International Journal of Horticultural Science 2006, 12 (2): 99–106
Agroinform Publishing House, Budapest, Printed in Hungary
ISSN 1585-0404

Calculation of climatic probability of winter and spring frost damages in the main peach and apricot growing districts of Hungary

Lakatos, L.[1], Szabó, Z.[2], Szalay, L.[3], Soltész, M.[2] & Nyéki, J.[2]

[1]*Department of Resource Management, Faculty of Agriculture, Centre of Agricultural Sciences, University of Debrecen*
[2]*Institute for Extension and Development, Centre of Agricultural Sciences, University of Debrecen*
[3]*Department of Pomology, Faculty of Horticultural Sciences, Corvinus University of Budapest*

Summary: The probability of winter and spring frost damages experienced in peach and apricot plantations has been assessed in 5 growing regions of Hungary (Szeged-Szatymaz, around the lake Balaton, Mecsekalja, hills of Buda, Mátraalja) and (Mecsekalja, hills of Buda, Pest-Gödöllő, Duna-Tisza köze, Mátra-Bükkalja) during the period between 1951 and 2000.

Frost tolerance of flower buds on a given shoot sample is expressed by the mean value assessed after frost damage (LT_{50}), and the meteorological records of the growing sites raised between 1951 and 2000 are used to calculate the probability of frost damage. In peach, the difference between growing sites and between varieties may become two fold as for the chance of repeated frost damage at a probability of 50 %. In apricot, the probability of frost damage may exhibit differences between growing sites up to 20 % as for susceptible varieties, and 16 % for frost tolerant varieties. Frost damage may vary between 4 and 18 % depending on the genuine frost tolerance of the varieties. Peach is afflicted by low temperature causing substantial losses of yield at the highest probability in the region Szeged-Szatymaz and at the lowest in Mátraalja. Apricot is, on the other hand, most endangered in the Duna-Tisza köze region, while the lowest probability of frost damage is expected around Mecsek and Buda.

The critical period of frost damage in the mid of January in Szeged-Szatymaz region, in Mecsekalja the mid of February showed the highest probability of frost damage. All growing sites are frequented at high chances by frost damages occurring during and closely after the blooming period. Duna-Tisza köze is mainly afflicted in early March, whereas Mátra-Bükkalja in mid of January and early March.

The probability of temperatures below zero degree has been assessed in all the 5 regions observed. Around April 5–8 the probability of freezing temperatures diminishes steeply at all sites, whereas the risk of frost increases again around April 9–11. That climatic peculiarity of should be taken into consideration in choosing growing sites or varieties.

Postulating the effects of a global warming up of the climate, the chances of avoiding frost damages at different growing sites by delaying the blooming dates are considered. According to our calculations, the delay of blooming by 5 days may diminish the risk of frost damage by 4–20 % at the growing sites examined, whereas a delay of 10 days reduces the risk by 37–85 % in both fruit species.

Calculations offered an answer on the question of climatic changes, whether the probability of winter and spring frosts damage changed during the 50 years. The long list of data shows the diminishing chances of winter frosts, while the probability of temperatures risking spring frost damages increased after the early 1970-es up to now.

Key words: blooming season, flower bud, low temperature

Introduction

Frost damage afflicts yearly the 200–300 000 ha cultivated surface of Hungary mainly during spring and autumn *(Szász & Tőkei, 1997)*. In winter and spring, temperature minima often damage also fruit trees, mainly peaches and apricots.

Rudinai Molnár (1913) stated that in each 15–20th year winter frosts caused remarkable losses (also trees died). *Nyujtó & Tomcsányi (1959)* registered around Kecskemét, *Horn (1965)* in Budapest the years since the 18th century, when heavy frosts caused damage in horticulture. *Nyujtó & Tomcsányi (1959)* concluded their survey of 150 years with the statistics: 16 "hard winters" and 25 marked with spring frosts both being considered to hit more or less the whole country.

The first comparison of apricot varieties from the point of view of frost resistance/susceptibility appeared in Hungary 1956, later of peaches in 1965, both by *Horn. Mohácsy* et al. *(1959)* explored the frost damage in leaf and flower buds of four peach varieties being attentive to the length of shoots and the position of the buds on the shoot. The partial frost damages do not destroy the flower primordia, but the rate of fruit set is impaired, moreover, the incidence of contamination by the fungus *Monilia* is increased *(Holb, 2003)*.

The means to assess frost tolerance in the organs of plants was developed by the artificial freezing technique *(Szabó,*

2002). For the purpose to facilitate an unbiased comparison of data *Proebsting & Mills (*1966*)* introduced the concept of LT_{50}, which is expressed with the temperature causing 50 % frost damage on the respective organ. The first application of the procedure on stone fruits was reported in Hungary by *Zayan (*1981*).*

Our examinations endeavoured to predict the probability of winter and spring frost damage in the main fruit growing regions of Hungary with special reference to apricot and peach varieties. It should be also assessed, which are the most afflicted periods of the year as well as the measure of damage expected.

