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Research on spring frost damage in cherries

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Abstract: A frost occurred in spring following high temperatures in Michigan in 2007. It caused important crop losses. In this study, the damage the frost had on the flower buds of some cherry cultivars on 'Gisela 5' at the Southwest Michigan Research and Extension Center (SWMREC) and different cherry scion/rootstock combinations at the Clarksville Horticultural Experiment Station (CHES) were determined. In cherries, the frost damage at SWMREC varied from 26.7% to 99.3% depending on the cherry cultivar while it varied from 41.9 to 99.3% at CHES depending on the cherry combinations. 'Rainier/Gisela 6' at CHES and 'NY119' at SWMREC were promising. The bud development stage during the freeze, the cultivar, the rootstock, the ages of the trees and the low temperature level were effective in the spring frost resistance.

Keywords: *Prunus avium* L.; low temperature; variety; rootstock; bud development stage

Spring frosts can become a risk for the production of cherries in some places in the world, from temperate climate regions through cold climate regions. Low temperatures in spring following high temperatures in late winter and early spring cause important economic losses. A bacterial canker infection often follows this low temperature damage. Thus, the annual yield is not only lost, but the health of trees is also damaged. Determining the low temperatures that damage trees is difficult since the damage depends on many factors, such as the cultivar, the pruning severity, the longevity of the freeze, the rapidity of the freeze, and thaw and the stage of dormancy the trees are at at the time of the freeze (Webster, Looney 1996). However, some data belonging to low temperature damaged tree organs have been determined by previous studies (Szabó et al. 1996; Blažková, Hlušičková 2002; Longstroth 2004; Kaya et al. 2021; Kaya, Kose 2022). Szabó et al. (1996) suggested that the cold hardiness of cherry varieties was genetically determined and varied greatly among varieties. Bargioni (1996) reported that crosses using resistant cultivars of *Prunus fruticosa* Pall., the steppe or ground cherry, probably achieved the best resistance during deep dormancy in Ukraine and Russia. Besides, several studies have also reported the effect of the cultivar on the cold resistance in the sweet cherry (Blažková 2004; Hogetweit, Jakobsen 2005; Miranda et al. 2005; Cittadini et al. 2006).

Rootstocks can also be effective against any spring frost damage mainly by advancing or delaying the flowering time of cultivar (Webster 1995; Lang et al. 1997; Moghadam, Mokhtarian 2004). In addition, rootstocks can also directly influence the resistance to frost damage (Durner 1990; Callesen, Vittrup 1996; Prive, Embree 1997; Lang et al. 1997; Quamme, Brownlee 1997; Blažková, Hlušičková 2002; Dziedzic et al. 2019; Narandžić et al. 2021). For examples, it has been considered that sour cherry selections are the most cold-hardy where 'Mahaleb' is hardier than 'Mazzard' (Webster, Schmidt 1996).

The frosts that occur time to time in nature allow a good opportunity to evaluate cultivars and rootstocks in terms of the cold resistance. Some artificial

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freeze tests in the laboratory have been undertaken to determine the resistance to frost damage of different cultivars in different developing stages (Strauch, Gruppe 1985; Chitu, Paltineanu 2006; Cittadini et al. 2006). However, there are not too many works evaluating the percentage of the injury of sweet cherry cultivars in natural frost events. This study aimed to determine the damage the spring frost caused that occurred in nature in 2007 in some cherry cultivars on different rootstocks.

MATERIAL AND METHODS

This study was carried out at the Southwest Michigan Research and Extension Center (SWMREC) and Clarksville Horticultural Experiment Station (CHES) in Michigan State University in spring 2007.

We used the sweet cherry cultivars such as 'Regina', 'Sandra Rosa', 'Tieton', 'Lapins', 'Christalina','Summit', 'Skeena', 'Rainier', 'NY119' (Test cultivar) and 'Jubelium' sour cherry cultivar with four old tree on Gisela 5 (Gi 5) rootstocks at SWMREC. The sweet cherry cultivar/rootstocks combinations with six year old ('Regina/Gi5', 'Regina/Gisela 6' ('Gi6'), 'Glacier/Gi5&6', 'Sweetheart/Gi6', 'Rainier/Gi5&6', 'Lapins/Gi5&6', 'Selah/Gi5&6', 'Summit/PIKU 1&3', 'Skeena/Gi6&12' and 'Skeena/W158') were used at CHES.

