EVALUATION OF EUROPEAN PLUM (*PRUNUS DOMESTICA* L.) CULTIVARS FOR SUSTAINABLE FRUIT PRODUCTION

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Abstract:

We evaluated European plum (Prunus domestica L.) cultivars grown in the collection orchard of the Fruit Growing Institute – Plovdiv, Bulgaria, for phenological development, spring frost tolerance, and fruit-weight stability, an indirect indicator of drought resistance. 'Stanley' was used as a reference cultivar. Full flowering extended from 27.03. to 14.04., and ripening from 07.07. to 21.09., so the collection covered about three months of the harvest season. The spring frost of 1 April 2019 damaged from 6% to 100% of the generative organs, depending on the cultivar. The coefficient of variation of fruit weight ranged from 3,69% to 40,55%. The introduced Romanian cultivars 'Tita' and 'Pitestian' combined low frost damage with stable fruit weight, while the Bulgarian 'Pagane' cv. combined very large fruit with stable fruit weight but lost all its flowers in the frost. 'Topgigant plus' showed high variability in fruit weight and browning of the fruit flesh around the stone. The results show large differences in adaptation among the cultivars and the need to evaluate each genotype under local conditions.

Keywords: *Prunus domestica*, flowering time, spring frost, fruit weight, drought resistance

INTRODUCTION

Prunus domestica L., also known as European plum, is cultivated in temperate climate regions, primarily in Central, Southern, and Southeastern Europe (Hanelt, 1997). In the Balkans, it is highly important, and many folklore events and traditions are associated with this fruit species. Across the Balkan Peninsula, people use the fruit fresh and in processing, particularly to produce traditional spirits (Botu et al., 2012). The Balkan Peninsula accounts for about 13% of the world's plum production, about 1.64 million tons a year, with Romania, Serbia, and Bosnia and Herzegovina ranking among the world's top 10 producers (FAOSTAT, 2025). The European plum (*Prunus domestica* L.) is also the most commonly grown fruit species in Bulgaria. Over the last three years (2023, 2024, and 2025), it has ranked second after sweet cherry in harvested areas and first in fruit production in the country (Agrostatistical Referencebook, 2025).

The sustainability and profitability of plum production depend largely on varietal innovation to meet farmers' needs, but also on other actors in the agri-food chain, such as industry, marketers, and consumers (Ruiz, 2026). Growers seek high, regular yields, self-fertility, disease tolerance, and a well-spread harvest period. Industry values soluble solids content, stone-to-flesh ratio, and suitability for drying or distillation. Consumers increasingly value fruit size, taste, sugar/acid balance, color, and nutritional and antioxidant content (García-Gómez et al., 2020).

However, plum and prune cultivation faces several challenges and limitations. Because changing biotic and abiotic factors affect plants, certain traits become more important in European plum (*Prunus domestica* L.). These include resistance to winter and late frosts and reduced susceptibility to heat damage in fruit (Neumüller et al., 2021). Climate change also brings earlier flowering and a higher risk of late spring frost damage, and in some regions, insufficient winter chilling and irregular cropping (Haokip et al., 2020). Among biotic threats, Sharka (*Plum pox virus*) is the most serious disease of European plum, alongside fungal and bacterial diseases such as brown rot (*Monilinia* spp.) and bacterial canker (Cambra et al., 2006). Cultivars that tolerate these stresses

reduce the need for chemical inputs and stabilize yields, so cultivar choice is directly a sustainability issue.

One major production challenge is the limited diversity of traditional varieties, with global production depending largely on a few cultivars. The cultivar “Stanley” dominates orchards and, according to Agrostatistics, accounts for 73.4% of Bulgaria's plum-growing area. Studies on new plum genetic resources and the establishment of new cultivars that meet the latest needs of both producers and consumers could change the prevalence of a single cultivar. Bulgarian producers are interested in new cultivars and opportunities to diversify their orchards (Bozhkova and Savov, 2016).

Countries with extensive breeding programs, such as Germany, Serbia, Romania, Bulgaria, and others, have released several new cultivars. Expanding cultivar choice requires information on performance under the agro-ecological conditions of the specific growing region. This study aimed to evaluate the agrobiological and pomological performance of European plum (*Prunus domestica* L.) cultivars from the Fruit Growing Institute – Plovdiv collection orchard to identify genotypes suitable for sustainable fruit production and as valuable breeding material for climate resilience under Plovdiv, Bulgaria, agro-climatic conditions.