Materials and methods

The database of the present study has been developed by *Szabó* et al. *(*2001*)* and *Szalay* et al. *(*2000*)* serving with a pool of LT_{50} parameters. Mean values of frost tolerance in the respective varieties have been calculated from a series of data raised over a period of 8 years according to the method described by *Lakatos* et al. *(*2005*).*

Growing sites:

The growing area of the 5 respective peach varieties are the following *(Timon,* 2000*)*:

- Szeged-Szatymaz
- Balaton area
- Mecsekalja
- Buda region
- Mátra alja

Regions of growing apricots:

- Mecsek area
- Buda region
- Pest-Gödöllő region
- Duna-Tisza köze (between the two rivers)
- Mátra-Bükkalja

Database of meteorological data comprises the daily minimum temperatures of the period between 1951 and 2000

Varieties examined:

The probability of frost damages in the three peach varieties have been computed

- *Redhaven* (yellow flesh, fresh consumption, good frost tolerance)
- *Babygold 6* (yellow flesh, processing type, intermediate frost tolerance)
- *Venus* (yellow flesh, nectarine fresh consumption, low frost tolerance).

The three apricot varieties are:

- *Ceglédi bíborkajszi* (low frost tolerance)
- *Gönci magyar kajszi* (intermediate frost tolerance)
- *Bergeron* (good frost tolerance).

Examination of flower buds:

All varieties and occasions were represented by 10 fruiting shoots, which served to assess frost damage. The buds were dissected longitudinally and examined by the naked eye or by stereo microscope. Where the pistil or the whole primordium turned brown, it was judged to be frozen.

The calculation of LT_{50} values:

Each variety or treatment was represented by at least 10 fruiting shoots. The buds to be compared were of the same size (development). As frost damage varied along the shoot, all buds are to be examined. The fruiting shoots having been sampled are kept for 24 hours on 0 °C temperature. Subsequently, the temperature was lowered every second hour by 2 °C until the target temperature has been achieved in a adjustable climatised camera of FISSONS & FEUTRON type. The treatment on the critical (target) temperature lasted 2–4 hours. Each time, 3–4 critical temperatures have been applied. The graphic representation of frost damages at different temperatures served as basis of computing the value of LT_{50} by means of regression analysis.

Assessment of frost damage

As the daily development of LT_{50} was known over the period between October 15 and April 1, it could be stated that there are a few days only, which have a lower minimum temperature than the LT_{50} values of the respective dates. Our purpose being the determination of the risk of frost damage of the critical periods as the probability of frost damage based on the records of the past 50 years between 1951 and 2000. The values gained mean meteorological probabilities.

The statistical parameters express the frequencies, variances and regression coefficients. The computations, figures and tables are performed by the Excel program.

Results

Probability of the incidence of winter frost damages

The probability of frost damages has been computed as a function of varieties, growing sites over the winter partitioning it into two-week periods. The following statements could be attempted:

The nectarine variety 'Venus' in the region of Szeged-Szatymaz was threatened the most by frost damage (46%). The following was the region around Lake Balaton (42%) and the third the region of Debrecen (40%). Except the sites of Mecsekalja – where at the and of January – but in any other regions the mid of January was the most afflicted date *(Table 1).*

The apricot cultivar 'Ceglédi bíborkajszi' suffered the most damage in the Duna-Tisza köze region (54%). The next was the Mátra-Bükkalja region (46%), the third frosty sites were the hills of Buda (36%). Most of the sites – except the Mecsekalja, where February and early March are critical –

Table 1 The probability of frost damage over the winter at the main growing sites of the nectarine variety 'Venus'.

Date of the mid of the period examined	Szeged-Szatymaz	Balaton surroundings	Mecsek-Mátra-	Buda region	Mátra-alja
Oct. 15	0	0	0	0	0
Nov. 1	0	0	0	0	0
Nov. 15	0	0	0	0	0
Dec. 1	4	2	0	0	2
Dec. 15	2	2	2	2	2
Jan. 1	8	10	6	2	4
Jan. 15	22	20	12	20	22
Feb. 1	12	16	14	8	10
Feb. 15	12	16	8	10	10
March 1	12	14	12	10	14
March 15	2	4	2	0	4
April 1	0	0	0	0	0
whole winter	**46**	**42**	**28**	**30**	**36**

the mid of January and again the early March are afflicted by frost damage (*Table 2*).

Table 2 The probability of frost damage over the winter at the main growing sites of the apricot variety 'Ceglédi biborkajszi'.

