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MULCHING METHODS AND THEIR EFFECTS ON THE YIELD OF TOMATO (*Lycopersicon esculentum,* Mill.) IN THE ZETA PLAIN

SUMMARY

The experiments were undertaken at the site of Zabljak meadow, Zeta plain fields in Donja Zeta.

Wheat straw and wood sawdust (materials of organic origin) and black and red coloured plastic foils were used for land mulching. The control was soil without mulch materials. The experiment was set up according to the block system in four replications, with a density of 2.08 plants per square meter. The row spacing was 1.2 m, and the distance between the plants was 0.4 m.

We hypothesised that tomatoes grown with different mulch materials should show differences in height, weight, shape, number of fruits and yield when compared with tomatoes cultivated on soil without mulching.

The best results were achieved with plants grown on soil covered with mulch foils. Application of the red foil resulted in the best vegetative growth of plants, and the greatest number, weight and size of fruits, as well as the highest total yield. Slightly lower results were obtained with cultivation with the black foil, and average results were achieved with the straw and the sawdust. The lowest production occurred on the soil without any mulch.

The yield with the red foil treatment was 3.55 kg (per plant) with the red foil treatment and 3.27 kg (per plant) with the black foil treatment. The yield with the soil covered with the straw and the sawdust was lower, with almost equal values of 2.53 kg (per plant) and 2.52 kg (per plant), respectively. The lowest tomato yield (2.47 kg per plant) was obtained on the soil without any mulch.

Keywords: experiment, mulching, tomato, soil, yield

INTRODUCTION

The Zeta plain in Montenegro is recognised for its intensive and successful plant production, mainly due to the area's favourable geographic-ecological conditions and the application of contemporary irrigation systems. The production of early vegetables has particular importance, and tomato is one of the most abundant cultures. Due to its high nutritive and health values, but also due

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to local availability during the entire year and low price, the tomato plays an important role in the nutrition of the local population.

To achieve a high-quality yield, the tomato requires high soil wetness during the entire growing (vegetation) period and moderate air humidity, which is associated with the tomato's high transpiration coefficient. In the Zeta plain, intensive vegetable production is undertaken on soil with a rather simple physical (mechanical) composition (sandy or shallow skeletal sandy) and a relatively low level of water retention (Fuštić and Đuretić, 2000.). Thus, the needs for irrigation are huge. Taken into consideration the recent climate changes, which are predicted to become more prevalent in the long term, the irrigation needs of the crop are set to increase.

In such a context, more attention will be given to alternative irrigation measures (crop rotation, pre-crops, sowing structure, proper soil cultivation and fertilisation, selection of particular varieties and sowing time), as well as to preventive, cheaper agro-technical options to combat draught and mediate its consequences (Molnar et al. 2001). These measures will be particularly important for terrains with limited options for irrigation.

Mulching is one option, which is applied regularly in our region in protected areas but also more often in open fields. Organic-natural materials (straw, sawdust and leaves) or different plastic and synthetic materials and foils are used for the mulch.

Many studies have investigated the many effects of mulching. It increases the fertility of soil, accelerates plant growth and fruit ripening (Wilhelm, 1990, Đurovka et al, 1996, Marković and Takač, 1998). Moreover, the wetness of the soil is retained for a longer time with mulching, and the temperature regime is regulated (Hanada, 1991, Streck et al., 1995, Maksimović and Jainu, 1996). Weed growth is also prevented, and biological activities of the soil are improved.

Recently, Mirecki (2009) investigated the influence of organic mulch-straw on production of broccoli under the climate-ecological conditions of the Zeta plain.

In this paper, we present the results of our experiments, and we highlight some positive effects of the application of various types of mulch on tomato production under the ecological conditions specific to the Zeta plain.

MATERIAL AND METHODS

Experimental set-up in the sample field: The sample field was established in the southern part of the Zeta plain in the Zabljak meadow, (GPS coordinates N 42º18'24.98", E 19º09'30.93").

Four types of covering material were used in the experiment: straw, sawdust, black foil and red foil; uncovered soil was used as the control.

Picture 1. Treatments applied in the sample field
(black foil, red foil, straw, sawdust and control)

A split-plot method (block system) was used with five options/treatments in four replications.