The temperature data were obtained from automated climatic monitoring equipment (onset Computer Crop., Bourne, USA) at SWMREC and CHES during the days with a frost.

The dead flowers were counted during the late full flowering period in order to determine the frost damage percentage. The experiment was set-up as a randomised block design by considering each tree a block. The flowers on eight shoots per tree were counted. Three trees for each cultivar were used. The data were analysed by an analysis of variance (ANOVA) using Statistical Analysis System (SAS) (SAS Institute, Cary, USA). Tukey's multiple range test compared the means. The frost damage percentages were transformed by arcsine prior to the analysis. To discuss the results, the critical spring temperatures for the sweet cherry bud stages (Longstroth 2004) in Table 1 were considered.

RESULTS AND DISCUSSION

Frost damage in the cherries at SWMREC. The largest bud flower damage due to the spring frost was seen in 'Skeena' and 'Christalina' being at the 4-tight cluster stage and 'Lapins' being at the 5-open cluster stage (Table 2). It is known that –8.3 C kills 90% of cherry flower buds while –3.3 °C kills 10% of cherry flower buds at the 4-tight cluster, while –6.1 °C kills 90% of cherry flower buds while –2.8 °C kills 10% of cherry flower buds at the 5-open cluster stage (Longstroth 2004). Generally, the temperature varied between –3.0 to –5.5 °C on an hourly basis on the 6^{th}–8^{th} of April over a 30 hour period (Table 3). On the 7^{th} of April, the minimum air temperature was –6.2 °C (Figure 1) and the damage percentage

Table 2. Phenological records and spring frost damage ratios of some cherry cultivars at SWMREC

Cultivar	Full bloom date	Bud development stage during freeze	Frost damage (%)
Regina	23 Apr	3 – green tip	50.0^{abc}
Sandra Rosa	22 Apr	4 – tight cluster	53.4^{abc}
Tieton	21 Apr	4 – tight cluster	51.9^{abc}
Lapins	20 Apr	5 – open cluster	77.1^{a}
Cristalina	22 Apr	4 – tight cluster	71.1^{a}
Summit	23 Apr	3 – green tip	62.6^{ab}
Skeena	23 Apr	4 – tight cluster	76.9^{a}
Rainier	22 Apr	4 – tight cluster	47.6^{abc}
NY119	22 Apr	4 – tight cluster	26.7^{bc}
Jubelium	28 Apr	bud swell	8.1^{c}

$^{a–c}$Means within the columns followed by different letters differ significantly (P < 0.05)

Table 1. Critical spring temperatures (°C) for the sweet cherry bud stages (Longstroth 2004)

Sweet cherries	Bud swell	Side green	Green tip	Tight cluster	Open cluster	First white	First bloom	Full bloom	Post bloom
Old temperature	–5.0	–5.0	–3.9	–2.2	–2.2	–1.7	–1.7	–1.7	–1.1
10% kill	–8.3	–5.6	–3.9	–3.3	–2.8	–2.8	–2.2	–2.2	–2.2
90% kill	–15.0	–12.8	–10.0	–8.3	–6.1	–4.4	–3.9	–3.9	–3.9

The old standard temperature is the lowest temperature that can be endured for 30 minutes without damage. This table shows the temperature that will kill 10% and 90% of the normal fruit buds

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Table 3. Hourly (Hr) temperatures (°C) at CHES (CH) and SWMREC (SW) on days with frost