Date of the mid of the period examined	Duna-Tisza köze region	Pest-Gödöllő region	Mecsek alja	Hills of Buda	Mátra-Bükkalja region
Oct. 15	0.0	0.0	0.0	0.0	0.0
Nov. 1	0.0	0.0	0.0	0.0	0.0
Nov. 15	0.0	0.0	0.0	0.0	0.0
Dec. 1	2.0	0.0	0.0	0.0	0.0
Dec. 15	2.0	2.0	0.0	0.0	2.0
Jan. 1	2.0	2.0	4.0	0.0	4.0
Jan. 15	14.0	16.0	8.0	12.0	20.0
Feb. 1	14.0	10.0	14.0	10.0	10.0
Feb. 15	12.0	14.0	8.0	12.0	12.0
March 1	20.0	16.0	14.0	12.0	18.0
March 15	16.0	4.0	6.0	8.0	12.0
April 1	8.0	2.0	10.0	4.0	10.0
whole winter	**50.0**	**32.0**	**34.0**	**36.0**	**46.0**

Similar conclusions are accurate in relation of the medium frost resistant peach cultivar 'Babygold 6'and apricot cultivar 'Gönci magyar kajszi'. The probability of damage is was less by 20–30% in relation to the susceptible 'Venus' nectarine, and less by 4–14 % in relation to 'Ceglédi bíborkajszi' apricot cultivars. In the region of Szeged-Szatymaz, 'Babygold 6' suffered at a probability of 38%, in the region of a Duna-Tisza köze, 'Gönci magyar kajszi' at a probability of 40%.

The well known frost tolerance of 'Redhaven' and 'Bergeron' cultivars suffered at a mean rate of 34–38%. The relative risk of damage compared with the most susceptible cultivars 'Venus' and 'Ceglédi bíborkajszi' was less with 40–50% and 4–18%, respectively.

During the period between October 15 and April 1, the probability of frost damage varied also between the growing regions because of the local weather conditions. In *Figure 1* it is clearly proved that the well known susceptible cultivar 'Venus' is most exposed to frost damage about the mid of January in the region of Szeged-Szatymaz and Balaton region (at 20–22%), in the Mecsekalja region at the end of January (at 13–14%).

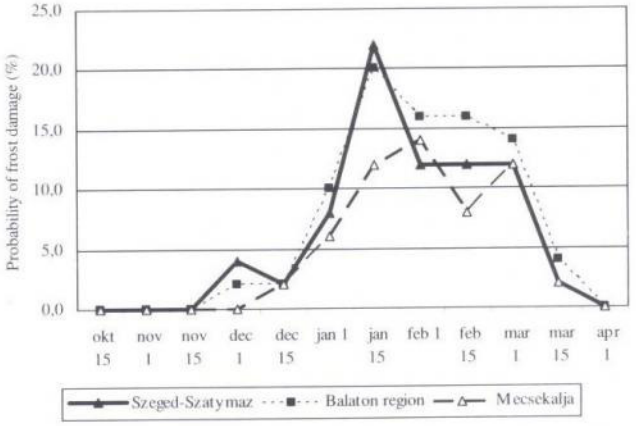

Figure 1 The probability of frost damage suffered by the nectarine cultivar 'Venus' over the years between the dates October 15 and April 1 in three growing regions (1951–2000).

The apricot cultivar 'Ceglédi bíborkajszi' is most exposed to the risk of winter frost damage in the regions of Mátra-Bükkalja and the hills of Buda at the mid of January (12–20%) (*Figure 2*). In the region of Duna-Tisza köze the risk is still high in early March (20%).

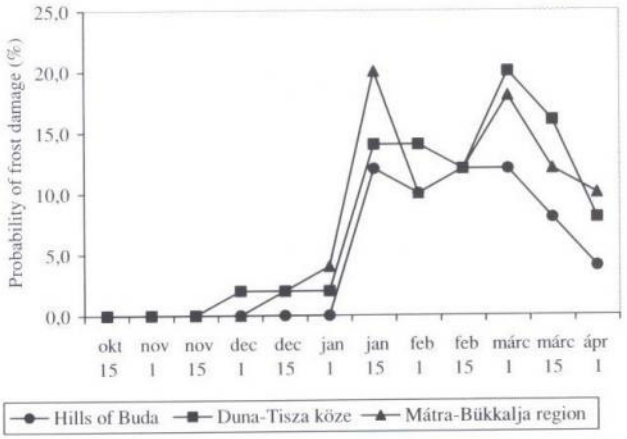

Figure 2 The probability of frost damage suffered by the apricot cultivar 'Ceglédi bíborkajszi' over the years between the dates October 15 and April 1 in three growing regions (1951–2000).

The risk of frost damage threatening the peach variety of good frost tolerance, 'Redhaven', between October 15 and April 1 in the region Szeged-Szatymaz culminated at the mid of January (to 16%). The maximal risk was at Mecsekalja in early February, whereas around the lake Balaton at the mid of February. At the region Mecsekalja, no dangerous frost damage is expected after early March in the cultivar 'Redhaven' (*Figure 3*).