The Dutch tomato hybrid *Gardel* F_1 was used, which is characterised by indeterminate (unlimited) growth, firm, smooth fruits, intensive red colour, good taste and an average weight of 190–220 g. This tomato can be produced in open fields and in protected areas (greenhouses or glasshouses).

Twenty plants were used for each treatment in each repetition, yielding a total of 100 plants for one repetition. Therefore, there were 400 tomato plants in this experiment. Sampling and measuring of the fruits were performed randomly on three plants in each option, once every eight days during the two-month fruit-bearing period.

All regular plant care measures were implemented in the sample field. The preparation of the sample field was performed in accordance with accepted standards: deep ploughing in the autumn followed by the application of fertilizers, regular nutrition with water-soluble fertilisers, application of a fertigation system (drop by drop), as well as regular protection against diseases and pests.

The results were statistically processed with Duncan's multirange test.

The soil in the experimental plot is deep alluvium (Fluvisol) with a sandy and clay texture. The mechanical (physical) composition of the soil was analysed using the International B pipette method. The total amount of sand varied from 61.17% at the surface layer to 77.43% in the 40–60 cm-deep layer (Figure 1), indicating a relatively low ability of the soil to absorb water and nutrients.

Table 1. Mechanical (physical) composition of the soil in the sample field

Profile depth (cm)	Coarse sand (%)	Fine sand (%)	Silt (%)	Clay (%)	Total sand (%)	Total clay (%)
0-20	**0.32**	60.86	27.90	**10.93**	61.17	**38.83**
20-40	**0.59**	65.56	23.93	**9.92**	66.15	**33.85**
40-60	**0.36**	77.07	14.32	**8.25**	77.43	**22.57**

The first layer, from 0 to 20 cm, has more clay, but the percentage of total sand increases with the depth, and the percentage of clay is lower at different depths (from 61.17% in the 0–20cm layer, 66.15% in the 20–40 cm layer and 77.43% in the 40–60 cm layer). The percentage of total clay (silt + colloidal clay) declines with the depth. Thus, the percentage is 38.83% in the first layer, 33.85% in the 20–40 cm layer and 22.57% in the 40–60 cm layer.

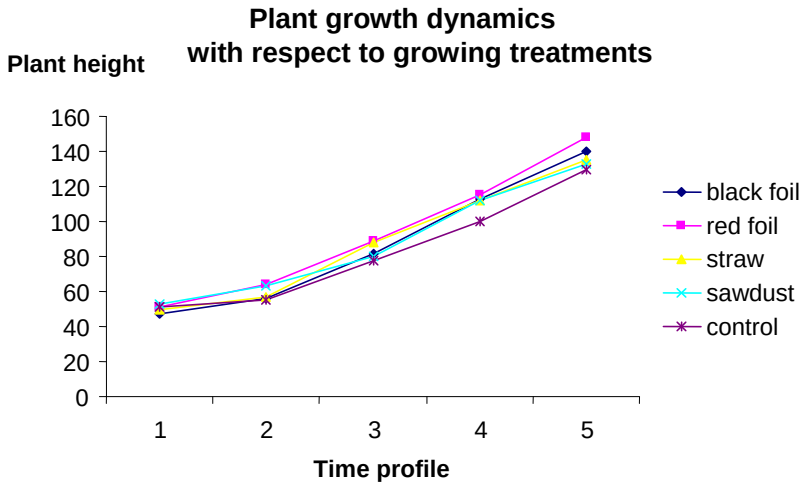
RESULTS AND DISCUSSION

Analysis of morphological characteristics

It is important to emphasise that the plants grown on the soil mulched with red foil were the tallest, reaching a maximum height of 148 cm. The application of black foil, straw and sawdust resulted in plants with a maximum height of 140 cm, 135 cm and 133 cm, respectively; the lowest height (130 cm) occurred with the plants grown on the uncovered soil (control). As the cultivation was on two stems and the top was not decapitated (cutting off), the plant stalk was forced upon reaching the string at a height of 135 cm to grow downwards. Similar results were reported by Mišković (2003) who noted a significant difference between growing tomatoes on two stems without decapitation and growing tomatoes on uncovered soil, reaching a maximum height of 110 cm.

The height that the main stem reaches is a variable trait, which depends on the way the stalk is formed, fertiliser, way of sowing and planting, crop density, irrigation and other agro-technical measures (Patron, 1981).

Plant growth dynamics are shown in Figure 1.



