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Vulnerability of sweet cherry cultivars to continuous periods of spring frosts in Plovdiv, Bulgaria

S. Malchev, S. Savchovska*

Fruit Growing Institute – Plovdiv, 12 Ostromila Str., 4004 Plovdiv, Bulgaria

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Abstract. *The periods with continuous freezing air temperatures reported during the spring of 2020 (13 incidents) affected a wide range of local and introduced sweet cherry cultivars in the region of Plovdiv. They vary from -0.6°C on March 02 to -4.9°C on March 16-17. The duration of influence of the lowest temperatures is 6 and 12 hours between March 16 and 17. The inspection of fruit buds and flowers was conducted twice (on March 26 and April 08) at different phenological stages after continuous waves of cold weather conditions alternated with high temperatures. During the phenological phase 'bud burst' (tight cluster or BBCH 55) some of the flowers in the buds did not develop further making the damage hardly detectable. The most damaged are hybrid El.28-21 (95.00%), 'Van' (91.89%) and 'Bing' (89.41%) and from the next group 'Lapins' (85.98%) and 'Rosita' (83.33%). A larger intermediate group form 'Kossara' (81.67%), 'Rozalina' (76.00%), 'Sunburst' (75.00%), 'Bigarreau Burlat' (69.11%) and 'Kuklenska belitza' (66.67%). Candidate-cultivar El.17-90 'Asparuh' has the lowest frost damage values of 55.00% and El.17-37 'Tzvetina' with damage of 50.60%.*

Keywords: buds, cherry, cold weather, damage, flower, frost, phenological stages

Introduction

Climate change and especially the variation of spring temperatures is reflected by changes in the timing of phenology which is dependent on a combination of internal (genetic) settings and environmental influences. Sweet cherries are among the first fruit crops in spring to start their development and therefore highly susceptible to late frost (Matzneller et al., 2015). Spring frost is a significant production hazard in nearly all temperate fruit-growing regions.

In the Plovdiv region of Bulgaria, a considerable number of incidences of spring frost damage on flowers of various fruit species occurred over the last decade – 2008, 2013, 2016, 2019 and 2020. This presents a challenge to the fruit growers reducing their crops and therefore lowering their income.

A numerous set of tools for determining chill requirements and risk assessment have been developed through the years (Luedeling, 2012; Luedeling and Gassner, 2012; Luedeling et al., 2012; Guo et al., 2015; Yang et al., 2020) as well as different frost damage prevention techniques exist (Angus, 1955; Heisey et al., 1994; Loseke, 2015). But to achieve sustainable results in addition to the above-mentioned practices it is necessary to use more resistant cultivars in areas with increased risk of spring frosts.

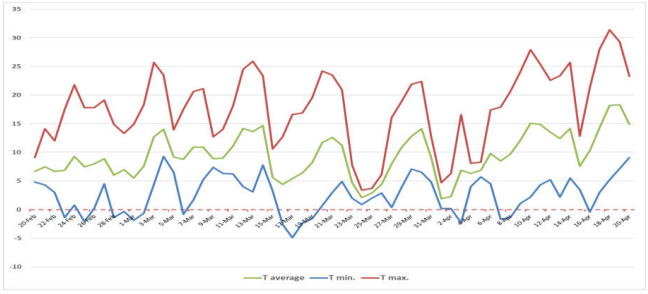
Worldwide several breeding programmes deal with coping with abiotic stress factors such as drought resistance, susceptibility to rain-induced fruit cracking, double fruiting and resistance to winter frost mainly in countries at the margins of traditional production areas or in very cold continental areas (Trajkovski, 1996; Granger, 1998; Kappel, 2008; Sansavini and Lugli, 2008; Quero-García et al., 2017).

The program for the selection of new cherry cultivars in Fruit Growing Institute (FGI) – Plovdiv, Bulgaria includes several breeding objectives in line with the market trends and the constantly changing preferences of consumers. A step, before submitting new selected hybrids (elites) as candidate-cultivars for testing, is to study their sensitivity to biotic and abiotic stress factors. The aim of this study is to determine the sensitivity of cherry cultivars and candidate-cultivars of FGI-Plovdiv to spring frost damage.

