The response of apple tree varieties to the anomalies in the water and temperature conditions in 2020

L V Grigoreva¹, D N Tsukanova¹ and E M Tsukanova²

¹Michurinsk State Agrarian University, 101, International st., Michurinsk, 393760, Russia
²I.V. Michurin Federal Research Centre, 30, Michurin st., Michurinsk, 393774, Russia
E-mail: grigorjeval@mgau.ru

Abstract. The authors establish that the destabilization of the water and temperature conditions in farming areas is currently the most significant factor limiting the development of fruit plants. The results of the weather monitoring in 2020 show significant deviations of the water and temperature conditions in that year from the long-time annual averages, the most significant of which are abnormally dry February and March, cold and humid May, as well as the alternating hot and cold spells and dramatic temperature drops between days and nights. The monitoring of the physiological parameters of apple trees showed that the vegetation period of 2020 featured an early start of plant growth, the suppression of photosynthesis in midsummer due to high air temperatures, low precipitation, and the late beginning of winter lethargy for apple trees.

1. Introduction
The fulfillment of the biological potential of a genotype under specific conditions is primarily defined by the climate of the region of cultivation. Throughout their life cycle, fruit plants are exposed to various adverse environmental factors that can cause damage to the molecular of cellular structures combined with the disruption of functions in plants. [1, 2]. These factors include dramatic temperature drops, air, and soil humidity, prolonged droughts and waterlogging, excessive solar and ultraviolet radiation, insufficient or excessive nutrients, environmental pollution, etc. [3-5]. The apple tree is a permanent crop.

Therefore, adverse consequences of damaging impacts may accumulate and gradually reduce the resilience and fertility of both specific plants and the plantation as a whole [4-6]. The environmental conditions of the recent decades increased the spread, aggressivity, and the range of harmful species, and the intensive use of chemical agents since the early 1980es resulted in a reduction of numbers of natural zoophages of 100-250 times in commercial apple plantations [7]. The ubiquitous use of harsh chemical agents to protect plants from pests and diseases damaged useful arthropods, which resulted in a booming propagation of sucking pests (ticks, blindworms) and leaf miners [8].

Thus, studying the response of different apple tree varieties to adverse external impacts is relevant as it helps determine the potential consequence of damages incurred, as well as develop and use a set of the most effective agricultural techniques for their mitigation [9, 10].
2. Materials and Methods
The research was carried out on the apple tree varieties at the plantations of I. V. Michurin Federal Research Centre. The trends in temperature and water conditions in the region in question were determined based on the climate archives of the Federal Service for Hydrometeorology and Environmental Monitoring of Russia (Roshydromet) in the Central Chernozem Region [11] and the data bank of Michurinsk agrometeorological station. The functional response of plants to various stress factors was evaluated based on the System for Functional Diagnostic of Fruit Plants using the IFSR-2 device (the fluorometric physiological status indicator) to determine the variable chlorophyll fluorescence in cells (Fv/Fm) that reflects the photosynthetic activity of cells and is expressed in relative units (RU) [12-14]. The dispersion of Fv/Fm value in one plant was calculated using the dispersion analysis method applied to the primary Fv/Fm values [14]. In each of the samples, at least 100 measurement points were considered and the resulting dispersion values were averaged. The dispersion of Fv/Fm in one plant serves as an independent indicator characterizing the stability of the functional systems of plants. This technique is described in detail in E.M. Tsukanova's book The Diagnostic System for Fruit Plants [14].

3. Results and discussion
Significant destabilization of both temperature and water conditions, as well as regular alternating of extreme weather periods, have become the main factors limiting the development of plants in the Central Chernozem Region over the last decades [15, 16]. The monitoring of weather conditions in 2020 showed significant deviations of the water and temperature conditions from the long-time annual averages.

![Figure 1. Water-temperature conditions of November, December 2019, and January 2020](image)

The most significant features of that year include the following:
- Abnormally high average daily temperatures in December 2019 - February 2020 (4-10°C higher than the long-time annual average) (Fig. 1);
- Abnormally high average daily temperatures in March (10-13°C above the long-time annual average) with medium and low air humidity, which provoked the early beginning of vegetation: bud scales started to burst in late March and early April (Fig. 1);
- Low (6-10°C below the long-time annual average) average daily temperatures combined with medium and high air humidity from April up to the first third of July, which also had negative impacts on the state of fruit plants and slowed down vegetation, prolonged the blossom time, and led to anomalies in fruit development (Fig. 2);
Figure 2. Water temperature conditions April-July 2020

- Favorable water and temperature conditions for the development of diseases in May and June and the weakening of the plants due to the weather anomalies resulted in a scab epiphytotic, while the dry and hot weather in late June and July caused a massive propagation of pests. Thus, according to N.Ya. Kashirskaya, plant protection lab supervisor and doctor of agriculture, scab developed on between 30 and 48% of the apple tree leaves and fruits (depending on the variety), and another 15-23% of the fruits were damaged by apple worms.

Figure 3. Water-temperature conditions of July-November 2020

- The alternation of hot (the maximum air temperature of +36.7°C) and cool (the maximum air temperature of +18.8 - +22.7°C) periods in July-September, and the significant drop between day and night temperatures (up to 19°C) resulted in a fast ripening and overripening of fruits and were one of the causes of yield losses incurred due to shedding (Fig. 2, 3);

- Low air humidity, especially in August – 1st-2nd thirds of October (almost no precipitation and air humidity 40-60% lower the standard for the period) had a negative impact on the preparation of fruit plants for winter lethargy, while the snap of cold temperature (up to -8.5°C) combined with the lack of snow cover in the second third of November resulted in damages to apple tree tissues (Fig. 3, 4);
The amplitude of the daily air temperature drop throughout the vegetation period was 3-4 times higher than the long-time annual average, which also had a negative impact on the functional state of apple trees (Fig. 5).

