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Evaluation of ten cultivars of determinate tomato (*Lycopersicum esculentum* Mill.), grown under different climatic conditions

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ABSTRACT

The influence of different climatic conditions on fruit yield and quality of 10 determinate tomato cultivars (*Lycopersicum esculentum* Mill.) was studied. The experiments were conducted in the mediteranean and central regions of Slovenia. The plants were grown on an open field in the Dragonja valley and Ljubljana and in a low tunnel in Ljubljana. Data indicated that the marketable yield was significantly higher in the Dragonja valley than in Ljubljana. The average yield per plant grown in the Dragonja valley was 3.02 kg, grown on the field in Ljubljana 0.6 kg and in the low tunnel 1.0 kg. The highest marketable yield among the salad tomatoes was obtained with 'Stormy F1' (4.05 kg per plant) and among the processing tomatoes with 'Hypeel 108 F1' (4.7 kg per plant) and 'Centurion F1'(4.1 kg per plant). Those cultivars had some good quality characteristics, important for their application (firmness, redness of skin, thickness of pericarp and succulence). Our research documented a significant yield enhancement of determinate tomato in low tunnel production for the central part of Slovenia.

Key words: determinate tomato, *Lycopersicum esculentum* L., cultivars, climatic conditions, yield, fruit quality

IZVLEČEK

VREDNOTENJE DESETIH KULTIVARJEV NIZKEGA PARADIŽNIKA (*Lycopersicum esculentum* L.), GOJENEGA V RAZLIČNIH KLIMATSKIH RAZMERAH

V raziskavi smo proučevali vpliv različnih klimatskih razmer na pridelek in kvaliteto plodov 10 kultivarjev nizkega paradižnika (*Lycopersicum esculentum* L.). Poskusa sta potekala na prostem v dolini reke Dragonje, v Ljubljani pa na prostem in pod nizkim tunelom. Rezultati kažejo, da je bil tržni pridelek, pobran v dolini reke Dragonje statistično značilno večji od pridelka rastlin, ki so bile gojene v Ljubljani. Povprečen pridelek v dolini Dragonje je bil 3,02 kg/rastlino, v Ljubljani na prostem 0,6 kg/rastlino in pod nizkim tunelom 1,0 kg/rastlino. Med kultivarji solatnega tipa nizkega paradižnika smo največji tržni pridelek ugotovili pri 'Stormy F1'(4,05 kg na rastlino), med kultivarji nizkega paradižnika za predelavo pa pri kultivarjih

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'Hypeel 108 F1'(4,7 kg na rastlino) in 'Centurion F1'(4,1 kg na rastlino). Pri omenjenih kultivarjih smo ugotovili tudi dobre lastnosti plodov, pomembne za namen uporabe, kot so čvrstost, obarvanost kožice, debelina perikarpa in sočnost. V Ljubljani je bil pridelek paradižnika gojenega v nizkem tunelu statistično značilno večji in kakovostnejši v primerjavi z gojenjem na prostem.

Ključne besede: nizek paradižnik, *Lycopersicum esculentum* L., kultivarji, klimatske razmere, pridelek, kakovost plodov

1 INTRODUCTION

Tomatoes belong to the plant family *Solanaceae*, the nightshade family, which includes potatoes, capsicums and eggplant, as well as the nightshade weed. The tomato (*Lycopersicum esculentum* Mill.) is native to the Andes region of South America. Tomatoes were introduced to Europe in the 1500s, although until the 1700s they were believed to be poisonous if eaten, because the foliage and some other green tissues of tomato plants contain tomatine, a toxic chemical. Tomatine is also present in unripe tomato fruit, but the levels are low enough to be non-toxic. Tomatoes are divided into two types. Determinate tomatoes, also called bush or dwarf tomatoes, grow to a certain height, then flower and set all their fruit within a short time. Each shoot on the determinate plant ends in a cluster, and consequently a fruit cluster. The harvest period for determinate tomatoes is generally short, making them good choices for canning (Moraru et al., 2004).