Hr	Wednesday (4/4)		Thursday (4/5)		Friday (4/6)		Saturday (4/7)		Sunday (4/8)		Mon./Thu. (4/9–10)	
	CH	SW	CH	SW	CH	SW	CH	SW	CH	SW	CH	CH
1	9.0	5.1	–5.4	–1.4	–4.7	–1.1	–7.1	–4.1	–4.8	–3.1	–3.7	–3.1
2	8.1	3.9	–6.0	–1.8	–5.0	–1.9	–7.3	–4.1	–4.8	–3.1	–3.3	–3.4
3	5.5	2.6	–6.2	–2.4	–5.2	–2.1	–7.6	–4.7	–5.3	–2.5	–3.3	–3.5
4	3.6	1.6	–6.3	–2.8	–5.0	–2.0	–7.9	–5.0	–5.3	–2.1	–3.9	–4.5
5	2.7	1.0	–6.3	–3.7	–5.0	–2.8	–7.8	–5.3	–4.8	–2.6	–3.9	–4.9
6	1.6	0.8	–6.1	–2.9	–5.2	–3.2	–7.4	–5.7	–4.5	–2.6	–3.7	–6.0
7	0.7	0.9	–6.0	–3.1	–5.4	–3.3	–7.2	–5.9	–4.2	–2.2	–3.5	–6.7
8	0.2	1.0	–5.9	–3.4	–5.3	–3.3	–6.9	–5.6	–3.9	–2.0	–3.6	–6.8
9	–0.5	0.7	–5.4	–3.1	–5.0	–3.0	–6.2	–5.2	–3.6	–1.8	–3.0	–5.6
10	–0.9	0.3	–5.0	–3.4	–4.8	–2.5	–5.6	–5.0	–3.1	–1.6	–2.0	–3.9
11	–1.2	–0.0	–4.8	–2.9	–4.6	–2.6	–4.8	–4.3	–2.5	–1.5	–1.2	–2.2
12	–1.4	–0.3	–4.1	–2.7	–4.0	–2.7	–4.5	–3.7	–1.8	–1.1	–0.3	–0.4
13	–1.5	–0.8	–3.8	–2.5	–3.6	–3.4	–4.8	–3.4	–1.4	–0.8	1.2	2.3
14	–1.6	–1.4	–3.8	–2.4	–3.5	–3.2	–4.2	–3.4	–0.7	–0.6	1.6	4.4
15	–1.8	–1.6	–4.0	–2.0	–3.4	–3.2	–3.3	–3.5	–0.6	–0.5	2.0	5.3
16	–2.1	–1.9	–3.8	–1.7	–3.4	–3.0	–3.1	–3.8	–0.5	–0.4	2.6	5.9
17	–1.9	–2.1	–3.4	–1.4	–3.7	–2.9	–3.0	–3.6	–1.1	–0.4	1.9	5.7
18	–2.8	–2.4	–3.1	–1.0	–4.1	–1.9	–2.9	–3.2	–1.2	–0.4	2.1	6.0
19	–3.1	–2.5	–2.8	–0.5	–5.2	–2.2	–3.7	–3.4	–1.3	–0.1	1.3	6.2
20	–3.5	–2.6	–2.8	–0.5	–5.8	–2.4	–4.2	–3.4	–1.6	–0.4	0.6	4.8
21	–3.8	–2.4	–3.2	–0.6	–5.9	–3.3	–4.6	–3.5	–1.9	–0.8	–0.5	2.8
22	–4.2	–1.8	–3.2	–0.4	–6.2	–3.8	–4.7	–3.8	–2.1	–1.0	–1.0	2.1
23	–4.4	–1.3	–3.3	–0.1	–6.4	–3.8	–4.9	–3.6	–3.1	–1.1	–1.0	1.9
24	–4.8	–1.3	–4.0	–0.2	–6.8	–4.0	–5.0	–3.2	–3.5	–1.2	–2.3	1.1

in 'Skeena', 'Christalina' and 'Lapins' varied from 71.1 to 77.1%. 'Summit' subjected to a frost at the 3-green stage followed these cultivars in terms of the percentage of damage. 62.6% of the flower buds of 'Summit' died at the –3.0 to –5.5 °C temperatures during the freeze. Longstroth (2004) suggested that –10 °C kills 90% of cherry flower buds while –3.9 °C kills 10% of cherry flower buds at the 3-green tip stage. 'Regina' being at the 3-green tip stage during the freeze and 'Rainier', 'Tieton' and 'Sandra Rose' being at the

