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PHYSIOLOGICAL STATE OF PLANTS AND QUALITY OF PLUM FRUITS GRAFTED ON THE ROOTSTOCKS OF VARIOUS STRENGTH OF GROWTH DEPENDING ON THE PLANT NUTRITION MODE

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ABSTRACT
The influence of the nutrition mode on the physiological state, productivity, and quality of the plum harvest of the Stanley variety on the rootstocks of various strengths of growth was investigated. The fertilizer system included the intra-soil application of the complex organic-mineral fertilizer based on peat and non-root dressings combined with the "Novosil" phytoregulator. The nutrition mode of plum plants was studied by the method of gross content diagnostics of elements in leaves and fruits. The significant increase of nitrogen and phosphorus content, number of functional pigments, free amino acids, and protein synthesis, especially in plants on the rootstock Best, was established during the period of the intensive shoot and ovary growth. In the early summer, the increase of calcium content and decrease of secondary metabolite one was found against the background of a decline of growth activity in plum leaves on the dwarf and medium rootstocks. The statistically reliable positive correlation between nitrogen, potassium, calcium and their content in plum fruits on the rootstock VVA 1 ($r = 0.68$, $r = 0.74$, $r = 0.52$) and rootstock Best ($r = 0.75$, $r = 0.84$, $r = 0.61$) was identified against the background of the application of fertilizers during the period of stress influence of abiotic factors in July. The green pigment content was also increased. The decline of protein content in leaves in the trees on the rootstock Best and rootstock PK SK 1 was minimal. At that time maximum losses of shared water were in plants on the rootstock cherry plum seedlings and minimum ones were on the rootstock PK SK 1. In early August the gross content of nitrogen, potassium, and calcium in the leaves of shoots increased with the application of fertilizers. In early September the excess of the sum of amino acids in plum leaves was 26,6-30,8% while the one in plum fruits was 12.5 and 23.5%; 24.2 and 11.5%; 17.3 and 19.6% on the rootstock VVA 1, rootstock Best, rootstock PK SK 1 respectively. The nutrition mode optimization promoted increasing of plant productivity on the rootstock Best and fruit weight on the rootstock VVA 1, rootstock Best, and rootstock PK SK 1.

Keywords: *Prunus domestica* plum; rootstocks; plant nutrition mode; physiological state; productivity

INTRODUCTION
Growing mainly on the rootstock cherry plum seedlings, *Prunus domestica* plum is widespread in industrial plantings of stonecrops of Krasnodar territory located in the west part of Caucasus and Ciscaucasia. The popularity of this culture is related to the precocity and the stable yield **(Eremin et al, 2000; Eremin, Prichko, Kekhaev, 2007; Eremin et al, 2010; Eremin and Brizhinov, 2011)**. The specific humid climate conditions are necessary for the successful growth and development of plum plants because the water holding capacity of tree bark and wood is unsatisfactory **(Miletić et al, 2007)**. The coefficient of water consumption to make a unit of tree mass dry matter and harvest is high, therefore, sufficient air humidity is necessary during the period of flowering and growth of shoots **(Gnezdilova and Doroshenko, 1984; Eremin, 2000; Bogdanov, 2003)**. The area is characterized by the diversity of soil and climate conditions: from temperate continental to subtropical one. There are also almost all main soils of the temperate zone that are suitable for intensive cultivation of the fruit growing industry there. Chernozem, forest, and meadow soils are the most common – Anthrosols **(IUSS Working Group WRB. 2014)**. The species composition of chernozems varies significantly changing from North to South. The main differences are in the organic matter content and the power of the humus layer, mechanical composition, soil compaction, presence of signs of salinity. Various degrees of erosion processes, the waterlogging in winter, and the formatting of verkhovodka (superficial water) are typical for foothills soils (grocerie agroseme texture-differentiated and agronomy structural-metamorphic) **(Shishov L. L et al, 2004)**. Alluvial agrohumus hydrometamorphic soils with small power of humus layer and a wide range of nutrition

