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Evaluation of plant growth regulators for control of dormancy in apricot (*Prunus armeniaca L.*)

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Abstract: In an environment where fruit production is increasingly affected by unpredictable weather patterns, it is important to look for ways to minimise the impact of climate change on production. Under Central European conditions, a limiting factor for apricot (*P. armeniaca* L.) growing in certain years is the occurrence of late spring frosts. One measure to eliminate their impact is to delay the actual flowering of the trees. This can be done by breeding or just by applying various plant growth regulators (PGRs). According to our results the varieties with a long dormancy period in the conditions of the Czech Republic are 'Velika Luka' (dormancy break 79 days from the beginning of December), then 'Bai Gon' with the same values, 'Chuang zhi hong' (dormancy break 73 days from the beginning of December) and hybrid form Lednice 'Pozdně kvetoucí', which had an average dormancy break 70 days from the beginning of December, even though in most years in field conditions it often blooms as one of the last genotypes. Next, we tested the effect of 6 active substances in 16 different concentrations on their ability to delay flowering. The results show that the application of Ethrel-based mixtures (concentrations of 0.05 and 0.5%) had the greatest influence, delaying flowering by up to 3–5 days, but also had the most destructive effect on tree health. The application of the commercial product Rhodofix (NAA-1-Naphthaleneacetic acid (NAA)–0.3%) and the application of a proprietary mixture based on NAA 1.0% did not have a very significant effect, with a delay in flowering of just 2 to 3 days. One interesting finding was that the application of the above products had a statistically significant effect on the ripening date of apricot fruit, with a difference of up to 4 days. Based on the results, the application of PGRs can affect the flowering time, but not in a completely fundamental way. Thus, protection against late spring frosts is therefore dependent on a combination of several approaches.

Keywords: *P. armeniaca*; PGRs; phytohormones; flowering; phenological stages

Apricot (*Prunus armeniaca* L.) is one of the most widely cultivated stone fruit trees. It is a difficult species to grow in many areas because different climatic conditions have a strong influence on fruit productivity (Quamme et al. 1982). Apricot is well known for its inflexibility to adapt to various climatic conditions. By prolonging the dormancy in some of the early flowering varieties, it might be possible to reduce apricot's susceptibility to injury in unsuitable environments, as well as make their annual

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growth more predictable and decrease their sensitivity to certain environmental stresses such as cold in winter (Yamane 2014).

Dormancy has been a long-studied issue in the field of horticulture, especially in fruit science (Lang et al. 1987; Campoy et al. 2011; Li et al. 2018; Yaacoubi et al. 2019; López-Bernal et al. 2020). Plants use this mechanism to protect sensitive tissue against unfavourable climatic conditions. Dormancy is a complex of phenomena that is important in temperate regions, and it is closely related to the proper development of new formed buds of fruit trees (Andreini et al. 2014). The dormancy break is controlled by various genetic and environmental factors (Viti et al. 2013). This process is different for every species. Thus, dormancy is related to a genotype-environment interaction. In the end of the summer, newly formed buds enter a period of inactivity While the mechanism of the influence of day length on dormancy control has not yet been sufficiently proved, the processes by which plants perceive cold to alter gene expression is moderately well understood (Horvath 2009). Hormonal regulation also plays an important role in dormancy, although the exact mechanism remains somewhat unclear (Rohde, Bhalerao 2007; Olsen 2010). Bud breaks are achieved by a change in hormone balance in the buds. Several studies have investigated the effects of the external application of GA (Reinoso et al. 2002) and cytokinin (Campoy et al. 2010) on bud break in *Prunus*. Recent findings have shown the influence of abscisic acid (ABA) as a potential mediator of the short-induced inhibition of growth and the initiation of bud dormancy in trees (Guak, Fuchigami 2001). The primary role of ABA in plants is to repress growth and promote organ senescence and abscission (Finkelstein 2013). In addition to ABA and GA, other 'Dormancy-breaking agents' are known, such as calcium cyanamide, hydrogen cyanamide and other nitrogen or sulphur chemicals, many of which are commercially manufactured (Ionescu et al. 2017). But their application has been limited or prohibited due to toxicity to humans (WHO 2020).

Ionescu et al. (2017) defined classical plant hormones as a fundamental factor that can influence flowering time. In addition, a study by Liu and Sherif (2019) added to the importance of ethephon in mitigating the effects of spring frosts by delaying flowering time in many fruit species, which has been known for decades. However, the application of ethephon may not be always optimal for the health of the tree (the occurrence of gummosis, lower fruit yield, floral anomalies, physiological chlorosis, and smaller fruit, etc.). The effect on dormancy is also known for compounds other than phytohormones, as demonstrated by a study by González-Rossia et al. (2008) describing changes in glucose and fructose levels that correlate to cold accumulation in *Prunus* spp. Another example of a stimulatory mechanism against spring frost is a study by Pakkish and Tabatabaienia (2016) focusing on the use of nitric oxide (NO). Treatment with NO significantly reduced frost damage to apricot blossoms when exposed to low temperature (–3 °C). The frost resistance of blossoms was correlated to an increase in sugar and proline content.

The effect of phytohormones on the delay of flowering date in apricots under Central European conditions and the method of their application is the aim of the research hypothesis of our paper. The purpose of the experiment was to determine and evaluate dormancy breaking in selected promising apricot genotypes while evaluating the effect of selected PGRs and phytohormones on dormancy and flowering prolongation with respect to protection against late spring frosts.

MATERIAL AND METHODS

The experimental site. The planting is situated at an altitude of 164 m a.s.l. The Lednice site in the South Moravian Region is one of the warmest in the Czech Republic. The annual average temperature is 9.1 °C and the average annual rainfall is 422 mm (1960–1991). The growing season for the area is from 19 April to 19 October, which is 178 days (Nečas et al. 2018). In 2018, the average temperature in the growing season was 19.4 °C (11.7 °C year-round), annual precipitation was 387.4 mm, and sunshine was 2 066.8 hours. In 2019, the average growing season temperature was 17.7 °C (11.5 °C year-round), annual precipitation was 528.1 mm, and sunshine was 1 982.9 hours. In 2020, the average growing season temperature was 16.8 °C (11.0 °C year-round), annual precipitation was 574.0 mm and sunshine was 1 872.1 hours. According to Quitt's classification, the area belongs to the warm zone W4. (Vachůn 2022). The experimental orchard is located in grounds of the Faculty of Horticulture in Lednice, MENDELU in Brno (GPS 48°47'21"N, 16°47'37"E, 182 metres a.s.l.), on the southern edge of the village. The land is char-

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acterized by simple geological conditions and is mostly flat. It is a geologically young area in which mainly Cenozoic Pleistocene and Holocene sediments are found. A large part of the area is covered with loess unconsolidated sediments of various thicknesses. The mineralogical composition is quartz, $CaCO_3$, with occasional clastic admixtures (Petránek 1993).

