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Effect of different organic mulches on soil temperature during cultivation of fall broccoli

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Abstract : *The aim of the paper was to present the effect of different types of organic mulches on soil temperature, during the cultivation of broccoli. The experimental work was carried out in 2011-2012, in the experimental field on University of Forestry – Sofia, with broccoli, cv. Fiesta F1. For the aim of the study were used different waste products from agriculture as organic mulches, which were: spent mushroom compost, barley straw, grass windrow and combination with spent mushroom compost and grass windrow. Mulched plots were compared with two control variants – hoed control plots, and non-hoed and non-weeded control plots. The mulching materials were spread manually in a 5-6 cm thick layer, after strengthen the seedlings of broccoli. The soil temperature was recorded once a week, at a depth of 0, 5, 10 and 15 cm, by calculating the average daily temperature, from mulching to harvesting. Mulching affects soil temperature. Least variation was recorded at mulched plots with straw, where temperature amplitude was 2.1-2.4 °C during the August. With the greatest variation in soil temperature of mulching plots were these mulched with grass windrow (4.0-4.4 °C).*

Keywords: *broccoli, barley straw mulch, grass windrow mulch, soil temperature, spent mushroom compost mulch*

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I. Introduction

Broccoli (Brassica oleracea var. Italica Plenk.), are from the Brassicaceae family. The main areas where the broccoli is grown are: North America, Europe, Asia and Latin America. [1]. According to Gray, A. R. (1982) [2], the types of broccoli Calabrese are part of the different types of broccoli and they are the most intensively growing group, which is represented by many varieties and hybrids F1. Broccoli, like other cole crops is cool season plant. They grow well at temperatures between 16-22 °C. It was established that the temperature stress can be most critical during the time of forming the heads of 5 to 10 mm/dm [3]. In order to get quality products temperature should not exceed 30 °C during the day and 18 °C at night about a month after planting, [1].

There is established dependence of the air temperature and its elements on the soil temperature at a depth up to 20 cm. The soil temperature is highest at the bare soil, and lower is under the plants cover [4]. In soil depth, the temperature also changes and it begins to increase with increasing the depth [5]. In the summer, when high air temperature is observed, high surface soil temperatures and large temperature differences in depth are also observed for uncovered soil. These differences can be minimized by using mulch [6, 7, 8]. Especially during the hot days at the end of August and the beginning of September, the soil temperature at depth of 5 cm differs visibly in the fall and in the mulched soil surface. It is on average 8 °C lower on the mulched surface with plant residues, as the temperature is also affected by the amount of plant residue on the soil [9].

The use of straw mulch in high temperature areas keeps soil temperature lower during the day and higher at night, thus protecting plants from temperature stress, which positively affects the growth and development of wheat [10]. The soil temperature at soil surface and at a depth of 5 cm was lower on mulched with straw mulch plots [11]. And at a depth of 10 cm it was lower and with less fluctuation on mulched plots than on non-mulched [12]. However, when mulching with straw, a possible immobilization of nitrogen in the soil should be considered [13]. One of the best materials for soil mulching is spent mushroom compost, especially for intensely growing crops [14]. Mulching with grass also has a positive effect on the quantity and quality of yield in a number of crops [15, 16]. It degrades more rapidly than other mulching materials, with a 10 cm layer of grass windrow being more effective than a 5 cm layer [17]. The grass windrow has a positive influence on the activity of soil enzymes and biomass in the soil [18]. Mulching improves plant growth, increases yields and quality [19, 20].

The aim of the experiment is to compare the effect of different types of organic materials used as mulch on the soil temperature.

II. Materials and methods

The experiment was conducted in 2011-2012, 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.