MATERIALS AND METHODS

The study was conducted under two consecutive research projects funded by the Agricultural Academy, Bulgaria, spanning the period 2018-2025. We grew the trees in a collection orchard at the Fruit Growing Institute in Plovdiv. The field collection maintained over 90 European plum (*Prunus domestica* L.) cultivars. The study included mainly modern cultivars introduced from Romania, Serbia, Germany, and other countries, as well as Bulgarian cultivars of interest to local growers. We recorded phenological observations, including flowering and ripening time, during 2018-2025 using the BBCH scale (Meier, 1997). ‘Stanley’ was used as a reference cultivar. Frost damage was assessed after a single event, on 1 April 2019. We recorded frost damage to flowers and young fruitlets three days later. For each plum cultivar, we studied 100 flowers located in 3 different crown directions and up to 2.00 m high. The results were expressed as the percentage of damaged flowers. We measured fruit biometrics, minimum, maximum, and average fruit weight (g) for an average sample of 25 fruits, yearly from 2022 to 2025, using a digital scale. Size uniformity was expressed through the coefficient of variation (CV%). We calculated the coefficient of variation (CV%) as the standard deviation divided by the mean, multiplied by 100, using the annual mean fruit weights for 2022-2025. Depending on data availability, three or four annual observations were included for each cultivar. We used fruit-weight variability as an indicator of drought resistance. A lower CV indicates more uniform fruit size and greater stability under water deficit. We grouped cultivars into low (CV 0-20%), moderate (20-40%), and high (>40%) variability.

RESULTS AND DISCUSSION

Phenological stage timing depends on a combination of internal (genetic) settings and environmental influences. Winter dormancy in fruit tree species ends when trees meet their chilling requirements, while the "flowering" phenophase occurs once they also meet their heat requirements (Ruiz et al., 2007; Zhuang et al., 2016). Chilling and heat requirements vary among different cultivars. In Plovdiv, in Bulgaria's South-Central Region, plum cultivars begin flowering at the end of March or the beginning of April, and in some years even at the end of April (Bozhkova and Savov, 2016). During our study period, the data confirm the flowering period reported in the literature. In years with higher spring temperatures, the earliest flowering cultivars are ‘Sirma’, ‘Top taste’, ‘Jojo’, ‘Ialomita’, ‘Roman’, ‘Top five’, ‘Top’ and ‘Čačanska lepotica’ (Table 1). These cultivars could flower up to six days before ‘Stanley’. For most of the remaining cultivars, the earliest flowering date is close to the earliest date of ‘Stanley’ (02.04), while for ‘Elena’ and ‘President’, ‘Plovdivska renkloda’, ‘Sineva’

and ‘Alesina ’, the earliest full flowering date is later, from +7 to +3 days. The data show considerable differences in flowering time among the studied cultivars, which is important for assessing the risk of spring frost damage. The earlier the flowering, the longer cultivars are exposed to extreme weather conditions (Milošević and Milošević, 2023). In the Plovdiv region, spring frosts occurred frequently over the last decade: 2008, 2013, 2016, 2019, and 2020 (Malchev & Savchovska, 2020). Thus, late frost injuries are a major limiting factor to production (Bozhkova & Ivanova, 2001; Bozhkova & Zhivondov, 2004). The effects of spring frosts on the reproductive organs of deciduous fruit trees vary widely and depend on the characteristics of both the freezing stress and the cultivar (Rodrigo, 2000).

Table 1. Variation of full flowering date in the period 2018-2025

Cultivar	BBCH 65 Earliest - Latest date	Compared to ‘Stanley’, days (earliest / latest)
Ialomita	29.03 – 10.04	–4 / –2
Tita	02.04 – 12.04	0 / 0
Romanta	02.04 – 09.04	0 / –3
Roman	29.03 – 12.04	–4 / 0
Pitestian	01.04 – 13.04	–1 / +1
Tophit plus	01.04 – 14.04	–1 / +2
Topgigant plus	05.04 – 14.04	+3 / +2
Topking	01.04 – 11.04	–1 / –1
Top star plus	02.04 – 14.04	0 / +2
Top taste	27.03 – 09.04	–6 / –3
Top five	29.03 – 09.04	–4 / –3
Top	29.03 – 09.04	–4 / –3
Stanley	02.04 – 12.04	0 / 0
Jojo	28.03 – 12.04	–5 / 0
Sirma	28.03 – 09.04	–5 / –3
Pagane	31.03 – 11.04	–2 / –1
Alesina	06.04 – 11.04	+4 / –1
Sineva	05.04 – 13.04	+3 / +1
Ulpiya	02.04 – 06.04	0 / –6
Plovdivska renkloda	06.04 – 13.04	+4 / +1
Čačanska lepotica	29.03 – 09.04	–4 / –3
Čačanska najbolja	01.04 – 11.04	–1 / –1
Elena	09.04 – 12.04	+7 / 0
President	09.04 – 12.04	+7 / 0