Tomato varieties can be categorized by their use. For instance, plum tomatoes are used for canning and have thick flesh and a reduced amount of pulp. Beefsteak tomatoes are very large and also have reduced pulp, which makes them excellent for sandwiches and sauces. Classic or salad tomatoes are juicy, since they have a lot of pulp, but this tends to fall out when they are sliced. Schuch and Bird (1994) reported that the most relevant qualities of tomatoes vary depending on their intended use: taste, appearance, color and handling characteristic are important for fresh tomatoes, while viscosity and solids are the most important attributes for processing tomatoes.
Tomato yield and biomass growth are closely linked to environmental, pedologic and climatic conditions. In the open field, sensitivity to low temperatures limits their geographic distribution and time of year for planting. In Slovenia, the production area for tomato has decreased in the last fifteen years, from 566 ha to 146 ha (Statistični letopis, 2003). Cultivation areas for determinate tomato here are often located in the climatic favourably mediterranean region, while the use of plastic tunnels to increase vegetative growth and subsequent yield is needed for successful production of determinate tomato in the middle part of Slovenia.

The aim of our work was to grow ten different cultivars of determinate tomato in two climatic regions, continental and mediterranean, and evaluate the yield and fruit quality for both fresh consumption and processing.

2 MATERIALS AND METHODS

Two parallel experiments were conducted in 2004, from June to September, one on the experimental field (298 m altitude) of the Biotechnical Faculty in Ljubljana, and the other on a field in the Dragonja valley, (10 m altitude). Six tomato cultivars for fresh consumption (salad tomato) and four processing tomato cultivars were planted. Salad cultivars were 'Empire F1', 'Heinz 1370', 'Stormy F1', 'Sun Chaser F1, 'Sunjay F1', 'Super red F1' and processing cultivars were 'Hypeel 347 F1', 'Hypeel 108 F1', 'St. Marzano' and 'Centurion F1'. Determinate tomato transplants were greenhouse-grown in a plug tray system, each in 5 cm deep by 5 cm wide transplant cells filled with peat-based substrate.

The soil characteristics of the two experimental fields are given in Table 1.

Table 1. Chemical properties of the soil (0-0.30 m)

Experimental field	pH –KCl	Organic matter (%)	P (mg $100g^{-1}$ P_2O_5)	K (mg $100g^{-1}$ K_2O)	Soil type
Ljubljana	7.2	2.5	27	21	Heavy clay loam
Dragonja valley	7,5	1,1	30	33	Sandy loam

Soil cultivation, as preparation for planting, was carried out in April (Dragonja valley) and in May (Ljubljana), when 0.15-metre-high and 1.4-metre-wide beds were created using a rotary tiller cultivator. All beds were covered with black PE mulch and uniformly irrigated using T-tape systems that delivered 500 litres $hour^{-1}$ of water per 100 m of tubing with emitting orifices spaced at 20 cm intervals. The experiment was laid out in a randomized complete block design having ten tomato cultivars as treatments. The treatments were replicated four times in Ljubljana and two times in the Dragonja valley. To protect tomato plants from low night temperatures and rainfall and consequent slow growth and infection with diseases, which are closely linked to wet growing conditions, the experiments at Ljubljana were conducted in the open field and in low tunnels. In the Dragonja valley, because of the dry, warm and windy microclimatic conditions, the trial was conducted only in the open field. For the low tunnels, 2.2 m plexiglass bars were fixed at 1.5 m intervals. Tunnels were covered with transparent polyethylene (0.18 mm thickness) film and kept open on both sides. Air temperature during the growing period were measured using a Thermograph (Casella, London, UK) and daily mean temperature was calculated with the equation:

$$T_{Dmean} = (T(7.00\ a.m.) + T(2.00\ p.m.) + 2*T(9.00\ p.m.))/4$$, where was:

T(7 a.m.)…. temperature, measured at 0700 hours
T(2 a.m.) ….temperature, measured at 1400 hours
T(9 p.m.)…. Temperature, measured at 2100 hours.

Forty-eight-day-old transplants were hand transplanted on June 4 in Ljubljana and June 6 in the Dragonja valley into two rows of 1.2–metre long plots with within- and between-row spacing of 0.30 m and 0.40 m, respectively. Plots contained 8 plants. One week before transplanting the plots were fertilised with N:P:K at 70:200:300 $kgha^{-1}$, which was broadcast incorporated. The remaining N (60 kgha-1) was applied via fertigation in six equal splits at 10-day intervals through irrigation water, which was passed through a fertilizer tank to which the calculated quantity of water soluble fertilizer ($Ca(NO_3)_2$) had been added. Irrigation was applied as required through a drip tape beneath the plastic mulch. Diseases were managed with applications of Score, 0.03% on July 24 (Ljubljana), Ridomil Gold MZ, 3 $kgha^{-1}$, July 7 and 28 (Ljubljana and Dragonja valley) and August 10 (Ljubljana).

