

The Late Spring Frost Hardiness of Some Apple Varieties at Various Stages of Flower Buds

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Geliş Tarihi: 21.03.2005

Abstract: In this study, survival rates of pistils of seven apple (*Malus x domestica* Borkh.) varieties at various stages from tight cluster to full bloom on trees were determined after frost that occurred on the morning at 3:00-8:00 of April 17, 2004 when the temperature dropped to -4 to -6 °C in the orchard. The survival rates of pistils of varieties ranged between 36.7 and 96.5% at tight cluster, 6.2 and 86.0 % at first pink and, 0.2 and 52.0 % at full pink stages after frost injury. 'Starkspur Golden Delicious' (18.0 %), 'Granny Smith' (33.0 %) and 'Canada Reinette' (36.7 %) were the least damaged apple varieties at various flower buds stages from tight cluster to first bloom on trees after frost.

Key Words: Apple, *Malus x domestica* borkh., late spring frost

Bazı Elma Çeşitlerinin Çiçek Tomurcuklarının Farklı Safhalarında İlkbahar Geç Donuna Dayanıklılığı

Öz: Bu çalışmada, meyve bahçesinde 17 Nisan 2004 sabahı 3:00-8:00 saatleri arasında meydana gelen ve sıcaklığın -4 ile -6 °C'e düştüğü dondan sonra 7 elma (*Malus x domestica* Borkh.) çeşidinin açılmamış tomurcuk safhasından çiçek safhasına kadar farklı gelişme safhalarındaki çiçek tomurcuklarında dişi organların canlılık oranları belirlenmiştir. Dondan sonra dişi organlardaki canlılık oranları, açılmamış tomurcuklarda % 36.7 ve 96.5, pembe ucun görüldüğü tomurcuklarda % 6.2 ve 86.0, pembe tomurcuklarda ise % 0.2 ve 52.0 arasında değişmiştir. Açılmamış tomurcuk safhasından çiçek safhasına kadar farklı gelişme safhalarındaki çiçek tomurcuklarında 'Starkspur Golden Delicious' (% 18.0), 'Granny Smith' (% 33.0) ve 'Canada Reinette' (% 36.7) dondan sora en az zarar gören çeşitler olmuştur.

Anahtar Kelimeler: Elma, *Malus x domestica* borkh., ilkbahar geç donları

Introduction

Late flowering is considered important to avoid disastrous spring frost damage. One objective in a number of breeding programs is to produce varieties that flower so late that practically all danger to the blossoms from late frost is past. Another contributory factor to crop losses due to late frost is the inherent susceptibility of the flowers to injury (Tsonev 1995; Lin et al. 2001; Hodun et al. 2002). Although there are differences in sensitivity of blossom to frost damage, selection for this character does not appear to have been carried out. Tetraploids and triploids such as 'Jonagold' and 'Mutsu', with larger cells, are more prone to damage than diploids. The hardiness of the tree to winter injury and the hardiness of the flowers to spring frost damage appear to be inherited independently (Janick et al. 1996). In temperate climates, losses due to frosts during bloom are more important than those due to low winter temperatures. Frost damage is highly dependent on the stage of development of the flower buds. From dormancy to fruit set, the flower bud undergoes a number of developmental stages that are associated with a progressive increasing vulnerability of pistil to low

temperatures. Thus, the early developing fruit is the most vulnerable stage. Stage of bloom development was significant in response to frost damage. At full bloom, the first symptom observed after thawing in apple flowers is a brown discoloration at the base of the style and damage may extend both to the style and to ovary, resulting in death of the placenta abortion of ovules, or formation of large breaks in the cortical tissue. Factors affecting spring frost hardiness are environmental, pruning, crop load, nutrition, rootstock, chemical and genotype. Spring frost hardiness in deciduous fruit is influenced primarily by genotype (Byrne 1986; Westwood 1993; Rodrigo 2000).

An understanding of the genetic control of freezing tolerance in woody perennials is important for the effective selection and development plants with a broader climatic adaptation. The objective of the present study was to determine the spring frost hardiness of some apple (*Malus x domestica* Borkh.) varieties at tight cluster, first pink, full pink, first bloom and full bloom stages.