Because plums in the Plovdiv region flower later, spring frost damages them less often than other fruit species, such as apricots, peaches, and sweet cherries. Even in 2025, a year characterized by extreme weather conditions nationwide, the most critical temperature drops occurred between March 23 and 25, when plum cultivars were generally in an early phenological growth stage (BBCH 53). Widespread frost damage was recorded in plum orchards, but no damage was observed this year in the micro-area where the collection orchard is located. However, in spring 2019, frost occurred during plum flowering, allowing us to test their vulnerability to these abiotic stress conditions. In late March 2019, temperatures dropped to -5ºC when the plum cultivars were in full flowering, and flowers were fading (65-67 BBCH). Damage ranged from 6% in ‘Tita’ to 100% in five genotypes. Plum trees bear far more flowers than they can carry to maturity (Seehuber et al., 2011). Flower damage up to 30% was considered non-critical. Five cultivars showed damage below 30%: ‘Tita’ (6%), ‘Stanley’ (12%), ‘Romanta’ (22%), ‘Pitestian’ (24%), and ‘Top taste’ (26%) (Figure 1). Four cultivars (‘Jojo’, ‘Sirma’, ‘Pagane ’, and ‘Pacific’) and one Romanian hybrid (HL 20-30) produced

no fruit this year. The wide range of responses indicates substantial genotypic variation in frost tolerance at flowering. The three cultivars with the lowest damage are the most reliable for frost-prone sites. The complete loss in the Bulgarian cultivars 'Pagane' and 'Sirma' is notable, since both are valued for fruit quality and productivity. This suggests that breeding programs should treat frost tolerance as a separate selection criterion.