Experimental plantings. The experiments and evaluation took place between 2018 and 2021 in an apricot planting on the grounds of the Faculty of Horticulture (FH) at Mendel University in Brno. The experimental planting of apricots was planted in 2011 on an apricot seedling rootstock with 5 × 3 m spacings in the free-growing dwarf training system without a terminal. The early apricot variety 'Leskora' bred at the Faculty of Horticulture in Lednice, flowering 2 to 3 days and ripening 16 to 19 earlier than the variety 'Velkopavlovicka' (a variety from the Hungarian Best group). Supplementary irrigation was not provided; planting treatment was carried out in the standard conventional mode.

The application of growth regulators. The growth regulators were applied in mid-September on a sunny day on two trees of each variant. Altogether, 22 trees were treated, and 2 untreated trees were the control. The application was performed using a backpack motorised sprayer (AM 162, Mountfield, Czech Republic). The application dose was 2 L of the application mixture per tree; the substances used to influence dormancy are listed in Table 1. To evaluate the effects of the applied PGRs, the date of flower bud emergence was compared with the untreated control trees. Furthermore, the flowering rate, the ripening period and general health status after application of the preparations were monitored. In almost all years of evaluation, the experiment was affected by late flower damage due to late spring frosts.

Table 1. A summary of PGRs and concentrations used in the experiment

Variant	Active substance	Concentration used
ABA	abscisic acid	0.03%
NAA	1-naphthylacetic acid	0.2%; 1.0%
IAA	3-indoleacetic acid	0.01%; 0.1%
Ethrel	ethephon 480 (g/l)	0.05%; 0.5%; 1.0%
Rhodofix	1-naphthylacetic acid 1.0%	0.30%
Protone	s-abscisic acid 200 g/kg	0.05%; 0.2%

ABA – abscisic acid; NAA – naphthaleneacetic acid; IAA – indoleacetic acid

The evaluation of the dormancy breaking. Dormancy breaking was evaluated under laboratory conditions at room temperature according to the methodology of Vachůn et al. (1975, 1984). This is a simple procedure when branches with flower buds are removed at 14-day intervals from December onwards; there must be at least 100 flower buds on the removed branches. Once approximately 50% of the flowers have bloomed, the genotype is considered to have emerged from endogenous dormancy. The actual evaluation of genotypes was always performed between December and almost the end of February each year, depending on the dormancy break of genotypes in evaluated year. The dormancy of selected varieties was evaluated within the apricot gene pool collection situated in the same location and under the same growing conditions as the varieties specified in the results (Table 2).

Statistical analyses. Statistica 12 and Microsoft Excel software were used for averaging the values and statistical analyses, where the one-way ANOVA (level of significance $\alpha = 0.05$) and Tukey HSD post-hoc tests were subsequently used to evaluate the statistical significance of the differences between values of individual traits.

RESULTS AND DISCUSSION

Evaluation of the effect of selected phytohormones on prolonging dormancy. After the annual autumn application, the experiment with phytohormones and growth regulators to prolong the dormancy of apricots was always evaluated in the spring of the following year. The application mixtures were applied in mid-September in 2018, 2019, and 2020, always on the same trees of the apricot variety 'Leskora'. The results collected each year of the experiment were similar for some variants and different for others.

The results show that after the first application (2018), there was a delay in tree budding compared to the untreated control group by 4 days for Ethrel 0.05%, 3 to 4 days for Ethrel 0.5%, 3 days for Ethrel 1%, Rhodofix 0.3% and NAA 1.0% (Figure 1). Moghadam, Mokhtarian 2006, concluded with similar results in their experiment. Other variants, including the commercial preparation Protone, had no significant effect on the flowering date. The situation was different for fruit ripening, where the effect of phytohormones was more significant (Fig-

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Table 2. The results of dormancy breaking evaluation for a selected range of varieties in the experimental years 2018-2021