Material and methods

Studies were conducted in experimental plantation on the territory of the Fruit Growing Institute - Plovdiv. Observations were carried out on sweet cherry cultivars created in the institute - 'Kossara', 'Rosita', 'Rozalina', 'Trakiiska hrushtyalka', candidate-cultivars El.17-90 'Asparuh' and El.17-37 'Tzvetina', and hybrid El.28-21. As standard cultivars for comparison were used 'Bigarreau Burlat', 'Bing', 'Lapins', 'Sunburst', 'Van' and the local variety 'Kuklenska belitza'. Studies were conducted in the spring of 2020 during which periods of unfavourable weather conditions alternated with high temperatures (Figure 1).

*e-mail: sashka.savchovska.1993@abv.bg



Fugure 1. Temperature fluctuations during the observation period

Monitoring of the phenological stages was conducted according to the methodology adopted in FGI-Plovdiv since 2014 (Malchev, 2016) (Table 1). Inspection of fruit buds and flowers was conducted two times after a continuous wave of cold weather. Frost damage was calculated by inspecting 100 flowers/buds in three replicates from each cultivar. Two early ripening cultivars were used to detect frost damage difference in height – below 1 m, at 1.5 m and above 3.5 m.

Table 1. Advance of the phenological stages of the monitored cultivars/hybrids during the observation period

Cultivar / Hybrid	Bud Swell (or BBCH 51)	Side Green (or BBCH 53)	Green Tip (or BBCH 54)	Bud Burst (Tight Cluster) (or BBCH 55)	Open Cluster (or BBCH 56)
Bigarreau Burlat	25-Feb	8-Mar	12-Mar	16-Mar	24-Mar
Bing	27-Feb	6-Mar	10-Mar	14-Mar	24-Mar
El.17-37 (Tzvetina)	25-Feb	8-Mar	10-Mar	14-Mar	24-Mar
El.17-90 (Asparuh)	24-Feb	4-Mar	9-Mar	14-Mar	24-Mar
El.28-21	23-Feb	5-Mar	11-Mar	13-Mar	23-Mar
Kossara	25-Feb	6-Mar	11-Mar	16-Mar	22-Mar
Kuklenska belitza	22-Feb	27-Feb	1-Mar	5-Mar	8-Mar
Lapins	28-Feb	8-Mar	11-Mar	16-Mar	24-Mar
Rosita	25-Feb	7-Mar	12-Mar	16-Mar	24-Mar
Rozalina	24-Feb	8-Mar	11-Mar	17-Mar	25-Mar
Sunburst	25-Feb	6-Mar	11-Mar	26-Mar	28-Mar
Van	25-Feb	5-Mar	10-Mar	13-Mar	24-Mar

Cultivar / Hybrid	Early White Bud (or BBCH 57)	White Bud (Popcorn) (or BBCH 59)	First Bloom (or BBCH 61 to 62)	Full Bloom (or BBCH 63 to 65)	Petal Fall (or BBCH 67)
Bigarreau Burlat	30-Mar	1-Apr	4-Apr	6-Apr	11-Apr
Bing	1-Apr	3-Apr	5-Apr	7-Apr	13-Apr
El.17-37 (Tzvetina)	25-Mar	29-Mar	7-Apr	8-Apr	13-Apr
El.17-90 (Asparuh)	27-Mar	4-Apr	7-Apr	7-Apr	13-Apr
El.28-21	1-Apr	3-Apr	7-Apr	9-Apr	13-Apr
Kossara	24-Mar	25-Mar	26-Mar	5-Apr	10-Apr
Kuklenska belitza	23-Mar	25-Mar	26-Mar	5-Apr	11-Apr
Lapins	26-Mar	28-Mar	4-Apr	6-Apr	12-Apr
Rosita	31-Mar	2-Apr	4-Apr	7-Apr	11-Apr
Rozalina	26-Mar	3-Apr	6-Apr	6-Apr	13-Apr
Sunburst	1-Apr	3-Apr	8-Apr	10-Apr	13-Apr
Van	26-Mar	3-Apr	7-Apr	9-Apr	13-Apr

Data was processed statistically by using the method developed by David B. Duncan (Duncan, 1955; Harter, 1960). The software used in the study is "R-3.1.3" in combination with "RStudio-0.98" and installed package "agricolae 1.2-2" (Mendiburu, 2015).

Results and discussion

The periods with continuous freezing air temperatures reported during the spring of 2020 affected a wide range of local and introduced cultivars in the region of Plovdiv (Tables 2 and 3). They vary from -0.6°C on March 02 to -4.9°C on March 16-17. The duration of influence of the lowest temperatures is 6 and 12 hours between March 16 and 17 (Table 4).