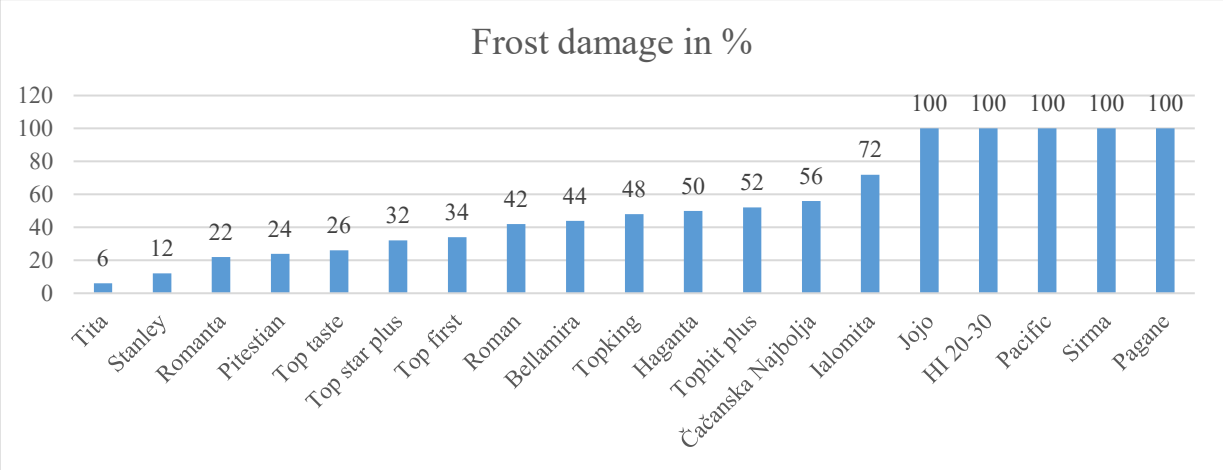


Figure 1. Frost damage on the plum flowers recorded in 2019

'Stanley' was officially registered as a cultivar in 1926, and in the 1980s it became the main cultivar in our country, gradually occupying much of the plum-growing area. To date, the cultivar is widely grown in Bulgaria and in many other European countries. Extending the ripening period and keeping plums fresh longer is one of the main breeding objectives. Cultivars whose fruits ripen earlier than those of 'Stanley' are more marketable. Ripening in the collection extended about three months, from July to September (Table 2). Ripening dates varied considerably among cultivars and across the years of investigation, reflecting differences in ripening characteristics and responses to climatic conditions. The reference cultivar 'Stanley' ripened earliest on August 19 and latest on September 10. According to the earliest recorded ripening dates, 'Čačanska Ranna' (July 07) and the Bulgarian candidate cultivar 'Alesina' (July 08) were among the earliest-ripening cultivars, maturing up to 43 and 42 days before 'Stanley', respectively. A large group including 'Top taste', 'Top five', 'Topgigant plus', and 'Topking' began ripening in the first half of August, between 8 and 12 days before 'Stanley'. In contrast, 'Romanta', 'Tophit plus', and 'Top' ripened later, 1, 6, and 11 days after 'Stanley', respectively. 'Romanta' and 'Sineva' were the closest in ripening time to 'Stanley'. The latest-ripening cultivars were 'President' and 'Elena'. Comparison of the latest recorded ripening dates revealed similar differences among cultivars.

Plum producers' incomes depend mainly on yield, which tree load and fruit weight usually determine. Plum quality also affects the fruit's marketability for both fresh consumption and industrial processing (Hamdani et al., 2022). Fruit weight is a key trait that determines yield, fruit quality, and consumer preferences. Attractive, medium-sized fruits are in demand (Guerriero et al., 2006). Fruit size is cultivar-specific. In our case, average fruit weight ranged from 27.02 g in 'Top king' to 70,68 g in 'Pagane' (Table 3). The Bulgarian cultivar 'Pagane' had the largest fruits by far, followed by 'Serdika', 'Topgigant plus', 'Top star plus', and 'Sirma'. The smallest average fruit weight was calculated for 'Top king' and 'Top five'.

Table 2. Ripening period of the cultivars and difference in days compared to the reference cultivar ‘Stanley’ for the period 2018-2025

Cultivar	Earliest date	Earliest vs. reference (days)	Latest date	Latest vs. reference (days)
Ialomita	10.07	-40	20.07	-52
Tita	22.07	-28	05.08	-36
Romanta	20.08	+1	24.08	-17
Roman	18.07	-32	10.08	-31
Pitestian	11.07	-39	27.07	-45
Tophit plus	25.08	+6	27.08	-14
Topgigant plus	10.08	-9	24.08	-17
Topking	11.08	-8	30.08	-11
Top star plus	24.07	-26	10.08	-31
Top taste	07.08	-12	25.08	-16
Top five	07.08	-12	25.08	-16
Top	30.08	+11	06.09	-4
Stanley	19.08	0	10.09	0
Jojo	26.08	+7	10.09	0
Sirma	23.07	-27	01.08	-40
Pagane	11.08	-8	26.08	-15
Alesina	08.07	-42	30.07	-42
Sineva	18.08	-1	22.08	-19
Ulpia	28.07	-22	17.08	-24
Plovdivska renkloda	21.07	-29	11.08	-30
Čačanska lepotica	10.07	-40	02.08	-39
Čačanska Najbolja	19.08	0	25.08	-16
Čačanska Ranna	07.07	-43	26.07	-46
Elena	10.09	+22	21.09	+11
President	07.09	+19	20.09	+10