Varieties	End of apricot dormancy			Date of flowering			Average end of dormancy	Average date of flowering
	2018/2019	2019/2020	2020/2021	2019	2020	2021		
Adriana	03.II	16.I	29.I	06.IV	26.III	19.III	26.I	27.III
Agat	31.I	06.II	01.II	10.IV	31.III	24.III	01.II	01.IV
Bai Gon	14.II	23.II	15.II	04.IV	25.III	18.III	17.II	26.III
Betinka	17.I	15.I	14.I	08.IV	29.III	22.III	15.I	30.III
Candela	17.I	15.I	18.I	06.IV	26.III	19.III	16.I	27.III
Farclo	03.I	18.I	31.I	08.IV	29.III	20.III	17.I	29.III
Goldrich	03.I	18.I	01.I	05.IV	22.III	15.III	07.I	24.III
Chuan xing	15.II	04.II	31.I	03.IV	23.III	15.III	05.II	24.III
Chuang zhi hong	14.II	06.II	15.II	05.IV	23.III	17.III	11.II	25.III
In bei xing	13.II	02.II	28.I	02.IV	23.III	14.III	04.II	23.III
Kompakta	03.II	05.II	04.II	04.IV	24.III	18.III	04.II	26.III
LE–5500	04.II	17.I	04.I	08.IV	29.III	20.III	19.I	29.III
LE–5959	17.I	10.II	17.I	12.IV	01.IV	25.III	25.I	02.IV
LE–6016	17.I	15.I	01.I	05.IV	22.III	19.III	11.I	26.III
Leala	03.I	10.II	15.II	08.IV	31.III	16.III	30.I	29.III
Leskora	03.I	19.I	03.I	07.IV	27.III	23.III	08.I	29.III
Mediabel	04.I	16.I	15.I	06.IV	26.III	21.III	12.I	28.III
Moi Chua Xing	12.II	21.II	31.I	06.IV	26.III	16.III	01.II	26.III
Nimfa	04.I	15.I	01.I	03.IV	21.III	14.III	07.I	23.III
Ninja	16.I	17.I	02.I	04.IV	25.III	18.III	12.I	26.III
Orangered	30.I	04.II	29.I	06.IV	26.III	19.III	31.I	27.III
Portici	04.I	15.I	16.I	02.IV	21.III	14.III	12.I	23.III
Pozdně kvetoucí	12.II	11.II	01.II	10.IV	31.III	23.III	08.II	01.IV
Pricia	19.I	15.I	01.I	03.IV	23.III	16.III	12.I	24.III
Samurai	19.I	15.I	01.I	04.IV	24.III	20.III	02.II	26.III
SEO	30.I	04.II	31.I	03.IV	23.III	16.III	12.I	24.III
Sophinka	14.II	19.I	18.I	03.IV	22.III	16.III	01.II	24.III
Salak	03.II	05.II	28.I	05.IV	26.III	20.III	27.I	27.III
Velika Luka	14.II	23.II	15.II	11.IV	31.III	24.III	17.II	01.IV
Velkopavlovická	17.I	17.I	29.I	06.IV	26.III	20.III	21.I	28.III
Vestar	30.I	04.II	28.I	08.IV	29.III	22.III	31.I	30.III
Wondercot	30.XII	15.I	03.I	03.IV	21.III	14.III	06.I	24.III
MN–VA–1 almond as control	13.II	10.II	29.I	03.IV	13.III	16.III	07.II	21.III

Late end of dormancy / late flowering
Early end of dormancy / early flowering
Late end of dormancy / early flowering

ure 2). Some variants showed a delay in maturation of as many as 3 to 5 days compared to the control group (most notably Ethrel). A similar effect of Ethephon was described in blueberry and peach by Liu and Sherif (2019); so was various damage to trees treated with the preparation. Unfortunately, all variants with Ethrel showed an adverse effect of gummosis, with very strong gummosis in the 0.5% and 1.0% concentrations (see photo documentation).

In post-application evaluation in 2019, the greatest effect on delay in flowering had that the application of Ethrel-based products with a delay in flowering of 2 to 4 days and the application of Rhodofix 0.3% and NAA 1.0% with a delay in flowering of 2 days. For the other variants, no effect was noted in the 2020 evaluation year. A difference was noted in the ripening time, when the biggest delay in ripening was not caused by (Ethrel/

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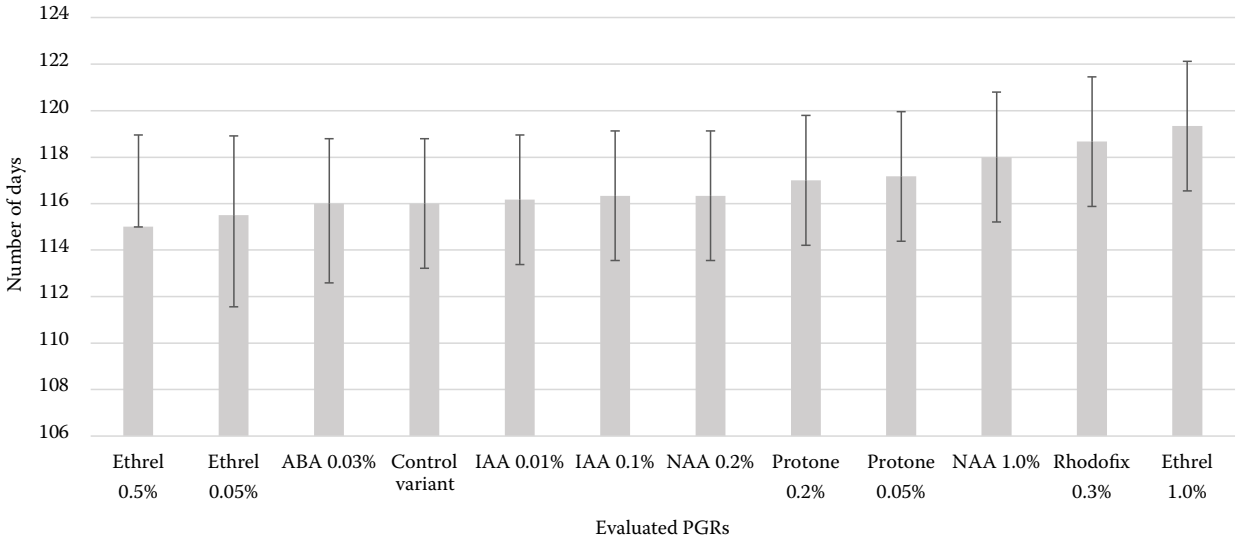

Figure 1. The average numbers of days from 1. December to start of flowering (2018–2021)
ABA – abscisic acid; IAA – indoleacetic acid; NAA – naphthaleneacetic acid

Ethephon as in 2018) but by NAA 1.0%, where the delay was 4 days. At other variants, the difference was only 1 to 2 days (Figure 2).

The most effective variant in 2020 was again the application of Ethrel at a concentration of 1.0%, which unfortunately, as in previous years, showed to cause strong gummosis (Figure 3). The difference in flowering between the untreated control group and this application was 5 days. Unfortunately, in the other variants with Ethrel (concentrations of 0.05% and 0.5%), the trees did not flower at all. Since the preparations were applied on the same trees for 3 successive years, it can be assumed that there was an overall inhibition of flower bud differentiation. Among the more effective variants were Ethrel 0.01% and Rhodofix 0.3% and, in the last year, Protone 0.05% (Table 3) with