Mulch type	Dates when the plant heights were measured (time profile)				
	1 (19.06)	2 (26.06)	3 (06.07)	4 (14.07)	5 (22.07)
Black foil	47.6	56.0	82.0	113.0	140.0
Red foil	51.5	64.0	89.0	115.0	148.0
Straw	50.0	57.0	88.0	112.0	135.0
Sawdust	52.5	63.0	80.0	112.0	133.0
Control	51.0	55.0	78.0	100.0	130.0

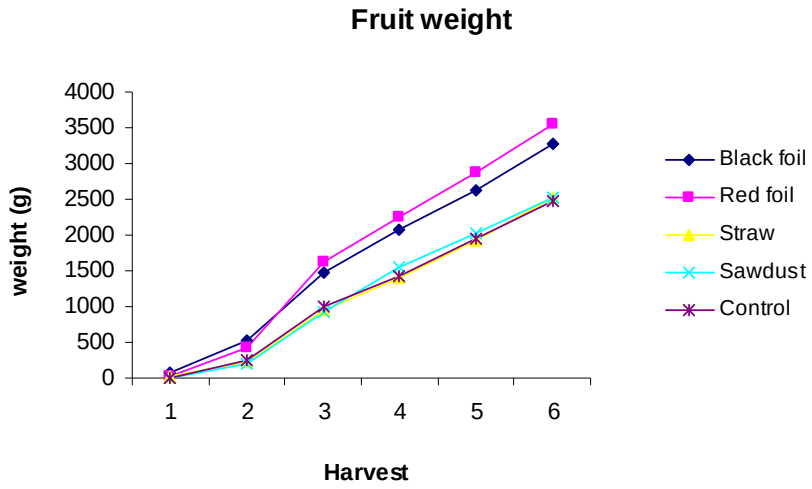
Figure 1. Plant growth dynamics with respect to the growing treatments

The results of the analysis showed that plant growth upon germination was uniform with respect to the treatments. After the first week, the growth accelerated with the red foil and the sawdust treatments. In the next ten days, the plants on the red foil continued to show the fastest growth, and the growth on the straw was also significantly accelerated. The plants on the other treatments exhibited slightly faster or almost the same growth. Until the end of the studied period, the growth of the plants was the most uniform and fastest on the red foil and the black foil treatments, followed by the straw treatment. Their growth was faster than the plants grown on the sawdust or the control.

The influence of the organic mulch on the tomato plant's height and fruit weight was previously studied in Bangladesh (Kayum et al., 2008). This study concluded that plants grown on straw were higher (115.8 cm) than those grown under a control, i.e. without mulch (100.8 cm), which is in line with our results.

Decoteau et al (1989) examined how different colour foil affects the yield of tomatoes and also obtained results similar to ours: the highest yield was obtained on the red rather than on the black foil.

Growth dynamics and the weight of the fruit weight are shown in Figure 2.



Harvest: 1 (29.07.2009), 2 (06.08.2009), 3 (16.08.2009), 4 (24.08.2009), 5 (01.09.2009), 6 (10.09.2009)

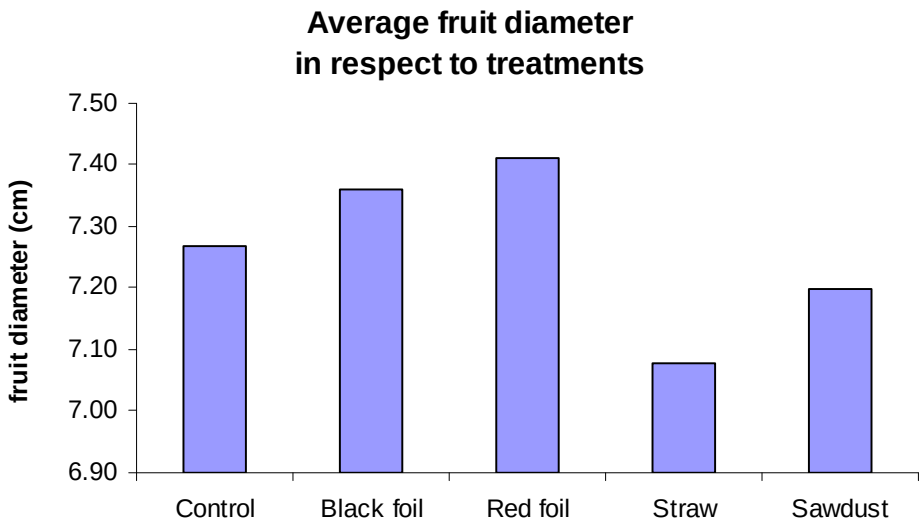
Treatment	Fruit weight (g)
Control	2470 a
Black foil	3268 b
Red foil	3545 b
Straw	2530 a
Sawdust	2516 a
significance	0.000 ***

Figure 2. Fruit weight per plant

The highest fruit weight per plant was obtained on the red foil (3.545 g), than on straw (2.530 g), sawdust (2.516 g) and the control (2.470 g).