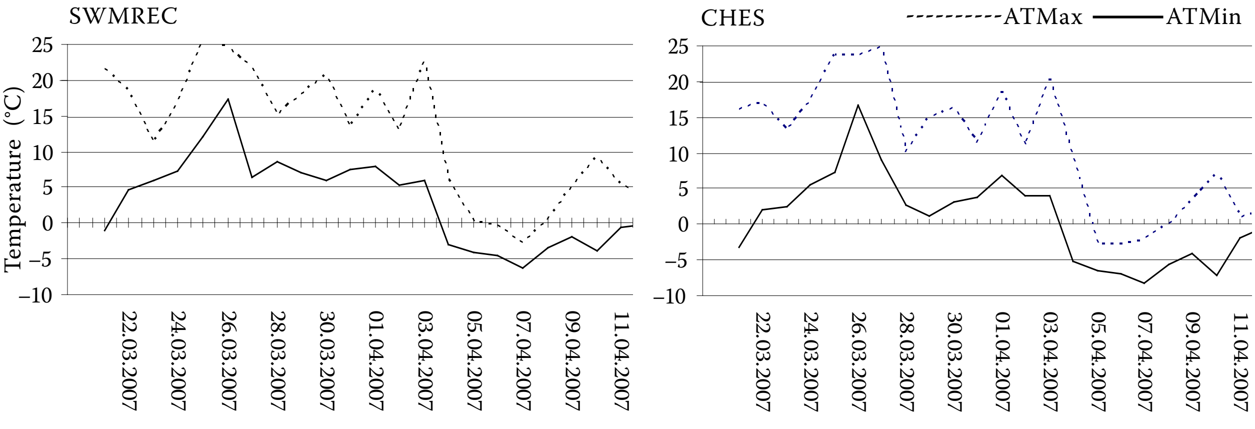

Figure 1. Daily temperatures

ATMax – average temperature maximum; ATMin – average temperature minimum

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4-tight cluster stage during the freeze were similar to each other in terms of the sensitivity to the spring frost with about 50% dead flowers. The test cultivar 'NY119' released from Cornell University was the hardiest among the sweet cherry cultivars although it was at the 4-tight cluster stage, like many of the other cultivars. The percentage of dead flower buds in this cultivar was only 26.7%. Some previous studies reported some cherry cultivars showed resistance to cold and frost (Stancevic et al. 1978; Fischer et al. 1984; Bargioni 1996; Anderson, Nugent 2003; Lang et al. 2003; Long et al. 2003; Blažková 2004). The least damage was seen in the 'Jubelium' sour cherry cultivar on 'Gi5' subjected to frost at the bud swell stage. Likewise, the flower buds were the hardiest during the winter when they were fully dormant.

Frost damage in the cherries at CHES. The same cultivars on the various rootstocks showed different response to cold resistance (Table 4). Generally, the frost damage was higher in the cultivars on the more dwarfing rootstocks, such as 'Gi5' and 'Piku 1', than the cultivars on the less dwarfing rootstocks, such as 'Gi6', 'Gi12' and 'Piku 3'. For example, all the cultivars on 'Gisela 5' were more damaged compared to the same cultivars on 'Gisela 6'. Differences among the rootstocks in terms of cold resistance have been indicated by some studies (Durner 1990; Webster 1995; Callesen, Vittrup 1996; Szabo et al. 1996; Webster, Schmidt 1996; Lang et al. 1997; Prive, Embree 1997; Quamme, Brownlee 1997; Blažková, Hlušičková 2002). Callesen, Vittrup (1996) reported that a big difference in the frost damage to flowers was found among the rootstocks and 'Colt' showed the most severe damage. Blažková (2004) evaluated some rootstocks from the Czech Republic and reported that 'P-TU-2' was the most winter hardy of the seedling rootstocks and 'P-HL-A' was the hardiest to winter of the clonal rootstocks. Edin et al. (1989) reported that 'GM8' was liable to spring frost damage.

Table 4. Some phenological time belonging to the bloom and frost damages of the examined combinations (CHES)

Combination	Full bloom date	Bud development stage during freeze	Frost damage (%)
Regina/Gi5	29 Apr	2 – side green	76.1^{cdef}
Regina/Gi6	29 Apr	2 – side green	65.8^{efg}
Glacier/Gi5	28 Apr	3 – green tip	91.1^{abc}
Glacier/Gi6	28 Apr	3 – green tip	90.0^{abc}
Sweetheart/Gi6	26 Apr	2 – side green	67.5^{defg}
Rainier/Gi5	27 Apr	2 – side green	59.9^{fg}
Rainier/Gi6	27 Apr	2 – side green	41.9^{g}
Lapins/Gi5	25 Apr	3 – green tip	66.0^{defg}
Lapins/Gi6	25 Apr	3 – green tip	46.2^{g}
Selah/Gi5	27 Apr	3 – green tip	87.4^{bcd}
Selah/Gi6	27 Apr	3 – green tip	80.1^{cdef}
Summit/Piku1	28 Apr	2 – side green	90.2^{abc}
Summit/Piku3	28 Apr	2 – side green	85.4^{bcde}
Skeena/Gi12	28 Apr	3 – green tip	97.0^{ab}
Skeena/Gi6	28 Apr	3 – green tip	99.3^{a}
Skeena/W158	28 Apr	3 – green tip	87.4^{bcde}

