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# SELECȚIA GENITORILOR DE PRUN PENTRU REZISTENȚA LA ÎNGHEȚURILE TÂRZII DE PRIMĂVARĂ

# SELECT THE PLUM GENITORS FOR RESISTANCE TO LATE SPRING FROST

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**Abstract**

**In recent years, climate changes more and more evident, have increased the risk of late spring frost during the flowering time with negative implications on fruit buds, flowers, fruit set and fruit production. The purpose of this paper is to evaluate some plum cultivars with different origins regarding the resistance to the late spring frosts in order to identify potential genitors for future breeding work. The research was carried out in plum demonstrative plots of Genetic - Breeding and Plant Propagation Departments by the Research Institute for Fruit Growing Pitesti, Romania, on 26 cultivars (7 from Romania, 15 from Germany, 1 from Serbia and 1 from Canada). In the last decade, spring frosts were observed in 2017 (-4,2 ºC, Aprilie, 21-22, young fruit stage), 2020 (-7,1ºC, Aprilie, 1-7, beggining of flowering), 2022 (-5,8ºC, Aprilie, 18-21, full flowering), 2023 (-6,4ºC, March, 29-30, green button) și 2025 (-5,7ºC, Aprilie, 7-11, full flowering). These climatic accidents caused damage of 80-100% in 2017, 18-90% in 2020, 15-45% in 2022, 7-65% in 2023 and 51% in 2025. Throughout this period, the least affected were 'Romanţa', 'Piteştean', 'Carpatin', 'Katinka', 'Hanka', 'Presenta', 'Elena', 'Topstar', 'Toptaste', 'Topfive', 'Tophit', 'Voyageur' and 'Stanley' cvs., the level of damage being very low (below 10%), and the percentage of fruit set being over 20%. All of these cultivars are recommended as genitors for resistance to late spring frosts in breeding programs.**

**Cuvinte cheie:** prun, schimbări climatice, înghețuri târzii, fenofaze, fructe legate, genitori.
**Keywords:** plum, climate changes, late frost, phenophases, fruit set, genitors.

## 1. Introduction

In Romania, plum is the most important species, the climatic conditions being favorable for the spread of plum cultivars belonging to the European group (Cociu et al., 1997). The area cultivated with plums in 2023 was 67,470 ha, which represents 46% of the area cultivated with fruit trees in our country (FAOSTAT, 2025). The fruit production registered in 2023 was 645.090 t, respectively 44.88% of all fruit production in our country (FAOSTAT, 2025).

The plum is a rustic species, less demanding of climatic factors and with great ecological plasticity.

However, major climate changes in recent years, with warm winters and early springs, have led to an increased risk of late spring frosts during the flowering period, with negative implications on fruit buds, flowers, fruit set and fruit production.

Also, the high temperatures in the first months of the year (January - April) led to a much earlier onset of the phonological stages of crop, earliness observed both in Romania (Chițu et al., 2015; Florea et al., 2019), and in other European countries, such as France (Atauri et al., 2010), Germany (Chmielewski et al., 2011), Scandinavia (Rivero et al., 2017) and Serbia (Milošević and Milošević, 2023).

Related to this aspect, in Romania, following phenological observations carried out for a period of over 50 years on the 'Tuleu gras' cv., an advance of the phenological stages was observed, respectively 19 days for stage 51 (bud swelling), 10 days for stage 53 (bud burst), 12 days for stage 61 (beginning of flowering) and 8 days for stage 69 (end of flowering) (Chițu et al., 2013; Florea et al., 2019; Butac et al., 2024). This advancement of phenological stages has the effect of increasing the risk of destroying of floral organs in the case of late spring frosts and, implicitly, the loss of fruit production (Chițu et al., 2013; Florea et al., 2019; Milošević and Milošević, 2023; Butac et al., 2024).

This is why, in plum breeding programs, in addition to the current objectives (tolerance/resistance to Plum Pox Virus, productivity, fruit quality, self-fertility, low vigour, different ripening times, etc.), it has become necessary to introduce the objectives of late flowering and resistance to late spring frosts (Butac, 2020).

