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Department of Agronomy

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Impact of various growing methods on tomato (*Lycopersicon esculentum* Mill.) yield and sensory quality

Dragan ŽNIDARČIČ[1], Stanislav TRDAN[2], Emil ZLATIČ[3]

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ABSTRACT

The effect of various growing methods of tomato (*Lycopersicon esculentum* Mill.) cv. Hector on fruit yield and sensory properties was examined. The growing methods used were: bare soil (BS), black plastic mulch (BPM), bare soil with polypropylene row cover (BS + RC) and black plastic mulch with polypropylene row cover (BPM + RC). The yields of all growing methods were reduced during growing season of extreme rainfall. The results show that the use of BPM + RC resulted in the highest total fruit yield (15.93 t ha^{-1}). By using row cover (BS + RC or BPM + RC) it has been observed that marketable yield could be significantly higher than in the BS and the BPM treatments. Plants grown in the BPM and in the BPM + RC yielded larger number of fruits in comparison to plants in the BS or in the BS + RC. The fruit height and diameter were not affected by the treatments. This study also gives a sensory characterisation of various growing methods as an indicator of suitability for growing and marketing of tomatoes. Tomatoes grown in the BPM + RC resulted in the highest total taste intensity.

Key words: tomato, black plastic mulch, polypropylene cover, yield, fruit quality, sensory evaluation

IZVLEČEK

VPLIV RAZLIČNIH TEHNIK GOJENJA NA PRIDELEK IN SENZORIČNE LASTNOSTI PARADIŽNIKA (*Lycopersicon esculentum* Mill.)

V raziskavi je bil proučevan vpliv različnih tehnik gojenja paradižnika (*Lycopersicon esculentum* Mill.) cv. Hector na pridelek plodov in njihove senzorične lastnosti. Tehnike gojenja so bile: gola tla (BS), črna plastična zastirka (BPM), gola tla, prekrita s polipropilenskim prekrivalom (BS + RC), in črna plastična zastirka skupaj s polipropilenskim prekrivalom (BPM + RC). Pridelki so bili zaradi intenzivnih padavin v rastni dobi nizki, ne

[1] B. Sc. Agr., SI-1111 Ljubljana, Jamnikarjeva 101, P. O. Box 2995

[2] Teach. Assist., Ph. D., ibid

[3] B. Sc. Food Sc. and Teh., ibid

glede na tehniko gojenja. Najvišji skupni pridelek plodov (15,93 t ha^{-1}) je bil dosežen ob obravnavi BPM + RC. S prekrivanjem (BS + RC ali BPM + RC) so bili doseženi statistično značilni višji tržni pridelki kot ob obravnavi BS in obravnavi BPM. Rastline, gojene na BPM in na BPM + RC, so dale več plodov v primerjavi z rastlinami, gojenimi na BS ali na BS + RC. Tehnike gojenja niso vplivale na premer in višino plodov. V raziskavi je bil prikazan tudi vpliv tehnik gojenja na senzorične lastnosti plodov, ki bi bile lahko kazalec pri pridelavi in trženju paradižnika. Paradižnik, gojen na BPM + RC, je imel skupaj najboljši okus.

Ključne besede: paradižnik, črna plastična zastirka, polipropilensko prekrivalo, pridelek, kakovost plodov, senzorično vrednotenje

INTRODUCTION

Tomato is one of the most valuable fruit vegetable grown in Slovenia, being grown in almost all home gardens as well as commercial operations. Although in botanical terms, tomato is a berry fruit, it is grown and consumed as vegetable. During 2000, the crop was cultivated over an area of 146 ha (Statistical Office RS, 2001).

Important factors to be considered for growing tomatoes are the variety, selection of site, type of soil, fertilization, stage of harvest and crop rotation. Black plastic mulch has been widely used in the production of fresh market tomatoes (Pan et al., 1999). The beneficial responses of tomatoes to black plastic mulch, such as higher total yields, earlier production and better fruit quality, have been discussed by many authors (Abdul-Baki et al., 1992; Call and Courter, 1989; Decoteau et al., 1989). Additional benefits of plastic mulches are their ability to conserve soil moisture, and their potential to direct rain water to the crop plants (Lamont, 1993) and reduce insect and disease problems (Greenough et al., 1990). Black plastic mulch was supposed to function as a mechanical barrier preventing a direct contact of the plant with the inoculum of the fungus in the soil (Trdan et al., 2001). Last but not least the edible product from a mulched crop such as tomato is cleaner and less subject to rots because soil is not splashed on the fruit.