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Materials and Methods

Flower buds samples were collected from 'Starkspur Golden Delicious', 'Starkrimson Delicious', 'Starking Delicious', 'Granny Smith', 'Canada Reinette', 'Amasya Kaşel' and 'Hüryemez' apple varieties at different flower buds stages from tight cluster to full bloom on trees, two days after frost that occurred on the morning at 3:00-8:00 of April 17, 2004 when the temperature dropped to -4 to -6 °C in the apple orchard of University of Ankara, Faculty of Agriculture Experiment and Research Farm near Haymana County, Ankara (Turkey) (39° 36' N, 32° 40' E, elevation = 1600 m) (Table 1).

Pistils in flower buds samples at tight cluster, first pink, full pink, first bloom and full bloom stages (Westwood 1993) were examined individually and classified as dead or alive based on tissue browning, two days after injury. The rates of flower bud stages on trees of apple varieties at the frost date, survival rate of pistils of varieties at each stage and survival rate of pistils on trees of apple varieties for spring frost hardiness was expressed as percentage.

Experimental design was a randomized complete block with tree replications. Each replication consisted of five trees. For each flower bud stage, twenty flowers were taken from each tree.

In the statistical analyses, percentages were converted into angle values and all the varieties were compared to each other. All data were subjected to analysis of variance at $P=0.05$ error level (MINITAB Inc.814-238-3280 WS 112102553). Means were separated using Duncan's multiple range test at $P\leq 0.05$.

Results

Stage of bloom development was significant in response to injury. The rate of pistils surviving at tight cluster was higher than the rate at later stages (Table 3). Survival rates of pistils of 'Starkspur Golden Delicious', 'Granny Smith' and 'Hüryemez' were significantly higher than that of other varieties at tight cluster stage (Table 3).

At the first pink stage, 'Starkspur Golden Delicious' also had the highest survival rate of pistils. 'Canada Reinette', 'Starking Delicious' and 'Starkrimson Delicious' had much lower rates than the others. There were no differences in survival rates of pistils between the three varieties at first pink stage (Table 3).

The highest survival rates of pistils were observed in 'Starkspur Golden Delicious' (48.2 %) and 'Granny Smith' (52.0 %) at the full pink stage. However, pistils of 'Starkrimson Delicious' and 'Starking Delicious' were severely damaged by the frost (Table 3).

At first bloom stage, there were flower buds on 'Granny Smith', 'Starkrimson Delicious' and 'Hüryemez' trees on April 17. Granny Smith's pistils had significantly higher survival rates than others (Table 3).

Only two apple varieties, 'Amasya Kaşel' and 'Hüryemez' had full bloom development stage at the frost date (Table 2) and, all of pistils browned after frost (Table 3).

Table 1. Temperatures in the apple orchard on April 17, 2004

Hour (A.M.)	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00
Temp. (°C)	-1	-2	-4	-5	-4	-6	-6	-5	0

Table 2. The percentage of the flower bud stages on trees of apple varieties at the frost date

Variety	Flower Buds Stage				
	Tight cluster (%)	First pink (%)	Full Pink (%)	First bloom (%)	Full bloom (%)
Starkspur Golden Delicious	32.7	46.3	21.0	-	-
Starkrimson Delicious	-	39.0	46.7	14.3	-
Starking Delicious	17.7	66.0	16.3	-	-
Granny Smith	21.0	44.7	27.3	7.0	-
Canada Reinette	90.0	10.0	-	-	-
Amasya Kaşel	-	-	-	-	100.0
Hüryemez	10.3	30.9	37.3	16.3	5.2

Table 3. Survival rates of pistils of apple varieties at various flower buds stages, two days after injury

Variety	Flower Buds Stage				
	Tight cluster (%)	First Pink (%)	Full pink (%)	First bloom (%)	Full bloom (%)
Starkspur Golden Delicious	96.5 a*	86.0 a	48.2 a	-	-
Starkrimson Delicious	-	15.3 c	4.3 c	0.0 b	-
Starking Delicious	36.7 c	6.2 d	0.2 c	-	-
Granny Smith	90.9 a	68.6 b	52.0 a	19.1 a	-
Canada Reinette	67.0 b	11.4 cd	-	-	-
Amasya Kaşel	-	-	-	-	0.0
Hüryemez	88.7 a	65.8 b	33.4 b	4.7 b	0.0

*Mean separation within columns, Duncan's new multiple range test, $P=0.05$.