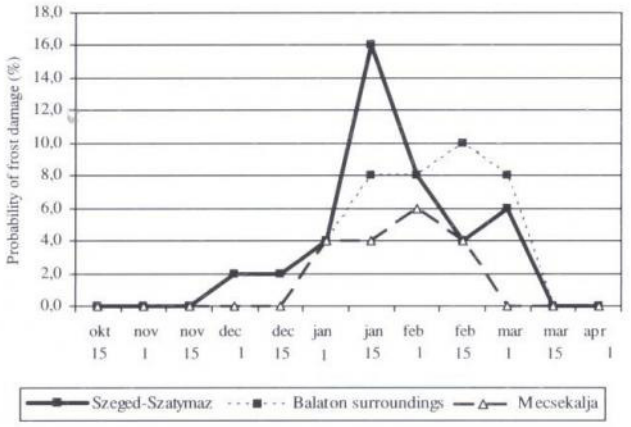

Figure 3 The probability of frost damage suffered by the peach cultivar 'Redhaven' over the years between the dates October 15 and April 1 in three growing regions (1951–2000).

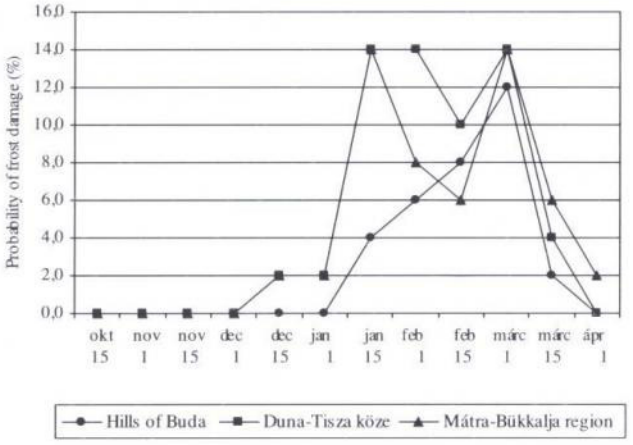

Figure 4 The probability of frost damage suffered by the apricot cultivar 'Bergeron' over the years between the dates October 15 and April 1 in three growing regions (1951–2000).

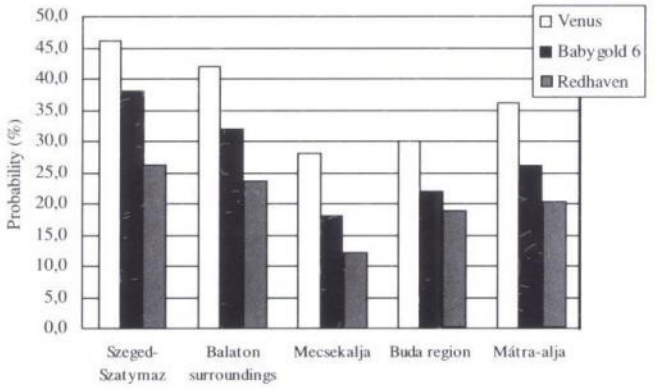

Figure 5 The mean probability of frost damage during the period between October 15 and April 1 in different peach varieties (1951–2000)

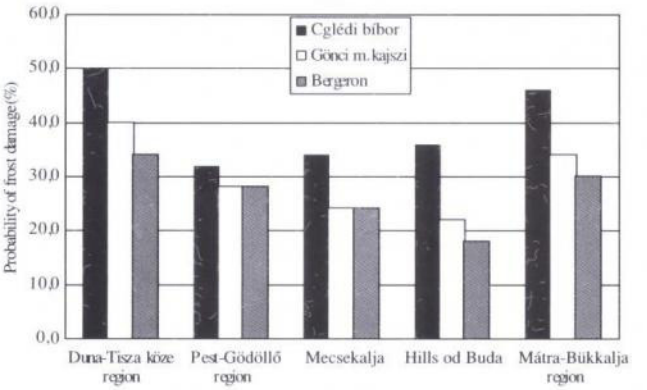

Figure 6 The probability of frost damage suffered by apricot cultivars over the years between the dates October 15 and April 1 in three growing regions (1951–2000).

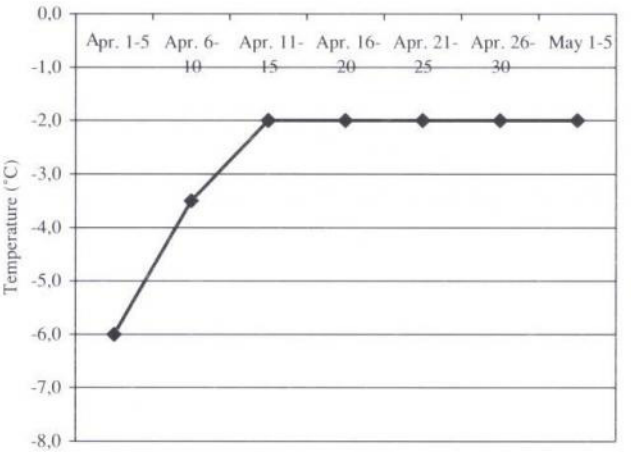

Figure 7 The empirical curve representing physiologically critical temperatures causing frost damage (50 %) during bloom in peach

