SZENT ISTVÁN UNIVERSITY

FROST TOLERANCE AND WINTER HARDINESS OF APRICOT AND PEACH VARIETIES

Doctoral dissertation

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1. Antecedents and objectives of work

Apricot and peach have been traditionally produced in Hungary for centuries despite the fact that neither of them is autochthonous in this region. There are many similarities in their origin and their production area indicating that they require similar environmental conditions. The greatest hazard of apricot and peach production in Hungary today lies in winter and spring frost damages owing to the inappropriate selection of varieties and production sites. Therefore, yield reduction occurs frequently, and it is almost impossible to give a reliable estimation on yield, which causes considerable uncertainty in the market. In this situation, the range of varieties have to be reconsidered and complemented with varieties that can be produced with higher yield stability. The genetic sources of frost and winter hardiness have to be surveyed, which can be used to improve new varieties or can be directly involved in cultivation. The main objectives of this work are to determine the real frost and winter hardiness of widespread varieties, to identify the factors influencing frost tolerance and to reveal the processes happening in the tissues of trees in winter.

There are a relatively great number of data available on the frost tolerance of apricot and peach varieties on the basis of field experiments (Szabó and Nyéki, 1988a, 1988b, 1991; Szabó et al., 1995, 1998; Nyujtó, 1988; Nyujtó et al., 1982; Smith et al., 1994). However, alterations in frost tolerance cannot be traced by the estimation of natural frost damages. For that purpose, laboratory methods are required. By the artificial freezing of plant parts it can be demonstrated that frost tolerance of flower and shoot buds and ligneous parts evolves gradually after the defoliation in autumn, and continuously decreases during ecodormancy (Hatch and Walker, 1969; Proebsting, 1970; Quamme, 1974; Hewett, 1996; Pedryc et al., 1999). Researchers detected great variability in frost tolerance between varieties of both apricot and peach. It has been also recognized that there is close relation between the pace of flower bud development in winter and the alteration of their frost tolerance (Solohov, 1970). The flower bud development of apricot and peach has been investigated by the sprouting of fruiting parts (Weinberger, 1967; Seif, 1990; Timon, 1998), the measuring of weight-gain (Brown and Kotob, 1957; Hatch and Walker, 1969; Andrés and Durán, 1999), the measuring of the pistil length (Molnár and Túri, 1974), and the observation of the pace of microsporogenesis (Banainé, 1981; Viti and Monteleone, 1991; Sebők, 1993; Ramina et al., 1995; Bartolini and Viti, 1999). One of the aims of the investigation of flower bud development is to determine the completion of endodormancy and the cold requirement of this completion. Using different types of methods, researchers have often got contradictory results. However, reference data prove that there is great variability in the cold requirement of apricot and peach varieties as well (Weinberger, 1967; Guerriero and Scalabrelli, 1982; Childers, 1983; Garcia, 1999). Consequently, the genetic background is available to improve the yield reliability of both fruit species near the northern border of their production area.

The main objectives of our research work were as follows:

- to find the genetic sources of good frost and winter hardiness from the available apricot and peach varieties on the basis of measurable parameters determining winter adaptation,
- to specify the frost tolerance of flower buds, shoot buds and shoots at different times during the winter dormancy,
- to define the pace of flower bud development by laboratory methods,
- to determine the cold requirement that is necessary for the completion of endodormancy of flower buds,
- to reveal the relation between the pace of development of generative organs and their frost hardiness,
- to evaluate the effects of variety, year of production and site of production on the processes happening during dormancy,
- to rank the examined apricot and peach varieties in accordance with their traits determining winter adaptation.

2. Materials and methods

Samples for the tests were taken from experimental and entrepreneurial plantations at the settlements of Szigetcsép, Pomáz, Siófok and Szatymaz. The preliminary tests were initiated in the autumn of 1994, while the detailed investigations were accomplished in 3 successive winters from 1997 on the 20 apricot and 12 peach varieties selected for the research.

The tested apricot varieties were as follows (sorted by their origin):

- Traditional Hungarian varieties: Ceglédi bíbor, Ceglédi óriás, Gönci magyar kajszi, Mandulakajszi
- Newly bred Hungarian variety: Harmat
- Rumanian varieties: Callatis, Comandor, Litoral
- French variety: Bergeron
- North-American varieties: Harglow, Hargrand, Harlayne, Orange Red, Veecot
- Mediterranean varieties: Cafona, Fracasso
- Central-Asian varieties: Szamarkandszkij rannij, Zard
- Hybrids: M 604 (*P. mandsurica x P. armeniaca*), Plumcot (*P. armeniaca x P. salicina*)

The following peach varieties have been tested:

- Hungarian local variety: Piroska
- Variety originated from Canada: Harko
- Varieties originated from the temperate zone of the USA: Babygold 6, Champion, Early Redhaven, Redhaven, Springcrest
- Varieties originated from California: Fairlane, Mayfire, Red June
- Varieties originated from Italy: Michelini, Venus

Apricot trees had been grafted on wild apricot stocks, while peach trees on wild peach stocks. Samples were taken from four trees of fruiting age of every variety in the assortment. Ten trees from each variety were randomly selected for sampling at each plantation. Plant protection and cultivation were the same for the trees at the plantations. For the investigations, fruiting parts were taken form the crowns at the height of 1,5-2 meters. From the apricot trees, fruiting parts shorter than 15 centimetres (short shoots) were collected, while from the peach trees, long shoots of full value with the length of 40-80 centimetres were gathered, since these are the most important parts from the viewpoint of fructification. The shoot buds, flower buds and ligneous tissues of these samples were examined in the laboratory.

2.1. Determination of the frost tolerance of plant parts with artificial freezing

Frost tolerance of flower buds, shoot buds and shoots were determined with artificial freezing method at different times of dormancy. The short shoots of apricots and long shoots of peaches were placed into computer-controlled climate chamber. After gradual cooling, the plant parts were kept at the experimental temperature for 4 hours. Then the temperature was gradually raised. With this procedure, we tried to imitate natural frost action. The rate of temperature change was 2 °C per hour. After taking the samples out of the climate chamber, they were kept at room-temperature for 24 hours. The extent of frost damage was determined by the visual analysis of the longitudinal segments of the buds and the crosswise segments of the shoots. Those tissues that had become brown were considered as damaged. We examined the segments of 200 buds and 10 shoots of each variety and each treatment. The objective of the examination was to define the value of LT_{50}, which indicates the temperature that causes 50% frost damage at the certain time. Therefore, at least 3 experimental temperatures were used at every examination time. The value of LT_{50} was determined by graphical procedure from the values of frost damages measured at the different temperatures, which we named the **mean value of frost tolerance**.

The artificial freezing tests were carried out twice a month from 15th December till blooming time, while in the last two years of the experiment the tests were executed from 15th October till blooming time. In this way, the frost tolerance of the generative and vegetative organs of the examined varieties throughout the winter dormancy was revealed.

2.2. Determination of the frost damage of flower buds and flowers with observations in the fields

Fruiting parts were collected from the trees at the end of the winter dormancy. The flower buds were cut longitudinally and the rate of frost damage during dormancy was defined on the basis of the coloration of tissues. 200 flower buds were examined from each sample. In those years when there were colds in the blooming period that caused considerable damages, the frost damage of the flowers was also examined. 100 open flowers of each variety were collected from the height of 2 meters then the flowers were unfolded to examine whether the organs were intact or had become brown.

2.3. Examination of the process of microsporogenesis

The anther initiatives of the flower buds developed in the middle of the short shoots of apricots and long shoots of peaches were taken out and were placed on object-slides. The anther initiatives were dyed with carmine acetic acid and were covered with cover glass. 6-8 flower buds were used from every sample for the examination. The cover glasses were pressed slightly to enable the tissues of the anthers to be seen. Afterwards, the preparations were examined under the microscope. Six developmental stages were able to be differentiated:

1. **archesporium stage** – homogenous and undifferentiated tissue,
2. **spike stage** – the developing pollen mother-cells form spikes,
3. **mother-cell stage** – the pollen mother-cells are separated,
4. **tetrad stage** – every mother-cell is divided to 4 haploid progeny-cells (microspores),
5. **spore stage** – the microspores are separated,
6. **pollen stage** – complete pollen-grains can be seen in the anthers.

The developmental stages transformed into one another gradually. This transformation usually took some days. To enable the statistical evaluation of the data, the day when 50% of the previous phenological stage and 50% of the new phenological stage could be observed with the microscope was considered as the day of the transformation.

2.4. Sprouting of flower buds

The fruiting parts collected from the trees twice a month during dormancy were placed into water at room-temperature. The rate of the sprouted flower buds and the time lapsed between the placing into water and the initiation of flowering were observed.

2.5. Measurement of the weight-gain of flower buds

100 flower buds were taken and measured from the fruiting parts of each variety. The measurement was carried out twice a month throughout the winter.

2.6. Determination of cold requirement (cold quantity required for the termination of dormancy)

Cold units accumulated till the initiation of each developmental stage of the flower buds were specified in the case of the examined varieties in accordance with four different calculation models.