Row covers are another important component of a tomato production system. Row covers are a flexible transparent covering which is installed over plants to reduce the need for insecticide, increase air temperature around the crop. Furthermore, their usage has been associated with increased plant growth, higher yields and earliness of harvest (Siviero and Biribin, 1997; Wells, 1985; Bonanno and Lamont, 1987; Hemphill et al., 1988; Jensen, 1990; Teasdale and Abdul-Baki, 1995).

Although the primary objective of tomato growers is to maximise the harvest of fruit per cultivation area, consumers put a great pressure on growers to improve both tomato yield and quality. In comparison to price, produce quality is a more important factor determining the purchase (Schwartz, 1995). Sensory evaluation consists, on one hand of identifying organoleptic qualities of a product and, on the other hand, of recording the satisfaction of the consumer. In order to attain eating quality, it is important to include all sensory characteristics (Auerswald et al., 1999).

Many studies have been conducted with black plastic mulch and row covers as treatments on several vegetable crops (Brown and Channell-Butcher, 1999; Purser,

1994; Gerber et al., 1983; Ibarra et al., 2001) but information is limited on the effects of these materials on the production and quality of tomato. In the efforts to determine the effects of this type of cropping system, the study was conducted to investigate the use of black plastic mulch alone or together with row covers (polypropylene fibril cover material) in the production of tomato. Hence, an experiment was conducted to compare fruit weight, number of fruits, fruit characteristics and to evaluate the sensory quality of fruits.

MATERIALS AND METHODS

The field plots were established in 2002 at the Experimental Station of the Biotechnical Faculty in Ljubljana. The tomato (*Lycopersicon esculentum* Mill.) used for the study was determinate tomato cv. Hector. Tomato seeds were sown into 72-cell styrofoam trays filled with commercial peat. The trays were placed in a greenhouse. The seedlings were liquid fed once per week using, 0.75 g litre^{-1} N, 0.55 g litre^{-1} P_2O_5 and 1.45 g litre^{-1} K_2O.

Standard agronomic practices such as fertilisation and plant protection measures were applied during the crop period. The plants were grown in a heavy clay loam soil in the second year after farmyard manure fertilization (30 t ha^{-1}). The field preparations began in mid-April when 0.15-metre-high and 1.1-metre-wide beds were created using a rotary tiller cultivator. Granular fertilizer was incorporated at pre-plant (350 kg ha^{-1}, 15N-15P-15K). Tomatoes were established on raised beds by hand transplanting on 21 April. All beds were uniformly irrigated using T-Tape systems that delivered 5 litres min^{-1} of water per 100 m of tubing with emitting orifices spaced at 30 cm intervals. Fertigation was applied once per week irrespective of rainfall, using a 120 mg l^{-1} N, 80 mg l^{-1} P_2O_5 and 120 mg l^{-1} K_2O.

The experimental design was a randomized complete block with treatments arranged factorially and replicated four times. The treatments were as follows: black plastic mulch (BPM), bare soil (BS), BPM with RC (polypropylene row cover) and BS with RC. Each treatment contained 24 plants in triple rows; only the centre row was used for data collection. Black plastic mulch was laid by a mulch applicator to the appropriate treatments. The wire hoops were erected over the appropriate beds and polypropylene (17 g m^{-2}) cover was laid immediately after planting. Approximately 30 days after transplanting the covers were removed.

Tomato fruits, which were handpicked at the pink to full-ripe stage, were selected randomly from each treatment in the centre rows only. Harvesting was carried out once weekly between 25 of June and 15 of August. The total fruit yield, marketable fruit yield, fruit number per plant and fruit diameter and fruit height were determined immediately after each harvest. Non-marketable yield of fruit included cracked and rotten tomatoes.

The sensory quality was evaluated after the last harvest in the middle of August. Sensory analysis is a method used to directly determine quality by means of human senses, independently of instrumental determinations (Stone and Sidel, 1992). Healthy fruits of uniform size (weight about 70 g) were stored at -18 ^{o}C for 24 hours. Before the evaluation they were thawed and sorted according to their size. Each tomato was cut in 12 equal segments. An 18-member panel (eight females/ten males, between 20 and 60 years old) was recruited from the staff and the students at Department of Food Science and Technology. From the same tomato, each panellist was given one segment cut in pieces, served in a small cup, and one whole segment. The method was fully described by Haglund et al. (1997).The taste attributes (sweetness, acidulous taste and bitterness) and consistency attributes (firmness and juiciness) were entered into an evaluation form. This method of evaluation is quantitative meaning that each descriptive criterion for each sample was scored on a scale from 0 to 9 (Guerineau et al., 2000). However, these five criteria had also to be summarised as the intensity of the total taste impression. The average rankings from each panellist were used to calculate the final assessment of each fruit treatment.