To achieve these two objectives, it is necessary to identify potential genitors with late flowering and resistance to late spring frosts and introduce them into controlled plum hybridization schemes.

## 2. Material and methods

*2.1. Plant material, field trial and climatic conditions*

The research was carried out in plum field trials located in the Genetics and Breeding and Plant Propagation laboratories of the Research Institute for Fruit Growing Pitesti, Romania, at the village Mărăcineni (Central part of Romania - 44°53'56" Northern latitude, and 24°51'35" Eastern longitude).

The trees were planted at a distance of 4 m between rows and 3 m between trees. The experiment was carried out in a randomized block design in 3 replications with 3 trees per variant. The trees were trained as an open vase, under non-irrigated standard cultural practices.

The climate neighbouring RIFG Pitesti is favorable for growing plum species. The average multi-annual temperature is 10.1°C, the maximum temperature is 38.8°C, whereas the minimum temperature is –24.4°C; total annual rainfall recorded is 673.2 mm.

This study involved 23 cultivars with different origin: six from Romania ('Carpatin', 'Centenar', 'Milenium', 'Piteștean', 'Romanța', 'Tita'), 15 from Germany ('Elena', 'Jojo', 'Joganta', 'Haganta', 'Hanita', 'Hanka', 'Katinka', 'Presenta', 'Topend plus', 'Topfive', 'Topgigant plus', 'Tophit', 'Topper', 'Topstar', 'Toptaste'), one from Serbia ('Čačanska Lepotiča') and one from Canada ('Voyageur'). This choice was due to the interest of growers for these cultivars, because of their resistance/tolerance to Plum Pox Virus, productivity and good fruit quality. As a control, 'Stanley', 'Tuley gras' and 'Anna Späth' cvs. were used, widespread in the commercial orchards from Romania.

*2.2. Measurements*

In the 2016 - 2025 periods the following determinations were carried out:

- phenological trait – beginning of flowering - appreciated by noting the date when the first flowers opened;
- fruit-setting capacity through natural pollination – counting a minimum of 200 flowers on control branches, of the set fruits and establishing the percentage of fruits set (%);
- fruits yield was determined by weighing the fruits on the tree (3 trees in 3 repetitions), in kg/tree;
- monitoring climatic accidents and their effect on the fruiting organs (counting 100 flowers/varieties and establishing the percentage of destroyed flowers/fruits).

*2.3. Statistical analysis*

For statistical interpretation of the results, the data were included in an Excel database and statistically interpreted with the SPSS 14.0 program, which uses the Duncan test (multiple t-test) for a 5% statistical assurance. Also, certain statistical indices, that as the average, standard deviation and coefficient of variation, were calculated.

## 3. Results and discussions

### 3.1. Beginning of flowering

Following the climate warming trend over the last 50 years, it has been observed that all fruiting phenophases occurred much earlier. For example on 'Tuleu gras' cv. in the continental climate of Romania, in the last half century, there was an advance of the phenological stages of 19 days for stage 51 (bud swelling), 10 days for stage 53 (bud burst), 12 days for stage 61 (beginning of flowering), and 8 days for stage 69 (end of flowering) (Fig. 1).

In Romania, the advance of flowering time was reported a few years ago by authors. Cosmulescu et al. (2010) observed that the flowering phenophases depend on the evolution of climatic factors and differ from one year to another. In 2007, Butac and Chitu reported an advance of the beginning of flowering of 11 days for 'Tuleu gras', 'Centenar', 'Stanley' and 'Anna Späth' in South part of the country. Later, in 2019, Gitea et al. reported an eight-day advance in flowering for the 'Centenar' and 'Anna Späth' cvs. and nine days for the 'Stanley' cv. Late flowering is very important for plum cultivars because late spring frosts may occur in early April (Gravite and Kaufmane, 2017).

During the period 2016-2025, the average date of the beginning of flowering in the Mărăcineni - Arges area was April 8, being 10 days earlier than the multiannual average of this phenophase (Fig. 2).