Table 2. Percentage of spring frost damage of two cultivars at different tree height

Tree height	Kossara	Bigarreau Burlat
above 3.5 m	45.00 [b]	78.14 [a]
1.5 m	81.67 [a]	72.71 [a]
below 1 m	80.00 [a]	78.23 [a]

*Different letters in the same column indicate significant difference ($p<0.05$)

Table 3. Spring frost damage of sweet cherry cultivars at 1.5m tree height

Cultivar / Hybrid	Frost damage, %		
	at 26-March	at 08-April	Total
Bigarreau Burlat	33.33 [c]	+35.78 [a]	69.11 [abc]
Bing	85.00 [a]	+4.41 [c]	89.41 [a]
El.17-37 (Tzvetina)	45.00 [bc]	+5.60 [c]	50.60 [c]
El.17-90 (Asparuh)	53.88 [abc]	+1.12 [c]	55.00 [bc]
El.28-21	81.51 [a]	+13.49 [bc]	95.00 [a]
Kossara	66.67 [abc]	+15.00 [b]	81.67 [abc]
Kuklenska belitza	55.38 [abc]	+11.28 [bc]	66.67 [abc]
Lapins	81.67 [a]	+4.31 [c]	85.98 [ab]
Rosita	57.33 [abc]	+26.00 [ab]	83.33 [ab]
Rozalina	71.67 [ab]	+4.33 [c]	76.00 [abc]
Sunburst	53.37 [abc]	+21.63 [b]	75.00 [abc]
Van	63.33 [abc]	+28.56 [ab]	91.89 [a]

*Different letters in the same column indicate significant difference ($p<0.05$)

In order to detect frost damage difference in height and to determine the most influenced parts of the trees, two early ripening cultivars 'Bigarreau Burlat' and 'Kossara' were inspected at three heights – below 1 m, at 1.5 m and above 3.5 m. The data showed no significant difference in height for 'Bigarreau Burlat' as the frost damage is in the range between 72.71% and 78.23%, whereas for 'Kossara' the frost damage above 3.5m is almost in half 45.00% and statistically proven (Table 2).

The inspection of fruit buds and flowers for all observed cultivars was conducted twice at different phenological stages after continuous waves of cold weather – on March 26 and April 08.

The first freezing temperature after the beginning of the vegetation period (Tables 1 and 4) was recorded on February 23 (-1.4°C), at the time only 'Kuklenska belitza' variety and hybrid El.28-21 were in the phenological phase 'bud swell' (BBCH 51). The following freezing temperatures were recorded on February 25 and 28 with duration of 5 hours and reached temperatures of -2.1°C and -1.4°C, at that time the cultivars 'Bigarreau Burlat', 'Kossara', 'Lapins', 'Rosita', 'Sunburst', 'Van' and El.17-37 'Tzvetina' are entering the phenophase 'bud swell'. On February 29 and March 01, temperatures of -1.9°C lasted 10 hours and were accompanied by snow cover. All cultivars and hybrids were advancing from 'bud swell' to 'side green' (BBCH 53) with the exception of 'Kuklenska belitza' – already in 'green tip' (BBCH 54). Snow cover insulated the plants from freezing temperatures and lessened their influence. On March 02 and 06 the reported temperatures were -0.6°C to -0.8°C with duration of 3 and 4 hours while the cultivars of 'Bing', 'Kossara' and 'Sunburst' were in 'side green' phase. In these two phases of development of the flowers, the influence of freezing temperatures is still weaker (Childers, 1975; Ballard et al., 1997).

Table 4. Spring frost events – occurrence and duration

Data of occurrence	Duration of the period, h	Average T°C for the duration	Minimal T°C for the duration	Snow cover (Yes/No)
23-Feb	2	-1.05	-1.4	No
25-Feb	5	-1.46	-2.1	No
28-Feb	5	-0.98	-1.4	No
29-Feb - 01-Mar	10	-1.1	-1.9	Yes
02-Mar	4	-0.35	-0.6	No
06-Mar	3	-0.73	-0.8	No
16-Mar	6	-1.65	-2.6	No
16-Mar - 17-Mar	12	-2.43	-4.9	No
18-Mar	6	-1.33	-2.4	No
19-Mar	7	-1.23	-1.6	No
03-Apr	6	-1.42	-2.3	Yes
07-Apr	4	-1.4	-1.7	No
08-Apr	5	-0.86	-1.4	No

During the phenological phase 'bud burst' (tight cluster or BBCH 55) of the cultivars 'Bigarreau Burlat', 'Kossara', 'Lapins', 'Rosita' and 'Rozalina', the duration of the freezing temperature is 12 hours with an average of -2.43°C and reaching -4.9°C. As a result, some of the flowers in the buds did not develop further making the damage hardly visible (Figure 2).

