# Grouping and evaluation of cultivars and elite nectarines according to resistance to negative spring temperatures

**Sashka Savchovska[1*], Neli Keranova[2]**
Agricultural Academy, Fruit-Growing Institute – Plovdiv[1], Bulgaria
Agricultural University Plovdiv[2]
[*]E-mail: *кirilova.savchovska93@abv.bg*

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**Abstract**
The objects of research are sixteen cultivars nectarines and elite, which data were reported for the period 2019-2021 on the territory of the Fruit Growing Institute - Plovdiv. The purpose of the study is to group and evaluate according to the degree of frost on their flowers. For this purpose, single factor analysis of variance and Tukey's test were applied for difference estimation as well as hierarchical cluster analysis. It was established that during the three years of research, the Sunfree cultivar freezes 100%, which made it the most susceptible variety to temperature effects. The least consequences of negative temperatures on the flowers are the least in the Gergana variety for 2019 (33%), the Morciani 90 for 2020 (84%), and the El. 4-151 in 2021 (72.66%). As a result of the studies, it was established that the resistance to low temperatures in different cultivars and elites is largely determined by the degree of coincidence of the phenological stages: early bloom and full bloom with those negative temperatures.

**Keywords:** frost; nectarines; phenological stages; clusters

## INTRODUCTION

Fruit crops need the accumulation of freezing temperatures during dormancy for the normal flowering and fruiting to take place (Bortolotto et. al., 2022). The resistance of peach trees to low temperatures depends on several factors: hereditary cultivar specificity, degree of nutrient supply, degree of hardening, nature of the cold (gradual or sharp decrease in temperature), and duration of its action.

Flower buds are most persistent in December when trees are in deep rest (Szalay et al., 1999). When temperatures rise, the thawing process is very rapid, so the cold hardiness of the flower buds drops sharply. This happens most often at the end of February and in March when flower bud development also begins (Petrov & Grigorov, 1981).

As well as being detrimental, the effect of freezing temperatures can also be beneficial, as when they are less pronounced they lead to the natural thinning of flowers and young shoots. (Chen et al., 2016).

In recent years, there has been earlier development of fruit buds in spring and later dormancy, which extends the growing season. A group of scientists conducted a long-term study and found that the flowering date was advanced by 11 days while the end of the growing season was delayed by 8 days (Li et al., 2016). By tracking phenological development, the impact of climate change can be tracked, the impact of freezing temperatures and the risk of frost can be assessed (Miranda et. al., 2013). Climate change in recent years affects the flowering process, which occurs earlier and leads to flower damage; it affects pollination and fruit ripening (Dirlewanger et al., 2012). Over the last few years, in the Plovdiv region, plum, apricot, peach, and cherry orchards have been damaged by negative spring temperatures (Malchev & Savchovska, 2020; Nesheva & Bozhkova, 2021; Keranova et al., 2021).

The aim of the present study was to investigate the influence and resistance of nectarine cultivars and elites to spring frost and, on the basis of the results obtained, to form groups of cultivars with similar characteristics; to evaluate and compare the genotypes under study with respect to the above-mentioned parameters.

## MATERIAL AND METHODS

The study was conducted at of Fruit Growing Institute - Plovdiv in 2019-2021. Nine varieties and seven elites were studied: Big top, Adriana, Sunfree, Morciani 90, Independence, Golden Grand, Autumnfree, Nektagrand 4, Gergana, and the elites: El. 4-168, El. 29-30, El. 3-158, El. 4-176, El. 23-42, El. 4-151 and El4-171. The effects of freezing temperatures on nectarine blossoms were recorded after a period of three to five days following the event. Three hundred flowers and buds were examined annually from all parts of the canopy, distributed in three replicates of one hundred each. In the present study, nectarine genotypes were grouped according to their degree of adaptation to climate variation by hierarchical cluster analysis using the method of intergroup linkage and a similarity measure of quadratic Euclidean distance. Comparative evaluation of varieties and elites was carried out using single factor analysis of variance and Tukey's test to assess differences at 0.05 level of statistical significance, the results of which provide information on the presence/absence of proven differences between them. The results are visualized by dendrogram and by diagrams. For the mathematical processing of the data, the statistical software IBM Statistics SPSS 24 (Landau & Everitt, 2004) was used as well as the capabilities of Microsoft Excel.