The latest cultivars in terms of the beginning of flowering were 'Tuleu gras', 'Pitestean' and most cultivars of German origin, with the exception of the 'Jojo' cv., which bloomed very early (6-7 April). Also, among the Romanian cvs., the 'Centenar' cv. bloomed very early. The majority of cultivars bloomed at the same time as the 'Stanley' and 'Anna Späth' cvs., but earlier than the 'Tuleu gras' cv.

Similar results regarding the flowering order of German cultivars were reported by Molnar et al. (2017) for the 'Topfive', 'Toptaste', 'Topend plus' and 'Jojo' cvs., by Stefanova and Popski in 2020 for the 'Topgigant plus' and 'Topend plus' cultivars, by Sotirov et al. (2022) for the 'Toptaste' cv. and also by Butac et al. (2022) for the 'Jojo', 'Haganta', 'Hanita', 'Topend plus', 'Topfive', 'Topfirst', 'Toptaste', 'Topgigant plus' cvs.

Regarding the flowering period of Romanian cultivars, Butac and Chitu (2007) reported the same trend of earlier flowering and the same period and order of flowering for the 'Centenar', 'Carpatin', 'Piteștean', 'Tita' and 'Tuleu gras' cvs.

Analyzing the phenophase of the beginning of flowering by year, it is observed that the earliest flowering occurred in 2016, 2017, 2019, 2020 and 2024 (beginning of April). Normal or near-normal years were 2018, 2021 and 2022 (between April 12 and 18) (Fig. 3).

In the last 10 years, climatic accidents have been recorded in 5 years at different phenophases (bud swelling, beginning of flowering, full flowering and young fruit), the damage being very high, even leading to the loss of the production (Table 1).

The most serious climatic accident was recorded in 2017, across all plum growing areas at the end of flowering and young fruit phenophases, production loss in the Southern part of the country being approximately 100%. On the 26 plum cultivars studied in the Maracineni area, negative temperatures of -4.2°C in the young fruit stage, led to a level of damage ranging between 92% and even 100% on some cultivars such as 'Jojo', 'Anna Späth', 'Centenar', 'Čačansca Lepotiča' and 'Voyageur', the differences between cultivars being significant (Table 2; Fig. 4).

In 2023, temperatures of -6.4°C recorded in the bud swelling stage caused damage ranging between 5 and 95% (Table 2; Fig. 5). The most resistant to spring frosts were 'Piteștean', 'Romanța', 'Milenium', 'Toptaste', 'Topstar', 'Topfive' and 'Haganta', cultivars which are recommended as genitors in breeding works for spring frost resistance.

In 2025, in the full flowering stage, negative temperatures of -5.7°C were recorded with a negative effect on cultivars such as 'Anna Späth', 'Jojo', 'Tuleu gras', 'Joganta', 'Tita', and 'Čačanska Lepotiča'. The other cultivars were slightly affected by the spring frosts (Table 2; Fig. 6).

Similar results regarding the sensitivity to late spring frosts of cultivars such as 'Jojo', 'Haganta' and 'Tophit' were also reported by Nesheva and Bozhkova in 2021, under the climatic conditions of Bulgaria.

The percentage of fruits set after negative temperatures was recorded in 2025. In Table 3, very significant differences between varieties regarding the percentage of fruits set are observed. Except for the cultivars 'Jojo', 'Joganta', 'Elena', 'Tophit', 'Čačanska Lepotiča', 'Tita', 'Tuleu gras' and 'Anna Späth', for most cultivars the percentage of fruits set was high (over 20%), which can ensure high and economical productions (Table 3).

During this period, the least affected cultivars were 'Romanța', 'Milenium', 'Piteștean', 'Carpatin', 'Katinka', 'Hanka', 'Haganta', 'Hanita', 'Presenta', 'Topstar', 'Toptaste', 'Topfive', 'Tophit', 'Topend', 'Topgigant' and 'Stanley', the level of damage being very low (below 10%), and the percentage of fruits set being over 20%. All these cultivars are recommended as parents for resistance to late spring frosts and have been introduced into the plum breeding program.

