УДК 634.11:631.524.82

4.1.4. Садоводство, овощеводство, виноградарство и лекарственные культуры (сельскохозяйственные науки)

# ВЛИЯНИЕ СХЕМ РАЗМЕЩЕНИЯ НА УСТОЙЧИВОСТЬ РАСТЕНИЙ ЯБЛОНИ К АБИОТИЧЕСКИМ СТРЕССОРАМ

Захарченко Анастасия Валерьевна
Аспирант
РИНЦ SPIN-код: 6618-6530

Чумаков Сергей Семенович
Доктор с.-х. наук, профессор
РИНЦ SPIN-код: 1785-8634
*Федеральное государственное бюджетное образовательное учреждение высшего образования «Кубанский государственный аграрный университет имени И.Т. Трубилина», Краснодар, Россия*

В статье представлены результаты изучения влияния схем посадки на устойчивость растений яблони сортов Ренет Симиренко, Голден Делишес Рейнджерс, Кубанское багряное, Фуджи, Гала (подвой М9) к абиотическим стрессорам в условиях прикубанской зоны садоводства в 2019–2024 гг. Варианты опыта: 4,0 × 1,5 м (контроль), 4,0 × 0,5 м, 4,0 × 1,0 м. У 4-х летних растений сортов Ренет Симиренко и Голден Делишес Рейнджерс наибольшая оводненность листьев наблюдалась во 2 декаде августа при контрольной схеме посадки, разница с опытными схемами посадки составила 2,5–8,8 %. У данных сортов отмечен наименьшие водный дефицит и водопотери в контроле, как и у сорта Гала. Наибольшая оводненность и наименьший водный дефицит листьев сортов Кубанское багряное и Фуджи отмечены при схеме посадки 4,0 × 1,0 м, наименьшие водопотери – при контрольной схеме посадки. В 8-ми летнем возрасте у растений сортов Ренет Симиренко и Голден Делишес Рейнджерс не обнаружено отрицательного влияния схем посадки на показатели засухоустойчивости. У растений сортов Кубанское багряное, Фуджи, Гала наибольшая засухоустойчивость отмечена при менее плотных схемах посадки. Содержание сахарозы и пролина у растений сорта Голден Делишес Рейнджерс повышается в вариантах опыта с менее плотными схемами размещения. Отмечено повышенное содержание сахарозы и пролина в варианте с сортом Фуджи, размещенным по схеме посадки 4,0 × 1,0 м. Растения сортов Ренет Симиренко, Голден Делишес Рейнджерс и Гала в 4-х летнем возрасте обладают большей морозоустойчивостью в уплотненных посадках, сорта Кубанское багряное и Фуджи, более

UDC 634.11:631.524.82

4.1.4. Horticulture, vegetable growing, viticulture and medicinal crops (agricultural sciences)

# INFLUENCE OF CULTIVATION SCHEMES ON THE RESISTANCE OF APPLE PLANTS TO ABIOTIC STRESSORS

Zakharchenko Anastasia Valerievna
Graduate student
RSCI SPIN code: 6618-6530

Chumakov Sergey Semenovich
Doctor of Agricultural Sciences, Professor
RSCI SPIN code: 1785-8634
*Federal State Budgetary Educational Institution of Higher Education "Kuban State Agrarian University named after I.T. Trubilin", Krasnodar, Russia*

The article presents the results of studying the effect of planting patterns on the resistance of apple trees of the Renet Simirenko, Golden Delicious Rangers, Kubanskoe Bagryanoe, Fuji, Gala varieties (rootstock M9) to abiotic stressors in the conditions of the Kuban horticultural zone in 2019–2024. Experimental variants: 4.0 × 1.5 m (control), 4.0 × 0.5 m, 4.0 × 1.0 m. In 4-year-old plants of the Renet Simirenko and Golden Delicious Rangers varieties, the highest leaf water content was observed in the 2nd decade of August with the control planting pattern, the difference with the experimental planting patterns was 2.5–8.8%. These varieties showed the lowest water deficit and water loss in the control, as well as in the Gala variety. The highest water content and the lowest water deficit of leaves of the Kubanskoe Bagryanoe and Fuji varieties were noted with the planting scheme of 4.0 × 1.0 m, the lowest water losses were with the control planting scheme. At the age of 8 years, no negative effect of planting schemes on drought resistance indicators was found in the plants of the Renet Simirenko and Golden Delicious Rangers varieties. In the plants of the Kubanskoe Bagryanoe, Fuji, Gala varieties, the highest drought resistance was noted with less dense planting schemes. The content of sucrose and proline in Golden Delicious Rangers plants increases in the experimental variants with less dense planting schemes. Increased sucrose and proline content was noted in the variant with the Fuji variety, planted according to the 4.0 × 1.0 m planting scheme. Plants of the Renet Simirenko, Golden Delicious Rangers and Gala varieties at the age of 4 years have greater frost resistance in dense plantings, the Kubanskoe Bagryanoe and Fuji varieties are more frost-resistant in less dense plantings. At the age of 8 years, the Golden Delicious Rangers variety showed greater морозостойки в менее плотных посадках. В 8-ми летнем возрасте сорт Голден Делишес Рейнджерс проявил большую морозостойкость при схеме посадки 4,0 × 0,5 м, остальные – при контрольной схеме размещения

