



EFFECT OF CULTIVAR, POSITION OF FRUITS IN TREE-CROWN AND OF SUMMER PRUNING ON SURFACE TEMPERATURE OF APPLES AND PEARS

Tomasz Lipa, Janusz Lipecki, Anna Janisz

Department of Pomology, University of Life Sciences in Lublin, Poland

ABSTRACT

Extensive studies (2006–2009) on the influence of apple and pear fruit surface temperature, in dependence on the fruit position in tree canopy and summer pruning, were conducted in a commercial orchard in Lublin district, Poland. There was a significant effect of fruit position in the canopy on heat accumulation in fruit surface. Fruits born in southern part of the canopy were more heated than those from other tree parts. It was found that a blush contributed to an increase of fruit temperature, especially those from southern parts of the canopy. Summer pruning significantly contributed to heat accumulation in apples. The percentage of fruits from summer pruned trees characterized by temperature $>35^{\circ}\text{C}$ was more than doubled in comparison with fruit from not treated trees.

Key words: temperature of apple, pear, summer pruning, blush

INTRODUCTION

The problem of damage to fruits caused by high temperature has been known for a long time [1]. In recent years it is becoming an increasingly frequent object of research, due to the climate warming and to the introduction of cultivation treatments conducive to the occurrence of damage. Their effect is a deterioration of fruit quality and the resultant losses to the producers. Schrader et al. [6] reported that in 2003 over 25% of the yield of apples in orchards in the State of Washington displayed sun-induced damage. Extensive reports on the subject were published concurrently by Schrader et al. [5, 6, 7, 8] and Wunsche et al. [9] in the USA, and by Piskoleczi et al. [2] and Racsko et al. [3, 4] in Hungary. According to Schrader et al. [5] symptoms of damage appear at fruit surface temperature of $46\text{--}49^{\circ}\text{C}$, and cells start to die at temperature of about 52°C . Whereas, according to Coutanceau [1] this takes place at air temperature of $35\text{--}38^{\circ}\text{C}$ in the shade. In Poland research of this type is relatively scarce, therefore an attempt was undertaken at performing a comparison of the heating of fruits of various apple and pear cultivars taking into

account their positioning in the tree-crown and colouring, as well as the effect of summer pruning of trees. The preliminary results of the study were presented in the periodical *Sad Nowoczesny* (Modern Orchard) in 2008.

MATERIAL AND METHOD

In July and August of the years 2006–2009 measurements of surface temperature of apples and pears were taken with the use of a hand-held infrared thermometer (Mini-Flash Infrarot Thermometer, TFA, Germany), which permitted measurements on a large number of fruits within a short time, without the need of picking them off the trees. The measurements were taken at weather conditions with as little wind as possible. Air temperature at 13⁰⁰ hours on the days of measurements was given on the basis of data from the Agrometeorological Station at the Experimental Farm Felin, situated ca. 5 km from the orchard.

The experimental material was the fruits of twelve apple-tree cultivars and two pear cultivars. The seven-year old apple trees were grafted on rootstock M.9, fusiform, spaced at 3.5 m × 1.5 m, and the pears were on rootstock quince S1 – spindle, spacing of 3.5 m × 1.5 m.

Year 2006. Comparison was made of surface temperatures of apples cv. 'Jonica', 'Šampion', 'Lobo', 'Paulared' and 'Delbarestivale' (the last one on 2 dates of measurement) and of pears cv. 'Lukasówka' on the southern and northern sides of trees growing in rows with east-west orientation. Surface temperature of apples cv. 'Gala Must' was determined on the northern and southern side of trees, taking into account the presence of blush. The measurements were taken on 100 fruits of each of the cultivars, situated on both sides of the trees.