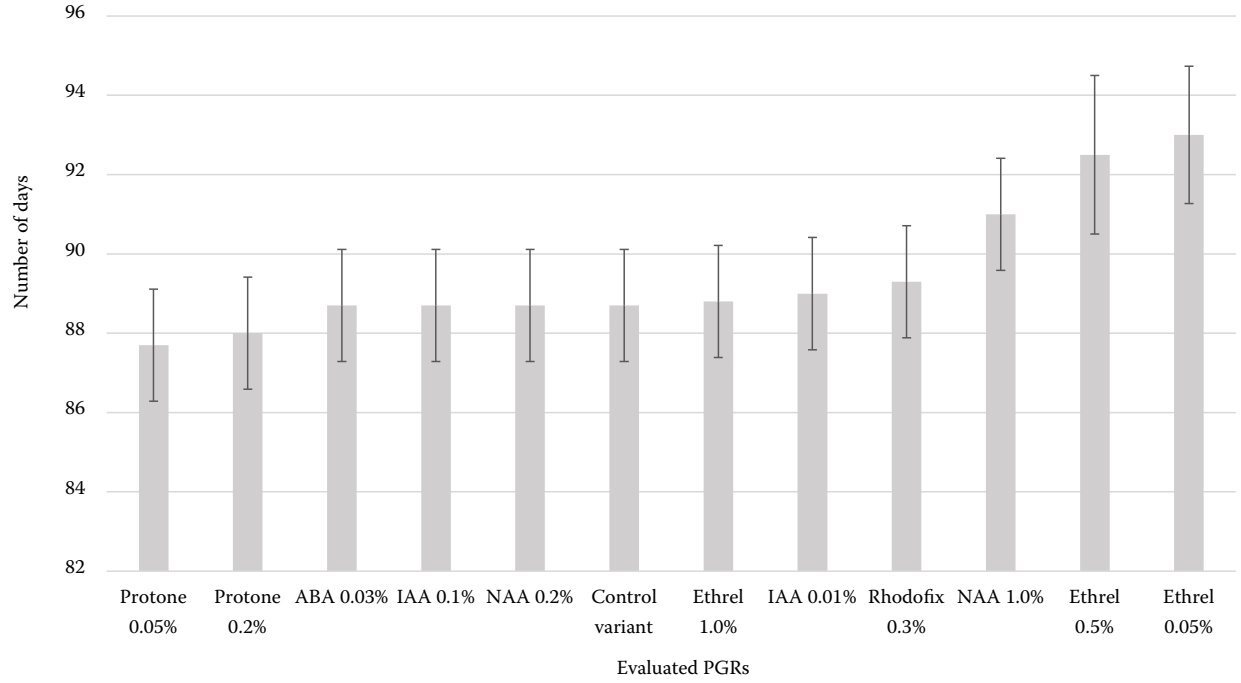

Figure 2. The average number of days from the start of flowering to fruit ripening time (2018–2021)
ABA – abscisic acid; IAA – indoleacetic acid; NAA – naphthaleneacetic acid

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Figure 3. Very strong glue flow after application of Ethrel in different concentrations

a 3-day delay in the flowering date compared to the control group.

Although the resulting difference in delayed bud break is not significant, it is interesting in the case of some variants (Ethrel, and NAA-based preparations) (Figure 4). The monitoring showed that the application of these substances had a more significant effect on fruit ripening, with a statistically significant result (Figure 5). Unfortunately, the spring weather also largely affected the course of the experiment and no significant and clear effect on delayed flowering was observed. Rather than flowering, the subsequent effect on ripening time was evident as the application of these substances demonstrated a significant effect on fruit ripening time. Importantly, it has been shown that in a certain way, if a suitable phytohormone or growth regulator is chosen and applied at a certain concentration, the onset of bud break could be delayed. Unfortunately, the spring weather had a significant influence on the experiment. The results also show that the application of the used phytohormones does not have any significant or clear effect on the delay of flowering. The flowering period and frost tolerance are influenced by many more factors that have not been recognised, acting in a more complex way than is allowed by the simple application of flowering regulators. Among others, the work of Demirtas et. al. (2010), demonstrated the effect of pruning

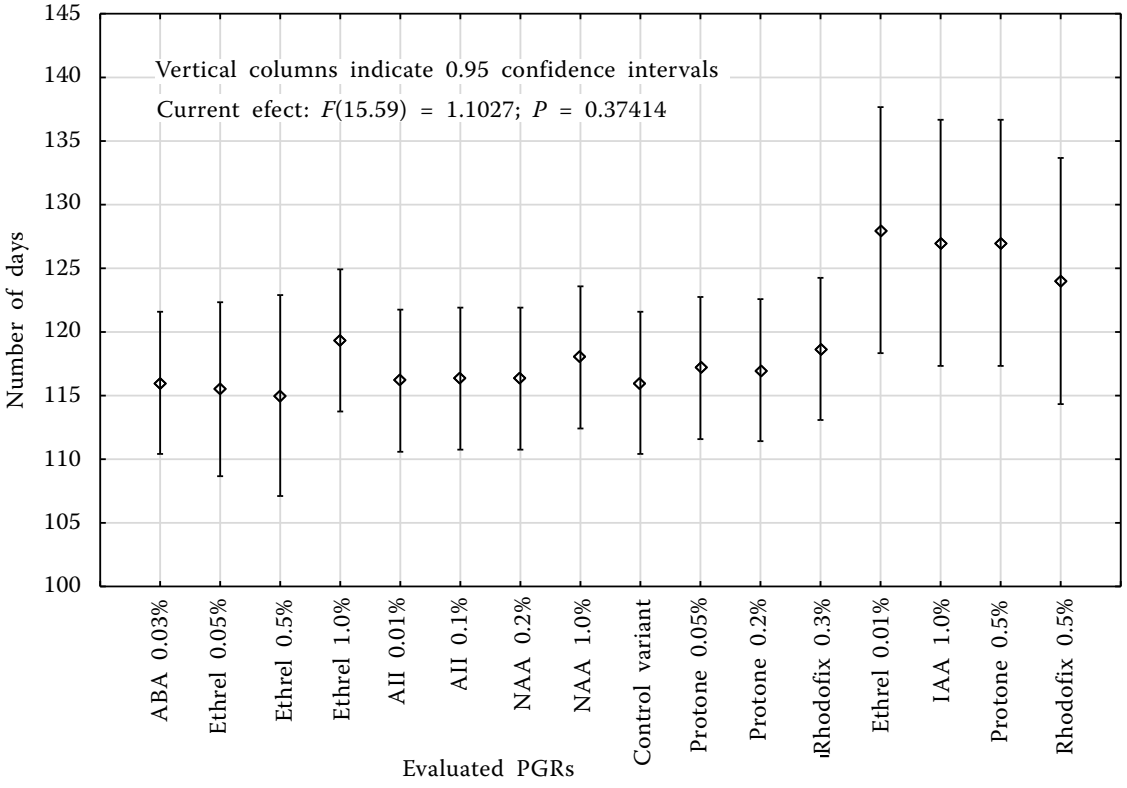

Figure 4. A statistical analysis of the effect of the application of PGRs on the start of flowering time of the 'Leskora' apricot variety