Different organic waste materials were used as mulch: barley straw, grass windrow and spent mushroom compost. Experience is carried out with the standard methods with four replicates and plot area of 3 m2. Six variants have been tested: 1) non-mulching control variant, where the plants are growing on bare soil plots, with hoeing (NMC); 2) non-weeding control variant, where the plants were growing without weeding, hoeing or mulching (NWC); 3) variant with barley straw mulch (BSM); 4) variant with grass windrow mulch (GWM); 5 variant with mulch of spent mushroom compost (SMCM); and 6) combination with mulch of spent mushroom compost covered with a layer of grass windrow mulch (SMC+GWM).

The barley straw was used uncut, grass windrow – two days after mowing and mushroom compost - after the end of the harvesting period of Agaricus bisporus. The combination of last variant is the following 5-6 cm spent mushroom compost, covered with a 1 cm layer of grass windrow. All mulches were applied on July 22-23, in both experimental years, by hands at a thickness of 5-6 cm, after strengthening the plants.

All elements of agrotechnical activities (basic and pre-sowing cultivation, irrigation, etc.) were the same for all treatments. The plants were irrigated by drip 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 end of July till the end of September. The soil temperature was measured with hand-held needle soil digital thermometer. The data were processed by single-factor ANOVA. The mean values of the control plot and other treatments were compared by a Fisher's LSD test

III. Results and Discussion

In the first experimental year (2011), the average daily air temperature during fall broccoli (end of July-September) was near the upper limit of the optimum for their development, and after 19th of September it fell below 20 °C. The maximum daily temperature during the growing period was on average between 25 and 30 °C, which is higher than the optimal, and even reached 32-35 °C. After 19th of September the maximum temperature dropped and moved within the limits of 22-25 °C. (Figure 1).

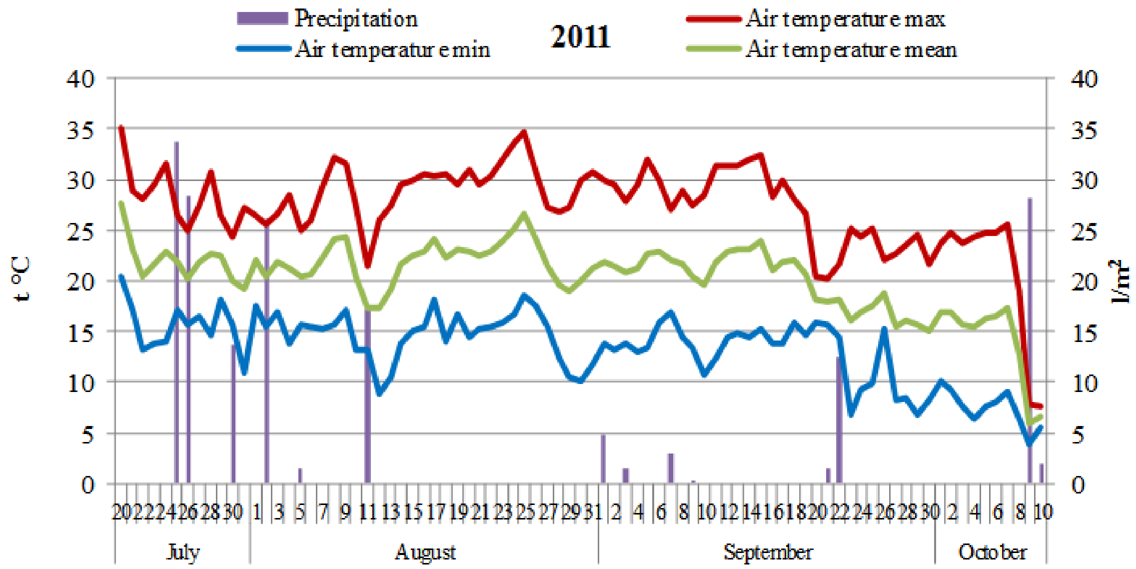

Figure 1. Average air temperature (maximum, minimum, mean) and amount of precipitation during the growing period of the broccoli for first year of the experiment (2011)

The second experimental year (2012) was warmer than the first, with variations in air temperature greater than in the same period in 2011. The maximum daily temperature ranged from 25-39 °C, registered three sharp drops in temperature - one in August and two in September, after which the temperature rose again, while the drops of minimum daily temperature were two in August and one in September.