However, between the red and the black plastic foil, on the basis of the obtained values, we concluded that there were no statistically significant differences. The same values were found for the control and the straw, the sawdust and the control and the sawdust and the straw, marked with the letters 'a' or 'b'. They showed no difference at the level of $p \leq 0.05$ according to Duncan's multiple range test.

Changes in the fruit diameters are given in Figure 3.



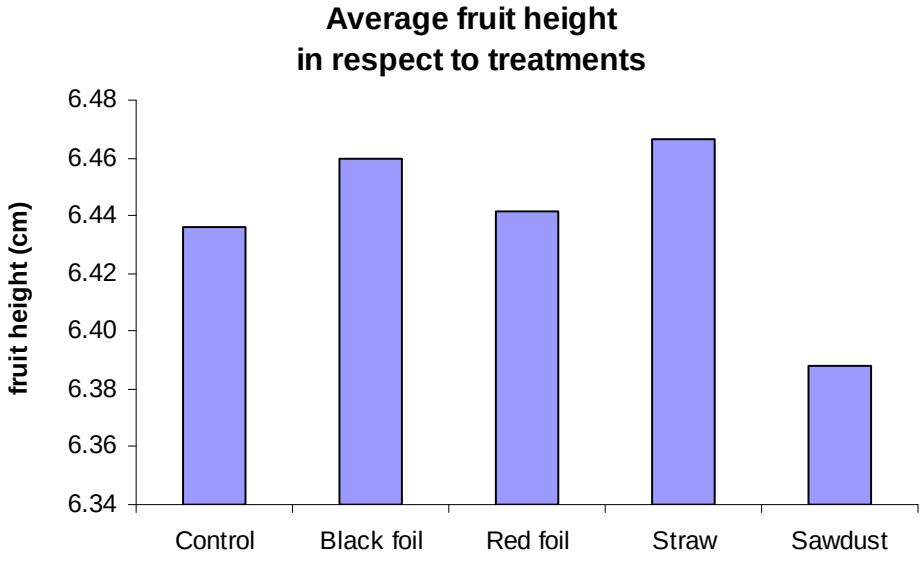
Treatment	Fruit diameter (cm)
Control	7,26 a
Black foil	7,36 a
Red foil	7,41 a
Straw	7,08 a
Sawdust	7,20 a
significance	0,514
	ns

Figure 3. Average fruit diameter with respect to the different treatments

The largest fruit diameter was obtained with plants grown on the red (7.41 cm) and black foil (7.36 cm). A slightly larger fruit diameter was obtained with plants grown on the unmulched soil (7.26 cm), followed by the sawdust (7.20 cm) and the straw (7.08 cm).

There were no significant differences at the level of significance of 95%.

Changes in the fruit size are given in Figure 4.



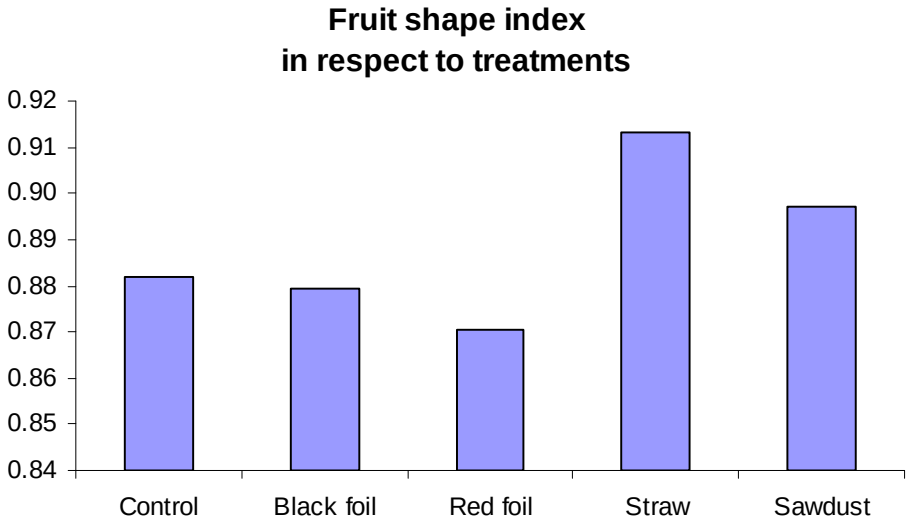
Treatment	Fruit height (cm)
Control	6.44 a
Black foil	6.46 a
Red foil	6.44 a
Straw	6.47 a
Sawdust	6.39 a
significance	0.994
	ns