frost resistance with the 4.0 × 0.5 m planting scheme, the rest - with the control placement scheme

Ключевые слова: ЯБЛОНЯ, СХЕМЫ РАЗМЕЩЕНИЯ, ЗАСУХОУСТОЙЧИВОСТЬ, МОРОЗОСТОЙКОСТЬ, САХАРОЗА, ПРОЛИН

Keywords: APPLE TREE, PLACEMENT SCHEMES, DROUGHT RESISTANCE, FROST RESISTANCE, SUCROSE, PROLINE

http://dx.doi.org/10.21515/1990-4665-209-067

## Introduction

During the growing season, fruit plants are often exposed to the negative impact of various environmental stress factors. Regular droughts in fruit crop cultivation areas, extreme temperatures and frequent temperature fluctuations are among the most significant environmental determinants limiting the growth and development of fruit plants worldwide [1].

In the south of Russia, the summer vegetation period of plants is characterized by frequent droughts, consistently high temperatures during the daytime and high solar activity, which disrupts the production process and causes significant losses in the yield of fruit crops.In autumn, elevated air temperatures combined with high soil moisture prolong the growth processes of perennial fruit crops and delay their transition to a dormant period. In wintersudden changes in temperature, sudden frostscause damage and death of fruit buds and cracking of wood.

One of the main strategies for sustainable production of fruit products under conditions of strong impact of abiotic stress factors is the improvement of agricultural practices for cultivating fruit plants [2]. Thus, it is known thatthe conditions and microclimate that develop in dense plantings are more favorable for the growth and development of trees, as they increasetheir resistance to adverse environmental factors[3, 4]. For example, in dense plantings, trees are less damaged by frost, since during the growing season there is a general weakening of the growth activity of plants, early termination of shoot growth, better ripening and preparation for winter [3]. Strongly illuminated plants can be damaged by sunlight, too intense sun can suppress photosynthetic processes [5].

So, in the period 2019–2024A study was conducted on the influence of dense planting patterns of apple trees of different varieties on resistance to stress factors of the summer and winter periods in the Kuban gardening zone.

**Objects and methods of research**

The studies were conducted in the period 2019–2024 in irrigated high-density apple tree plantings of 2016 using intensive cultivation technology in the conditions of the Kuban training farm (Kuban State Agrarian University) of the Kuban horticultural zone.The objects of the research are apple trees of the varieties Renet Simirenko, Golden Delicious Rangers, Kubanskoe Bagryanoe, Fuji, Gala, grafted onto the dwarf rootstock M9.

The experimental variants included the following layout schemes: 4.0 × 1.5 m (control), 4.0 × 0.5 m, 4.0 × 1.0 m. The variants were repeated six times. The plot size was tree – plot.

The main surveys, observations, field and laboratory experiments were carried out according to“Records, observations, analysis, and data processing in experiments with fruit and berry plants” (Uman, 1987), «The program and methodology for studying varieties of fruit, berry and nut crops” (Orel, 1999), the teaching aid “Planning research in fruit growing” (Krasnodar, 2016) [6, 7, 8].

To determine proline and sucrose, modern methods of studying the physiological and biochemical parameters of plant tissues were used using highly efficient analytical equipment based on the Instrumentation and Analytical Center and the Laboratory of Plant Physiology and Biochemistry of the Federal State Budgetary Scientific Institution North Caucasian Regional Research Institute of Horticulture and Viticulture [9, 10].