The higher maximum daily air temperature also reflected the average daily temperature during the broccoli growing season - it varied more and moved initially around 25 ± 3 °C, after 28th of August the average daily temperature is around 18-22 °C, until the temperature dropped below 15 °C on 16th of September. At the end of September, the average daily temperature rose again to favorable levels (Figure 2).

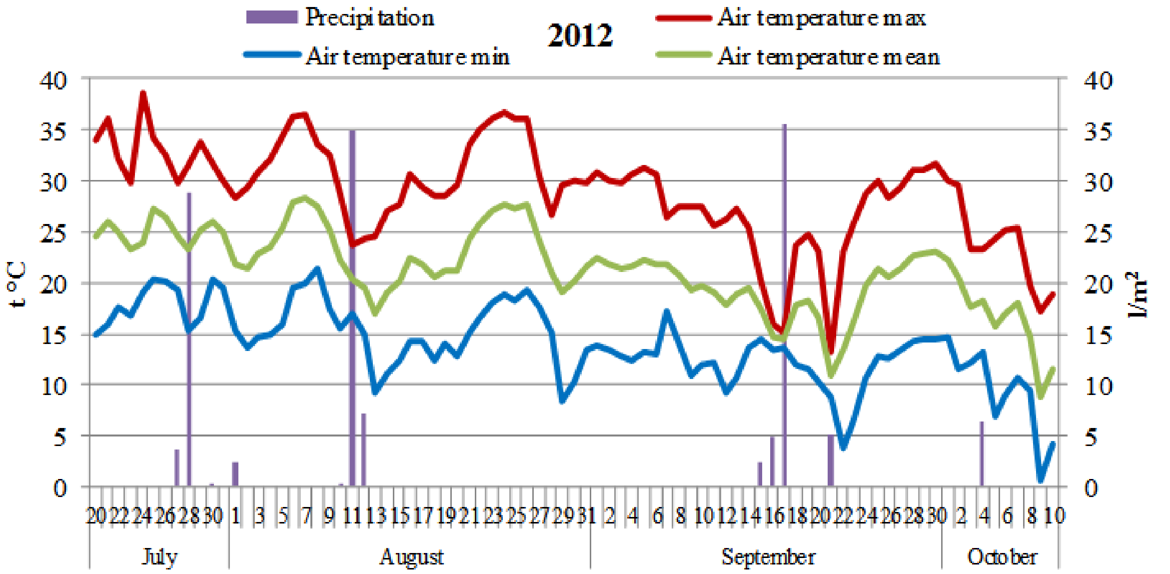

Figure 2. Average air temperature (maximum, minimum, mean) and amount of precipitation during the growing period of the broccoli for second year of the experiment (2012).

Figure 3 shows the data from the average daily soil temperatures in the four depths in all variants, for August 2012, as it has larger variations in temperature and including the first measurement conducted in late July.