The applied models were as follows:

1.) Number of hours under +7 ^oC (Porpáczy, 1964),
2.) Number of hours between 0 and +7 ^oC (a modification of the previous model implemented by us),
3.) Determination of the Chilling unit (CU) values in accordance with the method of Richardson et al. (1974),
4.) Sum of the mean daily temperatures between 0 and +10 ^oC in accordance with the method of Smykov (1985).

The reliability of the values of the different models were determined by the following method:

The mean daily temperatures from defoliation till flowering in the production sites were calculated in accordance with the measurements of the meteorological stations. Cold units accumulated till the initiation of the spike, mother-cell and tetrad stages were calculated (in hours and in ^oC) for each varieties in the experimental years by the four models described above. The cold unit values of the different years was averaged and the standard deviation was calculated. The coefficients of variation were specified in accordance with the method of Sváb (1981) since the magnitude orders of the values obtained by the models were different. In this way, the standard deviation values were reduced to the same common denomination, which enabled their comparison. The model with the least coefficient of variation was considered as the most reliable one.

2.7. Biometric methods

The evaluation of the data was performed by the programmes Excel 97 for Windows and SPSS 6.0 for Windows. The applied statistical methods for both fruit species were as follows:

- Calculation of averages and standard deviations.

- Bifactorial analysis of variance without repetition. Our aim was to determine the effects of the variety, site and year of production, as well as the variance of the times of the measurements and thus define the significance of each factor.
- Calculation of correlation. To determine the relation between the pace of microsporogenesis and the frost tolerance and also between the pace of microsporogenesis and the values of sprouting.
- Hierarchic cluster analysis to study diversity. The data-matrix of the examined varieties was analysed, which contained the following data: values of LT_{50} measured in the winters and early springs of 1998 and 1999, the times of the emerging of each stage of microsporogenesis, the cold units accumulated till this dates and the values of sprouting. Our objective was to determine and rank the varieties according to their type of adaptation. Prior to the analysis, each value was standardized in accordance with the Z-score method to avoid distortions occurring due to differences in magnitude orders. The ranking based on the Ward-method was applied in the cluster analysis and the dendrogram obtained in this way was used to characterize each variety group.

3. Results

3.1. Frost tolerance

3.1.1 Frost tolerance of flower buds

The flower buds of both species showed the highest frost tolerance at the end of endodormancy in December and January. At this time, temperatures between -17 and -26 °C were measured as the mean values of frost tolerance. This frost tolerance evolved gradually after the defoliation in autumn, and continuously deteriorated at the second half of the winter. The examined varieties were ranked on the basis of the frost tolerance of their flower buds.

Among the apricot varieties, 'Cafona' originated from the Mediterranean area was the most susceptible to frost, while 'Zard' from Central-Asia showed the highest frost tolerance. In the case of 'Cafona', temperatures between -17 and -20,5 °C were measured as mean values of frost tolerance at the end of endodormancy. Unfortunately, the flower buds of the five Hungarian varieties involved in the experiment showed similar frost tolerance. The varieties 'Ceglédi bíborkajszi' and 'Ceglédi óriás' were particularly susceptible to frost. The flower buds of these two varieties were significantly damaged under -20 °C in January. The mean values of frost tolerance of the flower buds of 'Gönci magyar kajszi' and 'Mandulakajszi' were better with 1-2 °C at the end of endodormancy, and deteriorated by a slower pace during ecodormancy than the varieties of Cegléd. The Canadian and French varieties, as well as the 'Veecot' and the 'M 604' had better frost tolerance than the Hungarian ones. The best values of their frost tolerance were around -22 °C. The flower buds of the apricot varieties 'Zard' and 'Plumcot' were found to have outstanding frost tolerance. The mean value of frost tolerance of 'Zard' was -24 °C in January 1998.

Among the examined peach varieties, 'Piroska' and 'Champion' showed the highest frost tolerance, while 'Venus', 'Springcrest' and 'Mayfire' were the most susceptible to frost. The mean value of frost tolerance of the flower buds of 'Piroska' and 'Champion' was around -23 °C at the end of endodormancy. Another important trait of these varieties is that their frost tolerance declined with a slower pace during ecodormancy than that of the other varieties. The peach varieties 'Redhaven', 'Early Redhaven', 'Babygold 6' and 'Harko' also seem to be appropriate for the reduction of frost damages occurring at the end of the winter at the Hungarian production sites. The variety 'Fairlane' requires further examinations due to the contradictory results on its frost tolerance. In Hungary, frequent yield reductions can be expected in the case of varieties with average or insufficient frost tolerance. All of the other examined varieties belong to this categories.