At both locations, the harvested fruit was graded into marketable and cull fruit (cracked and rotten). The first harvest in Ljubljana was on August 23 and the last harvest was on October 10. The crop in the Dragonja valley was harvested on September 22. Ten representative fruits of each individual cultivar harvested in Ljubljana were evaluated separately. The weight, length, width and thickness of pericarp of fruits were measured, color (redness) of the skin, firmness and juiciness were estimated. Data for total and marketable yield for both

locations were evaluated by analysis of variance and means were separated by Duncan's multiple range test at P≤ 0.05. The results are shown in the tables and figures.

3 RESULTS AND DISCUSSION

Temperature measurement

The results of air temperature for both locations are presented in Figure 1.

Day temperatures during the growing period ranged from 18 °C to 35 °C and night temperatures fell between 5 °C and 15 °C in the open field in Ljubljana. The daily mean temperature in the low tunnel was higher than in the open field in Ljubljana, by approximately 4-5°, on account of the higher temperatures in the evening, at night and early in the morning.

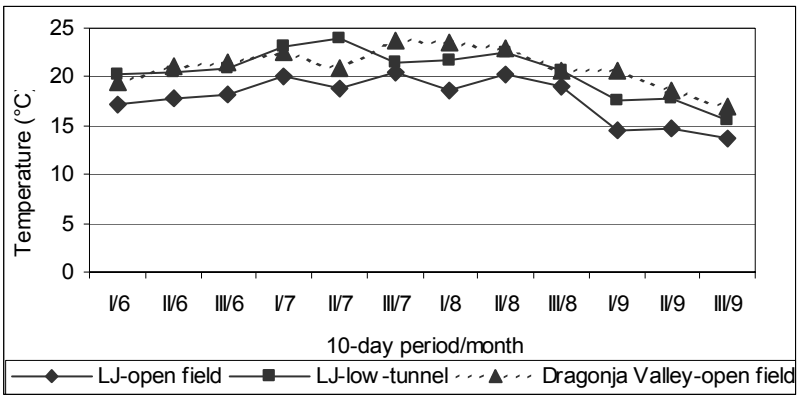

Figure 1: Daily mean temperatures during the growing period in °C 30 cm above the ground, in each 10-day period, outdoors in Ljubljana and Dragonja valley and in the low tunnel in Ljubljana in 2004.

Growth and yield performance

Due to moderate temperatures and rainy weather during June, July and August at the Ljubljana field, plant growth was slow and the first ripe tomatoes were not picked until August 23, about a two weeks later than usual. All cultivars exhibited an erect and bushy growth pattern and they grew without any physiological disorders. The results show great variation in fruit yield among the cultivars and between the growing locations, which is the result of different microclimatic conditions and the adaptability of different cultivars to growing conditions.