Figure 2. A cluster of flowers with frost damage occurrence at different stages of development (cv. 'Sunburst')

On the next two dates March 18 and 19, all varieties are between 'bud burst' and 'open cluster' (BBCH 56). The duration of influence is from 6 to 7 hours on these dates with freezing temperatures of -2.4°C and -1.6°C.

At this stage, the statistically processed results are divided into 3 groups. The group with the highest percentage of damage are 'Bing' (85.00%), 'Lapins' (81.67%) and hybrid El.28-21 (81.51%), followed by 'Rosalina' (71.67%) forming an intermediate group. The biggest group represents cultivars and hybrids with average damage – 'Kossara' (66.67%), 'Van' (63.33%), 'Rosita' (57.33%), 'Kuklenska belitza' (55.38%), candidate-cultivar El.17-90 'Asparuh' (53.88%) and 'Sunburst' (53.37%). This group has no significant difference between the group of the most damaged and the group of the least damaged. Candidate-cultivar El.17-37 'Tzvetina' and 'Bigarreau Burlat' were the least influenced by the low temperature showing significantly lower values - 45.00% and 33.33%, respectively (Table 3).

On April 03, at phenological phase 'white bud' (popcorn or BBCH 59) were cultivars 'Bing', 'Rosita', 'Rozalina', 'Van' and hybrid El.28-21 when the recorded temperature was -2.3°C for 6 hours. The last two freezing temperatures were recorded on April 07 and 08 with a duration of 4 and 5 hours and temperatures of -1.7°C and -1.4°C. On these dates, cultivars 'Bing', 'Sunburst', 'Van', 'Rosita' and candidate-cultivars El.17-90 'Asparuh' and El.17-37 'Tzvetina' and hybrid El.28-21 are between the stages of 'first bloom' (BBCH 61 to 62) and 'full bloom' (BBCH 63 to 65).

The second observation of flowers and buds on April 08 reported values lower than the first readings. With significantly higher percentage was 'Bigarreau Burlat' with additional 35.78%, followed by 'Van' (+28.56%) and 'Rosita' (26.00%). Group B consists of 'Sunburst' (+21.63%) and 'Kossara' (+15.00%), followed by intermediate group BC - hybrid El.28-21 (+13.49%) and 'Kuklenska belitza' (+11.28%). The lowest percentages were from group C El.17-37 'Tzvetina' with additional 5.60%, 'Bing' (+4.41%), 'Rozalina' (+4.33%), 'Lapins' (+4.31%) and El.17-90 'Asparuh' with an increase of only 1.12%.

The percentage values of the total (final) damage are divided into three distinct groups and two sub-groups. The most damaged are the hybrid El.28-21 (95.00%), 'Van' (91.89%) and 'Bing' (89.41%) from group A and from the next group 'Lapins' (85.98%) and 'Rosita' (83.33%). A larger intermediate group form 'Kossara' (81.67%), 'Rozalina' (76.00%), 'Sunburst' (75.00%), 'Bigarreau Burlat' (69.11%), 'Kuklenska belitza' (66.67%). Candidate-cultivar El.17-90 'Asparuh' has the lowest frost damage values of 55.00% and El.17-37 'Tzvetina' with damage of 50.60%.

Taking into account these results, we can say that the main influence on the frost damage rates is not only the negative values of the temperature but also the duration and number of incidents as well as the location of the flower buds and the phenological phase in which they are and the presence of snow cover.

Conclusion

From the conducted research the following conclusions can be summarized: 1) In the 'bud swell' and 'side green' phenological stages of development of the flowers, the influence of freezing temperatures is still weaker; 2) During the phenological phase 'bud burst' (tight cluster or BBCH 55) some of the flowers in the buds did not develop further making the damage hardly detectable; 3) Great importance for the impact of freezing temperatures on fruit buds have the values of the temperature but also the duration and number of incidents as well as the location of the flower buds and the phenological phase in which they; 4) The local variety 'Kuklenska belitza' has an average frost resistance, but better than most of the tested introduced commercial cultivars; 5) Hybrid El.28-21 is highly susceptible to spring frost damage and therefore not suitable for cultivar registration; 6) Candidate-cultivars El.17-90 'Asparuh' (55.00%) and El.17-37 'Tzvetina' 50.60% have the lowest frost damage values.

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