Adaptive phenological response of grape varieties orientalis C. Negr. on changes in weather and climatic conditions in the south of Russia

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Abstract. The studies were carried out in the temperate continental climate of southern Russia in the plantations of the Anapa ampelographic collection on the varieties Adisi, Kuldzhinsky, Tarnau belonging to the group orientalis C. Negr. It was found that the growing season duration of Adisi variety from budding to the full physiological maturity of grape berries decreased by 24 days, of Kuldzhinsky variety - by 23 days, of Tarnau variety - by 27 days. Regularities have been established that indicate a close and average positive correlation relationship between a decrease in the duration of the growing season and an increase in the sum of active air temperatures.

1. Introduction
Agroclimatic changes, in particular, in Krasnodar region, are an indubitable fact and undoubtedly affect phytocenoses. The culture of grapes is no exception, which must adapt to climate change in order to maintain its potential. Each variety has individual periods for vegetation phases passage [1-3]. According to the data of researchers Novikova L Yu, Naumova L G (2013, 2014) under extreme conditions, changes are observed in small annual cycles of ontogenesis, a shift in the timing and duration of the vegetation phases of grape plants [4, 5]. A change in grapes growing season is an adaptive response to environmental conditions.

On the duration of grape varieties growing season, namely, a reduction in the period of postembryonic development of flower organs and a reduction in the period of grapes flowering, according to L G Naumova and L Yu Novikova (2013), has an increased temperature air regime [6]. The most significant relationships between the grape plant and air temperature are also indicated by the researchers Spring J- L, Viret O, Bloesch B (2009), Koufos G, Mavromatis T, Koundouras S et al. (2012), V S Petrov et al. (2020) [7-9]. Consequently, the relevance of studies on climate influence on grapes ontogeny, in order to identify varieties with high adaptive potential, is beyond doubt.
In this regard, the purpose of this study is to assess the adaptive phenological response of grape varieties Adisi, Kuldzhinsky, Tarnau and the prospects for their use in unstable weather and climatic conditions in southern Russia.

2. Materials and research methods
The studies were carried out in the temperate continental climate of southern Russia in the plantations of Anapa ampelographic collection [10]. The objects of research were grape varieties - Adisi, Kuldzhinsky, Tarnau, according to the classification of A G Negrulya belonging to the convar orientalis Negr group. (oriental). Phenological observations were carried out using the method generally accepted in viticulture [11]. Meteorological data are presented according to the data of the meteorological station in the city of Anapa. Analysis of meteorological data and phenological cycles was carried out in the periods from 1975 to 1984 and from 2009 to 2018.

3. Research results and their discussion
Analyzing the weather conditions in the south of Russia during the study periods, it was noted that the average annual air temperature in the period from 2009 to 2018 relative to the period 1975-1984 increased by 1.5 °С. The average annual maximum and minimum temperatures also increased, and in absolute terms, the change in temperature was 1.2 °C and 2.2 °C, respectively. At the same time, the absolute minimum temperature decreased by 2 °C, from -18 to -20 °C (table 1). During the period of active growth and ripening of grapes (August), the greatest changes in air temperature were noted. Thus, the average temperature increased by 4 °C, and the maximum and minimum temperatures increased by 5.0 °C. At the same time, moisture supply during the period of active growth and ripening of berries (June II - August III) decreased by 15%, although the annual amount of precipitation increased by 8%.

### Table 1. Changes in weather conditions at the research site, Anapa city.

| Indicators                             | Years of observation | Change in indicators, ± | % |
|----------------------------------------|----------------------|-------------------------|---|
|                                        | 1975 – 1984          | 2009 – 2018             | in absolute terms |  |
| average annual Air temperature, °C     | 12.2                 | 13.7                    | +1.5                  | +12 |
| max average for a year                 | 20.9                 | 22.1                    | +1.2                  | +6  |
| max absolute                           | 37                   | 38                      | +1                    | +3  |
| min average for a year                 | 4.0                  | 6.2                     | +2.2                  | +55 |
| min absolute                           | -18                  | -20                     | -2                    | -11 |
| Precipitation, mm – for a year         | 532                  | 572                     | +40                   | +8  |
| during the period of active berries    | 111                  | 94                      | -17                   | -15 |
| grapes growth (II.06 – III.08)         |                      |                         |                       |     |

The transition of air temperature through physiologically significant parameters in the period from 2009 to 2018 relative to the period 1975-1984 occurs at an earlier date. So, the transition of temperature through biological zero (+10 °C) shifted by one day, after +12 °C (the beginning of eyes opening) by two days, after +14 °C (critical for flowering), by 6 days.