**Results and discussion**

The assessment of the drought resistance parameters of apple trees was carried out in the second and third age periods of the life of fruit trees (according to Schitt). The second period of growth and development of apple trees is characterized by active vegetative growth of trees, the beginning of fruiting and subsequent increase in the fruit yield. The third age period is characterized by the completion of the formation of the crown skeleton, a decrease in vegetative growth, and the onset of stable fruiting [11, 12, 13].

It should be noted that due to the use of a drip irrigation system, the soil moisture in the garden during the study periods was optimal for the cultivation of apple trees – within 70–85% of the field moisture capacity [13]. However, despite the favorable soil moisture indicators, which have a positive effect on the resistance of plants to unfavorable environmental factors, the high temperature regime and low relative air humidity, typical for the study area, can neutralize the role of soil moisture in the resistance of apple trees to drought.

The hydrometeorological conditions of the vegetation periods of the studied years varied significantly. Thus, in 2019 (the 4th year after planting apple trees and the second age period), the average June temperature was 4.8 °C higher than the average long-term norm, the amount of precipitation was 52% of the norm, the relative air humidity was 56.0%, which is 16.0% lower than normal values, respectively, dry conditions for plant growth developed, which is confirmed by the hydrothermal coefficient (HTC) equal to 0.5 (Table 1).

Table 1 – Hydrometeorological conditions of the growing seasons of 2019 and 2023.

| Year/month | 2019 | | | 2023 | | | Wed perennial. | | |
|---|---|---|---|---|---|---|---|---|---|
| | June | July | August | June | July | August | June | July | August |
| Air temperature, °C | 25.3 | 22.9 | 23.6 | 21.8 | 24.5 | 27.1 | 20.5 | 23.1 | 22.6 |
| Total precipitation, mm | 34.7 | 130.3 | 74.4 | 40.9 | 61.7 | 0,0 | 67.0 | 60.0 | 48.0 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Humidity, % | 56.0 | 63.0 | 54.0 | 71.0 | 59.0 | 50.0 | 67.0 | 58.0 | 64.0 |
| State Customs Committee | 0.5 | 1.8 | 1.0 | 0.6 | 0.8 | 0,0 | – | – | – |

Moisture supply in July was excessive with HTC = 1.8. The average temperature differed slightly from the norm, the relative air humidity exceeded the long-term average values by 8.6%, the amount of precipitation was more than twice the climatic norm. Hydrometeorological conditions in August were optimal for the growth and development of apple trees with HTC = 1.0 (sufficient moisture). The air temperature was 1.0 °C higher than the climatic norm, the amount of precipitation was 155.0% of the long-term average values, the relative air humidity exceeded the norm by 16.0%.

The summer conditions of 2023 (the 8th year after planting the apple trees and the third age period) were quite dry. In June, the air temperature deviations from the norm were +1.3 °C, the amount of precipitation was 61.0% of the long-term average, the relative air humidity exceeded the norm by 6.0% with an HTC of 0.6, which corresponds to a zone with insufficient moisture supply. July was more humid with an HTC of 0.8. The temperature differed from the norm by +1.4 °C, the amount of precipitation and relative air humidity were within the climatic norm. In August, extreme weather conditions for the growth and development of apple trees were noted, characterized by abnormally high temperatures, prolonged absence of precipitation and low relative air humidity. The temperature exceeded the norm by 4.5 °C, there was no precipitation, the relative air humidity was 50.0%, which is 22.0% below the norm.

Dry weather conditions typical for the south of Russia can have a negative impact on the development and productivity of apple trees [13, 14, 15]. Water deficit due to lack of precipitation and high evaporation of water from leaves during transpiration leads to a decrease in cell turgor, inhibition of photosynthesis and slowdown of growth processes. Heat stress against the background of high temperatures causes damage to cell membranes, protein breakdown, disruption of enzymes, and can contribute to a decrease in the quantity and quality of the fruit harvest. Low air humidity increases transpiration losses, aggravating the water imbalance. Summer droughts have a particularly negative impact on the preparation of fruit plants for the winter period [14].

In order to study the characteristics of the water regime of apple trees in dense planting patterns, an assessment was made of the dynamics of leaf water content during the summer growing seasons of 2019 and 2023 (Table 2).