Figure 4. Average fruit height with respect to the different treatments

The average fruit height on the straw was 6.47 cm. The average height was slightly lower on the black foil (6.46 cm), followed by the red foil and the control (6.44 cm). The lowest average fruit height (6.39 cm) was on the sawdust.

There were no significant differences at the level of significance of 95%.

The fruit shape index is shown in Figure 5. Considering that the significance value was >0.5, there was no statistically significant difference at the significance level of 95%.



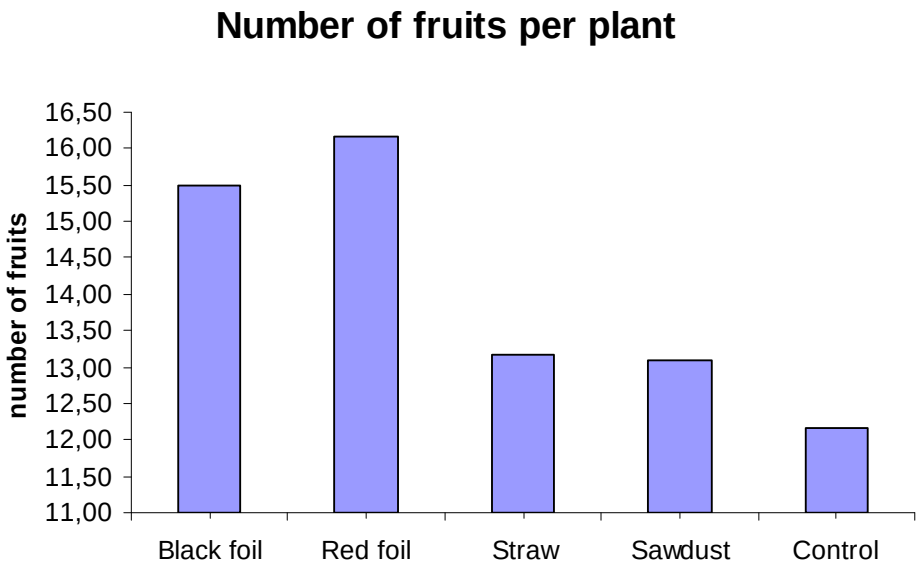
Treatment	Shape index
Control	0.88 a
Black foil	0.88 a
Red foil	0.87 a
Straw	0.91 a
Sawdust	0.90 a
significance	0.619
Treatment	Ns

Figure 5. Fruit shape index with respect to the different treatments

The fruit shape index shows that the fruits with an index of 0.80–0.90 that were cultivated on the black and the red foil, as well as on the soil (control), were slightly flattened. Fruits with an index of 0.90–1.00 were categorised as round fruits, and such fruits were obtained on soil mulched with the straw and sawdust.

As the significance value was more than 0.5, there were no statistically significant differences at the level of significance of 95%.

Dynamics of the changes in the number of fruits per plant are shown in Figure 6.