elements stock that are available for plants are prevalent in the river valleys **(Simakin, 1969; Negovelov et al, 1985; Eisert, Achkanov, Durgaryan, 1987; Lipchiu and Gagai 2014)**. At the same time, the main limiting factors which interfere with the realization of the productive potential of plum are the precipitation deficit in spring and summer against the background of intensive solar insolation and the physical and chemical properties of soil. The search of special technological methods and the selection of variety-rootstocks combinations and planting structures with compact bark that keep the plum plant resistance and the formatting of economically valuable signs of fruit quality are relevant due to the regional features of soil and climate conditions **(Sergeeva, Kuznetsova, Nenko, 2015; Sergeeva, Kuznetsova, Kovalenko, 2016)**.

Early studies have identified the nutrition mode features and the yield of *Prunus domestica* plum of varieties zoned in the region on the rootstock cherry plum seedlings. The field experiments were systematic and long-lasting which allowed us to draw a conclusion about the positive effect of regular application of mineral fertilizers on the reproductive function of the crop **(Sergeeva and Yatsenko, 1999).** Further research in this area (2014 – 2017) is linked with the intensification of production, the problem of rational selection varieties and rootstocks of *Prunus domestica* plum – components that help stabilize productivity of trees in various soil and climate area conditions for new industrial plantings **(Kuznetsova et al, 2011; Kuznetsova and Romanenko, 2014)**.

Scientific hypothesis

After analysis of dynamics of *Prunus domestica* plum plant productivity in the plantings of various structures and level of agricultural equipment in chernozem leached of the central zone of Krasnodar territory the working hypothesis about the regulation function of rootstock depending on the mineral nutrition mode of the crop that contributes to the formatting of physiological resistance to the negative impact of abiotic factors repeated in summer annually was ventured. That served as the basis for conducting experimental research in production conditions of influence of the systemic application of fertilizers on the functional state, productivity, and quality of plum fruits of the Stanley variety that is quite demanding to the soil and climate conditions on the rootstocks of various strength of growth.

MATERIAL AND METHODOLOGY

The object of research 2014 – 2017 is Prunus domestica plum plants of Stanley variety on the clonal rootstocks of various strength of growth: VVA 1, Best, PK SK 1, Pixy and cherry plum seedlings **(Figure 1)**.