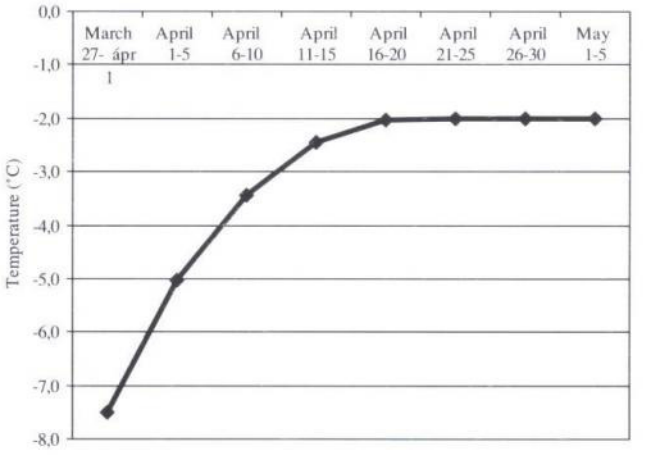

Figure 8 The function curve of LT_{50} during bloom in apricot. At the given temperature 50 % of flowers froze

In the apricot cultivar 'Bergeron', between October 15 and April 1, the risk of frost damage is the highest in the region Mátra-Bükkalja around the mid of January (14%), later diminishes in relation to other regions. The region Duna-Tisza köze is threatened between the mid of January – mid of February, then in early March, whereas the hills around Buda at the end of February. No risk is expected around Buda after mid of March (*Figure 4*), however, in the regions Mátra-Bükkalja, Duna-Tisza köze and around the lake Balaton, the risk still exists at a probability of 4–6%.

The probability of important frost damages of 3 peach cultivars at different growing regions over the whole winter