$^{a–g}$Means within the columns followed by different letters differ significantly ($P < 0.05$)

In the experiment, the largest damage was shown in the combinations of 'Skeena', 'Glacier' and 'Selah' subjected to frost at the 3-green tip stage and the 'Summit/Piku' combinations subjected to frost at the 2-side green stage (Table 4). Proebsting (1985) suggested that as the flower bud approaches swelling and expansion into blossoms, their susceptibility to freeze increases. On the 5th–8th of April, the temperature varied between –5.0 to –7.0 °C on an hourly basis over 62 hours (Table 3). On the 5th, 6th and 7th of April, the minimum air temperatures were –6.2, –7 and –8.2 °C, respectively (Figure 1). These temperatures killed 80.1 to 99.3% of the flower buds of the 'Skeena', 'Glacier' and 'Selah' combinations. According to Longstroth (2004), –10 °C kills 90% of cherry flower buds, while –3.9 °C kills 10% of cherry flower buds at the 3-green tip stage. The damage to the 'Lapins' combinations was less than those of the other combinations subjected to frost at the 3-green tip, although the combinations with the 'Lapins' were also subjected to frost at the 3-green tip. This case can be explained by the frost resistance differences of the cultivars (Bargioni 1996; Szabó et al. 1996; Blažková 2004; Hogetweit, Jakobsen 2005; Cittadini et al. 2006).

Among the combinations subjected to frost at the 2-side green stage, the biggest damage was shown in the 'Summit/Piku' combinations followed by the Regina and Sweetheart combinations (Table 4). The least damage with 41.9% to 59.9% was in 'Rainier/Gi5&6' at the 2-side green stage. At this stage, –12.8 C kills 90% of the flower buds while –5.6 °C kills 10% of the flower buds (Longstroth 2004). In fact, the temperatures during the frost event were between these limits (Table 3). As a result, the low temperatures of –5 to –7 °C caused a damage percentage

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of 41.9% to 90.2% to the flower buds with the combinations at the 2-side green stage (Table 4). The dead flower percentage differences between 'Summit/Piku 1&3' and 'Rainier/Gi5&6' subjected to frost at the same stage (2-side green stage) can also be due to the cultivar and rootstocks characteristics.

We observed that the trees at CHES were healthier than those at SWMREC after the frost and during the following summer although the temperatures at CHES were lower than those at SWMREC during the frost. While harvesting occurred from the remaining flowers at CHES, the amount of fruit was very low at SWMREC. Dying trees were even observed due to the frost at SWMREC, which may have resulted from the age of the trees. The trees at CHES were seven years old while those at SWMREC were four years old.

CONCLUSION

In the experiment, generally, the flower bud damage of all the cultivars varied depending primarily on their stage of development. In both locations, the combinations subjected to frost at an earlier stage were more damaged. For example, the higher frost damage of the 'Lapins' cultivar at SWMREC than at CHES was due to its being at an earlier stage. Generally, the cultivars on 'Gi5' and 'Piku 1' were more damaged than those on 'Gi6' and 'Piku 3'. This case has shown the importance of the rootstock on the cold resistance. Promisingly, the least damage occurred in 'NY119' on 'Gisela 5', which was subjected to the frost at the 4-tight cluster stage. It can be a promising cultivar in terms of frost resistance. 'Rainier' subjected to frost at the 2-side green on 'Gisela 6' at CHES was very hardy. Especially, when considering the fruit quality and market prices of 'Rainier', the 'Rainier/Gisela 6' combination is promising. However, other studies including frost tests on both cultivars should be carried out. As a consequence, the bud development stage during the freeze, cultivar, rootstock, age of the trees and low temperature level were effective in the spring frost resistance.

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