Fruit weight is a quantitative trait, genetically determined but strongly influenced by environmental and agrotechnical factors (Vachůn, 2003). Under water stress, yield decreases due to reduced fruit weight at harvest, pre-harvest fruit drop, or both (Lopez et al., 2012). In our study, we used variation in fruit weight over the years as an indirect indicator of cultivar drought resistance, based on the lowest fruit weight recorded in drought years. In 2023 and 2024, the summer temperatures in Plovdiv rose to 42-43°C and rainfall in July, August, and September was scarce. The calculated CV% shows the cultivars' potential to maintain fruit weight stability across years with different agro-climatic conditions. The highest variation in fruit weight was calculated for ‘Jojo’ (40,55%). This shows that it is a cultivar sensitive to seasonal conditions. A high variation was also recorded for ‘Topgigant plus’ (38,97%). Despite its large fruit and early ripening, ‘Topgigant plus’ showed high variability in fruit weight (CV 38.97%) and, under Plovdiv conditions, browning of the fruit flesh around the stone (Figure 1). This disorder is associated with heat stress and may relate to rising summer temperatures in the region (Popović et al., 2026). It reduces fruit quality, even though the cultivar is attractive for its fruit size and early ripening. The cultivars with variability of fruit weight (CV 0-20%) were ‘Top first’, ‘Tita’, ‘Top five’, ‘Pitestian’, ‘Ulpia’, ‘Top taste’, ‘Pagane’, ‘Alesina’, ‘Serdika’, ‘Sirma’, ‘Romanta’, ‘Čačanska najbolja’ and ‘Plovdivska renkloda’.

Table 3. Fruit weight, coefficient of variation (CV), and size variability of the cultivars

Cultivar	Minimum annual mean (g)	Maximum annual mean (g)	Overall mean (g)	CV (%)	Size variability
Top first	37,17	39,16	38,17	3,69	Low
Ruth Gerstetter	22,92	45,28	32,23	30,07	Moderate
Tuleu Timpuriu	33,36	58,33	43,60	30,00	Moderate
Čačanska lepotica	29,64	47,62	37,65	20,58	Moderate
Sirma	37,48	51,62	46,24	13,55	Low
Tita	37,68	40,75	40,05	5,28	Low
Alesina	33,09	43,79	39,04	13,06	Low
Pitestian	39,72	46,36	42,27	8,46	Low
Top star plus	32,50	59,75	48,84	29,51	Moderate
Top five	26,70	30,00	28,35	8,23	Low
Topgigant plus	35,98	71,33	49,30	38,97	Moderate
Plovdivska renkloda	28,12	42,99	34,71	18,33	Low
Romanta	27,73	38,58	33,60	16,31	Low
Top taste	30,12	40,36	35,64	11,80	Low
Stanley	24,16	44,21	34,85	25,43	Moderate
Pagane	58,43	80,17	70,68	12,95	Low
Jojo	21,36	51,41	35,03	40,55	High
Serdika	41,87	54,15	49,50	13,46	Low
Čačanska najbolja	37,29	53,89	45,70	18,41	Low
Top king	20,06	33,69	27,02	25,24	Moderate
Ulpiya	28,65	34,69	32,66	10,63	Low
Čačanska ranna	28,45	55,41	41,87	32,51	Moderate
Ialomita	24,49	46,62	33,38	35,01	Moderate



Figure 1. Browning of the fruit flesh around the stone in ‘Topgigant plus’

CONCLUSIONS

1. The results show large differences in adaptation among the cultivars. Among the evaluated cultivars, ‘Tita’ and ‘Pitestian’ combined stable fruit size with low frost damage, which suggests good adaptation to local conditions.
2. The cultivars differed widely in stability, showing that each genotype must be evaluated under local conditions. This underlines the value of studying and preserving genetic resources.

3. ‘Čačanska lepotica’, ‘Tita’, ‘Pitestian’ and ‘Top first’ are promising both for direct production and as breeding material for climate resilience.
4. ‘Pagane’ combines very large fruit with stable fruit weight, but its complete flower loss in the 2019 frost may limit its use to sites with a low risk of spring frost.