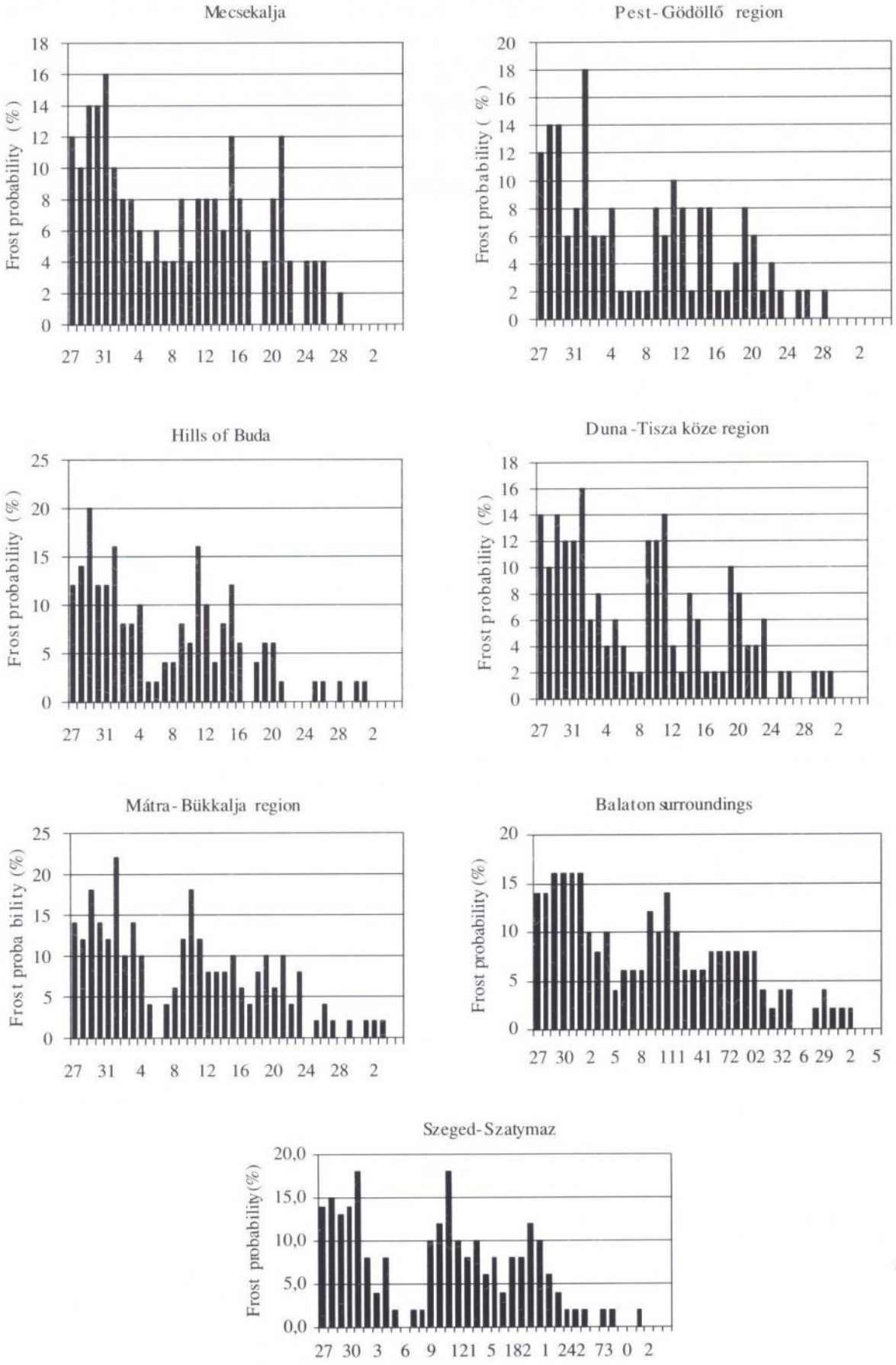

Figure 9 The probability of frost damage occurring between April 1 and May 5 at the 5 fruit growing regions examined during the 50-year-period (1951–2000)

allows the subsequent conclusions: the region of Szeged-Szatymaz is most afflicted, somewhat less the surrounding of the lake Balaton, whereas Mecsekalja is the most safe growing site (*Figure 5*).

Frost damage in apricot trees is most probable in the region Duna-Tisza köze, then in Mátra-Bükkalja and Pest-Gödöllő (*Figure 6*). The less afflicted, out of 5 regions compared, used to be the hills around Buda.

The probability of spring frost damages

The numerical expression of probabilities of spring frost damage has been attempted on an empirical scale for peach (*Figure 7*) and for apricot (*Figure 8*). In this way, the frequency of deleterious temperatures – at 2 m above ground being decisive – could be predicted for both species. It was supposed that the graphs will be valid for all other varieties as well as for all growing sites.

As for the estimation of the probability of spring frost damages within the period between April 1 and May 5 at the main growing regions, we refer to the statistics of the last 50 years. As a climatic peculiarity of Hungary, the probability of frost between April 5 and 10 used to be reduced, however, its occurrence increases between April 10–15 and again between April 20–25. That may become deleterious for both peach and apricot after bloom finished. In *Figure 9* proves that the low temperatures mentioned occur at all growing sites.

If we ask the question, what are the chances of frost damage during the spring coincident with the blooming process of fruit trees, especially the period between April 1 and May 5 in the main peach and apricot growing regions, the following answer could be given. The most afflicted period for peach is April 11–15. Especially at Mátraalja, Szeged-Szatymaz, and around the lake Balaton, the incidence of frost is high (12–14 %) as presented in *Figure 10*. At Szeged-Szatymaz, the subsequent, April 16–20 period is still threatened at a frequency of 10 %.

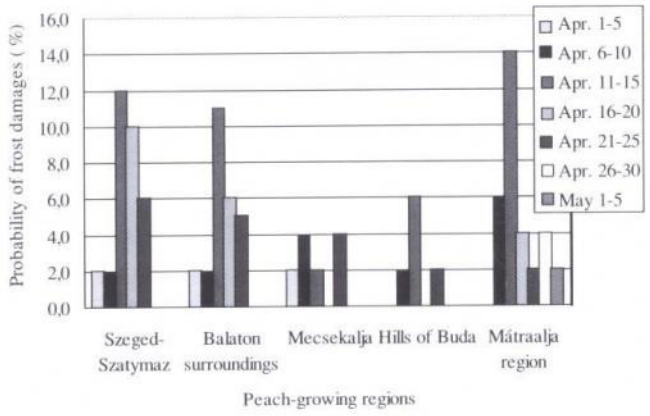

Figure 10 The probability of frost damage during the blooming season of peach in different regions of production (1951–2000)

For apricot trees, the most endangered period by spring frost damage is between March 31 and April 11–15. The most afflicted region is Mátra-Bükkalja (14 %) as shown in *Figure 11*. At the same region, the probability of damage is still 4 % during April 16–20, whereas in other regions the probability is 2 % only. Much later, during April 26–30 and May 1–5 the risk is again high, 2–4 %, in the region of Mátra-Bükkalja.

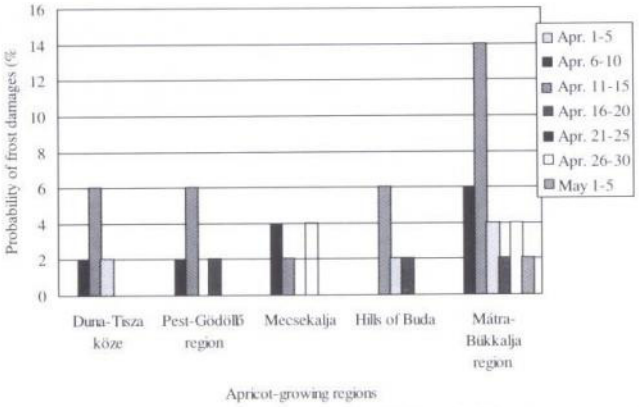

Figure 11 The probability of frost damage during the blooming season of apricot in different regions of production (1951–2000)

Comparing the probabilities of spring frost damage on the three peach varieties during the blooming period, it could be proved that between April 11 and 20, the risk of frost damage is six-fold in Szeged-Szatymaz and in the Balaton region than in Mecsekalja.