Having evaluated the examination results of the varieties, production sites and years of production, we realized that there were significant differences in the frost tolerance between the varieties and the years of production, while only minor differences were found between the production sites. The differences between the varieties are caused by their different hereditary traits. However, the weather conditions of the winter also have considerable effect on frost tolerance. The weather were significantly different from the average in two of the six experimental years. The winter of 1997-98 was extremely mild, while the weather was significantly colder than the average in the winter of 1995-96. In the first case, the plants responded to the environmental conditions with very fast development and changes in their frost tolerance, while in the second case, the plants' development and the changes in their frost hardiness were extremely slow. The weather of the other winters can be considered as average.

3.1.2. Frost tolerance of vegetative organs

The mean values of frost tolerance of shoot buds and shoots of 5 apricot and 5 peach varieties were determined in the middle of every months during the dormancy period of 1999-2000. The changes in the frost tolerance of shoot buds and shoots showed similar tendencies than that of the flower buds. Their frost hardiness have not developed totally for the defoliation in autumn. The values of frost tolerance became better and better by the end of December or the beginning of January, and became worse on the approach of spring.

The mean values of frost tolerance of apricot shoot buds on 15th October were between -12 and -15 °C. In the middle of the winter, the difference between the varieties was much larger, more than 10 °C, while it decreased on the approach of the blooming time. The mean value of frost tolerance of the shoot buds of the variety 'Cafona' originated from the Mediterranean area have not gone below -15 °C, while in the case of 'Zard', it was below -25 °C on 15th January. The frost hardiness of the shoot buds of the variety 'Bergeron' was worse with only a few °C than that of 'Zard', while the varieties 'Gönci magyar kajszi' and 'Ceglédi bíborkajszi' showed average frost tolerance values. From the examined organs, the frost tolerance of the shoots was the best during the whole dormancy period, their frost damage occurred at 5-6 °C lower than that of the buds.

The frost tolerance of peach shoot buds showed significant differences depending on the variety. The frost hardiness of the varieties increased till 15th January, and decreased afterwards. The mean values of frost tolerance reduced to -18 and -28 °C by the middle of January from the range of -9 and -19 °C. In comparison to autumn, the difference between the varieties declined by spring. The mean values of frost tolerance were between -10 and -14 °C. The shoot buds of 'Piroska' were proved to have the highest frost tolerance, while the shoot buds of 'Mayfire' and 'Venus' were the most susceptible to frost. 'Babygold 6' and 'Early Redhaven' showed average frost hardiness. Having examined the frost tolerance of peach long shoots, we experienced that there were minor differences in autumn and much larger differences in the middle of the winter between the values of the varieties with better frost tolerance ('Piroska', 'Early Redhaven', 'Babygold 6') and the values of the varieties that are more susceptible to frost ('Mayfire', 'Venus'). After the middle of December, these two groups separated definitely from each other. The frost tolerance of the long shoots of 'Venus' declined from 15th December after reaching -23 °C, while that of 'Mayfire' have never gone below -20 °C. The frost tolerance of the other three varieties increased till the middle of January. In this examination, 'Piroska' was found to have the best frost hardiness again with mean value of frost tolerance of -28 °C on 15th January.

Having compared the frost tolerance of the two bud types, we determined that in the first half of the winter dormancy the shoot buds, while in the second half the flower buds are more susceptible to frost.

3.2. Flower bud development

3.2.1. Determination of flower bud development with the examination of microsporogenesis

Among the examined apricot varieties, 'Zard' showed the slowest pace in pollen development in every year. 'Zard' was followed by the two interspecific hybrid varieties 'Plumcot' and 'M604'. The pollen development was relatively slow in the case of 'Harlayne', 'Bergeron', 'Harglow' and the Rumanian varieties 'Comandor' and 'Callatis'. The endodormancy of these varieties is long enough not to respond to the mild weather occurring in January with fast development, which is a very favourable trait in the viewpoint of yield reliability. From the Hungarian varieties 'Mandulakajszi' showed average pace of pollen development in comparison to the examined varieties. The flower bud development of the other Hungarian varieties was really fast. In the case of 'Ceglédi bíborkajszi' and 'Ceglédi óriás', the pace of development was similar to that of the Mediterranean varieties.

Among the peach varieties, the slowest pace of pollen development was found in the case of 'Piroska' and 'Champion'. These belong to the group of fresh consumed, downy varieties with white pulp. Among the fresh consumed varieties with yellow pulp 'Redhaven' and 'Early Redhaven', while among the nectarines 'Harko' showed slow flower bud development. The microsporogenesis of 'Venus', 'Springcrest' and 'Mayfire' was very fast. The remaining varieties were average considering their pace of bud development.