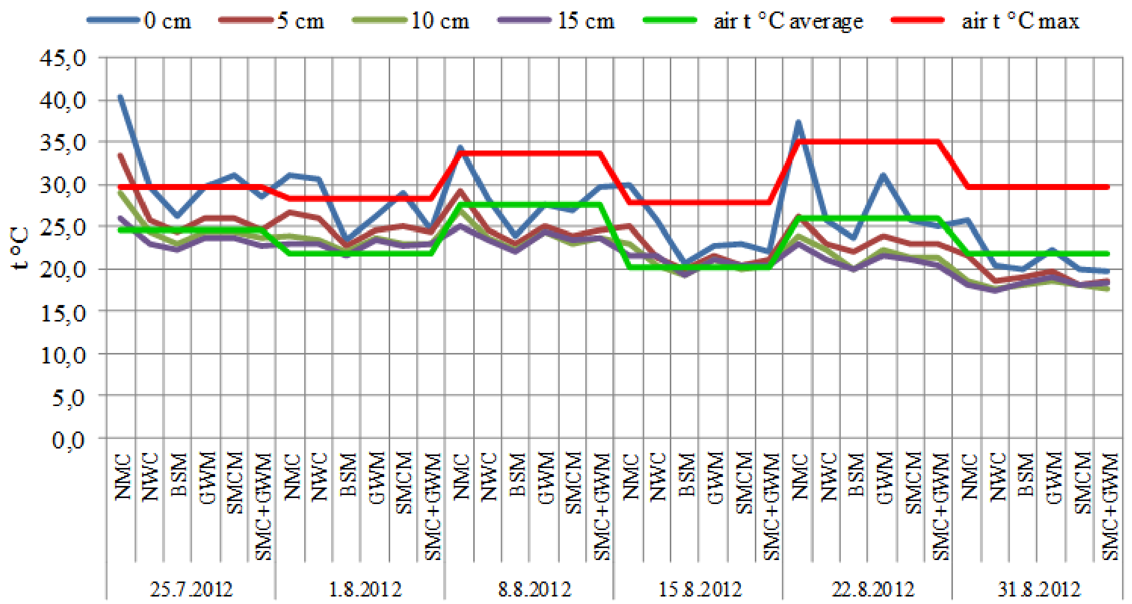

Figure 3. The average soil temperatures recorded in the summer in all treatments and in four depths, for 2012.

The figure clearly shows that the measured maximum daily air temperatures during this period had a greater influence on the soil temperature measured at the soil surface and at a depth of 5 cm. The soil temperatures of the other two depths were changing less. The largest differences in soil temperature, measured at the four depths, were recorded in the first control variant (NMC) where the soil under the plants was maintained by hoeing.

From the mulching variants with the highest soil temperature, measured on the soil surface, were three variants. At the beginning of the period, this was the variant with mulch of spent mushroom compost (SMCM), followed by the combined variant (SMC+GWM). From the third ten days of the month, the temperature on the soil surface in the grass windrow variant began to rise.

The closest values of soil temperatures, measured on the soil surface and the three depths, were in the straw mulch variant (BSM).

Figure 4 shows the data from the average daily soil temperatures in the four depths in all variants, for September 2012. The comparison was made with the minimum air temperatures, as there were two serious lowering temperatures in September.

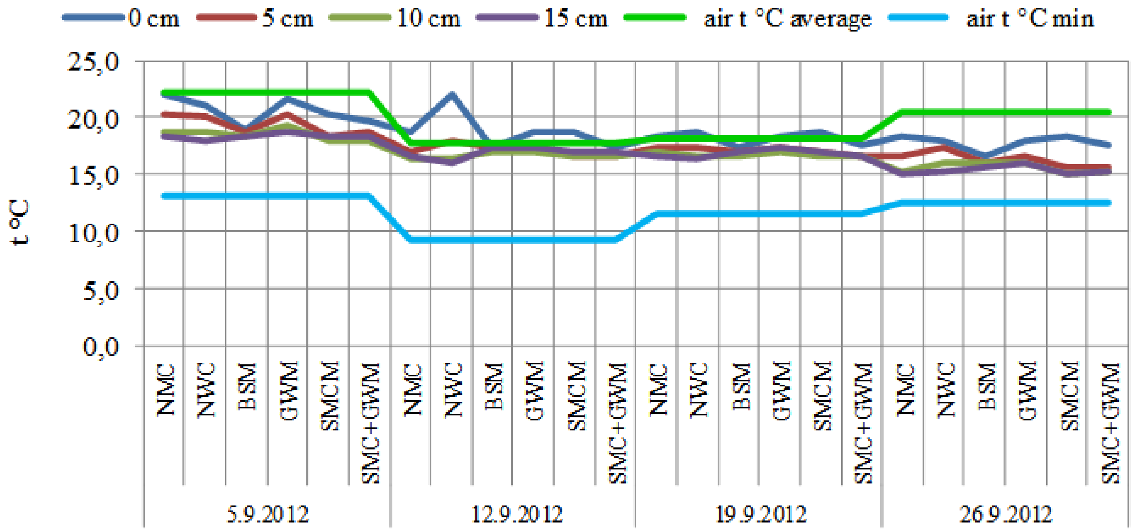

Figure 4. The average soil temperatures recorded in September for all treatments and in four depths.