For PGRs description see Table 1

https://doi.org/10.17221/135/2022-HORTSCI

Table 3. The average values of the effect of used PGRs on selected characteristics of apricot trees (2018–2021)

Tree No.	PGRs	Flowering richness	Beginning of flowering	Full flowering	Difference of days to control variety	Number of days from	
						December 1 to flowering	flowering to ripening
Evaluation in 2019							
1	Ethrel 0.05%	6	26.III	30.III	4	116	92
2	Ethrel 0.05%	6	26.III	30.III	4	116	92
1	Ethrel 0.5%	5	26.III	30.III	4	116	92
2	Ethrel 0.5%	5	25.III	29.III	3	115	92
1	Ethrel 1.0%	5	25.III	29.III	3	115	90
2	Ethrel 1.0%	5	25.III	30.III	3	115	91
1	Protone 0.05%	7	22.III	26.III	0	112	87
2	Protone 0.05%	7	22.III	26.III	0	113	87
1	Protone 0.2%	7	23.III	27.III	1	113	87
2	Protone 0.2%	7	23.III	27.III	1	113	87
1	Rhodofix 0.3%	8	25.III	29.III	3	115	90
2	Rhodofix 0.3%	8	25.III	29.III	3	115	90
1	IAA 0.01%	9	22.III	26.III	0	112	87
2	IAA 0.01%	9	23.III	26.III	1	113	87
1	IAA 0.1%	9	22.III	26.III	0	112	87
2	IAA 0.1%	9	22.III	26.III	0	112	87
1	NAA 0.2%	8	22.III	27.III	0	112	87
2	NAA 0.2%	8	22.III	26.III	0	112	87
1	NAA 1.0%	9	25.III	29.III	3	115	91
2	NAA 1.0%	9	25.III	29.III	3	115	91
1	ABA 0.03%	6	22.III	26.III	0	112	87
2	ABA 0.03%	6	22.III	26.III	0	112	87
1	control variant	8	22.III	26.III	0	112	87
2	control variant	8	22.III	26.III	0	112	87
1	Rhodofix 0.5%	–	–	–	–	–	–
2	Rhodofix 0.5%	–	–	–	–	–	–
1	Protone 0.5%	–	–	–	–	–	–
2	Protone 0.5%	–	–	–	–	–	–
1	Ethrel 0.01%	–	–	–	–	–	–
2	Ethrel 0.01%	–	–	–	–	–	–
1	IAA 1.0%	–	–	–	–	–	–
2	IAA 1.0%	–	–	–	–	–	–
Evaluation in 2020							
1	Ethrel 0.05%	5	24.III	30.III	4	115	94
2	Ethrel 0.05%	5	24.III	30.III	4	115	94
1	Ethrel 0.5%	3	23.III	29.III	3	114	94
2	Ethrel 0.5%	d	d	d	d	d	d
1	Ethrel 1.0%	5	22.III	29.III	2	113	94
2	Ethrel 1.0%	5	22.III	29.III	2	113	94
1	Protone 0.05%	6	20.III	27.III	0	111	92
2	Protone 0.05%	3	20.III	27.III	0	111	92
1	Protone 0.2%	6	20.III	27.III	0	111	92
2	Protone 0.2%	6	20.III	27.III	0	111	92
1	Rhodofix 0.3%	7	22.III	28.III	2	113	94

https://doi.org/10.17221/135/2022-HORTSCI

Table 3 to be continued

Tree No.	PGRs	Flowering richness	Beginning of flowering	Full flowering	Difference of days to control variety	Number of days from December 1 to flowering	Number of days from flowering to ripening
2	Rhodofix 0.3%	7	22.III	28.III	2	113	94
1	IAA 0.01%	7	20.III	27.III	0	111	93
2	IAA 0.01%	7	20.III	27.III	0	111	93
1	IAA 0.1%	7	20.III	27.III	0	111	93
2	IAA 0.1%	7	20.III	27.III	0	111	93
1	NAA 0.2%	6	20.III	27.III	0	111	93
2	NAA 0.2%	7	20.III	27.III	0	111	93
1	NAA 1.0%	5	22.III	30.III	2	113	96
2	NAA 1.0%	7	22.III	30.III	2	113	96
1	ABA 0.03%	5	20.III	27.III	0	111	92
2	ABA 0.03%	5	20.III	27.III	0	111	92
1	control variant	7	20.III	27.III	0	111	92
2	control variant	7	20.III	27.III	0	111	92
1	Rhodofix 0.5%	–	–	–	–	–	–
2	Rhodofix 0.5%	–	–	–	–	–	–
1	Protone 0.5%	–	–	–	–	–	–
2	Protone 0.5%	–	–	–	–	–	–
1	Ethrel 0.01%	–	–	–	–	–	–
2	Ethrel 0.01%	–	–	–	–	–	–
1	IAA 1.0%	–	–	–	–	–	–
2	IAA 1.0%	–	–	–	–	–	–
			Evaluation in 2021				
1	Ethrel 0.05%	n	n	n	n	n	n
2	Ethrel 0.05%	n	n	n	n	n	n
1	Ethrel 0.5%	n	n	n	n	n	n
2	Ethrel 0.5%	d	d	d	d	d	d
1	Ethrel 1.0%	1	1	1	1	1	1
2	Ethrel 1.0%	1	1	1	1	1	1
1	Protone 0.05%	8	8	8	8	8	8
2	Protone 0.05%	8	8	8	8	8	8
1	Protone 0.2%	8	8	8	8	8	8
2	Protone 0.2%	8	8	8	8	8	8
1	Rhodofix 0.3%	7	7	7	7	7	7
2	Rhodofix 0.3%	7	7	7	7	7	7
1	IAA 0.01%	7	7	7	7	7	7
2	IAA 0.01%	7	7	7	7	7	7
1	IAA 0.1%	8	8	8	8	8	8
2	IAA 0.1%	8	8	8	8	8	8
1	NAA 0.2%	8	8	8	8	8	8
2	NAA 0.2%	8	8	8	8	8	8
1	NAA 1.0%	6	6	6	6	6	6
2	NAA 1.0%	8	8	8	8	8	8
1	ABA 0.03%	7	7	7	7	7	7
2	ABA 0.03%	8	8	8	8	8	8
1	control variant	9	9	9	9	9	9