Thus, in the period 2018-2025, in the hybridization schemes, the cultivars 'Carpatin', 'Piteștean', 'Tita', 'Romanța', 'Milenium', 'Haganta' were used as maternal genitors and the cultivars 'Romanța', 'Milenium', 'Hanita', 'Haganta', 'Toptaste', 'Topstar', 'Topfive', 'Tophit', 'Topgigant plus' and 'Topend plus' were used as paternal genitors. There are currently 1,214 own-rooted hybrids in the selection field from the 2018, 2019, 2020, 2021 and 2022 generations. Also, from the 2023 and 2024 generations, there are 708 hybrids in the nursery, and in 2025, 9,495 flowers were pollinated, resulting in 2,373 hybrid stones (Table 4).

To verify the value of these cultivars with resistance to late spring frosts, fruit production was recorded in 2025, a year with climatic accidents. Thus, it can be seen that fruits varied between 3.70 kg/tree on 'Anna Späth' cv. and 35.30 kg/tree on 'Toptaste' cv. Statistical analysis of data on yield (kg/tree), using Duncan's multiple range test ($P \leq 0.05$), showed significant differences between the cultivars (Table 3). It can be observed that the cultivar 'Toptaste' had higher production than the 'Stanley' cv. known as one of the most productive plum cultivars. Compared to the control cv. 'Anna Späth', all studied cultivars had higher production, and compared to the control cv. 'Tuleu gras', all varieties recorded higher production except the 'Jojo' cv. They were noted for their high production (over 20 kg/tree, in the 10$^{th}$ year after planting) the following cultivars: 'Toptaste', 'Topstar', 'Piteștean', 'Stanley', 'Haganta', 'Hanaka', 'Presenta', 'Voyageur' and 'Čačanska Lepotiča'.

Our results confirmed the good yielding capacity of the German cultivars, characteristics reported by other authors as well, Blazek and Pistekova in 2009, Molnar et al. in 2016, Stefanova and Popski in 2020, Sotirov et al. in 2022, and Butac et al., 2022.

## 4. Conclusions

During the period 2016-2025, the average date of the beginning of flowering in the Mărăcineni - Arges area was April 8, being 10 days earlier than the multiannual average of this phenophase.

The latest cultivars in terms of the beginning of flowering were 'Tuleu gras', 'Pitestean' and most cultivars of German origin, with the exception of the 'Jojo' cv., which bloomed very early (6-7 April). Also,

among the Romanian cvs., the 'Centenar' cv. bloomed very early. The majority of cultivars bloomed in the same time as the 'Stanley' and 'Anna Späth' cvs., but earlier than the 'Tuleu gras' cv.

Regarding the resistance to late spring frost, the least affected cultivars were 'Romanța', 'Milenium', 'Piteștean', 'Carpatin', 'Katinka', 'Hanka', 'Haganta', 'Hanita', 'Presenta', 'Topstar', 'Toptaste', 'Topfive', 'Tophit', 'Topend', 'Topgigant' and 'Stanley', the level of damage being very low (below 10%), and the percentage of fruits set being over 20%. All these cultivars are recommended as parents for resistance to late spring frosts and have been introduced into the plum breeding program, already existing hybrids in the nursery and hybrid fields.