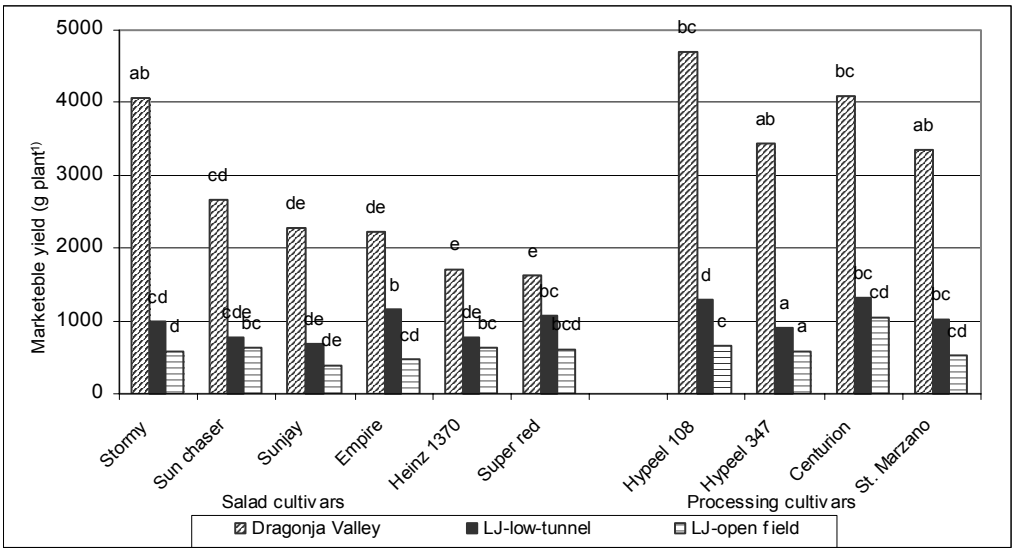

Figure 2: Average values of marketable yield of tomato cultivars harvested at different growing locations in g/plant. In relation to the growing location, means with the same letter are not significantly different according to Duncan's multiple range test at $P<0.05$.

Marketable yield was significantly higher in the Dragonja valley than in Ljubljana. Statistically significant differences among cultivars were found in the marketable yield at both growing locations. The results showed that 'Stormy F1' of the salad tomatoes harvested in the Dragonja valley and processing tomatoes 'Hypeel 108 F1' and 'Centurion F1' harvested at both locations had significantly larger yields than the other seven cultivars, whereas the lowest yield was recorded with 'Heinz 1370' and 'Super red F1' harvested at both locations and 'Sunjay F1' harvested in Ljubljana. These results are in accordance with those of Arin and Ankara (2001), Poysa (1991) and Abdul-Baki et al. (1996) who also observed yield differences in various tomato cultivars in different growing conditions. Todorov and Pevicharova (2003) also reported that foreign hybrid tomato cultivars showed higher variation of fruit yield, good adaptability, high yield potential and good quality compared to common (nonhybrid) cultivars.

Quality of the yield

Table 2: Percentage of marketable yield and cull yield (cracked and rotten fruits)

CULTIVAR	Treatment	YIELD (%)	
		Marketable	Cracked and rotten
Processing cv.			
Hypeel 108 F1	Dragonja valley	95.9	4.1
	Lj-low tunnel	79.4	20.6
	LJ- open field	51.4	48.6
Hypeel 347 F1	Dragonja valley	85.6	14.4
	Lj-low tunnel	73.1	26.9
	LJ- open field	44.2	55.8
Centurion F1	Dragonja valley	90.8	9.2
	Lj-low tunnel	80.5	19.5
	LJ- open field	64.1	35.9
St. Marzano	Dragonja valley	89.2	10.8
	Lj-low tunnel	72.4	27.6
	LJ- open field	36.2	63.8
Salad cv.			
Stormy F1	Dragonja valley	83.8	16.2
	Lj-low tunnel	52.8	47.2
	LJ- open field	28.2	71.8
Sun chaser F1	Dragonja valley	61.5	38.5
	Lj-low tunnel	59.5	40.5
	LJ- open field	43.2	56.8
Sunjay F1	Dragonja valley	85.6	14.4
	Lj-low tunnel	49.5	50.5
	LJ- open field	26.6	73.4
Empire F1	Dragonja valley	58.9	41.1
	Lj-low tunnel	61.1	38.9
	LJ- open field	27.9	72.1
Heinz 1370	Dragonja valley	58.3	41.7
	Lj-low tunnel	67.6	32.4
	LJ- open field	47.5	52.5
Super red F1	Dragonja valley	49.4	50.6
	Lj-low tunnel	71.9	28.1
	LJ- open field	43.4	56.6