Year 2007. Temperature measurements were taken for apples of cv. 'Delbarestivale', 'Gala Must', 'Šampion' and 'Paulared', as well as cv. 'Rubin', 'Rubistar' and 'Golden Delicious', and for pears cv. 'Concorde' in relation to their positioning in the tree-crown, and for apples cv. 'Gala Must' and 'Elise' in relation to the presence of blush, taking into account the positioning of the fruits on the trees (north – south). Ten measurements were taken for each of the above, in three replications. Moreover, the surface temperature was determined for 80 apples of cv. 'Lired', 'Paulared' and 'Delbarestivale', picked from the trees and positioned on a stable substrate, fully exposed to sunlight. The measurements were started at 12⁰⁰ hours and continued at 12¹⁵, 13⁰⁰, 14⁰⁰ and 15⁰⁰ and terminated at 17⁰⁰, when sunlight no longer fell directly on the fruits. Each of the measurements was repeated 3 times.

Year 2008. Comparison was performed of surface temperatures of apples cv. 'Delbarestivale' and 'Ligol' on trees on which summer pruning was performed and on trees on which no summer pruning was made. The measurements were made on 300 successive fruits on the southern side of trees subjected and non-subjected to summer pruning, at the height of about 150 cm. Moreover, comparison of surface temperatures was performed for apples of cv. 'Delbarestivale', 'Lired' and 'Summerred', picked from trees and exposed to sunlight, taking 8 measurements each on 10 apples of each of the cultivars (80 results).

Year 2009. Surface temperature measurements were made for apples of cv. 'Delbarestivale', 'Golden Delicious Reinders', 'Ligol' and 'Early Freegold', following the same method as in the preceding year in the stationary experiment. A comparison was performed of the heating of fruits without blush but differing primarily in the skin characteristics ('Golden Delicious' has dry skin, with no wax coating). The measurements were taken on two dates given in the tables (30th July – 50 measurements, and 16th August – 66 measurements).

The results were processed statistically using the analysis of variance for complete randomisation and the Duncan test.

RESULTS

Year 2006. Surface temperature of apples situated on the southern side of the tree-crowns was significantly higher than that of fruits on the northern side, the difference being 6.1°C (mean for all apple cultivars). Within the cultivars the differences were also significant in every case and fell within the range from 4.6°C ('Jonica') to 7.5°C ('Delbarestivale'). The greatest difference was noted in the case of pears cv. 'Lukasówka' for which it was 7.6°C. The presence of blush on the surface of apples cv. 'Gala Must' significantly increased their temperature on the southern side of the tree-crowns (by 1.6°C), but on the northern side the differences were insignificant at 0.8°C. Apples of that cultivar were heated significantly more on the southern side than on the northern, by 5.5°C (blush) and by 4.7°C (no blush). The results are presented in Table 1.

Table 1. Fruit surface temperature of apple and pear (°C) in dependence on position in the crown and blush presence (2006)

Species and cultivar		Date of measurements, the air temperature at 13 ⁰⁰	Northern side	Southern side
Apple	'Delbarestivale'	27 th July, 31.4°C 15 th August, 21.6°C	32.2 a* 22.2 a	39.7 b 27.8 b
	'Paulared'	25 th July, 30.7°C	30.6 a	35.9 b
	'Lobo'		29.7 a	36.6 b
	'Šampion'	23 th July, 30.1°C	29.1 a	35.7 b
	'Jonica'		29.5 a	34.1 b
Pear	'Lukasówka'		29.0 a	36.6 b
Apple	'Gala Must' with blush	15 th August, 21.6°C	22.1 aA	27.6 bB
	'Gala Must' without blush		21.3 aA	26.0 bA

* Results followed by the same letter in the row do not differ significantly at P = 0.05 according to Duncan's t-test

Year 2007. The average difference in surface temperature of apples depending on their positioning in the tree-crown (north – south) was 8.6°C, varying from 5.3°C ('Golden Delicious') to 11.0°C ('Rubinstar'), and in the case of pears cv. 'Concorde' – 10.9°C. Blush on apples of both cultivars significantly increased the heating of fruits on the southern side of the tree-crowns: by 12.2°C ('Gala Must') and 7.9°C ('Elise'). The surface of fruits without blush was heated significantly more on the southern side than on the north, by 7.7°C and 5.0°C, respectively, for the two cultivars. On the southern side of the tree-crowns blush significantly increased the temperature of apple skin: by 4.4°C in the case of cv. 'Gala Must' and by 3.0°C for cv. 'Elise', while on the northern side there were practically no significant differences (Table 2).