During the examination of the varieties of both species, it has been revealed that the pace of pollen development is genetically determined, since the relative order of the varieties was almost the same year by year. However, this hereditary trait was significantly influenced by the weather, which was manifested in the considerable differences between the years. The differences between the six years were evaluated by the results of the Hungarian apricot varieties. The fastest flower bud development was registered in 1998. The pollen mother-cells have already been developed between 10^{th} and 20^{th} January, and the reducing division has also been initiated in January, or in the case of the variety 'Mandulakajszi' in the first days of February. At the end of February, complete pollen-grains were found in the anthers. In this year, blooming was also initiated unusually early, at the beginning of March. The pace of efflorescence was slowed down by the cold weather occurred at the beginning of the blooming period, and it was extended to almost a month. The flower bud development was the slowest in 1996. The pollen mother-cells were developed by the middle of March, and their reducing division was completed at the end of March, which is approximately two months later comparing to the year 1998. Pollen-grains were developed at the beginning of April, after a short microspore stage, and the flowers opened very late, only at the end of April. In the remaining four years, the microsporogenesis of the examined Hungarian apricot varieties can be described as follows: the tetrad stage occurred at the second half of February, while blooming initiated at the end of March and beginning of April. The occurrence of tetrad stage showed a difference of more than two months between the two extreme years. The pace of flower bud development in 1997, 1999 and 2000 was nearly the same, and it corresponded to the average of the examined years.

3.2.2. Determination of flower bud development with other methods

In the course of the sprouting of fruiting parts of Hungarian apricot varieties, the rate of sprouting - with the exception of 1996 - was already between 5 and 25 % on 1st January. For the blooming of the initiated buds, an incubation of approximately 25 days was required at this time. In 1996, blooming was first experienced on the fruiting parts collected on 15th January. The tendency to blooming increased with almost the same pace in every year, while the required incubation time continuously decreased. The 50 % blooming rate occurred between 10th January and 1st February in the experimental years. By 1st March - with the exception of 1996 - every flower bud was sprouted, and a period of 5-8 days was required for this blooming. In 1996, the rate of blooming was 94 % at this time. In 1998, the rate of blooming was 100 % already on 15th February. The weight of apricot flower buds was not changed significantly till the beginning of February in the years of the experiment. Then their weight slowly increased, while 2-3 weeks prior to blooming a fast weight-gain of the buds was initiated.

The fruiting parts of 12 peach varieties were sprouted at Szigetcsép in three consecutive winters. All the flower buds of the fruiting parts collected in December remained dormant each year. At the beginning of January in 1999 and 2000, an inconsiderable sprouting rate could only be observed. In 1998, almost 20 % of the flower buds was sprouted at the beginning of January, and the 50 % sprouting rate was reached at the earliest date - on the 15th January - in this year. In the following two years, half of the buds was sprouted in the first days of February. Almost all flower buds were sprouted on the fruiting parts collected on 1st March independently of the year. An incubation period of 25-27 days was required for the blooming of the initiated flower buds at the beginning of January in each year. By the beginning of March, this incubation time reduced gradually to 7-8 days. The weight-gain of peach flower buds initiated at the beginning of February, and continued at a much slower pace up to the time of efflorescence comparing to that of the apricot varieties.

3.3. Cold requirement

The amount of cold required for the termination of endodormancy of the flower buds was determined by the method developed by us. In the course of this method, the initiation of the spike stage was considered as the termination of endodormancy, and the number of hours between 0 and +7 °C was summarized.

Two varieties were examined from the Mediterranean apricots. The cold requirement of 'Cafona' was 828 hours, while in the case of 'Fracasso' 852 hours were measured. The cold requirement of the five examined Hungarian varieties was between 840 and 852 hours similarly to that of the Mediterranean varieties. The cold requirement of the examined Rumanian varieties, and the varieties 'Hargrand', 'Szamarkandszkij rannij', 'Veecot' and 'Orange Red' was around 900 hours. Values exceeding 1000 hours were measured in the case of six varieties only. The cold requirement of the varieties 'Harglow', 'Harlayne', 'Bergeron' and 'Plumcot' slightly exceeded 1000 hours, while 'M 604' required 1284 hours, and 'Zard' 1428 hours of cold.

The two peach varieties with the longest endodormancy were 'Champion' originated from the USA (1320 hours of cold requirement) and the Hungarian local variety 'Piroska' requiring 1496 hours of cold. None of the peach varieties showed values below 1000 hours. Even 'Mayfire' originated from California required a cold amount exceeding 1000 hours (1048 hours). Similar values were measured in the case of the Italian varieties ('Venus' 1080 hours, 'Michelini' 1096 hours), and the 'Springcrest' bred in the State of Georgia in the USA (1080 hours). The cold requirement of the remaining peach varieties was around 1200 hours.