## RESULTS AND DISCUSSION

In 2019, four dates with freezing temperatures were recorded, two of which coincided with the full bloom and petal fall phenophases. Sunfrey, Autumnfree, Nectagrande 4 and El. 4-176 were under the influence of negative temperatures in the full bloom phase (Table 1).

As a result of the comparative evaluation of nectarine cultivars, it is proved that throughout the study period, the highest frost kill rate was found in Sunfree (100%). This is conditioned by the earliest start of its phenological development, as a result of which it is most exposed to the influence of freezing temperatures (Figure 5, Table 2).

Figures 1-3 present the variations of temperature fluctuations recorded over the years of the study for the respective time periods.

The damage reported for Autumnfree is (98%) and for El. 4-176 is 95.33%. Nektagrand 4 was found to have a low percentage of frost damage in 2019, although freezing temperatures coincided with its full bloom. Thus, in the group least affected by negative temperatures are Nektagrand 4 (47.66%), Gergana (33%), El. 4-151 (49.33%) and El. 23-42 (49.66%). These varieties show a difference of more than 200% compared to other cultivars. As the sensitive phases in the cultivar Gergana were passed before the freezing temperatures, the percentage of damage was lower. Elite 4-151 was transitioning from full bloom to petal fall and El. 23-42 was in the petal fall phase. The different phase of development at the onset of freezing temperatures is decisive for the degree of damage (Dimitrov & Akova, 2021). In 2020, negative temperatures occurred on four consecutive days coinciding with the beginning of flowering and full flowering phenophases of all observed cultivars and elites. Temperatures recorded this year were also the lowest, with -2.6°C on 16 March and reaching -4.9°C on 17 March. Due to the length of the period of low temperatures, cultivars highly resistant to temperature anomalies do not stand out. In all of them, frost resistance ranged from 94.66% in El. 4-151, to 100% in Sunfree. A small difference in the proportion of damaged flowers is only Morsiani 90 (84%), which is in the phase of the beginning of flowering on March 16.

In 2021, the recorded negative temperatures compared to the previous two years are not as low, and they are recorded in late March and early April, so there is an added column in Table 1 with most flowers with petals forming a hollow ball. The temperatures coinciding with the full bloom phenophase were on 4 April (-0.8°C) and 6 April (-0.4°C). In this period in full bloom are: Independence, Nectagrand 4, Gergana and the elites 3-158, 4-151, 4-168, 29-30. Despite the phenophase, significantly lower