Table 2 – Effect of placement patterns on the water content of apple tree leaves of different varieties, %

| Variety | Planting scheme | 2019 | | | | 2023 | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 2nd decade of June | 2nd decade of July | 2nd decade of August | average | 2nd decade of June | 2nd decade of July | 2nd decade of August | average |
| Renet Simirenko | 4.0 x 1.5 m (k) | 63.1 | 58.5 | 58.0 | 59.9 | 70.5 | 58.5 | 53.0 | 60.7 |
| | 4.0 x 0.5 m | 68.5 | 57.5 | 52.9 | 59.6 | 69.3 | 57.2 | 54.5 | 60.3 |
| | 4.0 x 1.0 m | 66.4 | 58.1 | 54.9 | 59.8 | 66.1 | 60.7 | 56.2 | 61.0 |
| Golden Delicious Rangers | 4.0 x 1.5 m (k) | 69.0 | 64.2 | 56.5 | 63.2 | 66.2 | 60.2 | 53.6 | 60.0 |
| | 4.0 x 0.5 m | 65.8 | 57.8 | 52.3 | 58.6 | 65.0 | 63.4 | 52.9 | 60.4 |
| | 4.0 x 1.0 m | 69.3 | 59.9 | 55.1 | 61.4 | 67.5 | 56.2 | 49.8 | 57.8 |
| Kuban crimson | 4.0 x 1.5 m (k) | 65.4 | 59.2 | 57.9 | 60.8 | 69.7 | 67.5 | 56.2 | 64.5 |
| | 4.0 x 0.5 m | 69.4 | 60.0 | 53.1 | 60.8 | 60.6 | 56.2 | 51.3 | 56.0 |
| | 4.0 x 1.0 m | 66.2 | 61.5 | 60.2 | 62.6 | 67.5 | 62.4 | 55.1 | 61.7 |
| Fuji | 4.0 x 1.5 m (k) | 65.3 | 58.8 | 57.3 | 60.5 | 61.6 | 58.6 | 55.4 | 58.5 |
| | 4.0 x 0.5 m | 67.1 | 59.0 | 53.1 | 59.7 | 55.2 | 50.4 | 47.6 | 51.1 |
| | 4.0 x | 68.3 | 60.0 | 59.4 | 62.6 | 60.5 | 58.3 | 52.5 | 57.1 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1.0 m | | | | | | | | |
| Gala | 4.0 x 1.5 m (k) | 72.0 | 68.0 | 62.3 | 67.4 | 68.4 | 65.2 | 58.3 | 64.0 |
| | 4.0 x 0.5 m | 65.2 | 61.4 | 52.1 | 59.6 | 62.4 | 59.6 | 50.5 | 57.5 |
| | 4.0 x 1.0 m | 60.4 | 61.4 | 58.5 | 60.1 | 68.0 | 62.8 | 57.5 | 62.8 |

It was noted that in the summer period of 2019, the water content of the leaves of the apple trees in all experimental variants was average and fluctuated within 52.5–72.0%. Among the group of medium-sized varieties (Renet Simirenko and Golden Delicious Rangers), the following pattern was noted: with increasing thermal stress in July and August, the highest leaf water content was observed with the control planting scheme, for the Renet Simirenko variety, a significant difference with the control - 5.3 and 8.8%, was established in August, for the Golden Delicious Rangers variety, the difference with the experimental variants with less dense placement of trees was 6.7 and 9.9% in July and 2.5 and 7.4% in August. Also, the best leaf water content with the control planting scheme was shown by the vigorous variety Gala - on average, over the months of observations, the difference with the experimental variants with denser placement schemes was 10.8–11.6%. The highest water content of the leaves of the vigorous varieties Kubanskoe Bagryanoe and Fuji was noted with a planting scheme of 4.0 × 1.0 m - the difference with the control was 3.0–3.5%, respectively.

The study of the leaf water content of the Renet Simirenko variety in the summer of 2023 showed an insignificant difference between the experimental variants, which may indicate that the compaction of plants of this variety does not have a negative effect on the resistance of plants to drought. The leaf water content of the Golden Delicious Rangers variety with a planting scheme of 4.0 × 0.5 m also differed slightly from the control variant of the experiment and was 4.5% higher than in the experimental variant with a planting scheme of 4.0 × 1.0

m. In the group of vigorous varieties, the highest water content was noted in the control - the difference with a denser placement of trees varied within 1.9–13.2%.

The total leaf water content index does not allow for a comprehensive description of the water regime of plants; for a comprehensive assessment of drought resistance, the water deficit of apple tree leaves was additionally determined in field and laboratory conditions. Water deficit is a state of insufficient saturation of cells with water, which occurs due to an imbalance between intensive transpiration and limited absorption of moisture from the soil.

