produced seedlings. Planting in the open field wass made on 21-22 May in both experimental years. Each plot was of 1.20 m wide and 3 m long. It contained two parallel rows of plants at 60 cm distance between rows and plants within rows were separated by 20 cm.
The experiment was carried out by randomized complete block design with six treatments and three replications. The tested treatments were: bare soil, maintained weed-free by hoeing – control plot(BSCP); non-mulched and non-hoeing (weeded) control plot (NMCP); mulch from spent mushroom compost (SMCM); mulch from barley straw (BSM); mulch from grass windrow (GWM); mulch from green stalk residues from weeds (WRM).
As weed residues mulch we used widely distributed weeds: common amaranth (*Amaranthus retroflexus* L.), fat-hen (*Chenopodium album* L.), and cockspur *(Echinochloa crus-galli* L.). In 2012 we used them separately, to could check if they will take roots again. In 2013 we used them mixed together as they grew naturally.
The mulches were applied to the soil surface by hands at a thickness of 5-6 cm, after the seedlings of pepper were strengthen – on 11 – 12 of June in both experimental years.
All elements of agrotechnical activities (basic and pre-sowing cultivation, irrigation, etc.) were the same for all treatments. The plants were irrigated by sprinkler irrigation system.
The soil temperature was monitored at soil surface (0 cm depth) and at a depth of 5, 10 and 15 cm, once of week, three times a day, throughout the period from the beginning of July till the end of September. The soil temperature was measured with hand-held needle soil digital thermometer.
Means were separated by application of Duncan's Multiple Range Test at $p \leq 0.05$.

RESULTS AND DISCUSSIONS

The average mean air temperature during the growing period (June – September) of both experimental years (2012-2013) was within the borders of optimum temperature of pepper cultivation, with one exception – on September, 2013, when the average mean temperature was 16.7 °C.
In spite of the optimum mean air temperature, the maximum air temperature, which was measured during the growing period, was higher than optimum for growing pepper (Table 1.).
Monitoring of soil temperature started in the beginning of July and continued until the end of September. This covered the hot summer period and lasted until the end of harvest. The maximum air temperature had an effect on bare soil temperature.
The average soil temperatures recorded in the middle of the August in all treatments and in four depths are presented in Figure 1. The soil temperature was measured at four depths (0, 5, 10 and 15 cm). We compared them with average daily air temperatures, to present the fluctuation in soil temperatures in different depths.

Table 1 Average air temperature (maximum, minimum, mean) and amount of precipitation during the growing period of the pepper for both years of the experiment.

	Average air temperature (°C)						Amount of precipitation (mm)	
	2012			2013			2012	2013
	max	min	mean	max	min	mean		
May	20.6	9.7	15.2	24.0	11.2	17.6	131.4	31.9
June	28.2	14.8	21.5	24.8	13.0	18.9	8.9	113.6
July	32.1	17.5	24.8	26.6	14.2	20.4	41.2	61.2
August	30.9	15.2	23.1	29.4	15.9	22.6	45.0	13.0
September	26.4	12.2	19.3	23.2	10.2	16.7	48.2	21.0