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## Tables and Figures

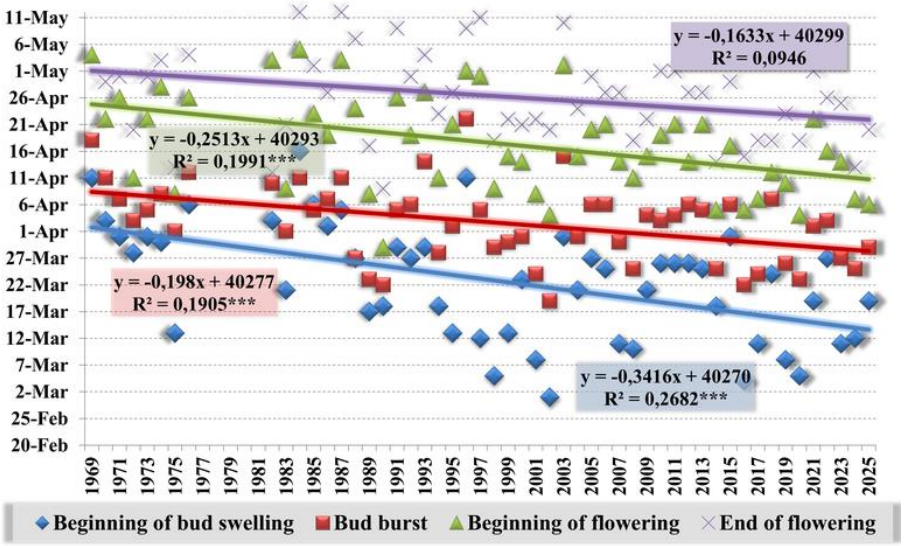


**Fig. 1. Multiannual dynamics of the first fruiting phenophases ('Tuleu gras', 1969-2025)**

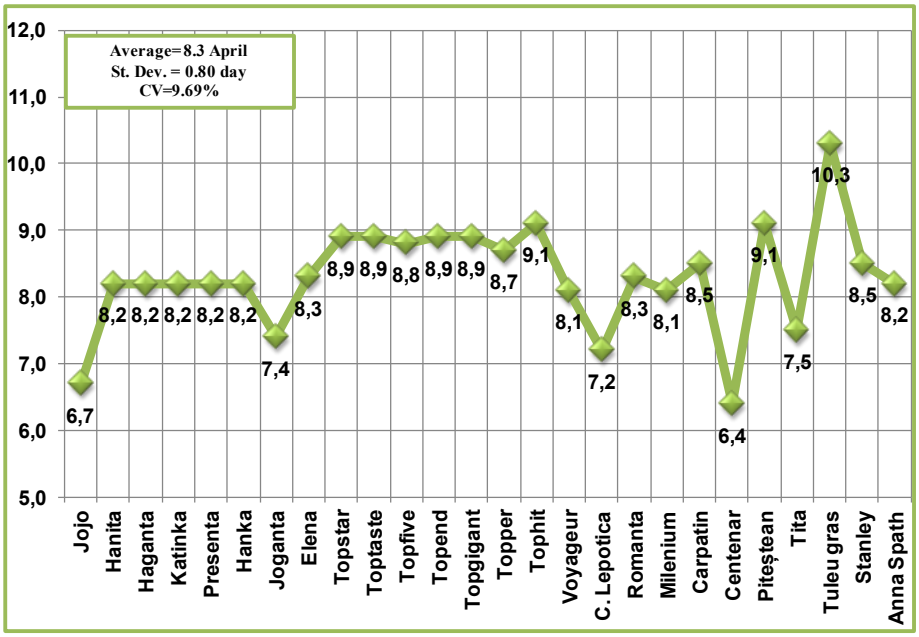


**Fig. 2. Beginning of flowering (average 2016 – 2025)**

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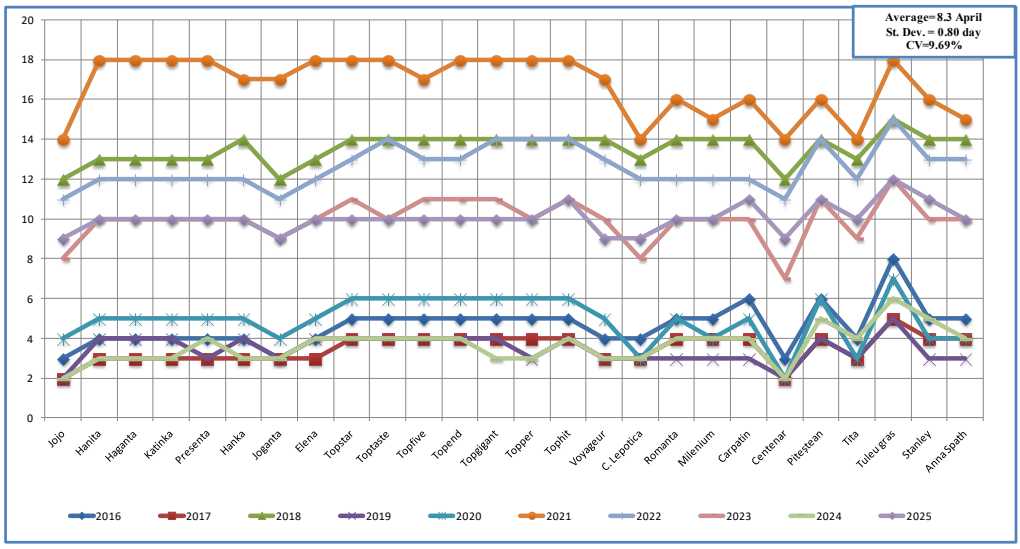