On apricot, the risk of frost damage during April 11–20 is two-fold higher in the Mátra-Bükkalja region than in the hills of Buda.

The dates of bloom vary over 2–3 weeks in different parts of the country, therefore, the prediction of risk could be improved by the knowledge of the specific probabilities of the individual growing sites. Blooming of peach starts in the south, in Szeged-Szatymaz and Mecsekalja, then it progresses to the north, i.e. 5 days later in the Buda region, in Mátraalja 3 days, in the Balaton region 2 days later. Apricot starts blooming earlier than peach but the delay between Mecsekalja and Buda are 8 days, Mátraalja 12 days, Balaton region 4 days later.

On that basis, the probabilities of frost damages are calculated. Most endangered region of peach growing during the blooming period is Mátraalja, the next is Szeged-Szatymaz followed by the surrounding of Balaton. Mecsekalja is the safest area from the point of view spring frost damage.

Apricots are the most threatened in the region Mátra-Bükkalja, with less probability around Buda, then in Duna-Tisza köze and Pest-Gödöllő. The less endangered region is Mecsekalja.

Peach trees would, certainly, suffer frost damages less by 4–20 % with a 5-day-delay of bloom in the regions examined (*Figure 12*). The reduction of risk would be the most accentuated in Mecsekalja, whereas the less around the lake Balaton. A delay of blooming dates by 10 days could reduce frost damages at a rate of 37–85%.

The delay of blooming dates of 5 days would reduce the risk of spring frost damage by 1–20 % in apricots at the growing sites examined (*Figure 13*). The reduction of risk would be pronounced at Mecsekalja, whereas less perceptible around Buda. A delay of 10 days would increase

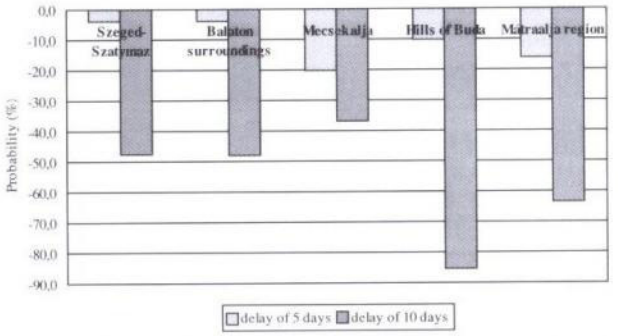

Figure 12 The reduction of risk regarding spring frost damage in peach at different growing regions, if the dates of blooming would be delayed by 5 or 10 days.

the reduction to 37–85 % over the regions. The expected climatic changes would influence frost damages in the regions of Duna-Tisza köze and Pest-Gödöllő the most, whereas in Mecsekalja the less.

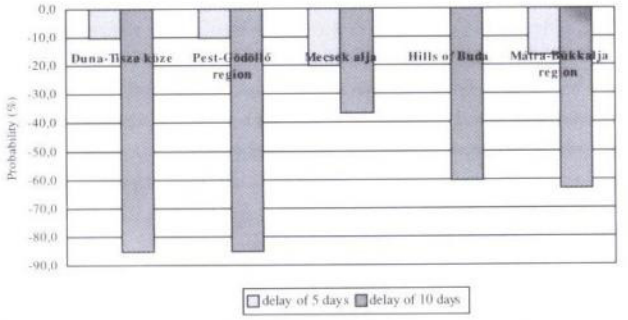

Figure 13 The reduction of risk regarding spring frost damage in apricot at different growing regions, if the dates of blooming would be delayed by 5 or 10 days.

The probability of winter and spring frost damage

For both, frost tolerant and susceptible peach varieties the risk of winter and spring frost damages is the most dangerous in the region Szeged-Szatymaz. The susceptible variety 'Venus' suffers at a double rate of frequency here than in the region Mecsekalja, where the probability of winter and spring frost damages is the lowest.

For apricot, the frost damage of the whole year (winter+spring) is most threatening in the region Duna-Tisza köze. There, the susceptible variety 'Ceglédi biborkajszi' endangered at a probability of 20 % more than in the region Pest-Gödöllő, the less risky one.

It is a important question to be answered that the probability of winter and spring frosts whether did it diminish during the last 50 years at the main growing sites of the country. The years of the 1970-es proved to be favourable from the point of view of less important winter and spring frosts. During the whole period of 50 years, the highest frequency of winter and spring frost damages occurred in the 1960-es. The successive data of temperatures measured at the different growing regions along the year suggest the following statements: The frequency of winter frost damages diminished, whereas the frequency of damages due to the spring frosts increased from the 1970-es up to the present, in both, peach (*Figure 14*) and apricot (*Figure 15*).