Thus, the water and temperature conditions in 2020 were rather complicated and had a negative impact on the functional state of apple trees. The monitoring of photosynthetic activity of apple tree tissues of Zhigulevskoye, Lobo, Sinap Orlovsky, Orlik, Bogatyry, Martovskoye, common Antonovka, and Ligol varieties showed significant deviations of Fv/Fm throughout the entire measurement period.
Starting from February, the Fv/Fm of Martovskoye and Ligol varieties reached 0.47-0.5 RU, which corresponds to the last third of March. By mid-March, this value for all of the varieties in questions reached 0.75-0.8 RU, which corresponds to the first or second thirds of May (Fig. 6).

The cold spells in April and the second third of May resulted in a dramatic reduction of photosynthetic activity until the process almost stopped (0.25-0.32 RU) (Fig. 6). We must note the high index dispersion in one plant, especially evident in Ligol variety, which signifies that all of the plant's functional systems are out of balance (Fig. 7). The growth of photosynthetic activity of leaves in late September and October up to 0.72-0.75 RU (the standard for this period is 0.5-0.4 RU) shows that the vegetation process was prolonged, increasing the risk of damaging the plants in winter. The high dispersion of Fv/Fm during the period further aggravates the situation.

Further on, Fv/Fm values were 20-40% lower than the standard throughout the vegetation season, i.e. the functional state of apple trees was rather low (Fig. 8).
Among the varieties analyzed, Ligol and Sinap Orlovsky had the lowest values. The leaves of Bogatyry and common Antonovka varieties featured higher average photosynthetic activity throughout the vegetation period. They also had the lowest value dispersion in one plant. All of the above signifies that these two varieties are well-prepared against winter stress factors, while Ligol and Sinap Orlovsky feature very high damage risks.

4. Conclusions
The water and temperature conditions in 2020 featured multiple deviations from the long-time annual averages, the most significant of which include the abnormally dry February and March, cold and humid May, as well as the alternation of hot and cold spells and dramatic temperature drops between days and nights.

The analysis of physiological parameters of various apple tree varieties showed the following:
- Abnormal early beginning of plant growth;
- The inhibition of vegetation and prolonged blossom time due to the cold spells in May and early June;
- The suppression of photosynthesis in July due to high air temperatures and low precipitation;
- The prolonged vegetation and late beginning of winter lethargy due to the long period of high temperatures and favorable humidity in October.

References
[1] Hänninen H 2016 The Annual Cycle Under Changing Climatic Conditions, Boreal and Temperate Trees in a Changing Climate: Modelling the Ecophysiology of Seasonality Springer, Netherlands, Dordrecht pp 263-335
[2] Bellante G J, Powell S L, Lawrence R L, Repasky K S and Dougher T 2014 Hyperspectral Detection of a Subsurface CO$_2$ Leak in the Presence of Water Stressed Vegetation PloS one 9(10) e108299
[3] Legave J-M, Guédon Y, Malagi G, El Yaacoubi A, Bonhomme M 2015 Differentiated responses of apple tree floral phenology to global warming in contrasting climatic regions Front. Plant Sci. 6 1054
[4] Bita C E and Gerats T 2013 Plant tolerance to high temperature in a changing environment: scientific fundamentals and production of heat stress-tolerant crops Frontiers in Plant Science. Crop Science and Horticulture 4 1-18
[5] Matveev S 2003 Dendroindication of the dynamics of the state of pine plantations in the Central Forest-Steppe (Voronezh: VSU) 272 p

[6] Vitra A, Lenz A, and Vitasse Y 2017 Frost hardening and dehardening potential in temperate trees from winter to budburst New Phytol. 216 (1) 113-123

[7] Kashirskaya N Ya, Kochkina A M 2019 Modern systems for protecting apple tree plantations from scab Achievements of science and technology of the agro-industrial complex 33(2) 50-51

[8] Polukhin A A, Knyazev S D, Efremov I A 2020 The Conceptual Model of Innovative Development of Industrial Gardening Studies in Systems, Decision, and Control 282 333-345

[9] Grigoreva L V 2015 Agrobiological aspects of increasing the productivity of apple trees in plantations of the Central Development Commission of the Russian Federation: doctoral dissertation (Michurinsk) 446 p

[10] Grigoreva L V 2018 Biological Growth Peculiarities of the Cuttings of Various Rootstocks in a Horizontal nursery International Journal of Pharmaceutical Research and Allied Sciences 10(4) 632-640

[11] Meteorological data archives 1931-2017 “Tsentral'no-Chernozemnoye UGMS” (Tambov and Voronezh)

[12] Genty B, Briantais J M and Baker N R 1989 The relationship between the quantum yield of photosynthetic electron transport and quenching of chlorophyll fluorescence Biochimica et Biophysica Acta 990 87-92

[13] Gitelson A, Chivkunova O, Zhigalova T, Solovchenko A 2017 In situ optical properties of foliar flavonoids: implication for non-destructive estimation of flavonoid content Journal of Plant Physiology 218 258–264

[14] Tsukanova E 2011 System for diagnosing the state of fruit plants. Express diagnostics of the functional state of plants and evaluation of the effectiveness of the technology (Lap Lambert Academic Publishing) 292 p

[15] Tsukanova E and Tkachev E 2009 Diagnosis of damages of apple plants in the early stages of the development of the reaction Agro XXI 10-12 8-10

[16] Tsukanova E and Tkachev E 2019 Altered climate dynamics in the East-European forest-steppe incites fruit plants injury IOP Conf. Ser.: Earth Environ. Sci. 226 012034