**Fig. 3. Beginning of flowering (2016 – 2025 periods)**

**Table 1. Climatic accidents recorded in the last 10 years in Romania**

| Year | Period | Minimum temp. °C) | Phenophase | Level of damages (%) |
|---|---|---|---|---|
| **2017** | April, 21-22 | -4.2°C | young fruits | 92-100 |
| **2020** | April 1-7 | -5.8°C | beginning of flowering | 18-90 |
| **2022** | April 18-21 | -5.8°C | full flowering | 15-45 |
| **2023** | March, 29-30 | -6.4°C | bud swelling | 7-65 |
| **2025** | April 7-11 | -5.7°C | full flowering | 5-100 |

**Table 2. Damage (%) caused to plum by late frosts, Maracineni, Romania**

| No. | Cultivar | Damage 2017 (%) | Damage 2023 (%) | Damage 2025 (%) |
|---|---|---|---|---|
| 1 | Jojo | 100 a | 90.67 ab | 91.67 a |
| 2 | Hanita | 95 cd | 21.33 hi | 17.67 l |
| 3 | Haganta | 92 e | 15.67 ijk | 12.33 mn |
| 4 | Katinka | 99 a | 23.67 h | 21.67 k |
| 5 | Presenta | 95 cd | 21.67 hi | 31.67 ij |
| 6 | Hanka | 96 bc | 20.33 hij | 16.67 l |
| 7 | Joganta | 99 a | 75.67 c | 78.67 c |
| 8 | Elena | 98 ab | 37.33 f | 34.33 h |
| 9 | Topstar | 92 e | 5.33 lm | 4.00 r |
| 10 | Toptaste | 92 e | 4.67 m | 5.33 r |
| 11 | Topfive | 92 e | 11.33kl | 8.67 p |
| 12 | Topend plus | 93 de | 14.33 jk | 11.67 no |
| 13 | Topgigant plus | 93 de | 16.00 ijk | 14.33 m |
| 14 | Topper | 92 e | 64.33 d | 60.33 e |
| 15 | Tophit | 92 e | 26.33 gh | 21.67 k |
| 16 | Voyageur | 100 a | 35.33 f | 33.67 hi |
| 17 | Čačanska Lepotiča | 100 a | 59.67 de | 57.67 f |
| 18 | Romanța | 95 cd | 10.67 klm | 7.67 p |
| 19 | Milenium | 95 cd | 11.00 klm | 9.67 op |
| 20 | Carpatin | 95 cd | 20.67 hij | 18.33 l |
| 21 | Centenar | 100 a | 31.67 fg | 29.67 j |
| 22 | Piteștean | 92 e | 4.67 m | 4.67 r |
| 23 | Tita | 98 ab | 74.33 c | 71.67 d |
| 24 | Tuleu gras | 93 de | 87.33 b | 84.67 b |
| 25 | Stanley | 98 ab | 57.67 e | 51.33 g |
| 26 | Anna Späth | 100 a | 94.33 a | 92.67 a |
| **Average** | | **96.00** | **36,00** | **34.32** |
| **Standard deviation** | | **3.16** | **29,07** | **29.19** |
| **Coefficient of variation (%)** | | **3.31** | **80,76** | **85.06** |

*Duncan multiple ranges test. Mean values followed by the same letter within a column are not significantly different (P≤0.05).