Among the group of medium-sized varieties in the second age period of tree growth and development, the lowest water deficit of leaves was noted in the control variant, the difference with the experimental variants was 34.5–46.3%. When studying this indicator in the third age period, its change in favor of denser placement schemes was observed. Thus, the lowest water deficit in the leaves of the Renet Simirenko variety was noted with a planting scheme of 4.0 × 1.0 m - the difference with the control was 24.0%. The lowest water deficit of leaves of the Golden Delicious Rangers variety was noted with schemes of 4.0 × 0.5 m and 4.0 × 1.0 m - the difference with the control was 9.9 and 6.9%, respectively (Table 3).

Table 3 – Effect of placement schemes on water deficit of apple tree leaves of different varieties, %

| Variety | Planting scheme | 2019 | | | | 2023 | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 2nd decade of June | 2nd decade of July | 2nd decade of August | average | 2nd decade of June | 2nd decade of July | 2nd decade of August | average |
| Renet Simirenko | 4.0 x 1.5 m (k) | 7.5 | 3.0 | 6.1 | 5.5 | 11.2 | 7.4 | 13.8 | 10.8 |
| | 4.0 x 0.5 m | 8.2 | 4.4 | 9.5 | 7.4 | 8.6 | 6.1 | 13.1 | 9.3 |
| | 4.0 x 1.0 m | 9.2 | 4.1 | 8.8 | 7.4 | 4.8 | 8 | 11.9 | 8.2 |
| Golden Delicious Rangers | 4.0 x 1.5 m (k) | 6.6 | 2.1 | 7.4 | 5.4 | 4.9 | 8 | 17.5 | 10.1 |
| | 4.0 x 0.5 m | 10.8 | 3.7 | 9.2 | 7.9 | 6.2 | 5.4 | 15.7 | 9.1 |
| | 4.0 x 1.0 m | 7.5 | 5.5 | 9.0 | 7.3 | 7.5 | 6.2 | 14.5 | 9.4 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Kuban crimson | 4.0 x 1.5 m (k) | 6.0 | 2.8 | 12.4 | 7.1 | 6.8 | 5.2 | 10.6 | 7.5 |
| | 4.0 x 0.5 m | 11.0 | 7.1 | 10.6 | 9.6 | 13.4 | 11.5 | 17.4 | 14.1 |
| | 4.0 x 1.0 m | 4.7 | 7.0 | 8.4 | 6.7 | 3.6 | 7.8 | 12.3 | 7.9 |
| Fuji | 4.0 x 1.5 m (k) | 7.2 | 6.4 | 8.1 | 7.2 | 4.6 | 3.2 | 11.4 | 6.4 |
| | 4.0 x 0.5 m | 11.6 | 5.7 | 10.5 | 9.3 | 13.2 | 9.3 | 15.5 | 12.7 |
| | 4.0 x 1.0 m | 5.4 | 2.8 | 7.4 | 5.2 | 6.8 | 10.4 | 12.7 | 10.0 |
| Gala | 4.0 x 1.5 m (k) | 8.5 | 3.1 | 5.2 | 5.6 | 5.0 | 11.5 | 13.0 | 9.8 |
| | 4.0 x 0.5 m | 10.3 | 5.4 | 11.6 | 9.1 | 9.2 | 12.4 | 18.5 | 13.4 |
| | 4.0 x 1.0 m | 11.2 | 6.0 | 9.0 | 8.7 | 3.2 | 8.6 | 17.1 | 9.6 |

The vigorous Fuji variety had a lower water deficit of leaves with a larger planting scheme - the difference with the compacted experimental variants was 98.4 and 56.2%. The Kubanskoe Bagryanoe and Gala varieties had a lower water deficit with planting schemes of 4.0 × 1.5 m and 4.0 × 1.0 m, the difference between the indicators was not significant.

Also, one of the most important parameters of drought resistance is water-holding capacity, which shows the ability of plants to resist dehydration. The water-holding capacity of apple leaves was determined after 4 hours of wilting (Table 4).