The ability of a grape plant to change the timing of phenophases onset can be considered as an adaptation between the requirements of the species and habitat conditions. The reaction of grape varieties Adisi, Kuldzhinsky, Tarnau to changes in weather conditions was considered for each phase separately and for the whole growing season, from the beginning of eyes opening and until the full physiological ripeness of berries.
During the active growing season of Adisi variety, from the beginning of bud opening to the full physiological ripeness of berries, in 2009-2018 there is an increase in the average air temperature by 2.62 °C, compared to 1984-1987 (table 2). The beginning of bud opening in the studied cultivar took place in 2009-2018 at the same time, but flowering and ripening occurred 6 days earlier. The onset of full physiological maturity of Adisi grape berries during the study period from 2009 to 2018, compared to 1984-1987, was observed on August 30 and September 22, respectively. The difference in the onset of the phenophase of full physiological maturity was 23 days. The growing season of Adisi variety in 2009-2018, compared to 1984-1987, decreased by 24 days. A decrease in the growing season, in our opinion, occurred as a result of an increase in temperature, which activated physiological, biochemical and growth processes of grapes.

Table 2. Influence of weather changes and climatic conditions on the growing season of grape varieties Adisi, Anapa city, ampelocollection.

| Indicators     | Beginning of bud opening - beginning of flowering | Beginning of flowering - beginning of berry ripening | Beginning of ripening - full physiological maturity of berries | Beginning of bud opening - full physiological maturity |
|----------------|---------------------------------------------------|-----------------------------------------------------|---------------------------------------------------------------|-----------------------------------------------------|
| Years of observation | 1984-2009-2018 | 1984-2009-2018 | 1984-2009-2018 | 1984-2009-2018 |
| Vegetation time | 21.IV-22.IV-9.VI | 9.VI-3.VI | 5.VIII-30.VII | 22.IX-30.VIII-22.IX |
| Duration of vegetation, days | 48 | 42 | 57 | 48 | 31 | 154 | 130 |
| Air temperature, °C average | 15.38 | 16.84 | 21.35 | 23.81 | 20.7 | 25.18 | 19.25 | 21.87 |
| maximum | 27.38 | 28.88 | 32.98 | 35.16 | 31.95 | 34.87 | 33.88 | 36.31 |
| minimum | 3.38 | 6.74 | 11.45 | 14.39 | 8.15 | 15.65 | 2.68 | 6.74 |
| temperature amplitude | 7.62 | 6.84 | 8.82 | 7.68 | 9.45 | 8.73 | 8.6 | 7.7 |
| the sum of active temperatures | 693 | 687 | 1219 | 1362 | 1007 | 778 | 2919 | 2827 |
| Precipitation, mm | 80 | 52 | 25 | 90 | 38 | 19 | 143 | 160 |

When studying the reaction of Kuldzhinsky grape variety to weather conditions changes in the periods 1975-1980, and 2009-2018, in general, during the growing season from the beginning of budding to the full physiological ripeness of berries, an increase in the average air temperature in the second period by 1.89 °C was noted. With an increase in air temperature in 2009-2018 the growing season of the grape plant variety Kuldzhinsky, in comparison with 1975-1980, decreased by 23 days and amounted to 128 days. The beginning of the growing season took place at the same time, and the greatest reduction in the duration of the phenophases was noted in the period from the beginning of bud opening to the beginning of flowering and in the phase of the beginning of ripening to the full physiological maturity of berries and, respectively, was 7 and 14 days. So, the flowering of Kuldzhinsky variety in 2009-2018 on average began on May 31, while in 1975-1980 on June 8. Ripening of berries of the studied variety in the period 2009-2018 happened 19 days earlier, namely on July 15, while in 1975-1980 on August the 4th. Full physiological maturity on average over the period of research came on September 15, while in 2009-2018 – on August 23 (table 3).
Table 3. Influence of weather changes and climatic conditions on the growing season of grape varieties Kuldzhinsky, Anapa city, ampelocollection.