Table 4. The survival rates of pistils on tree of apple varieties after frost

Variety	Survival rate (%)
Starkspur Golden Delicious	82.0 a
Granny Smith	67.0 b
Canada Reinette	63.3 b
Hüryemez	40.4 c
Starking Delicious	10.2 d
Starkrimson Delicious	7.7 d
Amasya Kaşel	0.0 e

*Mean separation within columns, Duncan's new multiple range test, $P=0.05$.

In this study, the late spring frost hardiness of apple varieties was determined (Table 4) according to both the rates of flower bud stages on trees at the frost date (Table 2) and the survival rates of pistils of varieties at each stage (Table 3). The flower bud stage was the latest in 'Canada Reinette' at the time of the frost (Table 2). In this variety, 90% and 10% of the flower buds were at tight cluster and at full pink stages, respectively. However it was more damaged by the frost compared to 'Starkspur Golden Delicious' and 'Granny Smith' (Table 4). 'Starkspur Golden Delicious' had significantly the highest survival rate of pistils on the tree (82 %) after injury. Similar flower stages were recorded in 'Starkspur Golden Delicious' and 'Granny Smith'. Only 7% of the flowers in 'Granny Smith' were in the first bloom stage (Table 3). However, the survival rate of pistil in 'Granny Smith' was 67 %. There were no significant differences in the survival rates of pistil between 'Granny Smith' and 'Canada Reinette'. 'Hüryemez' had lower survival rate (40.4 %) than those varieties. Despite the rate (66.0 %) of flower buds at first pink stage, the survival rate of pistils on tree of 'Starking Delicious' was only 10.2 %. 'Starkrimson Delicious' had similar the survival rate (7.7 %). 'Amasya Kaşel' apple variety was early bloomed and its all flower buds were at the full bloom stage on April 17. This variety was the most damaged and all of the pistils on the tree browned after injury.

Discussion

Our results showed that the late spring frost damage of pistils was variable according to stages of flower bud development and genotypes. 'Starkspur Golden Delicious', 'Granny Smith' and 'Canada Reinette' were the least; however 'Starking Delicious', 'Starkrimson' and 'Amasya Kaşel' were the most damaged apple varieties at various flower bud stages from tight cluster to first bloom on trees following the frost at -4 to -6 °C during eight hours. Proebsting and Mills (1978) indicated that during blossom bud development from dormancy to post bloom T_{50} rose to near -3 °C for 'Delicious' apple, 'Bartlett' pear, 'Bing' cherry, 'Elberta' peach, 'Early Italian' prune, and some apricots. In controlled freezing tests, -6.1 °C was determined as the critical temperature for 50 % (T_{50}) kill of 'Delicious' apples at tight cluster. But 'Delicious' apples have been more susceptible than the average laboratory value on several occasions. The researcher's data showed that 20-100% of 'Delicious' apple buds killed at tight cluster and 95-100 % of buds killed at full pink and first bloom between -3.9 °C and -6.1 °C. The result on 'Starking Delicious' and 'Starkrimson' of the present study (Table 3) are in general agreement with this study. Also, Simons and Doll (1976) reported that 'Starkrimson' was more sensitive variety than 'Golden Delicious' to late spring frost.

Conclusion

It was determined that the rate of the late spring frost damage depended on both the flower bud development stages at frost date and hardiness of the pistils of apple varieties to low temperatures. 'Starkspur Golden Delicious', 'Granny Smith' and 'Canada Reinette' were more hardiness than 'Hüryemez' and especially 'Starking Delicious', 'Starkrimson' and 'Amasya Kaşel' to late spring frost.

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