In September the measured minimum daily temperatures were near and below 15 °C, as on 12th September measured minimum air temperature was below 10 °C and on 22nd of September – below 5 °C.

However, the measured minimum daily temperatures did not have a strong influence on soil temperatures during this period. In all variants, they remained within the range of 15-20 degrees Celsius.

In early September, they were around 20 °C (except soil surface temperature, which was above 20 °C), slowing down till the end of September. The lowering of the temperature in the mulched variants was smooth and only at the end of September was recorded the temperature of 15 °C and it was at a depth of 15 cm. In general, the temperatures in the individual variants were almost equalized - both between variants and in depth.

And in September again with the closest values of soil temperatures, measured on the surface and in depth, was the variant with BSM (Fig. 4).

It was used the Fisher's LSD test to made comparisons between the average soil temperatures of the NMC and the other variants. The comparison was made with the average temperatures of the measurements made in August, adding to them the temperatures measured at the end of July. Two of the four measured soil temperatures were compared - those measured on the soil surface and those at a depth of 15 cm. Based on these two measured temperatures, were made a calculation of the temperature amplitudes for each variant. The temperature amplitudes of the mulching variants together with the non-weeding variant were also compared to the temperature amplitude of the hoed NMC using the Fisher's LSD method (Table 1).

The influence of the mulching on the soil surface temperature was clearly expressed during the two years of the study, while at a depth of 15 cm the differences in the soil temperatures were minimal and had not been proved. Depending on the effect of the air temperature on the soil surface temperature, the tested variants can be arranged in the following descending order: NMC > NWC > GWM > SMCM > SMC+GWM > BSM, for August and during both experimental years.

In August soil temperature measured on the surface of the NMC was the highest because the soil surface was kept free from weeds by hoeing and soil in the first month was directly heated by the sun before the plants to develop and form a canopy over the soil. The soil temperature at the NWC, which was also non-mulched, was lower and closer to the temperatures of the mulched variants as the weeds were not removed and they gradually covered the soil surface. In September was exactly the opposite – NWC had the higher surface temperature than NMC, because the non-mulched soil surface cooled faster.

The temperature amplitudes in August were higher than those in September during the both experimental years. They were smaller in the mulching variants than the NMC. The temperature amplitudes at the NWC were similar to those with mulching soil surface as the weeds overshadow the soil. Smallest soil temperature amplitudes were in BSM, as the straw sustained lower soil temperatures than other mulch materials.

Overall, in September, the temperature amplitudes were small and almost the same, so only in some variants there were proven differences with the control (Table 1).

Table 1. Average daily soil temperature (at 0 cm and at 15 cm depth), temperature amplitude between two levels ($T_{amp}=T_{0cm}-T_{15cm}$) and mean temperature during growing period of broccoli (2011-2012)