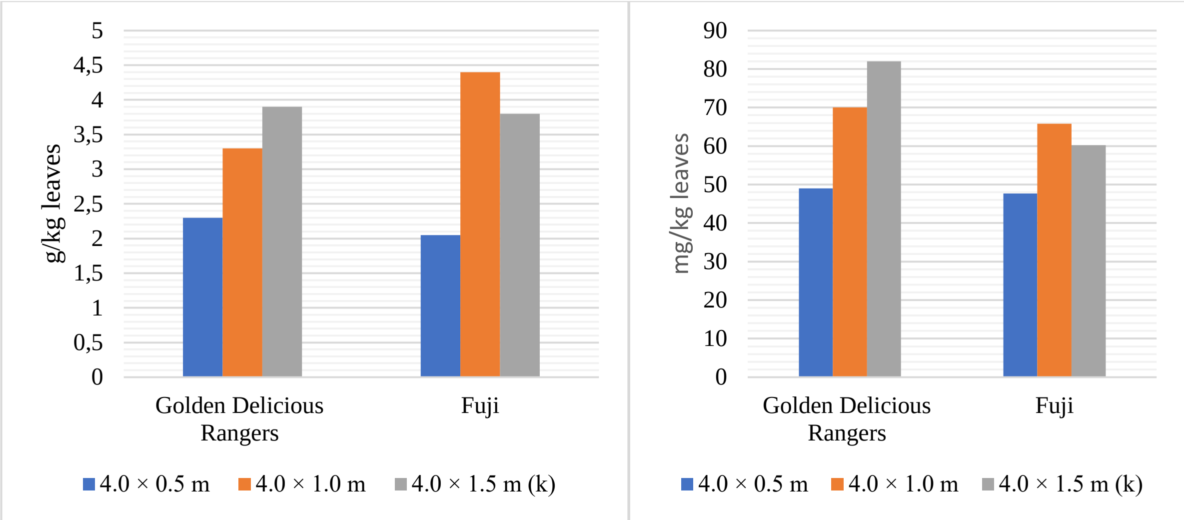
Table 4 – Effect of placement patterns on the water-holding capacity of apple tree leaves of different varieties, %

| Variety | Planting scheme | 2019 | | | | 2023 | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 2nd decade of June | 2nd decade of July | 2nd decade of August | average | 2nd decade of June | 2nd decade of July | 2nd decade of August | average |
| Renet Simirenko | 4.0 x 1.5 m (k) | 11.3 | 5.2 | 13.3 | 9.9 | 16.3 | 12.6 | 25.2 | 18.0 |
| | 4.0 x 0.5 m | 15.6 | 8.1 | 15.2 | 13.0 | 13.8 | 15.3 | 23.6 | 17.6 |
| | 4.0 x 1.0 m | 14.8 | 6.4 | 13.0 | 11.4 | 12.5 | 11.2 | 19.4 | 14.4 |
| Golden Delicious Rangers | 4.0 x 1.5 m (k) | 13.9 | 5.5 | 12.2 | 10.5 | 18.0 | 18.6 | 29.1 | 21.9 |
| | 4.0 x 0.5 m | 16.5 | 7.6 | 14.9 | 13.0 | 14.4 | 17.5 | 27.4 | 19.8 |
| | 4.0 x 1.0 m | 17.9 | 6.3 | 13.1 | 12.4 | 18.2 | 15.0 | 30.4 | 21.2 |
| Kuban crimson | 4.0 x 1.5 m (k) | 8.2 | 6.6 | 10.5 | 8.4 | 10.5 | 9.8 | 13.4 | 11.2 |
| | 4.0 x 0.5 m | 14.4 | 7.5 | 14.3 | 12.1 | 15.3 | 12.6 | 22.6 | 16.8 |
| | 4.0 x 1.0 m | 12.0 | 6.2 | 15.6 | 11.3 | 8.4 | 9.5 | 17.6 | 11.8 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Fuji | 4.0 x 1.5 m (k) | 8.4 | 6.6 | 9.1 | 8.0 | 13.0 | 11.4 | 15.7 | 13.4 |
| | 4.0 x 0.5 m | 9.6 | 6.8 | 14.5 | 10.3 | 15.2 | 16.3 | 21.2 | 17.6 |
| | 4.0 x 1.0 m | 10.3 | 5.9 | 12.8 | 9.7 | 15.0 | 12.5 | 19.2 | 15.6 |
| Gala | 4.0 x 1.5 m (k) | 9.5 | 7.2 | 13.4 | 10.0 | 15.1 | 14.2 | 29.3 | 19.5 |
| | 4.0 x 0.5 m | 11.2 | 5.9 | 17.6 | 11.6 | 17.3 | 22.6 | 28.2 | 22.7 |
| | 4.0 x 1.0 m | 10.7 | 6.5 | 16.1 | 11.1 | 13.0 | 19.1 | 21.6 | 17.9 |