REFERENCES

1. Ministry of Agriculture; Agrostatistical Referencebook; 2025; Sofia; Ministry of Agriculture; Bulgari
2. Botu M, Tomić L, Cvetković M, Gjamovski V, Jemrić T, Lazović B, Ognjanov V, Pintea M, Sevo R, Achim G, Bozovic D, Carka F, Čiček D, Fruk G, Jaćimović V, Kiprijanovski M, Juraveli A, Hjalmarsson I; Balkan pomology – Plums; 2012; Exaktaprinting AB; Sweden
3. Bozhkova, V. & Ivanova, D; Damage to some plums and mirobalan plum cultivars from the late spring frost in 2001; 2001; Journal of Mountain Agriculture in the Balkans. 4(1), 70 -77.
4. Bozhkova, V. & Zhivondov A.; Resistance of plum flowers to late spring frost; 2004; Journal of Mountain Agriculture in the Balkans; 7(4), 413-419.
5. Bozhkova, V., & Savov, P.; Performance of eleven plum cultivars under agroclimatic conditions of Plovdiv region, Bulgaria; 2016; Agricultural Science and Technology, 8(2), 136-139.
6. Cambra, M., Capote, N., Myrta, A., & Llácer, G.; Plum pox virus and the estimated costs associated with sharka disease; 2006; EPPO Bulletin, 36(2), 202-204.
7. FAOSTAT: Crops and livestock products – Plums and sloes (production quantity); 2025; Food and Agriculture Organization of the United Nations, Rome. https://www.fao.org/faostat/en/#data/QCL
8. García-Gómez, B. E., Salazar, J. A., Nicolás-Almansa, M., Razi, M., Rubio, M., Ruiz, D., & Martínez-Gómez, P.; Molecular bases of fruit quality in Prunus species: An integrated genomic, transcriptomic, and metabolic review with a breeding perspective; 2020; International Journal of Molecular Sciences, 22(1), 333.
9. Guerriero, R., F. Lomi, and C. D'Onofrio, Influence of some agronomic and ecological factors on the constancy of expression of some descriptive characters included in the 131 UPOV apricot descriptor list; 2006; Acta Hortic. 717, 51-54.
10. Hamdani, A., Hssaini, L., Bouda, S., Adiba, A., & Razouk, R.; Japanese plum behavior under water stress: impact on yield and biochemical traits; 2022; Heliyon, 8(4).
11. Hanelt, P.; European wild relatives of Prunus fruit crops; 1997; Bocconea, 7, 401-408.
12. Haokip, S. W., Shankar, K., & Lalrinngheta, J.; Climate change and its impact on fruit crops; 2020; Journal of Pharmacognosy and Phytochemistry, 9(1), 435-438.
13. Lopez, G., Hossein Behboudian, M., Girona, J., & Marsal, J.; Drought in deciduous fruit trees: implications for yield and fruit quality; 2012; In Plant responses to drought stress: from morphological to molecular features (pp. 441-459). Berlin, Heidelberg: Springer Berlin Heidelberg.
14. Malchev, S., & Savchovska, S.; Vulnerability of sweet cherry cultivars to continuous periods of spring frosts in Plovdiv, Bulgaria; 2020; Agricultural Science and Technology, 12(4), 348-352.
15. Meier, U.; Growth stages of mono- and dicotyledonous plants; 1997; Blackwell, Berlin
16. Milošević, N., & Milošević, T.; Impact of climate change on plum (Prunus domestica L.); 2023; In Cultivation for Climate Change Resilience, Volume 2 (pp. 257-278). CRC Press.
17. Neumüller, M., Dittrich, F. and Holzapfel, C.; Recent achievements and future challenges in breeding for European plum cultivars: finding the suitable genetic resources for important traits; 2021; Acta Hortic. 1322, 1-6;
18. Popović B, Nikićević N, Tešević V, Urošević I, Mitrović O, Leposavić A, Korićanac A. Heat-Damaged Fruits of ‘Čačanska Lepotica’ as a Raw Material for Plum Spirit Production; 2026; Possibilities for Improving Product Quality. Foods. 15(11):1855.
19. Rodrigo, J.; Spring frosts in deciduous fruit trees: morphological damage and flower hardiness; 2000; Scientia Horticulturae, 85(3), 155-173.
20. Ruiz, D.; Apricot and plum breeding challenges; 2026; Acta Hortic. 1450, 381-388; DOI: 10.17660/ActaHortic.2026.1450.50.
21. Ruiz, D., J. A. Campoy, and J. Egea; Chilling and heat requirements of apricot cultivars for flowering; 2007; Environmental and Experimental Botany 61, no. 3, 254-263.
22. Seehuber, C., Damerow, L., & Blanke, M.; Regulation of source: sink relationship, fruit set, fruit growth and fruit quality in European plum (Prunus domestica L.)—using thinning for crop load management; (2011); Plant Growth Regulation, 65(2), 335-341.
23. Vachůn, Z.; Variability of 21 apricot (Prunus armeniaca L.) cultivars and hybrids in selected traits of fruit and stone; 2003; Hort Sci. (Prague) 30, 90-97.

24. Zhuang, W., B. Cai, Z. Gao, and Z. Zhang; Determination of chilling and heat requirements of 69 Japanese apricot cultivars; 2016; European Journal of Agronomy, 74, 68-74.