| Indicators                                | Beginning of bud opening - beginning of flowering | Beginning of flowering - beginning of berry ripening | Beginning of ripening - full physiological maturity of berries | Beginning of bud opening - full physiological maturity |
|-------------------------------------------|--------------------------------------------------|-----------------------------------------------------|---------------------------------------------------------------|-------------------------------------------------------|
| **Years of observation**                  | 1975-1980, 2009-2018                             | 1975-2009, 1980-2018                                | 1975-2009, 1980-2018                                          | 1975-2009, 1980-2018                                   |
| **Vegetation time**                       | 18.IV-8.VI, 17.IV-31.V                           | 8.VI-4.VIII, 31.V-16.VII                            | 4.VIII-15.IX, 15.IX-23.VII                                    | 18.IV-17.IV-23.VIII                                    |
| **Duration of vegetation, days**         | 51                                               | 57                                                  | 43                                                            | 151                                                   |
| **Air temperature, °C**                   |                                                  |                                                     |                                                               |                                                       |
| **Average**                               | 15.52                                            | 22.4                                                | 20.82                                                         | 19.58                                                 |
| **Maximum**                               | 29.22                                            | 34.74                                               | 35.25                                                         | 36.31                                                 |
| **Minimum**                               | 4.3                                              | 11.42                                               | 8.6                                                           | 4.3                                                   |
| **Temperature amplitude**                 | 8.03                                             | 9.27                                                | 8.88                                                          | 7.63                                                  |
| **The sum of active temperatures**        | 766                                              | 1295                                                | 2928                                                          | 2726                                                  |
| **Precipitation, mm**                     | 60                                               | 40                                                  | 33                                                            | 133                                                   |

The beginning of bud opening of Tarnau variety, in contrast to Kuldzhinsky and Adisi in the period 2009-2018 happened two days later than in 1975-1980 (table 4). However, flowering and the beginning of maturation of Tarnau variety, on average for the period 2009-2018, occurred 5 days earlier, compared to 1975-1980. Full physiological ripeness of berries in 2009-2018 came on August 24, which is 23 days earlier than in 1975-1980. Thus, the duration of the growing season of Tarnau variety in 2009-2018 decreased by 27 days.

Table 4. Influence of weather changes and climatic conditions on the growing season of grape varieties Tarnau, Anapa city, ampelocollection.

| Indicators                                | Beginning of bud opening - beginning of flowering | Beginning of flowering - beginning of berry ripening | Beginning of ripening - full physiological maturity of berries | Beginning of bud opening - full physiological maturity |
|-------------------------------------------|--------------------------------------------------|-----------------------------------------------------|---------------------------------------------------------------|-------------------------------------------------------|
| **Years of observation**                  | 1975-1980, 2009-2018                             | 1975-2009, 1980-2018                                | 1975-2009, 1980-2018                                          | 1975-2009, 1980-2018                                   |
| **Vegetation time**                       | 18.IV-8.VI, 21.IV-3.VIII                         | 3.VI-28.VII, 3.VI-17.IX                             | 24.VIII, 21.VIII                                              |                                                       |
| **Duration of vegetation, days**         | 51                                               | 67                                                  | 35                                                            | 152                                                   |
| **Air temperature, °C**                   |                                                  |                                                     |                                                               |                                                       |
| **Average**                               | 15.5                                             | 22.02                                               | 20.74                                                         | 19.5                                                  |
|                                           | 16.72                                            | 23.62                                               | 25.75                                                         | 21.79                                                 |
Changes in the timing and duration of the growing season of varieties Adisi, Kuldzhinsky and Tarnau belonging to the orientalis C. Negr group occurred with an increase in average, maximum and minimum air temperature, as well as the sum of active temperatures. In individual phases, the greatest changes were observed in the period from the beginning of ripening to the full physiological maturity of grapes. At this stage, with an increase in average, maximum and minimum air temperature, as well as the sum of active temperatures, the vegetation of plants in the varieties Adisi, Kuldzhinsky and Tarnau decreased by 24, 23 and 27 days, respectively.