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Table 3 to be continued

Tree No.	PGRs	Flowering richness	Beginning of flowering	Full flowering	Difference of days to control variety	Number of days from	
						December 1 to flowering	flowering to ripening
2	control variant	9	9	9	9	9	9
1	Rhodofix 0.5%	7	7	7	7	7	7
2	Rhodofix 0.5%	7	7	7	7	7	7
1	Protone 0.5%	8	8	8	8	8	8
2	Protone 0.5%	8	8	8	8	8	8
1	Ethrel 0.01%	7	7	7	7	7	7
2	Ethrel 0.01%	7	7	7	7	7	7
1	IAA 1.0%	6	6	6	6	6	6
2	IAA 1.0%	6	6	6	6	6	6

IAA – indoleacetic acid; ABA – abscisic acid; NAA – naphthaleneacetic acid; n – without flower buds; d – tree died

on flower bud differentiation and flowering itself. The above clearly shows that further work is needed on the experiment and that a longer period of experimental work will be needed to evaluate it.

Flowering richness is the first prerequisite for a successful fruit harvest. However, the differentiation of flower buds depends on many limiting factors; first, the weather and second, a balanced level of the determining phytohormones. It is quite logical that by exogenous application of substances containing phytohormones, such as PGRs, the balance may be disturbed and consequently an alteration in fertility may occur. The plant hormones that considerably influence flower bud differentiation are gibberellic acid (GA), abscisic acid (ABA), zeatin riboside (ZR), and indoleacetic acid (IAA) (Blázquez, Weigel 1999).

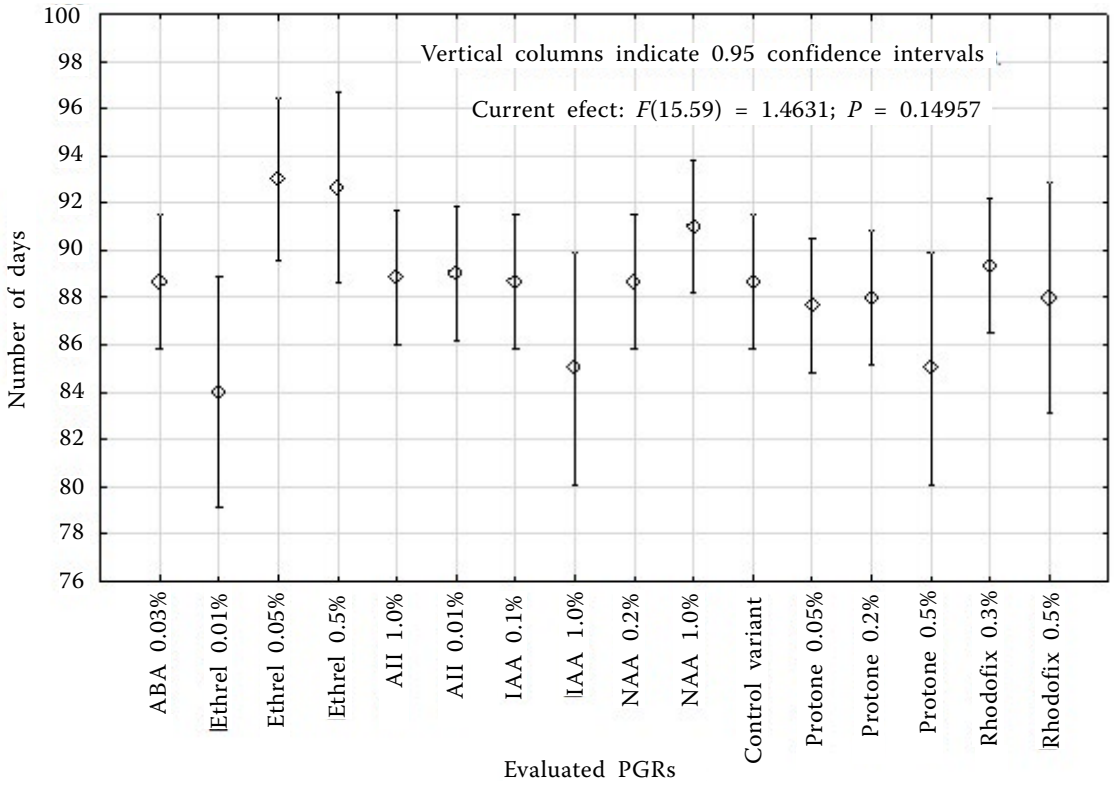

Figure 5. A statistical analysis of the effect of the application of PGRs on the ripening time of the fruits of the 'Leskora' apricot variety