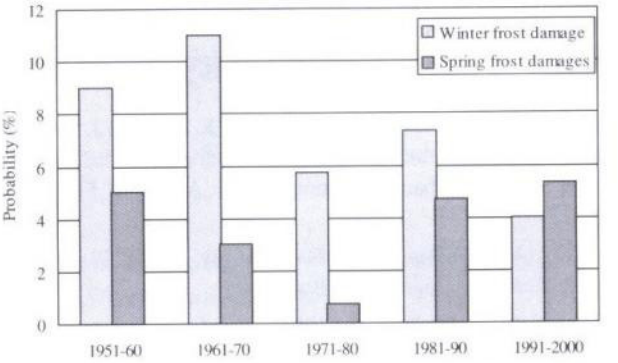

Figure 14 The risks of the winter and spring frost damage in plantations of the peach variety 'Venus' estimated on the basis of mean of data raised at 6 growing regions.

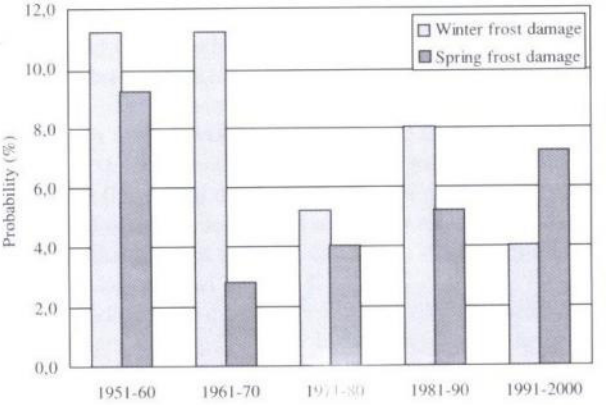

Figure 15 The risks of the winter and spring frost damage in plantations of the apricot variety 'Ceglédi biborkajszi' estimated on the basis of mean of data raised at 5 growing regions.

The probabilities of frost damages calculated for apricot are rather similar to those for peach. However, the practical application of the findings presented requires still some further improvement. The values could be applied for individual varieties and growing sites, moreover, the extent of damage on the flowers may be associated with the respective temperatures. The weather during the blooming process may also compensate for previous winter and spring frost damages with higher rates of fruit set on the few flowers, which survived.

Aknowledgements

Research was supported by the research grant OMFB 00063/2004.

References

Holb, I. J. (2003): The brown rot fungi of fruit crops (*Monilinia* spp.) I. Important features of their biology (Review). International Journal of Horticultural Science. 9 (3-4):23–36.

Horn, E. (1956): Kajszibarackfák rügypusztulása. Biológiai Közlemények. 4(1):61–65.

Horn, E. (1965): Télállóság és fagytűrőképesség vizsgálata egyes őszibarackfajtáknál. Kertészeti és Szőlészeti Főiskola Közleményei. 29:121–133.

Lakatos, L., Szabó, Z., Szalay, L., Soltész, M., Racskó, J. & Nyéki, J. (2005): Az őszibarack téli fagytűrését jellemző számítási módszer: „Agro-21" Füzetek- 39: 17–35.

Lakatos, L., Szabó, Z., Szalay, L., Nyéki, J., Racskó, J. & Soltész, M. (2005): A téli és tavaszi fagykárok gyakoriságának valószínűsége Magyarországi őszibarack termőtájakon: „Agro-21" Füzetek 39: 102–113.

Mohácsy, M., Maliga, P. & ifj. Mohácsy, M. (1959): Az őszibarack. Mezőgazdasági Kiadó, Budapest.

Nyújtó, F. & Tomcsányi, P. (1959): A kajszibarack termesztése. Mezőgazdasági Kiadó, Budapest. 330.

Proebsting, E. L. & Mills, H. H. (1966): A standardized temperature-survival curve for dormant Elberta peach fruit buds. Proc. Amer. Soc. Hort. Sci. 103(6):842–845.

Rudinai Molnár, I. (1913): Gyakorlati gyümölcstermesztés. Orsz. M. Gazd. Egy., Budapest.

Szabó, Z. (2002): Csonthéjas gyümölcsüek termésbiztonságának egyes tényezői. Akadémiai Doktori Értekezés, MTA, Budapest (Manuscript).

Szabó, Z., Szalay, L. & Papp, J. (2001): Connection between the developmental stage and the cold hardiness of flower buds of peach varieties. V. International Peach Symposium. July 8–11. Davis, Ca (USA), Abstracts, Poster.

Szalay, L., Papp, J. & Szabó, Z. (2000): Evaluation of frost tolerance of peach varieties in artificial freezing tests. Acta Horticulturae. 583:407–410.

Szász, G. & Tőkei, L. (1997): Meteorológia mezőgazdáknak, kertészeknek, erdészeknek. Mezőgazda Kiadó, Budapest.

Timon, B. (2000): Őszibarack. Mezőgazda Kiadó, Budapest.

Zayan, M. A. (1981): Különböző kajszibarackfajták hidegtűrésének alakulása szénhidrát, fehérje és az aminosav tartalom függvényében. Kandidátusi Értekezés, MTA, Budapest (Manuscript).