**Table 1.** Phenological development by dates for the period 2019-2021

| № | Cultivar Nectarine | 2019 | | | 2020 | | | 2021 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Beginning of flowering: 61-62 | Full flowering 63-65 | Flowers fading 67 | Beginning of flowering 61-62 | Full flowering 63-65 | Flowers fading 67 | Most flowers with petals forming a hollow ball 59 | Beginning of flowering:61-62 | Full flowering 63-65 | Flowers fading 67 |
| 1 | Morciani 90 | 22-Mar | 26-Mar | 29-Mar | 16-Mar | 22-Mar | 30-Mar | 28-Mar | 31-Mar | 5-Apr | 9-Apr |
| 2 | Big top | 19-Mar | 23-Mar | 25-Mar | 16-Mar | 21-Mar | 29-Mar | 25-Mar | 31-Mar | 5-Apr | 9-Apr |
| 3 | Sunfree | 21-Mar | 25-Mar | 28-Mar | 11-Mar | 16-Mar | 26-Mar | 12-Mar | | | |
| 4 | Autumnfree | 21-Mar | 25-Mar | 29-Mar | 14-Mar | 17-Mar | 27-Mar | 24-Mar | 30-Mar | 5-Mar | 9-Apr |
| 5 | Independence | 19-Mar | 23-Mar | 25-Mar | 13-Mar | 17-Mar | 27-Mar | 26-Mar | 31-Mar | 4-Apr | 7-Apr |
| 6 | Golden Grand | 20-Mar | 24-Mar | 26-Mar | 14-Mar | 18-Mar | 26-Mar | 25-Mar | 30-Mar | 3-Apr | 7-Apr |
| 7 | Adriana | 20-Mar | 24-Mar | 27-Mar | 13-Mar | 16-Mar | 25-Mar | 25-Mar | 30-Mar | 3-Apr | 7-Apr |
| 8 | Nektagrand 4 | 20-Mar | 25-Mar | 29-Mar | 17-Mar | 23-Mar | 4-Apr | 25-Mar | 31-Mar | 6-Apr | 10-Apr |
| 9 | Gergana | 18-Mar | 22-Mar | 24-Mar | 14-Mar | 17-Mar | 25-Mar | 27-Mar | 1-Apr | 4-Apr | 7-Apr |
| 10 | El.3-158 | 20-Mar | 24-Mar | 28-Mar | 16-Mar | 21-Mar | 27-Mar | 25-Mar | 30-Mar | 4-Apr | 7-Apr |
| 11 | El.4-151 | 20-Mar | 23-Mar | 27-Mar | 17-Mar | 22-Mar | 30-Mar | 28-Mar | 1-Apr | 6-Apr | 10-Apr |
| 12 | El.4-168 | 20-Mar | 25-Mar | 29-Mar | 16-Mar | 21-Mar | 26-Mar | 24-Mar | 31-Mar | 4-Apr | 8-Apr |
| 13 | El.4-171 | 21-Mar | 26-Mar | 29-Mar | 16-Mar | 16-Mar | 23-Mar | 25-Mar | 30-Mar | 5-Apr | 9-Apr |
| 14 | El.4-176 | 21-Mar | 25-Mar | 28-Mar | 14-Mar | 16-Mar | 24-Mar | 25-Mar | 30-Mar | 5-Apr | 9-Apr |
| 15 | El.29-30 | 18-Mar | 22-Mar | 24-Mar | 13-Mar | 16-Mar | 27-Mar | 25-Mar | 30-Mar | 4-Apr | 8-Apr |
| 16 | El.23-42 | 18-Mar | 21-Mar | 25-Mar | 17-Mar | 22-Mar | 31-Mar | 1-Apr | 4-Apr | 8-Apr | 13-Apr |

**Table 2.** Comparative evaluation of nectarine varieties by one-way analysis of variance and Tukey's test at a significance level of 0.05

| Cluster № | Cultivar Nectarine | 2019 | | 2020 | | 2021 | |
|---|---|---|---|---|---|---|---|
| | | Mean | Std. Dev. | Mean | Std. Dev. | Mean | Std. Dev. |
| 1 | Big top | 91,66[b] | 2,51 | 97[abc] | 2 | 98[ab] | 1 |
| | El. 4-168 | 90,33[bc] | 3,51 | 98[ab] | 2 | 97,66[abc] | 1,52 |
| | Adriana | 98[ab] | 3,46 | 98[ab] | 2 | 99[a] | 1 |
| | El. 29-30 | 97,66[ab] | 0,57 | 99[a] | 1 | 97,33[abc] | 1,52 |
| | Sunfree | 100[a] | 0 | 100[a] | 0 | 100[a] | 0 |
| | El. 3-158 | 96,66[ab] | 1,52 | 96,33[abc] | 2,51 | 91[abcd] | 6,55 |
| | El. 4-176 | 95,33[ab] | 1,15 | 99[a] | 1 | 92[abcd] | 2,64 |
| 2 | Morciani 90 | 95,66[ab] | 0,57 | 84[d] | 3,6 | 99[a] | 1 |
| | El. 4-171 | 97,33[ab] | 1,15 | 91,33[c] | 3,21 | 96,33[abc] | 1,52 |
| | Independence | 83[c] | 2 | 98,33[ab] | 1,52 | 98,33[a] | 1,52 |
| | Autumnfree | 98[ab] | 1 | 92,33[bc] | 3,78 | 85[d] | 7 |
| | Golden Grand | 92[b] | 2,64 | 91,3[3c] | 2,51 | 73,33[e] | 2,51 |
| 3 | Nektagrand 4 | 47,66[d] | 2,51 | 97[abc] | 1 | 87,66[cd] | 3,05 |
| | El. 23-42 | 49,66[d] | 3,21 | 97,66[abc] | 0,57 | 94,66[abcd] | 3,51 |
| | Gergana | 33[e] | 5,56 | 96,66[abc] | 1,52 | 88[cd] | 4 |
| | El. 4-151 | 49,33[d] | 3,05 | 94,66[abc] | 2,51 | 72,66[e] | 4,5 |