3.4. Examination of correlation and diversity

In the course of the statistical analysis, strong correlation was demonstrated between the pace of microsporogenesis and the changing of frost tolerance. The flower buds of the varieties with slower pollen development had higher tolerance to frost during winter in the case of both species. The difference between the varieties was the largest in the most critical period, i.e. in January and February, while it declined on the approach to the blooming time, although it remained considerable even in March.

The complex evaluation of the experimented apricot and peach varieties were accomplished by cluster-analysis in accordance with the laboratory examinations of the traits determining the winter adaptation of the flower buds (Figures No. 1 and 2). The four factors of the cluster-analysis were the followings: the frost tolerance of flower buds, the pace of their microsporogenesis, their tendency to efflorescence, and their cold requirement. The examined apricot and peach varieties were divided into four groups on the basis of the results obtained by the examination of diversity (Tables No. 1 and 2).

Figure 1

Result of the examination of diversity of apricot varieties on the basis of their traits determining winter hardiness

Dendrogram using Ward Method

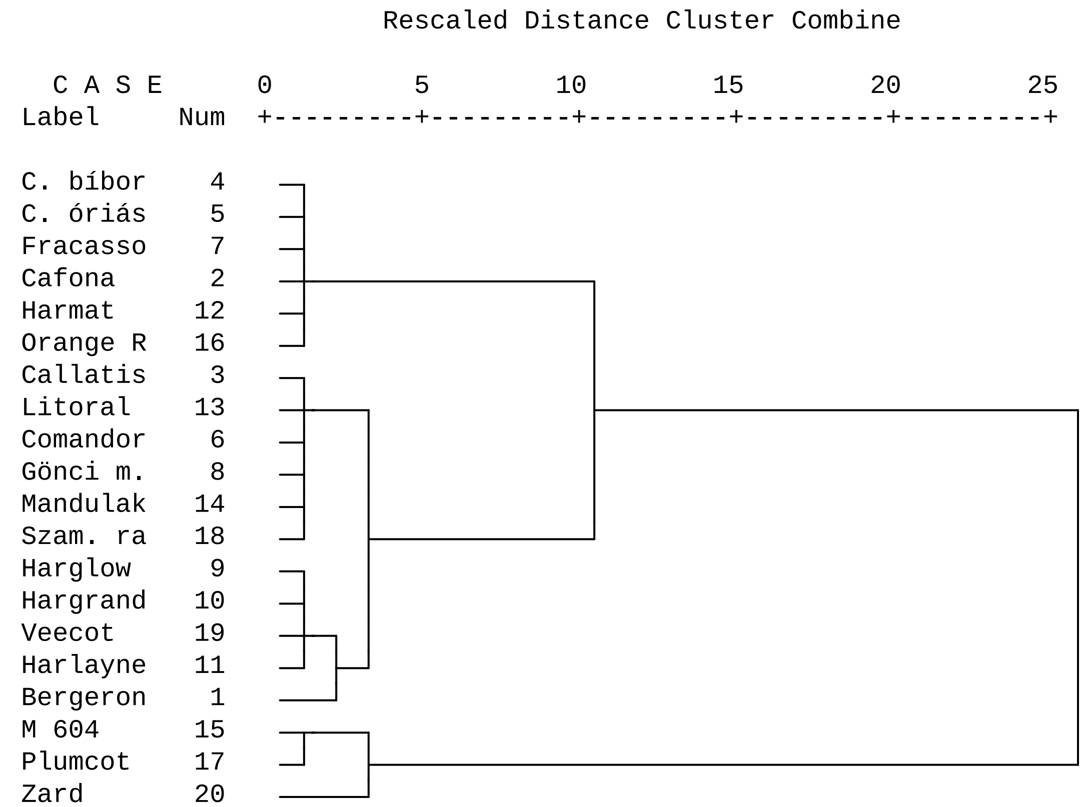

Figure 2

Result of the examination of diversity of peach varieties on the basis of their traits determining winter hardiness