Number of fruits per plant

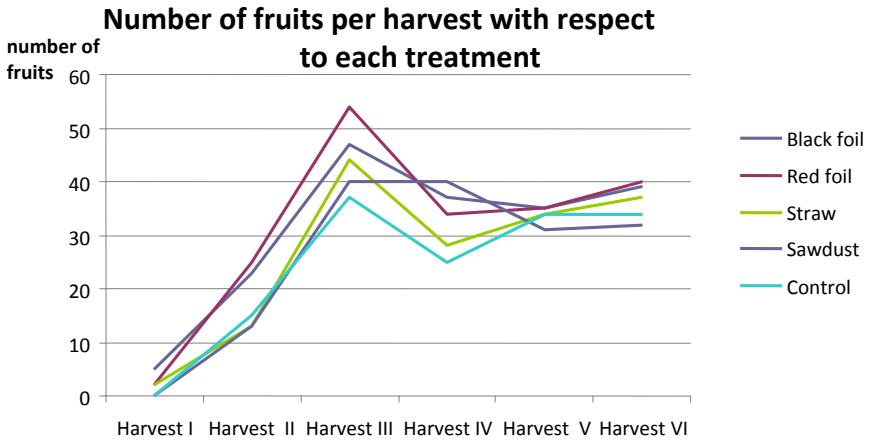
	Groups	Treatments	Means
Black foil	ab	1	15,50000
Red foil	a	2	16,16667
Straw	abc	3	13,16667
Sawdust	bc	4	13,08333
Control	c	5	12,16667

Figure 6. Number of fruits per plant

The highest number of fruits per plant (16.17) was recorded in the plants grown on the red foil, and there was a statistically significant difference between those on the red foil compared with those on the straw (13.17), the sawdust (13.08) and the control 12.17.

However, as the significance level was 95%, we concluded that there was no significant difference between the plants grown on the black and the red foil or between those grown on the straw and the sawdust and the sawdust and the control.

The values for the fruits per harvest are shown in Figure 7.



Mulch type	Harvest I	Harvest II	Harvest III	Harvest IV	Harvest V	Harvest VI
Black foil	5	23	47	37	35	39
Red foil	2	25	54	34	35	40
Straw	2	13	44	28	34	37
Sawdust	-	13	40	40	31	32
Control	-	15	37	25	34	34

Figure 7. Overview of the number of fruits per harvest with respect to each treatment

Growth occurred on the black foil (Figure 7) in the second (23 fruits) and the third harvest (47 fruits), but in the fourth (37) and the fifth (35) harvests the growth was slightly lower than in the previous harvests. Growth also occurred in the sixth harvest (39 fruits).

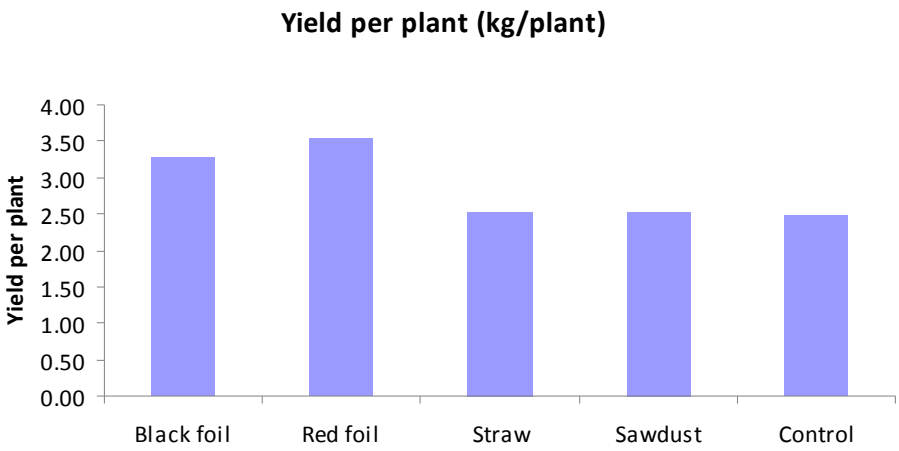
Furthermore, production on the red foil (Figure 7) yielded high values in the second (25 fruits) and the third harvest (54 fruits) but showed a decrease in the fourth harvest (34 fruits). There was also growth in the fifth harvest (35 fruits) and in the sixth harvest (40 fruits).

Cultivation on the organic mulch, straw and sawdust resulted in almost identical values of fruits per harvest (Figure 7.). The fruits increased rapidly in size in the second and the third harvests (13 fruits in the second harvest for both the straw and sawdust treatments, but 40 fruits for the sawdust and 44 fruits for the straw treatments in the third harvest). However, the growth was reduced in the fourth harvest with cultivation on the straw (28 fruits). The number of fruits increased in the fifth and the sixth harvests (34 fruits and 31 fruits on the straw

and the sawdust, respectively, in the fifth harvest and 27 fruits and 32 fruits on the straw and the sawdust, respectively in the sixth harvest).