In the Dragonja valley, 90% of yield from processing cultivars and 66% of salad cultivars were marketable. The average proportion of marketable yield was much lower in Ljubljana. Only 48% of the yield from processed cultivars and 36% of yield from salad cultivars grown on the open field were marketable. Results were better when the tomatoes were grown under tunnels, where 76% (processing cultivars) and 60% (salad cultivars) of the yield was marketable. Gerber et al. (1988) obtained similar results with pepper, in which they observed that tunnelling increased the fruit yield and quality of pepper. In the Dragonja valley, 'Hypeel 108 F1' had the highest percentage of marketable yield, followed by 'Centurion F1', 'St. Marzano' and 'Hypeel 347'. Among the salad cultivars, 'Stormy F1' and 'Sunjay F1' had the highest percentage of marketable yield, followed by 'Sunchaser F1', 'Empire F1', 'Heinz 1370' and 'Super red F1'. In the field in Ljubljana, the percentage of cracked and rotten yield of processing tomato was highest with 'St. Marzano', followed by 'Hypeel 347 F1', 'Hypeel 108 F1' and 'Centurion F1'. Among the salad cultivars, the highest percentage

of rotten and cracked yield was found with 'Sunjay F1', 'Stormy F1' and 'Empire F1', followed by 'Sun chaser F1', 'Heinz 1370' and 'Super red F1'.

Fruit measurements and quality evaluation

The performances of the ten cultivars of determinate tomato are presented in Table 3. The quality evaluation was considered as a trend for comparing the cultivars, and the results were not statistically analysed.

Table 3: Fruit characteristics and quality attributes for 10 determinate tomato cultivars

Cultivar Processing cv.	Average fruit weight (g)	Average fruit length (cm)	Average fruit width (cm)	Thickness of pericarp (mm)	Redness* (1-5)	Firmness* (1-5)	Juiciness* (1-5)
Hypeel 108 F1	88.0	8.0	4.2	8.6	4.5	3.7	1.6
Hypeel 347 F1	105.2	7.1	4.7	8.6	4.0	5.0	1.6
Centurion F1	79.7	5.2	4.6	7.8	4.2	4.9	2.6
St. Marzano	71.1	7.4	3.8	7.8	4.8	3.6	1.8
Salad cv.							
Stormy F1	169.4	5.4	6.8	7.2	5	4.6	2.6
Sun chaser F1	192.1	6.3	6.4	7.4	3.8	2.9	2.8
Sunjay F1	204.3	6.4	7.1	6.2	4.8	2.3	3.6
Empire F1	189.7	5.7	6.7	6.8	3.0	1.4	3.6
Heinz 1370	133.4	4.7	5.8	5.6	3.5	2.1	4.6
Super red F1	145.3	5.7	6.0	6.4	3.5	3.6	3

* 1.....bad or low 5.....very good or high

The results show great variation in fruit size and quality characteristics among the cultivars. Processing tomatoes had a lower average fruit weight, but thicker pericarp compared to salad tomatoes. Among the processing cultivars, 'Hypeel 347 F1' had heavier fruits (105 g) than other processing cultivars. 'St. Marzano' produced the smallest fruit (71 g). The intensity of redness of the fruit skin, thickness of pericarp and amount of pulp (juiciness) are very important attributes for processing tomatoes. Two cultivars, 'Hypeel 108 F1' and 'Hypeel 347 F1', had the thickest pericarp (8.6 mm) and the smallest amount of pulp. The redness of the fruit skin varied from 4.0 with 'Hypeel 347 F1' to 4.8 with 'St. Marzano'. Among the salad cultivars, the heaviest fruits were recorded with 'Sunjay F1' (204 g) followed by 'Sunchaser F', 'Empire F1' and 'Stormy F1'. 'Heinz 1370' and 'Super red F1' had the smallest fruits, with poorly coloured fruit skin. The important characterictics for salad tomato cultivars are firmness of fruit and amount of pulp (juiciness). The results show that 'Stormy F1' was the firmest of the salad tomatoes and the redness of the skin was also the highest.

4 CONCLUSIONS

The present investigation was based on the fact that tomato fruit yield and quality are closely linked to the growing conditions. The aim of our work was to evaluate the adaptability of different determinate tomato cultivars, those for fresh consumption and those for processing, to different microclimatic conditions and to estimate the fruit

yield and quality of fruits. The experiments were conducted in mediteranean and central regions of Slovenia. Data indicated that the marketable yield was significantly higher in the Dragonja valley in comparison to Ljubljana. 'Stormy F1' had the highest marketable yield among the salad tomatoes and 'Hypeel 108 F1' and 'Centurion F1' among the processing tomatoes. These cultivars had some good quality characteristics, important for their application. Our research also showed significant yield enhancement of determinate tomato in low-tunnel production for the central part of Slovenia.

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