Data were subjected to analysis of variance, and means were separated by Duncan's multiple range test at $P \leq 0.05$.

Table 1: Descriptive characters of the profile of tomatoes and instructions for the panel

Profile attribute	***Description***
Taste attributes	
Total taste	The characteristic of total taste intensity that occurs in the tomatoes. Scale: 0 = low taste intensity, 9 = high taste intensity.
Sweetness	The intensity of sweet taste. Scale: 0 = low sweet taste, 9 = high sweet taste.
Acidulous taste	The intensity of acidulous taste. Scale: 0 = low acid taste, 9 = high acid taste.
Bitterness	The aftertaste which remains after the tomato has been expectorated. Scale: 0 = no bitter taste, 9 = much bitter taste.
Consistency attributes	
Firmness	The force needed to chew the sample 10 times. Scale 0 = little force, 9 = much force.
Juiciness	Degree of juiciness perceived while chewing the sample. Scale 0 = little juicy, 9 = very juicy.

RESULTS AND DISCUSSION

Yield and fruit characteristics

Fruit yield data of tomato by various growing methods are presented in Table 2. Yield of all tomato growing practises were generally reduced during the exceptionally rainfall growing time. Tomato fruits were exposed to heavy tomato late blight (*Phytophthora infestans* (Mont.) de Bary) pressure.

Table 2: Effects of various growing methods on fruit yield of tomato*

Treatment	Yield (t ha^{-1})		Non-marketable fruits (%)
	Total	Marketable	
BS	11.65 a	4.27 a	64.66 a
BPM	12.49 a	4.36 a	64.66 a
BS + RC	12.49 a	7.21 b	43.86 b
BPM + RC	15.93 b	6.72 b	50.23 b

*Values in the same column with different letter are significantly different (level of significance 5%)

The cumulative total fruit yield at the end of the experiment per unit area, with the exception of marketable yield, was significantly enhanced by the use of BPM + RC. The total weight yield in BPM + RC extrapolated to 15.93 tonnes per hectare, while the other growing methods produced the equivalent between 11.65 and 12.49 tonnes per hectare. In agreement with other studies on other crops (Purser, 1994; Loy and Wells, 1982; Soltani et al., 1995), this dramatic increase in tomato yield where BPM

and RC were used together, is partially due to an increase in air and soil temperatures around the plant-growing environment.

When marketable tomato yields were compared from the various growing methods, it should be noted, however, that the use of row covers significantly increased marketable yield per unit area. Tomatoes grown in BPM + RC and the BS + RC produced higher yields (6.72 and 7.21 t ha^{-1}, respectively) than those grown in BS and the BPM (4.27 and 4.36 t ha^{-1}, respectively).

An increase in percentage of non-marketable fruits and a decrease of marketable yield was observed in the no cover treatments (BS and BPM). The percentage of non-marketable fruits was lower in the row cover treatments (BS + RC and BPM + RC). As in other studies, fruits produced under row covers were less stressed than fruits produced without covers (Abdul-Baki et al., 1992; Pan et al., 1999).

Table 3: Effects of various growing methods on fruit characteristics of tomato*

Treatment	Fruit $plant^{-1}$ (No.)	Fruit weight $plant^{-1}$ (kg)	Fruit diameter (cm)	Fruit height (cm)
BS	18.08 a	1.29 a	10.06 a	5.58 a
BPM	20.83 b	1.41 a	9.50 a	5.24 a
BS + RC	18.06 a	1.38 a	10.22 a	6.02 a
BPM + RC	20.91 b	1.77 b	10.67 a	5.87 a

*Values in the same column with different letter are significantly different (level of significance 5%)

The growing method had a significant effect on number of fruit per plant. Fruit height per plant was significantly increased by the BPM (20.83) and by the BPM + RC (20.91) as compared to the BS (18.08) and BS + RC (18.06) treatments. The BPM appeared to enhance fruit number but not fruit weight per plant.