Table 2. Fruit surface temperature of apple and pear (°C) in dependence on position in the crown and blush presence (2007)

Species and cultivar		Date of measurements, the air temperature at 13 ⁰⁰	Northern side	Southern side
Apple	'Delbarestivale'	7 th August, 26.8°C	26.1 a	34.6 b
	'Paulared'		26.8 a	37.2 b
	'Šampion'		26.2 a	34.0 b
	'Rubin'		26.7 a	34.8 b
	'Rubinstar'		26.6 a	37.6 b
	'Gala Must'		26.4 a	35.7 b
	'Golden Delicious'	12 th August, 27.7°C	26.5 a	31.8 b
	'Gala Must' with blush	7 th August, 26.8°C	25.4 aA	37.6 bB
	'Gala Must' without blush		25.5 aA	33.2 bA
	'Elise' with blush		26.1 aA	34.0 bB
	'Elise' without blush		26.0 aA	31.0 bA
Pear	'Concorde'		26.0 a	36.9 b

Explanation: see table 1.

In the stationary experiment, already after 15 minutes of exposure of apples to sunlight a significant difference appeared in surface temperature between fruits with blush and without. After one and two hours the differences remained at a similar level, but they were not statistically substantiated, while after three hours they again attained the level of statistical significance. At 17⁰⁰ hours the temperature of the apples dropped by about 10°C and was not significantly differentiated with relation to the presence of blush or its absence (Table 3). Apples of cv. 'Delbarestivale' were heated less intensively than those of the other cultivars, and statistically significant differences were noted in two cases (at 13⁰⁰ and 15⁰⁰) (Table 4).

Table 3. Fruit surface temperature of apple (°C) measured at 22nd August (at the air temperature at 13⁰⁰ – 31.2°C) in the stationary experiment, in dependence on blush presence, independently on cultivars (2007)

The hour of measurement	With blush	Without blush
12	27.1 a	26.4 a
12 ¹⁵	30.7 b	29.2 a
13	38.5 a	37.3 a
14	43.5 a	42.4 a
15	44.5 b	43.5 a
17 (without sunlight)	34.0 a	33.9 a
Mean	36.4 a	35.5 a

Explanation: see table 1.

Table 4. Fruit surface temperature of apple (°C) measured at 22nd August (at the air temperature at 13⁰⁰ – 31.2°C), in the stationary experiment, in dependence on cultivar, independently on blush presence (2007)

The hour of measurement	'Delbarestivale'	'Paulared'	'Lired'
12	26.7 a	26.3 a	27.3 a
12 ¹⁵	29.8 a	30.1 a	30.0 a
13	37.0 a	38.2 b	38.6 b
14	42.1 a	43.3 a	43.4 a
15	43.2 a	44.3 b	44.6 b
17 (without sunlight)	34.0 a	33.9 a	34.0 a
Mean	35.5 a	36.0 a	36.3 a

Explanation: see table 1.

Year 2008. Summer pruning of trees caused a significant increase in the heating of apples of both cultivars tested: by 1.3°C ('Delbarestivale') and 1.9°C ('Ligol'). On trees of cv. 'Delbarestivale' pruned in the summer temperature above 35°C was recorded for 16.3% of apples, and on trees without pruning that percentage was 7.7. The corresponding figures for cv. 'Ligol' were 20.4 and 8.3%. No significant differences were found in the surface temperature of fruits of various cultivars in the stationary experiment, but the largest amounts of apples with temperature exceeding 25°C were noted in the case of cv. 'Lired' (41.3%), followed by cv. 'Summerred' (40.0%), and the lowest for cv. 'Delbarestivale' – 28.8%. These results support the observations from 2007 that fruits of cv. 'Delbarestivale' have the lowest tendency towards heating relative to other cultivars. The results are presented in Tables 5 and 6.

Table 5. The influence of summer pruning on apple surface temperature on the southern side of tree-crown (2008)

Cultivar	Date of measurements	The air temperature at 13 ⁰⁰	Apple surface temperature (°C)	
			trees with pruning	trees without pruning
'Delbarestivale'	13 th August	28.8°C	28.9 a	30.2 b
	19 th August	27.6°C	30.5 a	31.8 b
	20 th August	28.8°C	30.6 a	31.8 b
	mean		30.0 a	31.3 b
'Ligol'	6 th September	30.0°C	30.2 a	32.1 b

Explanation: see table 1.