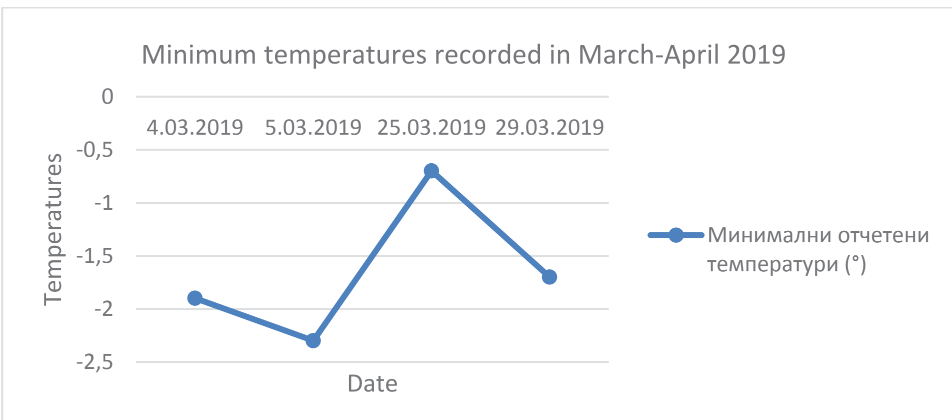


**Figure 1.** Minimal measured temperatures for March-April.2019

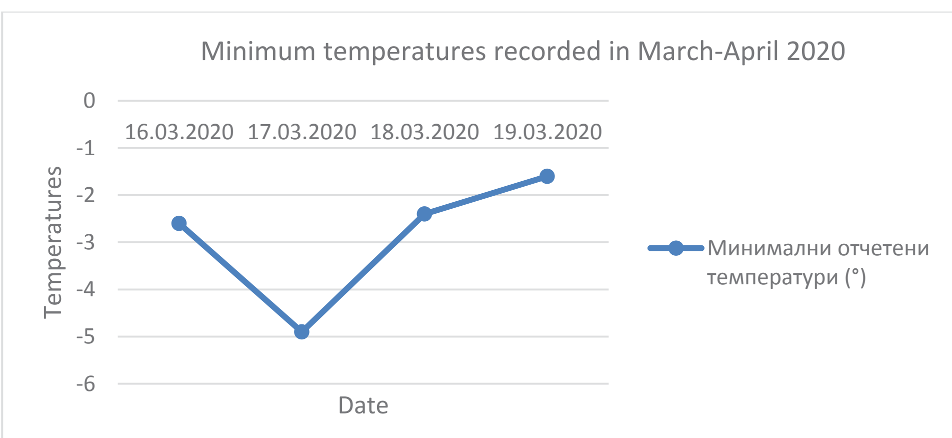


**Figure 2.** Minimal measured temperatures for March-April, 2020

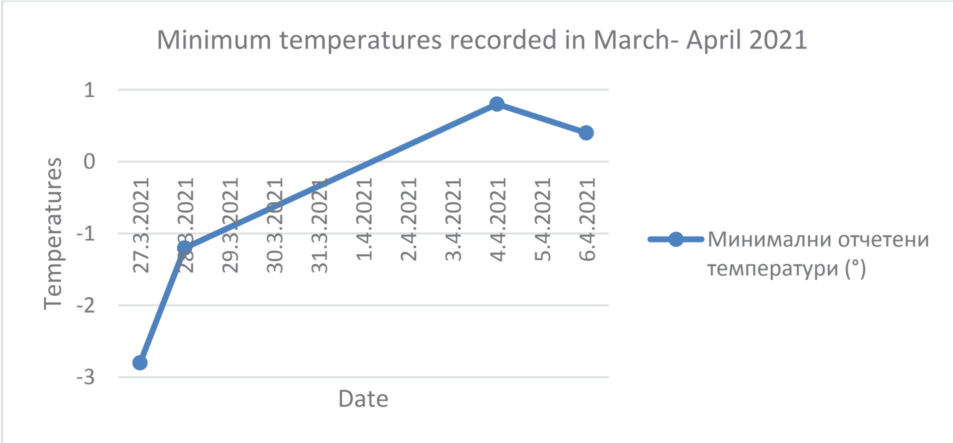


**Figure 3.** Minimal measured temperatures for March-April, 2021

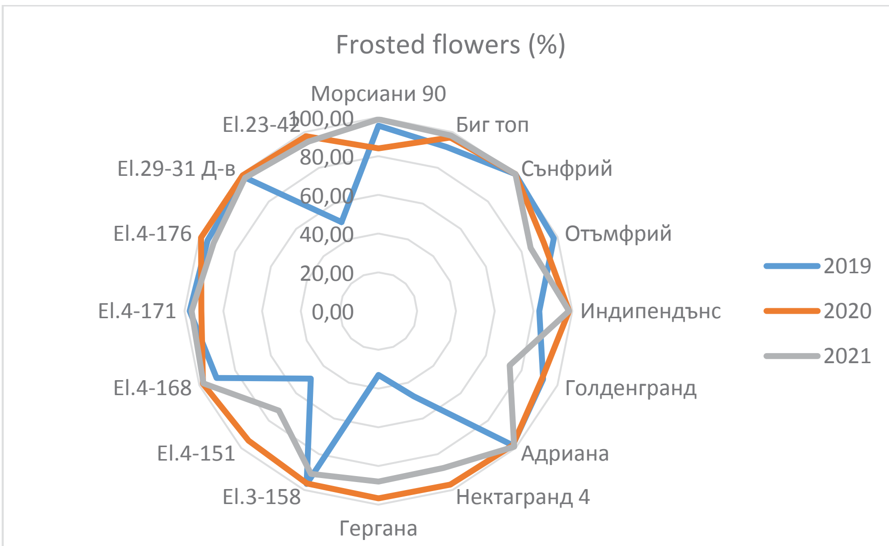


**Figure 4.** Share of frozen flowers in the period 2019-2021

damage was recorded in El. 4-151 (72.66%), Nectagrand 4 (87.66%) and Gergana (88%). These results prove that not only phenophase is important but also temperature. The varieties mentioned are not so sensitive to the negative temperatures in this phase of development. With a low rate of dead flowers (fruiting bodies) are Goldengrand (73, 33%) and Otumfrey (85%).

The applied hierarchical cluster analysis grouped the studied cultivars and elites into three clusters according to the degree of resistance to low temperatures (Figure 5).

The first cluster consists of cultivars that have proven over the three-year study period to be highly sensitive to low temperatures, resulting in a proportion of frosted flowers exceeding 90%. The second cluster consists of varieties that have shown tolerance to low temperatures in one of the three years: Morsiani 90 (2020), El. 4-171 (2020), Independence (2019), Otumfrey (2021), and Golden Grand (2021). The third cluster comprises varieties that were minimally affected by temperature anomalies in 2019 (the proportion of frosted flowers ranged from 33% to 50%). This group includes the cultivar Gergana, which stood out as the most resistant due to its earlier phenotrophic development in 2019 compared to all other cultivars for each of the years of the study.