The results indicated that the difference in fruit weight per plant between different growing methods was statistically significant only in the BPM + RC treatment (1.77 kg $plant^{-1}$). No significant differences occurred in fruit weight among other treatments. Final cumulative results from all harvests showed that BPM + RC provided an 18-27% increase in fruit weight per plant compared to all other treatments, respectively.

There were only slight differences in the fruit diameter (ranged from 9.50 to 10.67 cm) and fruit height (ranged from 5.24 to 6.02 cm) due to growing methods. These fruit characteristics were not significantly affected by the treatments.

Sensory analyses

In Table 4, we summarised the 6 attributes which had been outlined during the test with significant changes of intensity. For each descriptive criterion per tomato, the average scores given by the panellists were subjected to analyses of variance.

Table 4: Effects of various growing methods on sensory quality of tomato*

Treatment	Attribute					
	Total taste	Sweetness	Acid. taste	Bitterness	Firmness	Juiciness
BS	5.78 a	7.69 a	4.72 a	5.64 a	7.01 a	6.04 a
BPM	5.64 a	7.21 a	6.02 b	5.42 a	6.12 b	6.12 a
BS + RC	6.02 a	5.48 b	5.87 b	5.76 a	6.05 b	6.05 a
BPM + RC	6.74 b	5.62 b	6.90 c	5.90 a	5.92 b	7.12 b

*Values in the same column with different letter are significantly different (level of significance 5%)

The results from field experiments indicate the importance of growing method on the sensory quality of tomato fruits. Panellists indicated that the total taste intensity was significantly affected by the growing method. Tomatoes grown in the BPM + RC were scored higher for total taste intensity than tomatoes grown in the other treatments. The tomatoes grown in the BS treatment (control treatment) and tomatoes grown in BPM, were significantly sweeter than tomatoes grown in the BS + RC and in the BPM + RC. Panellists showed the most preference for acidulous taste only for the tomato grown in the BPM + RC. The tomatoes of the control treatment (BS) scored the lowest in acidulous test, while tomatoes grown in the other treatments were more acidulous. Sensory analyses of bitterness showed no significant differences between the treatments. Evaluating of the firmness criterion, panellists could detect a significant difference between the growing methods. The tomatoes from BS treatment were firmer compared to the tomatoes from the other treatments. Panellists showed a preference for the juiciness of the tomatoes grown in the BPM + RC compared with other treatments.

The average rankings from each panellist were also illustrated in the form of a 'spider web' plot (Figure 1).

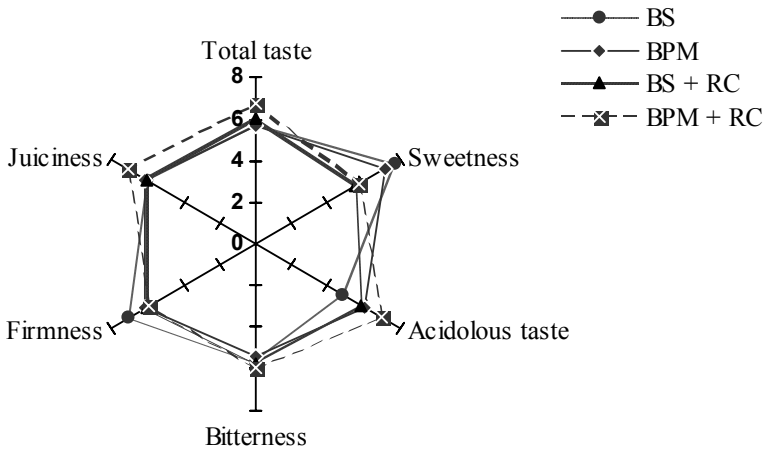

Figure 1: Sensory profiles of different growing method of tomato fruits

CONCLUSIONS

The tomato is one of the most widely accepted vegetables in Slovenia. As more tomatoes are being consumed, the growers have to grow plants with high yield and good quality adapted to their environment. Among the requirements for the optimal growing method, the sensory quality for fresh consumption as well as the marketable yield per unit area are of primary importance.

The results of the presented research show that under Slovenian ecological conditions, black plastic mulches and row covers used alone or in combination offer the grower a management tool which can increase yield and quality. In plants grown with no row cover, the presence of plastic mulch resulted in higher plant yield compared to plants grown in bare soil.

Growing methods used in our experiment also influenced the sensory qualities of tomato. The sensory parameters described in the study must be considered when fresh tomato is handled and marketed.

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