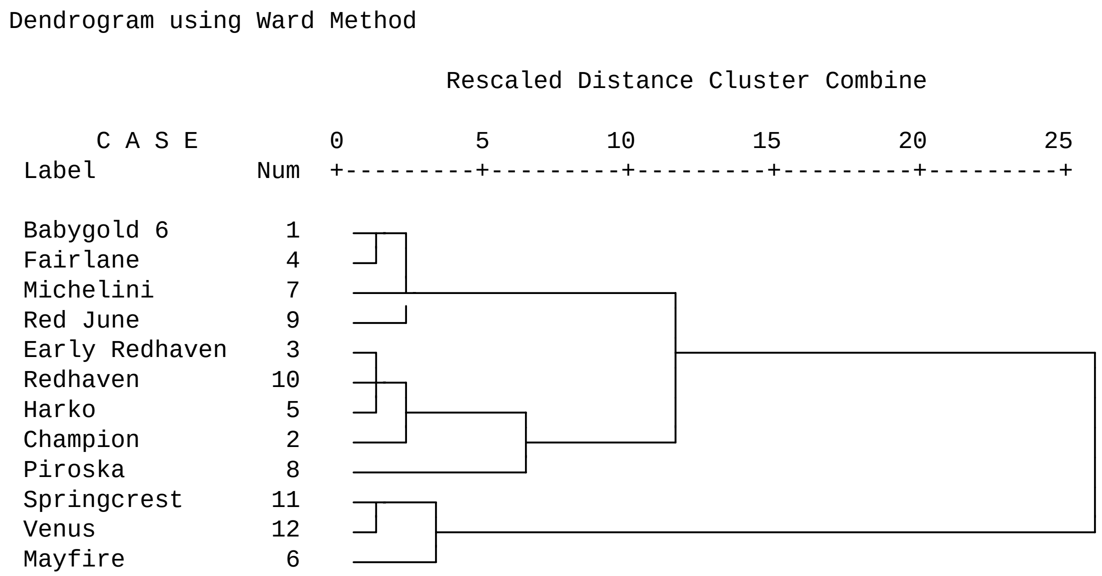

Table 1

Groups of apricot varieties sorted by their traits determining frost and winter hardiness

Group	Apricot varieties	Description of the group
Group 1	Zard Plumcot M 604	Varieties with the best frost and winter hardiness. Can be safely produced at every production sites of Hungary. Their flower bud development is slow in winter, their endodormancy is usually terminated only in February. The development of tetrad stage can be expected at the end of February or at the beginning of March. Their cold requirement significantly exceeds 1000 hours, in the case of 'Zard' it approaches 1500 hours. The frost tolerance of their flower buds is excellent. The flower buds are only damaged under -23 or -24 °C during endodormancy, and their frost hardiness decreases slowly during ecodormancy. Owing to the slow bud development in winter, their blooming occurs late, which is favourable from the viewpoint of avoiding spring frosts.
Group 2	Bergeron Harlayne Harglow Hargrand Veecot	Their frost tolerance and winter hardiness is adequate. Can be safely produced at hilly sites, and also recommended for the plains but only in a lower quantity. The endodormancy of their flower buds is terminated in the middle of January in average years. Their cold requirement is around 1000 hours. During endodormancy, their flower buds can tolerate frosts under -20 °C, and their frost tolerance does not decrease too fast during ecodormancy. They bloom at an average time or late.
Group 3	Szamark. rannij Mandulakajszi Callatis Comandor Litoral Gönci magyar kajszi	Their frost and winter tolerance is average. Their production is only recommended at protected, hilly sites with favourable microclimate. Their flower buds develop fast during winter, the endodormancy of the flower buds usually terminates at the end of December or at the beginning of January. Their cold requirement is between 800 and 900 hours. The frost tolerance of their flower buds is good during endodormancy, they can tolerate temperatures under -20 °C, but they develop fast during ecodormancy. Most of them bloom early, but there are some varieties with later blooming time ('Mandulakajszi').
Group 4	Orange Red Fracasso Harmat Ceglédi óriás Ceglédi bíbor Cafona	Their frost and winter hardiness is insufficient. These varieties cannot be produced successfully in Hungary. The endodormancy of their flower buds terminates already at the second half of December. Their cold requirement is low - between 800 and 900 hours. Their flower buds are susceptible to frost. Owing to the fast bud development, they bloom early, which increases the risk of spring frost damages.

Table 2

Groups of peach varieties sorted by their traits determining frost and winter hardiness

Group	Peach varieties	Description of the group
Group 1	Piroska	Variety with the best frost tolerance. Its winter hardiness is excellent. Can be safely produced at every production sites of Hungary. Its cold requirement is almost 1500 hours. Its flower bud development is slow in winter. Its endodormancy is usually terminated only in February. The tetrad stage is developed only in March. The frost tolerance of its flower buds is excellent. The flower buds are only damaged under -23 °C during endodormancy. Their frost hardiness decreases slowly during ecodormancy. They can tolerate frosts under -20 °C even in February. Owing to the very slow bud development in winter, its blooming occurs late, which is favourable from the viewpoint of avoiding spring frosts.
Group 2	Champion Harko Early Redhaven Redhaven	Their frost tolerance and winter hardiness is adequate. Can be safely produced at hilly sites, and also recommended for the plains but only in a lower quantity. The endodormancy of their flower buds is terminated at the end of January or at the beginning of February in average years. Their cold requirement is around 1300 hours. During endodormancy, their flower buds can tolerate frosts under -20 °C, and their frost tolerance does not decrease too fast during ecodormancy. They bloom at an average time or late.
Group 3	Babygold 6 Michelini Fairlane Red June	Their frost and winter tolerance is average. Their production is only recommended at protected, hilly sites with favourable microclimate. The endodormancy of the flower buds usually terminates at the second half of January. Their cold requirement is around 1100 hours. The frost tolerance of their flower buds is average. Their blooming occurs at an average time.
Group 4	Venus Springcrest Mayfire	Their frost and winter hardiness is insufficient. These varieties cannot be produced successfully in Hungary. The endodormancy of their flower buds usually terminates in January, but sometimes this occurs already at the end of December. Their cold requirement is 1000 hours. The frost tolerance of their flower buds is insufficient. During endodormancy, frosts under -18 °C cause considerable damage, and frost tolerance decreases fast on the approach of the blooming time. Owing to the fast bud development, they bloom early, which increases the risk of spring frost damages.