There were no fruits produced on the soil (control) (Figure 7). There were 15 fruits in the second harvest, but the value in the third harvest was extremely high (37 fruits). This decreased in the fourth harvest (25 fruits), and higher numbers of fruits were recorded once again in the fifth (34) and sixth (34) harvests.

Analysis of the yield per plant is presented in Figure 8.



	Groups	Number of fruits per plant treatments	g per plant
Red foil	a	2	3545,42
Black foil	a	1	3268,33
Straw	b	3	2530,42
Sawdust	b	4	2516,67
Control	b	5	2470,00

Figure 8. Yield per plant

The highest yield per plant was obtained with the plants cultivated on the soil covered with mulch foils. The highest yield was obtained with the red foil treatment (3.55 kg), and a slightly lower yield was obtained on the black foil (3.27 kg). There were no statistically significant differences at the significance level of 95%. Yields on the soil covered with the organic mulch (straw and sawdust) were almost identical, with a slightly higher yield obtained on the straw (2.53 kg) than on the sawdust (2.52 kg). The lowest yield (2.47 kg was found with the tomato plants cultivated on the soil (control).

DISCUSSION. Overall, the analysis of the application of different mulch types point to positive effects of mulching and highlight differences with respect to mulching materials (Deiser, Eichin, 1992). The results of previous studies of the effects of mulching have justified the application of this agro-technical measure.

Unlike determinate varieties, which exhibit limited stem growth, indeterminate tomato varieties are characterised by unlimited growth of the plant main stem (Brežnev, 1964). An indeterminate tomato variety was used in our experiments. The height of the plants increased continually during the experiment in all of the treatments. Mišković (2003) reported similar results, observing a highly significant difference in the height of tomatoes grown on two stems without the removal of tops; the plants reached a maximum height of 110 cm when grown on soil. The formation of the tomato stem depends on whether it is grown in a protected area (greenhouse or glasshouse) or in an open field. The largest total yield was obtained with varieties cultivated on one stem and without cutting the tops off. Plants that emerge earlier require decapitation after the fourth inflorescence (Damjanović et al., 1992a, 1992b).

Similar experiments were also conducted in Cuba of the effects of organic mulch (rice straw with rice husks and bran and rice straw alone) and black-white foil (control) on the growth and the yield of cherry tomato (Rodriguez, 2007). The plants mulched with the rice bran were taller (96.75 cm) than with the foil treatment (89.92 cm) or the rice straw without bran (87.97 cm).

The **average fruit weight** differed with respect to the type of treatment, showing a significant difference when grown on the red and the black foil compared with the other treatments. According to our results, the largest average fruit weight was obtained with the plants grown on the soil mulched with the red (224 g) and the black (211 g) foil. Florao (2010) reported similar results in a study conducted in Kentucky, noting that the largest average fruit weight was obtained with plants mulched with red foil (227 g) and black foil (186 g). This study also subjected the data to statistical analysis using Duncan's multiple range test.

Number of fruits per plant is one of the most important characteristics of the yield (Takač, 1992). Large-fruited varieties produce significantly less fruits per plant than small-fruited varieties. Other research has suggested that when growing plants on one stem, the number of fruits varies from 37 to 47, whereas the number falls to 24 to 30 when the plants are grown on one stem with four inflorescences. According to Mišković (2003), when growing on two stems, the most fruits were also obtained in the third harvest (86). We found similar results, obtaining the most fruit from plants grown on the red foil (54).

According to Florao (2010), a larger **average fruit size** was obtained with plants cultivated on a red foil (3.9 cm) than with plants cultivated on soil mulched with a black foil (3.5 cm). Taber and Smith (2009) stated that the smallest sized fruits occurred with tomatoes mulched with a red foil (4.9 cm) and a black foil (5.4 cm), and that the largest were found on a red/black combination (7.0 cm). Our study showed no significant differences in fruit size per treatment.

The largest fruit occurred on plants cultivated on the red foil (7.41 cm) and the smallest on the straw (7.08 cm).

Calculations of the **fruit shape index** showed no statistically significant difference (>0.5). Interestingly, the highest fruit shape index was with plants cultivated on the straw and the sawdust, and the least was on the red foil. The fruits of the plants with an index of 0.8–0.9 that were cultivated on the black and the red foil and on the soil were slightly flattened. The fruits of the plants cultivated on the soil mulched with the sawdust and the straw had an index of 0.9–1.0 and were categorised as round fruits.