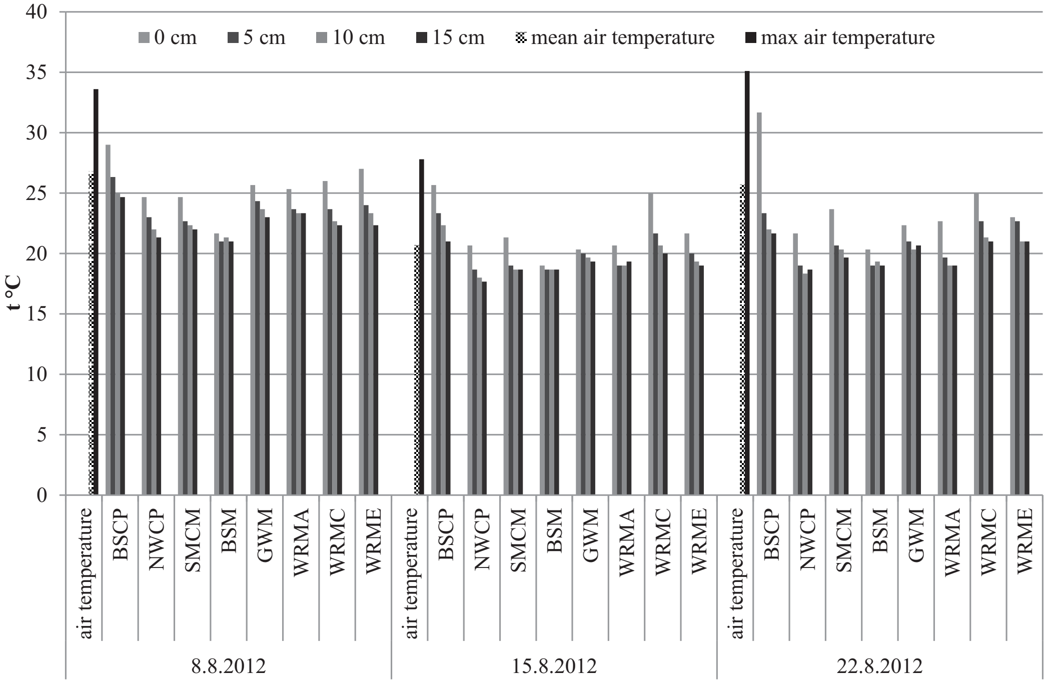

Figure 1 Average daily air temperatures, compared with average soil temperatures recorded in the middle of the August in all treatments and in four depths

The largest temperature differences are recorded at a depth of 0 and 15 cm. The temperature, recorded on the soil surface level of the bare soil control plot (BSCP) was always higher than temperature on the soil surface of the mulched plots (Table 2 and Table 3). However, temperatures of the soil surface of this option was not higher than the average air temperature, which is due to shading of the soil surface by the leaves of pepper.

In BSCP treatment were recorded and the highest temperature amplitudes between average daily soil temperatures on soil surface and at a 15 cm depth, which were significantly higher. The highest temperature amplitude (7.5°C) was recorded in July, 2012 (Table 2), which was the hottest month during the experimental period, the average soil temperature, was also higher (26.5°C) than optimum soil temperature for pepper roots (18-22°C).

The soil surface temperatures, measured at the mulched plots where always lower than the temperatures measured at the bare soil control plot. The soil temperature under different mulches was also affected by the type of used mulch materials.

Lowest soil temperature measured at the soil surface was recorded under barley straw mulch (BSM). This may be due to the fact that mulch of straw has a bright surface and reflects the sun's rays, preventing overheating of the soil surface. On the other hand keeps the temperature in the lower soil layers and was considered the smallest temperature range between 0 and 15 cm depth in the soil. The fluctuation in soil temperature at different levels is between 0.6 °C (in August, 2012) and 1.4 °C (in August and September 2013). Badaruddin et al., 1999, indicates that the use of straw mulch in areas with high temperatures maintaining the temperature in the soil below the day and higher during the night, and thus protects plants from heat stress. At this mulched treatment was recorded and lower average soil temperature (17.2 °C) than optimum soil temperature for pepper roots (18-22 °C).

In the treatment with weed residues mulch temperatures measured on the soil surface and a depth of 15 cm were higher in the first months, compared to other mulch options. This is due to the fact that under the influence of high air temperatures and moisture in the soil, fresh green plant matter begins to decompose, intensifying the microbiological activity of the soil surface. This leads to the maintenance of higher soil temperatures, as compared to other ground cover materials.

In 2012 we used green stalk weed residues (WRM) as mulch separately, to check if they will take roots again and to study them as a mulch material. The mulch from *Amaranthus retroflexus* L. (WRMA), the mulch from *Chenopodium album* L. (WRMC) and the mulch from *Echinochloa crus-galli* L. (WRME) were decomposed almost at the same time. They didn't take roots again and covered soil surface good in the beginning. The differences in measured soil temperature among these treatments are not significant, with one exception – the temperature amplitude, recorded at WRMA (2.6 °C) in August, 2012 was smaller than at other two treatments. In 2013 we used them mixed together as they grew naturally (Table 2 and Table 3).

At the end of the vegetation of pepper in 2012,mulch from weed residues (WRM) was wilted, was thin and because we used the whole stems, they are no longer covered well the soil surface and because of this the temperature at a depth of 15 cm in September was low and almost close to temperature variations without mulch .

Grass windrow was applied as mulch (GWM) after one – two days, not as fresh as weed residue mulch. The averages mean soil temperatures, which were recorded during the experimental years, were close to the borders of optimum soil temperature levels (17.6-22.2 °C).

Mulch from spent mushroom compost (SMCM)also maintained a higher temperature than barley straw mulch (Table 2 and Table 3). The dark color of this mulch affected the soil temperature and in September the averages mean soil temperatures, for both experimental years, were in the borders of optimum soil temperature levels (18.1-18.2 °C).