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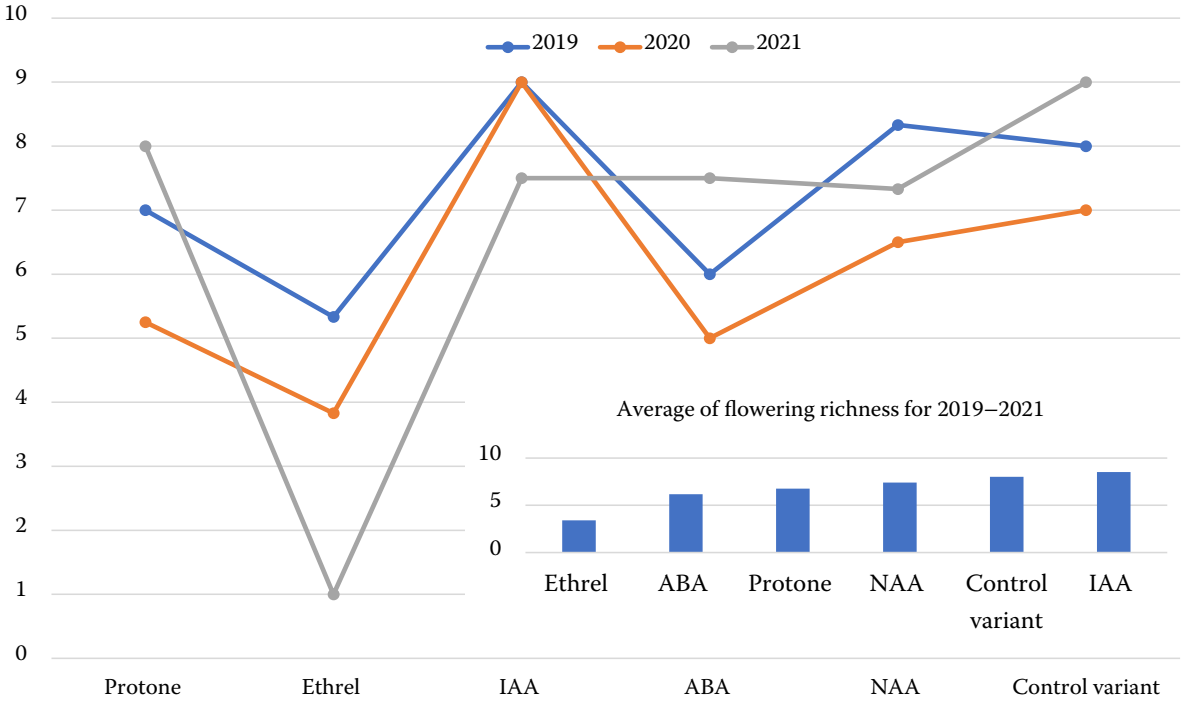

Figure 6. Flowering richness values in each year of evaluation and the average per experiment

Their effects on flowering vary between plants (Feng et al. 2006; Peng, Wang 2006). Our results indirectly confirm these facts because, as the graph in Figure 6 shows, there was a general decrease in the flowering rate with the repeated application of the PGRs used, especially for Ethephon (Ethrel). This may be caused by the fact that these PGRs have an antagonistic effect on phytohormones stimulating flower bud differentiation (Figures 7 and 8). This means that the balance in the levels of individual phytohormones affecting flowering was disturbed.

Figure 7. The application of ABA 0.03% has no effect on flower set and beginning of flowering

An evaluation of the dormancy breaking in varieties. Breeding and a selection of varieties with slow dormancy break and later flowering is oneway to eliminate the negative impact of late spring frosts, which are increasingly affecting apricot growers due to climate change.

Thirty-two apricot varieties were evaluated for dormancy breaking and an almond tree genotype (MN–VA–1) was evaluated as a control. The findings show significant differences in dormancy breaking in different years (Table 2). The results clearly show that varieties with long dormancy under the conditions found in South Moravia include mainly 'Velika Luka' (originally from Croatia, average dormancy break on 17 February, which is 79 days from the beginning of December) and Chinese 'Bai Gon' with the same values as 'Velika Luka' and also Chinese 'Chuang zhi hong' (with average awakening on 11 February, which is 73 days from the beginning of December) (Figure 9). The last variety after the control was a hybrid originating in Lednice (CZ)

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Figure 8. Comparison of trees after application of Ethrel without flower buds on the left and on the right untreated trees fully planted with flower buds

with the working name 'Late Flowering', with a dormancy break on average around 8 February (70 days), although in most years under field conditions it flowered last, even after the varieties that showed a long dormancy period in the evaluation. The variety 'Orangered', which in our study ranged rather closer to the middle of the observed values of dormancy break and flowering practically belonged to the varieties more affected by frost under the conditions of the Czech Republic. However, interestingly, according to the work of Campoy et al. 2011, this variety is listed as recommended for risk regions.

On the other hand, the early maturing variety 'Wondercot' with an average dormancy break on 6 January (37 days from the beginning of December), the frost-resistant variety 'Goldrich' with dormancy break on 7 January (38 days), and the early variety 'Ninfa' with the same dormancy break as 'Goldrich', resulted as varieties with very early dormancy break. Among the varieties with a rapid exit from dormancy are also early ripening varieties, such as: 'LE–6016' (the earliest ripening hybrid from the Lednice breeding programme), 'Leskora', 'Ninja', 'Pricia', 'Porticia' and 'Samourai'.