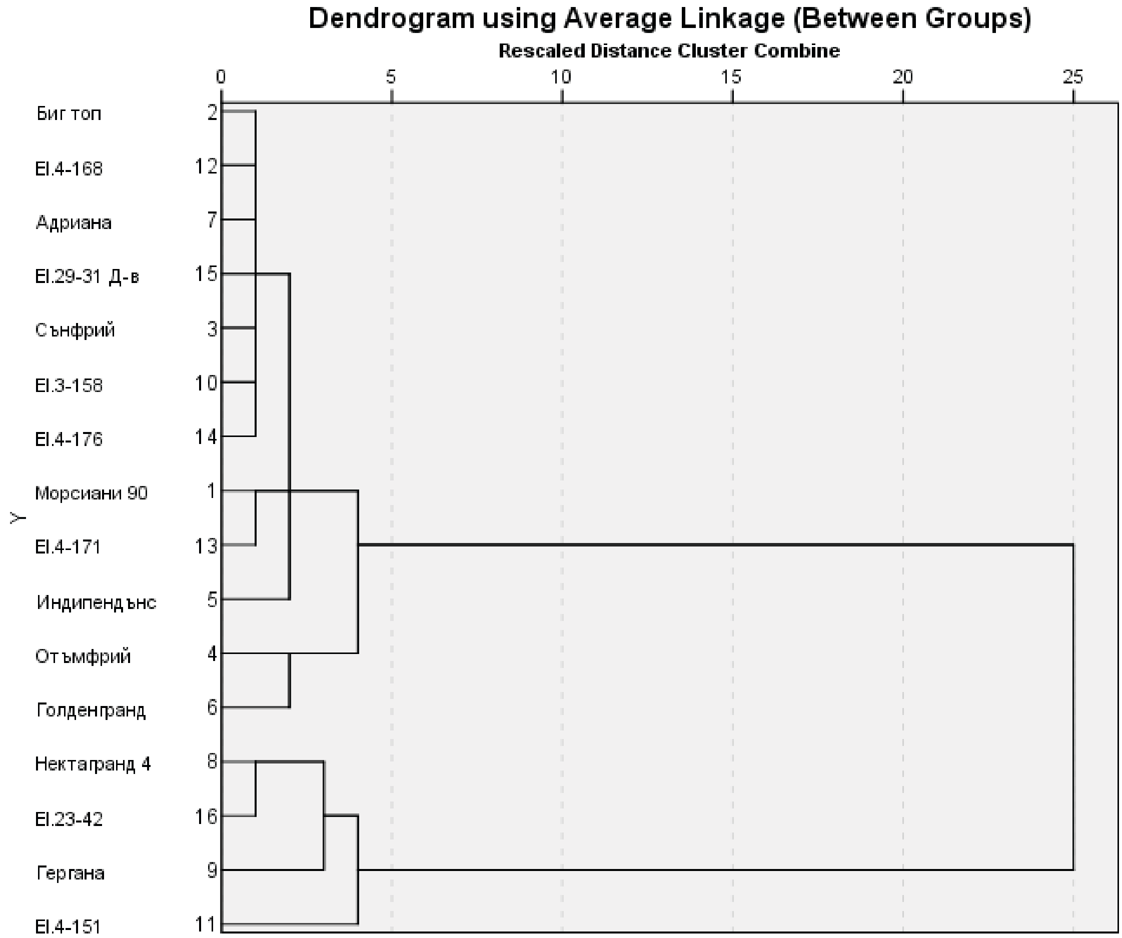


**Figure 5.** Grouping of cultivars and elite nectarines according to degree of frost by hierarchical cluster analysis

## CONCLUSIONS

The most resistant to spring frosts in full bloom are the flowers of the cultivars Gergana and Nektagrand 4, as well as El.4-151. The cold hardiness of the flower organs is influenced by the following factors: the specific phenological phase, the specific freezing temperature, and its duration. Due to its earlier phenological development, the variety Sunfrey is most vulnerable to the effects of spring frosts.


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