The patterns of a decrease in the duration of the growing season with an increase in air temperature are confirmed by indicators of a close and average positive correlation dependence on the sum of active air temperatures ($r = 0.81 - 0.72$). The duration of the growing season, from the beginning of budding to the beginning of flowering, is in a close and medium negative correlation dependence on the average temperature ($r = -0.79 - -0.5$). The duration of ripening of grape berries has a close and moderate negative relationship with the average and minimum air temperature ($r = -0.6 - -0.37$), as well as moderate negative with the maximum air temperature ($r = -0.37 - -0.26$) (table 5).

**Table 5.** Correlation dependence of vegetation phases duration of grape plants on air temperature and precipitation.

| Sign of correlation | Beginning of bud opening | Beginning of flowering | Beginning of ripening - full physiological maturity of berries | Beginning of bud opening - full physiological maturity |
|---------------------|--------------------------|-----------------------|---------------------------------------------------------------|-----------------------------------------------------|
|                      | Adisi        | Kuldzhinsky | Tarnau          | Adisi       | Kuldzhinsky | Tarnau          | Adisi       | Kuldzhinsky | Tarnau          |
| Air temperature, °C  |              |              |                 |              |              |                 |              |              |                 |
| average              | -0.79        | -0.5         | -0.68           | 0.19        | -0.24       | -0.3            | -0.54       | -0.42       | -0.32           | -0.74        | -0.75         | -0.88         |
| maximum              | 0.07         | 0.36         | 0.18            | 0.31        | -0.27       | -0.1            | -0.37       | -0.26       | -0.07           | -0.56        | -0.6          | -0.76         |
| minimum              | -0.76        | -0.51        | -0.59           | -0.22       | -0.31       | -0.8            | -0.6        | -0.66       | -0.37           | -0.68        | -0.48         | -0.51         |
| temperature amplitude| 0.49         | 0.03         | -0.02           | 0.1         | 0.06        | 0.75            | 0.48        | 0.15        | -0.53           | 0.72         | 0.66          | 0.48          |
| the sum of active temperatures | 0.83 | 0.85 | 0.87 | 0.88 | 0.93 | 0.93 | 0.92 | 0.85 | 0.87 | 0.72 | 0.81 | 0.8 |
| Precipitation, mm    | 0.21         | 0.53         | 0.44            | 0.21        | 0.08        | 0.32            | 0.37        | 0.42        | 0.69            | 0.03         | 0.02          | 0.31          |
4. Conclusion
The change in key climate indicators has been established, so the average annual air temperature in the period from 2009 to 2018 relative to the period 1975-1984 increased by 1.5 °C. Due to climate changes, in the Black Sea agro-ecological zone of viticulture in the south of Russia, some varieties have changed in terms and duration of the growing season. Thus, the growing season of Adisi variety from budding to full physiological ripeness of grape berries was reduced by 24 days, in Kuldzhinsky variety - by 23 days, in Tarnau variety - by 27 days.

The decrease in the duration of the growing season occurred due to the shift in the timing and duration of growing season phases. Duration of the growing season of Adisi variety from the beginning of eyes opening to the beginning of flowering decreased by 6 days, from the beginning of flowering to the beginning of ripening of berries by 1 day, from the beginning of ripening to full physiological ripeness of berries by 17 days, of Kuldzhinsky variety, respectively, by 7, 2 and 14 days, of Tarnau variety for 9, 11 and 8 days.

In the course of statistical data processing, regularities were established that testify to a close and average positive correlation between a decrease in the duration of the growing season and an increase in the sum of active air temperatures.

The duration of the growing season, from the beginning of budding to the beginning of flowering, is in a close and medium negative correlation with the average air temperature, the ripening of grape berries has a close and moderate negative relationship with the average and minimum temperature, as well as a moderate negative relationship with the maximum air temperature. In our opinion, the described changes and calculated patterns indicate a high adaptive potential of these varieties, which is very important for further planning of sustainable industrial viticulture in unstable weather conditions in the south of Russia.

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