It was determined that in the summer period of 2019, the highest water-holding capacity was shown by apple trees of all the studied varieties, located according to the control planting scheme. In 2023, the highest water-holding capacity of the leaves of the Renet Simirenko variety was noted with a planting scheme of 4.0 × 1.0 m - the difference with the control was 20.0%, the Golden Delicious Rangers variety with a planting scheme of 4.0 × 0.5 m - the difference with the control was 9.6%. Also, the lowest water losses when compacted to 1.0 m in a row were noted for the Gala variety - the difference with the control was 8.2%. The highest water-holding capacity of the Kubanskoye Bagryanoye variety was shown with planting schemes of 4.0 × 1.5 m and 4.0 × 1.0 m, the difference between which was insignificant. Lower water losses in the Fuji variety were observed with the control planting scheme – the difference with the experimental variants was 16.4–31.3%.

Biochemical adaptation of domestically bred apple varieties to abiotic factors of the summer period is achieved by synthesizing an increased amount of protective compounds - proline, sucrose. The results of studying these indicators are shown in Figure 1 (using the Golden Delicious Rangers and Fuji varieties as an example).




A b

Figure 1 – Comparative characteristics of biochemical parameters of apple trees using the Golden Delicious Rangers and Fuji varieties as an example, depending on the plant placement scheme:
a – sucrose content, g/kg leaves; b – proline content, mg/kg leaves

The increase in sucrose content by 15.8–114.6% and proline by 9.3–37.9% in the variant with the Fuji variety, planted according to the 4.0 × 1.0 m planting scheme, indicates greater drought resistance of plants, compared to other experimental variants. On the contrary, drought resistance of Golden Delicious Rangers plants increases in experimental variants with less dense planting schemes – the sucrose content increases to 69.6%, proline – to 67.3%.

It is known that relatively winter-hardy varieties are characterized by lower tissue water content and its sharp decrease in winter. Thus, to study the degree of frost resistance of plants of the studied varieties depending on the compaction of plantings, the water content of apple tree shoots was assessed in the 2nd decade of December 2020 and the 3rd decade of January 2024 (Table 5).

Table 5 – Effect of placement patterns on water content of shoots of apple trees of different varieties, %

| Variety | Planting scheme | 2020 | 2024 |
|---|---|---|---|
| Renet Simirenko | 4.0 x 1.5 m (k) | 47.9 | 44.4 |
| | 4.0 x 0.5 m | 43.6 | 49.6 |
| | 4.0 x 1.0 m | 46.2 | 47.3 |
| Golden Delicious Rangers | 4.0 x 1.5 m (k) | 49.7 | 53.5 |
| | 4.0 x 0.5 m | 44.9 | 50.6 |
| | 4.0 x 1.0 m | 48.3 | 51.8 |
| Kuban crimson | 4.0 x 1.5 m (k) | 41.8 | 47.4 |
| | 4.0 x 0.5 m | 52.7 | 55.7 |
| | 4.0 x 1.0 m | 40.5 | 52.6 |
| Fuji | 4.0 x 1.5 m (k) | 48.4 | 52.9 |
| | 4.0 x 0.5 m | 56.3 | 56.4 |
| | 4.0 x 1.0 m | 46.2 | 56.0 |
| Gala | 4.0 x 1.5 m (k) | 53.9 | 51.3 |
| | 4.0 x 0.5 m | 50.6 | 57.5 |
| | 4.0 x 1.0 m | 53.5 | 54.9 |

It was noted that under the winter conditions of 2020, plants of the Renet Simirenko, Golden Delicious Rangers, and Gala varieties had greater frost resistance (in terms of shoot water content) in denser plantings — the difference with other experimental options was up to 9.6%. On the contrary, plants of the Kubanskoye Bagryanoye and Fuji varieties, planted according to the 4.0 × 0.5 m planting scheme, were characterized by lower frost resistance: compared to other experimental options, the water content was 16.3–30.1% lower. The difference between the 4.0 × 1.0 and 4.0 × 1.5 m planting schemes was insignificant. Under the winter conditions of 2024, the lowest shoot water content with the densest planting scheme was observed in Golden Delicious Rangers plants — the difference with the control was 5.4%. The remaining varieties showed the greatest frost resistance under the control planting scheme.