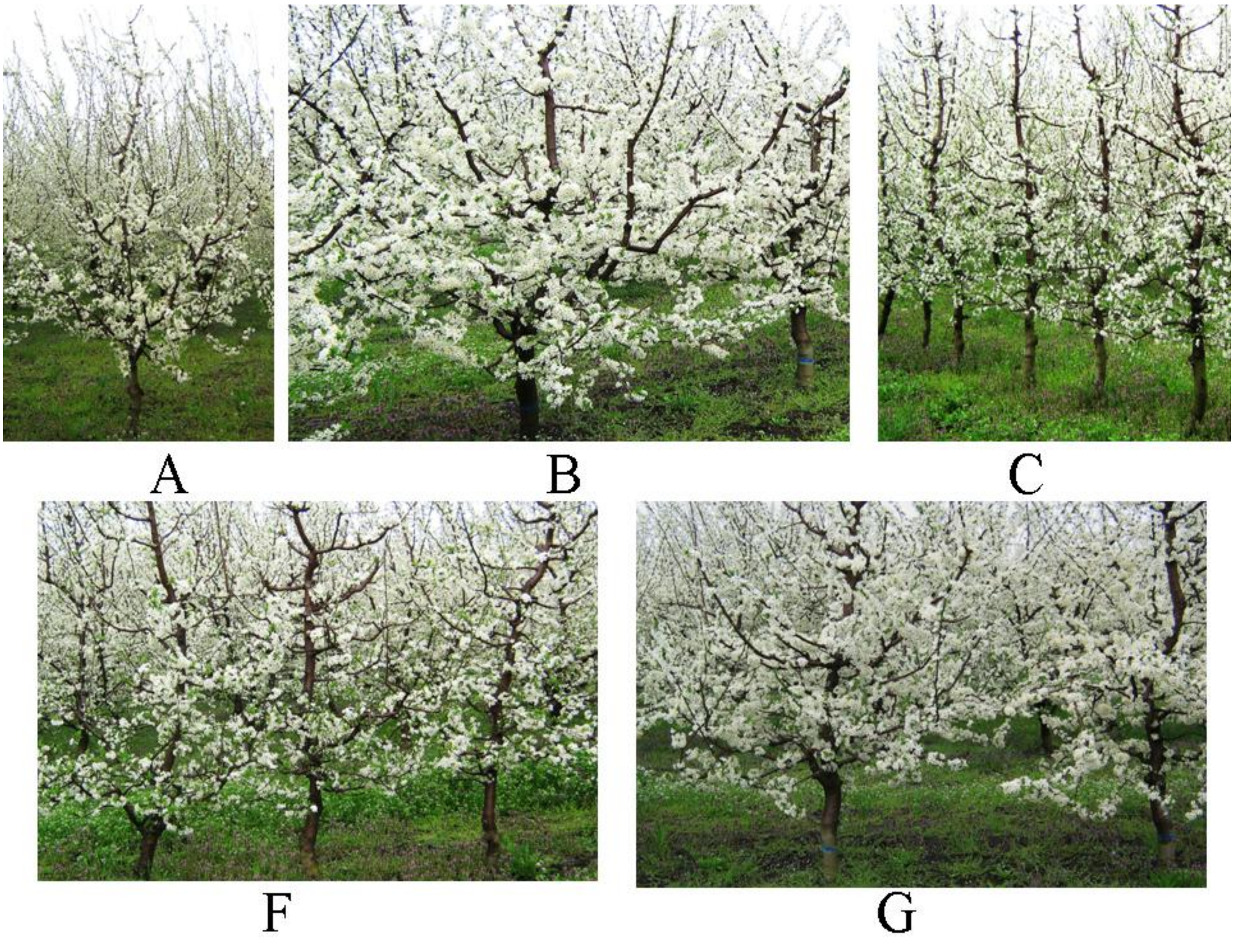

Figure 1 Experienced *Prunus domestica* plum Stanley variety on the rootstocks.
Note: A – *VVA 1*, cross Microcerarus tomentosa (*Thunb) Erem. et Yushev*) x (*P.cerasifera Ehrh*.); B – *Best*, *Prunus pumila L. x Prunus cerasifera Enrh*; C – *PK SK 1*, cross of hybridization *Microcerasus pumila L. x Prunus cerasifera Ehrh*; F – *Pixy*, nursling *Prunus domestica subsp. Insititia (L.)*; G –*cherry plum seedlings (Prunus cerasifera Ehrh)*.

Rootstock characteristics: *VVA 1* is the frost-resistant, but unstable to drought rootstock of domestic selection. Plum trees come into the fruiting quickly and have a crown 50% less than ones on cherry plum seedlings.

Best is the winter-hardy resistant to high temperatures medium rootstock. It has a positive influence on the precocity and the productivity of grafted trees which have an average drought tolerance.

PK SK 1 is the frost-resistant and drought-tolerant, resistant to bacterial cancer medium rootstock of domestic selection that has high productivity of the mother plants and plum trees on it.

Pixy – the easily propagated semi-dwarf rootstock of English selection that has a positive influence on the productivity and the plum tree crown compactness and gives a lot of growth in the garden. Besides, its tolerance to drought and frost-resistance is mediocre. The disadvantages of this rootstock as all seed ones are the late entry of plum trees to fruiting, the low percentage of rootstock yield from winter with low negative temperatures, and the difficulty of use in intensive gardening.

Cherry plum seedlings – the high rootstock that is high adaptative to the wide range of stress factors affecting the South of Russia. Its compatibility with all known varieties of plum is the cause of prolonged use in the North Caucasus.