Fruit yield depends on many factors. The most relevant are the genetic characteristics of the variety, agro-ecological conditions of the region and the application of agro-technical measures. In our study, the largest yield per plant was achieved with the plants cultivated on the soil covered with mulch foils. When mulched with the red foil, the yield was 3.55 kg per plant, but the yield was slightly lower on the black foil, 3.27 kg per plant. The yields on the soil covered with the organic mulch (straw and sawdust) were almost the same; they were slightly higher on the straw (2.53 kg per plant) and the sawdust (2.52 kg per plant), whereas the control had the lowest yield (2.47 kg per plant). Wallace et al. (2004) investigated differences in the effects of the foil mulch on tomato production on plain soil in Texas. They reported a higher yield with the foil mulch than without mulching. The largest yield was obtained with a silver foil, then black foil, red foil and the least on the soil.

CONCLUSION

Based on our analysis of the effects of different mulching methods on the yield of tomato (*Lycopericon esculentum,* Mill.), we may conclude the following:

-The tallest plants occurred with the red foil mulch and the lowest with cultivation on the soil (control);

- Cultivation on the red foil yielded the largest number of tomato fruits, whereas cultivation on the soil (control) yielded the lowest number of fruits;

- The highest weight of fruits was achieved again by mulching the soil with the red foil and the lowest with cultivation on the soil (control);

- The tallest tomato plants were those cultivated on the straw and the lowest were those cultivated on the red foil and on the soil (control);

- Cultivation on the red foil resulted in fruits with the largest diameter, whereas cultivation on the straw mulch yielded fruits with the smallest diameter;

- The largest yield per plant was achieved on the soil mulched with the red foil, and the smallest occurred with cultivation on the soil (control) without the application of mulching materials.

The fruit shape index indicates that fruits with an index of 0.80–0.90, cultivated on the black and the red foil, as well as on the soil (control), were

slightly flattened. Fruits with an index of 0.90–1.00 were categorised as round fruits, and such fruits were obtained on the soil mulched with the straw and the sawdust.

Our study confirms the findings of previous research, i.e. the most successful tomato production occurs on soil mulched with red foil. Therefore, based on our findings, we recommend that tomato producers mulch soil with a red foil. Moreover, our study demonstrates that good results can be obtained with straw and sawdust mulches. Average results were achieved for tomatoes cultivated on the straw and sawdust mulches, and the poorest results were obtained for those cultivated on soil only without any application of mulching materials.

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NAČINI MALČOVANJA I NJIHOV EFEKAT NA PRINOS PARADAJZA *(Lycopersicon esculentum, Mill.)* NA PODRUČJU ZETSKE RAVNICE

SAŽETAK

Postavljanje ogleda i eksperimentalni dio istraživanja sprovedeni su na lokalitetu Žabljačke livade, područje Zetske ravnice.

Za malčovanje zemljišta korišćena je slama od pšenice i pilotina od drveta, (materijali organskog porjekla) i plastična folija crne i crvene boje. Kontrola je vršena na zemljištu bez malč materijala. Ogled sa paradajzom je postavljen po blok sistemu, u četiri ponavljanja, sa sklopom od 2,08 biljaka/m^2. Međuredno rastojanje je 1,2m, a rastojanje između biljaka 0,4 m.

U istraživanju se pošlo od predpostavke da gajenje paradajza na različitim malč materijalima treba da ukaže na razlike u visini, masi, obliku, broju plodova i prinosu, u odnosu na gajenje na zemljištu bez primjene malča, kod proizvodnje na otvorenom polju.

Bolji rezultati ostvareni su kod biljaka gajenih na zemljištu prekrivenom malč folijama. Primjena crvene folije rezultirala je najbolji vegetativni porast biljaka zatim, broj, masu i krupnoću ploda, kao i ukupan prinos (3,55kg/biljci). Nešto lošiji rezultati postignuti su kod gajenja na crnoj foliji (3,27 kg/biljci), a prosječni na slami (2,53kg/biljci) i pilotini (2,52kg/biljci). Najslabija proizvodnja je ostvarena na zemljištu bez primjene malča (2,47 kg/biljci).

Ključne riječi: ogled, malčovanje, paradajz, zemljište, prinos.