**Table 3. Fruit set (%) and yield/tree in 2025, Maracineni, Romania**

| No. | Cultivar | Fruit set (%) | Yield (kg/tree) |
|---|---|---|---|
| 1 | Jojo | 5.30 p | 5.20 l |
| 2 | Hanita | 21.50 kl | 19.10 f |
| 3 | Haganta | 25.30 ij | 22.10 e |
| 4 | Katinka | 28.40 fg | 18.70 f |
| 5 | Presenta | 31.90 e | 26.70 c |
| 6 | Hanka | 29.60 f | 23.40 de |
| 7 | Joganta | 9.70 o | 8.40 k |
| 8 | Elena | 12.50 n | 16.80 g |
| 9 | Topstar | 42.10 b | 33.50 b |
| 10 | Toptaste | 44.30 a | 35.30 a |
| 11 | Topfive | 39.80 c | 24.30 d |
| 12 | Topend plus | 24.70 j | 17.80 fg |
| 13 | Topgigant plus | 26.30 hij | 17.50 fg |
| 14 | Topper | 20.00 l | 12.10 ij |
| 15 | Tophit | 14.80 m | 18.60 f |
| 16 | Voyageur | 27.60 gh | 21.80 e |
| 17 | Čačanska Lepotiča | 13.70 mn | 22.40 e |
| 18 | Romanța | 36.70 d | 16.60 g |
| 19 | Milenium | 35.30 d | 14.90 h |
| 20 | Carpatin | 26.90 ghi | 13.50 i |
| 21 | Centenar | 22.10 k | 11.40 j |
| 22 | Pitești an | 36.40 d | 32.60 b |
| 23 | Tita | 13.30 mn | 13.60 hi |
| 24 | Tuleu gras | 12.60 n | 6.90 k |
| 25 | Stanley | 38.70 c | 33.80 ab |
| 26 | Anna Späth | 3.60 r | 3.70 l |
| | **Average** | **24.73** | **18.87** |
| | **Standard deviation** | **11.56** | **8.71** |
| | **Coefficient of variation (%)** | **46.73** | **46.13** |

*Duncan multiple ranges test. Mean values followed by the same letter within a column are not significantly different (P≤0.05).

**Table 4. Genitors used and results obtained in the plum breeding program in the 2018-2025 period (Mărăcineni, Romania)**

| Period | Genitors maternal | Genitors paternal | No. of hybrids in the selection field | No. of hybrids in the nursery | No. of flowers pollinated | No. of hybrids stones |
|---|---|---|---|---|---|---|
| 2018-2025 | Carpatin, Pitești an, Tita, Romanța, Milenium, Haganta | Romanța, Milenium, Hanita, Haganta, Toptaste, Topstar, Topfive, Tophit, Topgigant plus, Topend plus | | | | |
| 2018-2022 | | | 1,214 | | | |
| 2023-2024 | | | | 708 | | |
| 2025 | | | | | 9,495 | 2.373 |

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**Fig. 1. Fruits affected by late spring frosts from April, 17-24, 2017, Maracineni, Romania ('Centenar' – left and centre and 'Jojo' - right)**

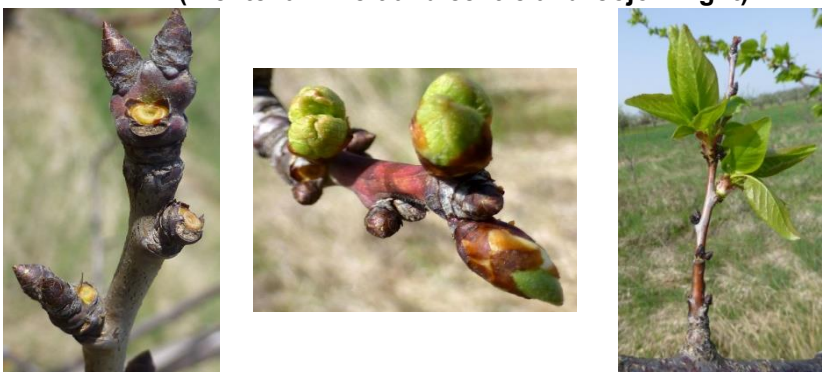

**Fig. 2. Fruit buds affected by late spring from March, 29-30, 2023, Maracineni, Romania**

**Fig. 3. Flowers affected by late spring frosts from April, 7-11, 2025, Maracineni, Romania ('Anna Spath' - left and 'Jojo' - right)**