3.5. New scientific results

- A method to measure frost and winter hardiness has been developed on the basis of the examinations of 20 apricot and 12 peach varieties representing the most important variety groups.
- The actual frost tolerance of flower buds, shoot buds and shoots of apricot and peach varieties with different genetic features, and the dynamics of the changes in frost tolerance during the winter dormancy period has been determined.
- It has been defined that the shoot buds of apricots and peaches are more susceptible to frost than the fruit buds at the first half of the dormancy.
- The course of microsporogenesis of the examined apricot and peach varieties has been specified and numerically defined for statistical evaluation.
- A strong correlation between the pace of microsporogenesis and the frost tolerance of flower buds has been revealed.
- It has been demonstrated that the examination of microsporogenesis is the most applicable method to determine the termination of endodormancy. At the same time, it has been justified that the pace of flower bud development cannot be reliably defined by the sprouting of shoots and the measuring of weight-gain.
- A new method has been developed to calculate the amount of cold required for the termination of endodormancy of flower buds, and the cold requirement of the examined varieties has been specified. Our method is more reliable that the previously used calculation procedures, but further experiments are needed to make it more precise.
- The examined apricot and peach varieties have been ranked by their frost tolerance and winter hardiness in accordance with the complex statistical evaluation.

4. Conclusions and proposals

As a result of our work, we managed to select those apricot and peach varieties from the available ones that are promising for the production and breeding in Hungary from the viewpoint of yield reliability.

Among the apricot varieties, 'Zard' originated from Central-Asia showed significantly better frost and winter tolerance in the experiments than the varieties spread in our country. The endodormancy of its flower buds is much longer, and the cold requirement is greater than that of the Hungarian varieties. The two interspecific hybrid varieties 'Plumcot' and 'M 604' also had excellent frost tolerance. Thus, the genetic sources to improve the frost tolerance of the apricot should be sought at the primary gene-centre of the species, or among the hybrids bred by crossings with other species. Unfortunately, these varieties do not have the best fruit quality, therefore the genes responsible for their frost tolerance should be transferred into the cultivated varieties by biotechnological methods. This method is not yet developed in the case of the apricot. Traditional breeding with crossings promises more assured results, but in this case several cross-backs are required to ensure good fruit quality. According to our experiment, the apricot varieties 'Bergeron', 'Hargrand' and 'Harglow' had good frost and winter tolerance and good fruit quality at the same time.

The peach varieties with the best frost tolerance was the downy ones with white pulp. The variety 'Piroska' selected in Hungary should be highlighted with its excellent fruit quality. Unfortunately, this variety is not multiplied by the tree nurseries in the recent years. The variety 'Champion' can also be used as genetic source to improve frost tolerance. Varieties with good frost hardiness were found in several variety groups. Among the downy varieties with yellow pulp, 'Redhaven' and 'Early Redhaven' spread throughout the world had good frost tolerance, while among the nectarines, the variety 'Harko' bred in Canada belong to this category.

Our results demonstrate that the domestication of apricot and peach varieties improved in countries which have similar weather conditions that Hungary can be successful. Varieties originated from California, Italy and other mediterranean or subtropical regions are usually not suitable for the enlargement of Hungarian variety range, or detailed examinations should be executed prior to their cultivation to check whether they can adapt to the ecological features of our country.

By the specification and the partial modification of the previously used procedures, we developed a method that enables the determination of the frost and winter tolerance of a larger genetic range (new varieties, clones, hybrids) by laboratory methods not only in the case of apricot or peach, but other fruit species as well. The three main element of our method are the followings: determination of the frost tolerance of flower buds with artificial freezing, the observation of the pace of microsporogenesis, and a new calculation method to specify the cold amount required for the termination of endodormancy of flower buds.

We hope that our research will help to make the Hungarian apricot and peach production more successful.

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