## Conclusion

The study of the parameters of apple plant resistance to abiotic stressors allowed us to identify varieties that are least susceptible to the influence of unfavorable factors with dense planting. In the second age period of growth and development of fruit plants, the highest leaf water content, lower water deficit and greater water-holding capacity were noted in the group of medium-sized varieties Renet Simirenko and Golden Delicious Rangers when planted according to the 4.0 × 1.5 m planting scheme (control), which allows us to consider them more drought-resistant with a more sparse planting. The content of sucrose and proline in plants of the medium-sized Golden Delicious Rangers variety increases in the experimental variants with less dense planting schemes, which confirms the fact of its drought resistance with less dense planting schemes. In the third age period of growth and development of apple plants, it was revealed that compaction of plants of the Renet Simirenko and Golden Delicious Rangers varieties does not have a negative effect on the resistance of plants to drought.

In the group of vigorous varieties in the second and third age periods of growth and development of apple trees, the plants showed the greatest resistance to drought when placed on planting schemes of 4.0 × 1.0 m and 4.0 × 1.5 m (control). Strong compaction had a negative effect on the drought resistance indicators of plants of these varieties. An increased content of sucrose and proline was determined in the variant with the vigorous Fuji variety, placed according to the planting scheme of 4.0 × 1.0 m, which indicates greater drought resistance of plants in this variant of the experiment.

In the second age period, plants of the Renet Simirenko, Golden Delicious Rangers and Gala varieties have greater frost resistance in dense plantings, while the Kubanskoe Bagryanoe and Fuji varieties, on the contrary, are more frost-resistant in less dense plantings. In the third age period, the Golden Delicious Rangers variety showed greater frost resistance with a planting scheme of 4.0 × 0.5 m, the rest - with a control placement scheme.

**References**

1. Doroshenko T.N. Resistance of fruit and ornamental plants to temperature stressors: diagnostics and ways of improvement: Monograph / T.N. Doroshenko, N.V. Zakharchuk, D.V. Maksimtsov - Krasnodar: Kuban State Agrarian University, 2014. – 174 p.

2. Li X. et al. Insights into the molecular mechanisms underlying responses of apple trees to abiotic stresses //Horticulture research. – 2023. – T. 10. – No. 8. – S. uhad144.

3. Grigorieva L.V. Agrobiological aspects of increasing apple productivity in plantations of the Central Black Earth Region of the Russian Federation: dis. … Doctor of Agricultural Sciences: 06.01.08 / Grigorieva Lyudmila Viktorovna. Michurinsk, 2015. 426 p.

4. Koltunov, V.G. Ways of intensification of fruit growing / V.G. Koltunov, V.I. Cherepakhin // Works / Kuban Agricultural Institute. - Krasnodar, 1972. - Issue. 62. - P. 101-104.

5. Laužikė K. et al. Orchard planting density and tree development stage affects physiological processes of apple (Malus domestica Borkh.) tree //Agronomy. – 2020. – T. 10. – No. 12. – S. 1912.

6. Program and methodology for studying varieties of fruit, berry and nut crops / edited by E.N. Sedov, T.P. Ogoltsova. Orel: VNIISPK, 1999. – 608 p.

7. Ryazanova L. G. Research planning in fruit growing [Text]: a tutorial / L. G. Ryazanova, I. V. Gorbunov // Ministry of Agriculture of the Russian Federation, Federal State Budgetary Educational Institution of Higher Professional Education "Kuban State Agrarian University". – Krasnodar: KubSAU, 2016. – 93 p.: ill.

8. Records, observations, analyses, data processing in experiments with fruit and berry plants: Methodological recommendations / Edited by G.K. Karpenchuk and A.V. Melnik. – Uman: Uman. Agricultural Institute, 1987. – 115 p.

9. Nenko N.I., Ilyina I.A., Petrov V.S., Sundyreva M.A. Physiological and biochemical methods for studying initial and selection material / Modern methodological aspects of organizing the selection process in horticulture and viticulture // Krasnodar: SKZNIISiV. 2012. P. 530–540.

10. Nenko, N.I., Ilyina, I.A., Vorobyova, T.N. [et al.] Modern instrumental and analytical methods for studying fruit crops and grapes / Under the general editorship of N.I. Nenko. - Krasnodar: SKZNIISiV, 2015. – 115 p.

11. Ulyanishchev M.M. Apple tree. – M.: Kolos, 1968 – 319 p.

12. Schitt P.G. Age periods of woody and shrubby fruit plants // Selected works. – M.: Kolos, 1968. - P. 168–180.

13. Fruit growing / Ed. by V.A. Kolesnikov. – M.: Kolos, 1979. – 415 p.

14. Kushnirenko M.D. Physiology of water exchange and drought resistance of fruit plants, 1975.