Table 6. The influence of cultivar on apple surface temperature. Stationary experiment (2008)

Cultivar	The air temperature at 13 ⁰⁰ , 31 st August	Apple surface temperature (°C)
'Delbarestivale'	20.9°C	24.2 a*
'Summerred'		24.3 a
'Lired'		24.4 a

* Results followed by the same letter in the column
do not differ significantly at P = 0.05 according to Duncan's t-test

Table 7. The influence of cultivar and the term of measurement on apple surface temperature. Stationary experiment (2009)

Cultivar	Apple surface temperature (°C)	
	30 th July	16 th August
	The air temperature at 13 ⁰⁰ – 28.1°C	The air temperature at 13 ⁰⁰ – 30.9°C
'Golden Delicious Reinders'	37.1 a	39.3 b
'Delbarestival'	36.5 a	39.1 ab
'Ligol'	37.2 a	39.0 ab
'Early Freegold'	36.5 a	38.7 a

Explanation: see table 6.

Year 2009. Measurements taken on 30th July did not reveal significant differences among the fruits of various cultivars in terms of their skin temperature. On 16th August, however, significantly less intensive heating was noted in the case of apples of cv. 'Early Freegold' as compared to 'Golden Delicious Reinders' (Table 7).

DISCUSSION AND CONCLUSIONS

In the described study, the surface temperature of apples and pears on the trees exceeded 45°C only in a few cases, which according to Schrader et al. [5] means the possibility of occurrence of damage. This explains why in this study no thermal damage was encountered on fruits on the trees. High temperatures were much more frequently attained by apples in the stationary experiment. The positioning of apples in the tree-crown was found to have a significant effect on their heating. Depending on the cultivar, fruits situated on the southern side of the tree-crown reached higher temperatures than those on the northern side. The average differences in the years of the experiment were 6.1°C and 8.6°C, which is a result similar to that reported in a review paper by Piskolczi et al. [2]. This indicates the need for greater attention, than in recent years, to the direction of tree rows in orchards – the north-south orientation may appear to be more favourable. Data given in Table 2 indicate that the surface temperatures of apples of the cultivars studied were similar (the measurements were taken within a short period of time, i.e. under comparable thermal conditions). One should only take note of the tendency of less intensive heating of apples of cv. 'Delbarestivale' compared to the other cultivars. This was supported by the results of stationary experiments conducted in the years 2007 and 2008. The probable cause of that was the absence of blush on apples of that cultivar compared to the fruits of cv. 'Paulared', 'Lired' or 'Summerred', as that regularity was not observed in 2009, comparing apples of cv. 'Delbarestivale' with the fruits of other cultivars without blush. The blush significantly increased the heating of apples on the southern side of tree-crowns of cultivars 'Gala Must' and 'Elise' in 2006 and 2007. This was also observed by Racsko, Thurzo and Dren [3]. Those authors demonstrated notable differences among apple cultivars in terms of their susceptibility to thermal damage: the most sensitive cultivars included 'Golden Delicious' and its mutations, and cv. 'Jonica', while among the most resistant were 'Gala' and 'Topaz'. Differences among cultivars in their sensitivity to high temperatures were already reported by Coutanceau [1] in 1953. However, the results obtained in the study presented herein do not provide a basis for the formulation of fully substantiated conclusions on the differences among the cultivars; perhaps they would appear at higher temperatures. The summer pruning of trees caused a significant increase in the heating of apples, though the differences were relatively small. Based on the results obtained we can conclude that the effect of summer pruning and other cultivation measures on the heating of fruits and on the possibility of occurrence of damage should be taken into account, especially in the case of cultivars with fruits having skin blush.

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Tomasz Lipa
Department of Pomology
University of Life Sciences in Lublin
Leszczyńskiego 58, 20-068 Lublin, Poland
e-mail: tomasz.lipa@up.lublin.pl

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