	Average soil temperature (°C)							
	August				September			
	0 cm	15 cm	T amp	mean	0 cm	15 cm	T amp	mean
2011								
NMC	**30,4**	**20,9**	**9,4**	**24,4**	**20,6**	**17,8**	**2,8**	**18,6**
NWC	24,6***	19,9	4,7***	21,3	21,4	17,5	3,9 ns	19,1
BSM	21,1***	19,0	2,1***	19,7	18,8	18,3	0,5*	18,4
GWM	24,4***	20,4	4,0***	21,6	20,4	18,5	1,9 ns	19,2
SMCM	23,8***	19,8	4,0***	21,0	20,3	18,3	2,0 ns	18,7
SMC+GWM	22,9***	19,7	3,2***	20,7	19,2	18,0	1,2 ns	18,3
$LSD_{.05}$ *	3,03	ns	2,14		ns	ns	1,73	
$LSD_{.01}$ **	4,08	ns	2,88		ns	ns	2,38	
$LSD_{.001}$ ***	5,41	ns	3,82		ns	ns	3,24	
2012								
NMC	**33,1**	**22,8**	**10,3**	**26,8**	**19,8**	**16,7**	**3,1**	**17,7**
NWC	26,7**	21,6	5,2***	23,4	19,9	16,4	3,5 ns	17,9
BSM	23,0***	20,6	2,4***	21,6	17,8	17,1	0,7**	17,2
GWM	26,6**	22,2	4,4***	23,7	19,2	17,3	1,8 ns	18,0
SMCM	25,9**	21,9	4,0***	22,9	19,0	16,8	2,2 ns	17,3
SMC+GWM	24,9***	21,4	3,6***	22,7	18,1	16,8	1,3*	17,1
$LSD_{.05}$ *	4,58	ns	2,69		ns	ns	1,50	
$LSD_{.01}$ **	6,18	ns	3,63		ns	ns	2,05	
$LSD_{.001}$ ***	8,19	ns	4,81		ns	ns	2,80	

Figure 5 shows the relationship between the average soil temperatures measured in the different variants and the average yield obtained from each of them during the two years of study.

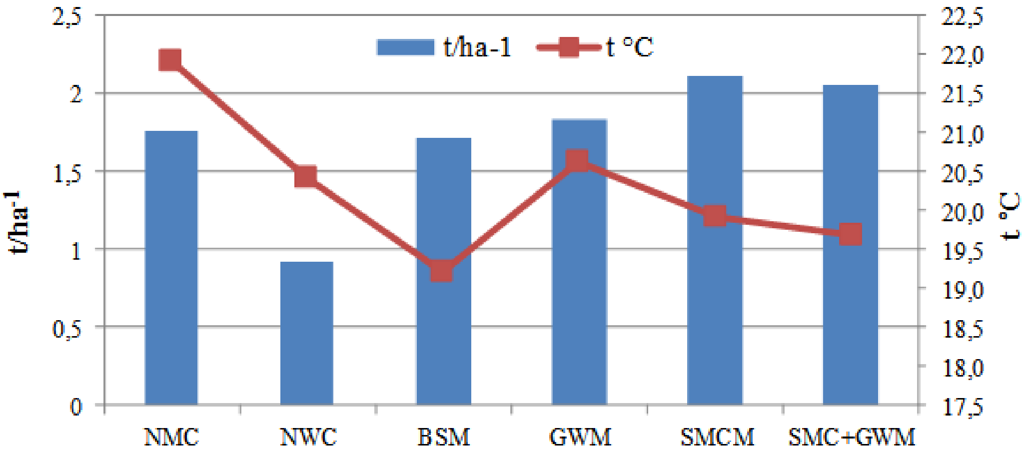

Figure 5. The influence of average soil temperatures on the average yield of broccoli (2011-2012).

It is seen that the lowest yield was obtained from the NWC, due to the competition with the weeds. The predominant weed species were small-flower galinsoga *Galinsoga parviflora* and redroot pigweed *Amaranthus retroflecsus*. Gradually, small-flower galinsoga covered the plots, which led to low yield. The highest yields were obtained from variants that are mulched by SMCM and SMC+GWM, because SMC act as a fertilizer during the growing season.

IV. Conclusion

Mulching affect soil temperature as the effect is more pronounced in late July through August on the soil surface. The temperature is lower in mulching variants compared to non-mulching control. According to their influence on the soil temperature, the mulching materials can be arranged in the following descending order: grass windrow, spent mushroom compost, spent mushroom compost plus grass windrow, barley straw. The differences in the effect on the soil temperature between the mulching materials, is small – only with 2-4 degrees Celsius.

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