Table 2 Average daily soil temperature (at 0 cm and at 15 cm depth), mean temperature and temperature amplitude between two levels ($T_{amp}=T_{0cm} - T_{15cm}$) during growing period of pepper, 2012

	Average soil temperature (°C)											
	July				August				September			
	0 cm	15 cm	mean	T amp	0 cm	15 cm	mean	T amp	0 cm	15 cm	mean	T amp
BSCP	30.2a	22.7a	26.5	7.5a	28.0a	21.4 ns	24.7	6.6a	23.5a	16.8ns	20.1	6.7a
NMCP	22.3b	19.5b	20.9	2.8b	21.8b	19.0 ns	20.4	2.8c	18.3b	16.0 ns	17.2	2.3b
SMCM	23.0b	21.1b	22.1	1.9c	22.0b	19.8 ns	20.9	2.2c	19.3b	17.0 ns	18.2	2.3b
BSM	20.7c	19.6b	20.2	1.1d	20.0c	19.4 ns	19.7	0.6e	18.0b	16.8 ns	17.4	1.2c
GWM	23.2b	21.2b	22.2	2.0c	22.6b	20.8 ns	21.7	1.8d	18.3b	17.0 ns	17.7	1.3c
WRMA	23.4b	20.9b	22.2	2.5b	22.4b	19.8 ns	21.1	2.6c	18.8b	16.5 ns	17.7	2.3b
WRMC	24.2b	21.1b	22.7	3.1b	23.8b	20.4 ns	22.1	3.4b	17.8b	15.8 ns	16.8	2.0b
WRME	23.9b	21.0b	22.5	2.9b	23.4b	20.2 ns	21.8	3.2b	18.3b	15.8 ns	17.1	2.5b

Values with the same letter within years are not significantly different (Duncan's Multiple Range Test at $p \leq 0.05$)

Table 3 Average daily soil temperature (at 0 cm and at 15 cm depth), mean temperature and temperature amplitude between two levels ($T_{amp}=T_{0cm} - T_{15cm}$) during growing period of pepper, 2013

	Average soil temperature (°C)											
	July				August				September			
	0 cm	15 cm	mean	T amp	0 cm	15 cm	mean	T amp	0 cm	15 cm	mean	T amp
BSCP	25.8a	19.0a	22.4	6.8a	27.6a	20.9ns	24.3	6.7a	21.2a	14.6ns	17.9	6.6a
NMCP	19.2b	17.9b	18.6	2.3b	21.2b	18.5ns	19.9	2.7b	18.0b	15.8ns	16.9	2.2b
SMCM	19.8b	18.1b	19.0	1.7c	21.8b	19.6ns	20.7	2.2b	19.1b	17.0ns	18.1	2.1b
BSM	18.2b	16.9b	17.6	1.3c	19.7b	18.3ns	19.0	1.4c	17.8b	16.4ns	17.2	1.4c
GWM	18.7b	17.6b	18.2	1.1c	22.0b	20.4ns	21.2	1.6c	18.2b	16.9ns	17.6	1.3c
WRM	18.8b	17.2b	18.0	1.6c	22.8b	20.1ns	21.5	2.7b	18.7b	16.7ns	17.7	2.0b

Values with the same letter within years are not significantly different (Duncan's Multiple Range Test at $p \leq 0.05$)

The mulch protects the soil from strong overheating during midday hours and cooling at night, which explains the small temperature differences between the measured surface temperatures of the soil in mulched treatments and soil temperatures at a depth of 15 cm. This is in agreement with other researchers: Chen et al., 2004, 2005, 2007 demonstrated a reduction in the maximum temperature of the soil, increase of the minimum temperature, and a reduction in amplitude between day and night temperatures. Pinamonti, 1998, also indicated that mulching reduces fluctuations in soil temperature.

CONCLUSIONS

The bare soil surface is more affected by the air temperature and this is more strongly expressed by temperature fluctuations in the depth of the soil.

Mulches affected the soil surface temperature and keep it moderate. The soil temperature under different mulches was also affected by the type of used mulch materials.

With the least variation in the soil temperature is the treatment with mulch of barley straw, which maintains a temperature in the range of 19-22 °C in August and 17-19 °C during the first two ten-day periods of September.

With the wide variation in soil temperatures of mulch are two treatments: mulch from green weed residues and mulch from grass windrow. It was established in July and August, when the green weed residues and grass windrow used for mulching, decomposed.

Mulch of barley straw maintains moderate soil temperature and protects the soil from rapid temperature fluctuations in depth.

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