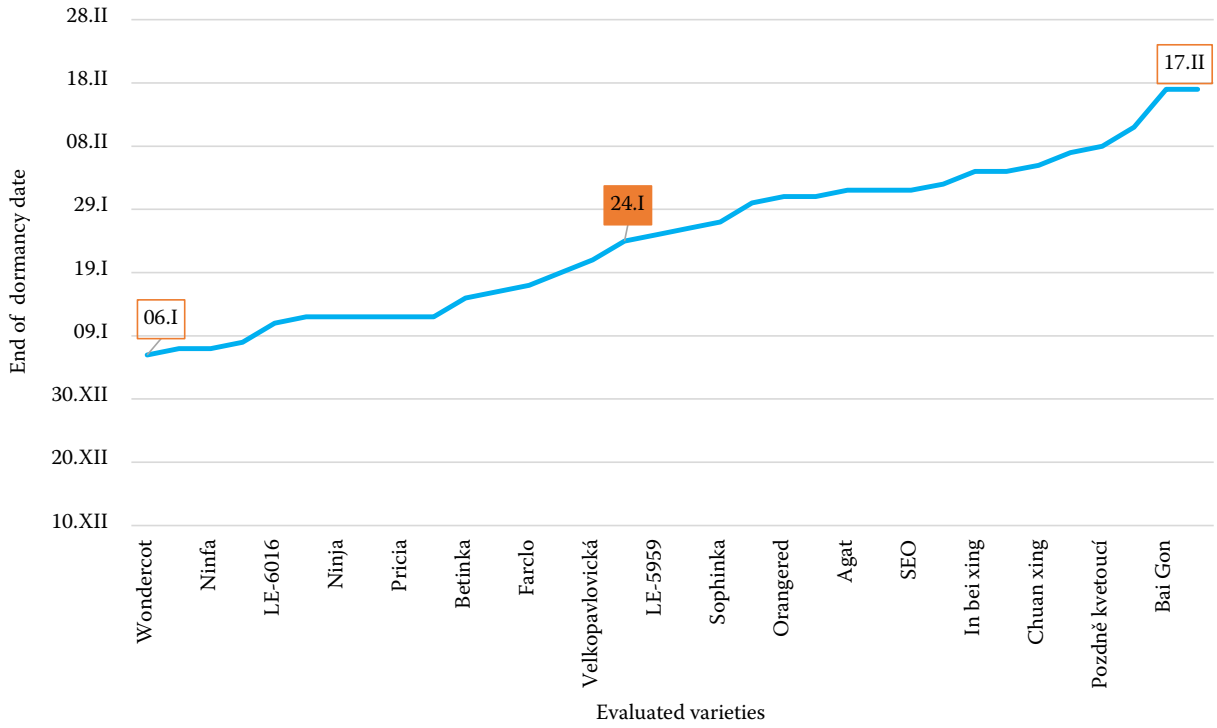

Figure 9. Average dormancy breaking values for the evaluated apricot varieties for the 2018–2021 period

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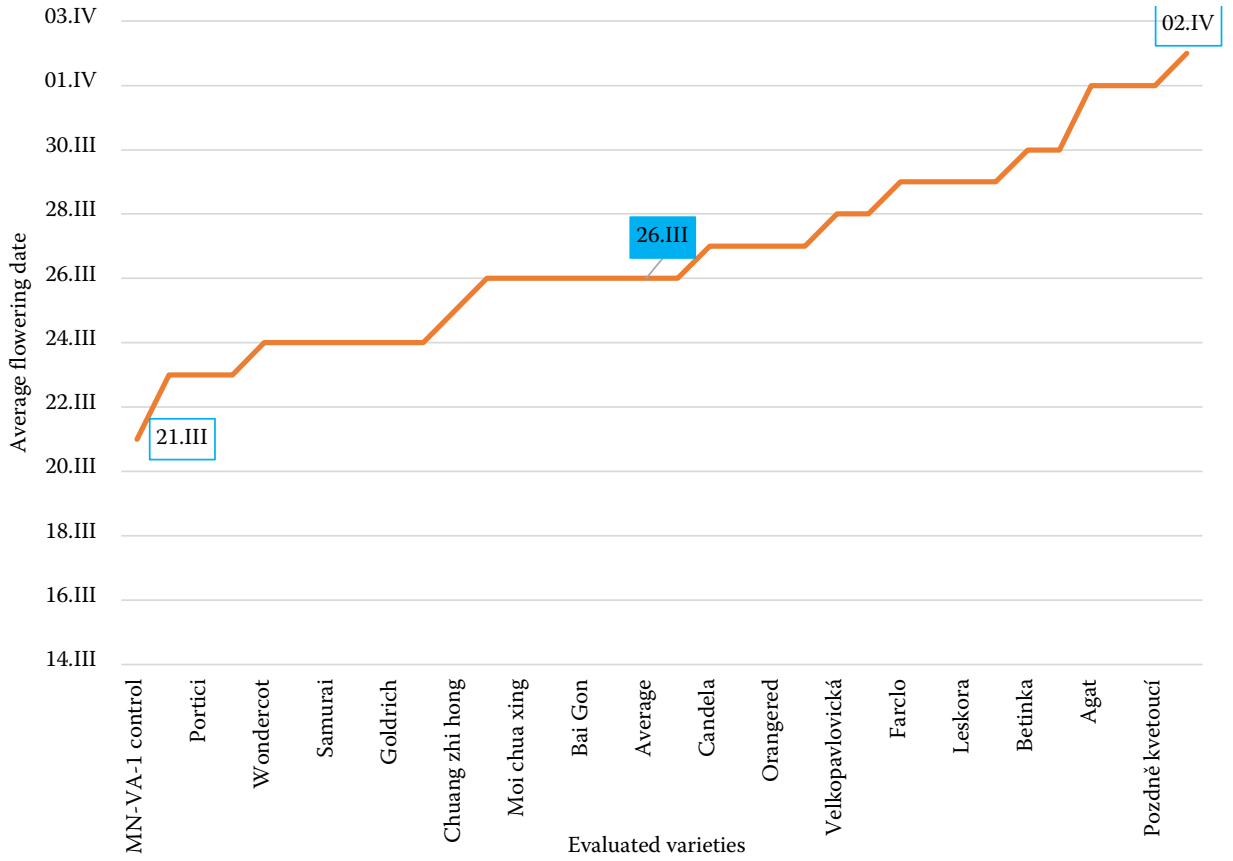

Figure 10. Average flowering values for the evaluated apricot varieties for the 2019–2021 period

In general, most of the early ripening apricot varieties broke from dormancy earlier than the later ripening varieties, but this was not always the case with flowering. The graph in Figure 10 ranks the varieties by their average flowering date. A comparison of the graphs in Figures 9 and 10 shows that there is only a little correlation between dormancy breaking and apricot flowering. Only at the varieties of 'Velika Luka' and 'Late Flowering' the late dormancy break correlated with late flowering. On the other hand, at the variety 'Ninfa', the results show that the earlier the dormancy break occurred, the earlier it was flowering.

CONCLUSION

Finding a way to prolong the dormancy period is a long-standing topic and will continue to be one of the goals of breeding and research activities. Our research and other studies have proved that there is no direct correlation between dormancy and the onset of flowering. There are many other factors that influence flowering dates. The results of our experiment suggest that although the use of the selected PGRs did not have a significant and definite effect on delaying flowering in some way, it may be a helpful, along with other measures, to combat climate change and its negative impact on fruit production. The observation that the application of PGRs extends the ripening period also supports the theory of the potential of this kind of research. It is very clear that further research in this field must be conducted and more substances with PGR effects must be involved to verify more combinations and concentrations. Unfortunately, research focused on this issue is particularly time-consuming and material intensive.

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