The material for the study was obtained in industrial plantings of *Prunus domestica* plum of the close corporation "Plodovod" (Krasnodar) planted in 2006. Geographically, the experimental site is located in the central plains of the Krasnodar Territory. Height above sea level varies from 19 to 32 m. The climate is temperate-continental. The layout of plants is 5 x 2 m. The trees are cultivated without any support. The system for crown formatting of plum trees is spindle-shaped ensuring the greatest productivity of the variety in thickened plantings, according to several authors **(Rakićević et al, 2007)**. The forming complex pruning was carried out in the late spring on the formed ovary of fruits. Performing corrective cropping in July allowed plants to save a full ovary and realize the generative function as much as possible. The equilibrium balanced crown with fruit buds that were formed in the last summer-early autumn and had a high winter and frost resistance was created by the subsequent removal of growth points from the vegetative shoots, the thinning, and the lightening of thickened parts. The annual spring inspection of the freezing of flower buds in trees of various growth strength showed no damage from the return of cold weather and the killing frosts after the beginning of flowering. The blooming score was 4,8-5,0 in all versions of the experiment annually.

The soil of the experimental plot is the agrosem clay-illuvial low-humus heavy-duty **(Shishov L. L et al, 2004)**. The plot is aligned according to the terrain and the value of agrochemical indicators of the soil. The agrochemical study of its soil and plants was conducted using common methods and GOST standards of chemical diagnostics **(GOST standards 26204-91; 26213-91; 26951-86; Voskresenskaya, 2006; Yaroshenko and Sergeeva, 2020)**. The complex organic-mineral chlorine-free fertilizer based on peat (Organic Mineral Fertilizer from Russian abbreviation: ОМУ) was applied at a dose of 5.0 t. ha^{-1} in the garden soil in the middles at the distance 1 – 1.2 m from the trunk of the tree in optimal agrotechnical times. The effect of Organic Mineral Fertilizer was prolonged due to the content of organic-mineral complexes with humic compounds allowing to fix nitrogen and potassium in the exchange form and decrease their mobility in the soil. The phosphorus in fertilizer was presented in a form digested easily by plants. The fertilizer was granular with a mass fraction of nitrogen (in ammonium form) of 7.0%, total phosphorus (P_2O_5) of 7.0%, potassium (K_2O) of 8.2%, humic compounds of 2.5%. The non-root dressings of 0,5% solutions of special complex mineral fertilizers were applied in combination with biologically active agents thrice during the vegetative period. The fertilizers of N18P18K18Mg1S1.5 and N12P12K35Mg2S0.7 brands were used. They included Fe, Cu, Zn, Mn, B, Mo trace elements in chelated form. The non-root cultivation with fertilizer water solutions was conducted by means of the knapsack sprayer. The version with no Organic Mineral Fertilizer application and trees spraying with no addition of any fertilizers was controlled. There were 6 accounting trees in the control and experimental version. The tests were performed in four replications. The total area of the research site – 2 ga.

Laboratory tests of plants' physiological state (determining amino acids) were conducted on three analytical surfaces according to the recommended methods **(Nenko et al, 2015)**. The chlorophyll (a+b) content in the leaves was determined in dynamics using the spectral method on the spectrophotometer Unico 2800 ("United Products & Instruments", USA). The water content in leaves was analyzed by the weight method according to the M.D. Kushnirenko technique **(Kushnirenko, 1986)**. The elemental composition plants were conducted using common methods **(Voskresenskaya, 2006)**.

The metrological observations allowed us to evaluate the degree of the negative impact of abiotic factors in the summer and establish the beginning of the stressful situation for plum plants during the study.

Agrobiology accounting was carried out according to the recommended methods **(Sedov and Ogoltsova, 1999)**.

Statistical analysis

The statistical analysis was performed in accordance with the recommended method **(Volkov, 2005)**. Calculations were performed using a software package Microsoft Office 2010 ("Microsoft, Inc.", USA). The *p*-value was used ($p < 0.05$) for checking the null hypothesis to quantify the idea of statistical significance.

RESULTS AND DISCUSSION

The agrochemical indicators of the plot soil were explored before laying the experiment. The humus content of the topsoil varied between 3.05 – 3.17% (LSD ($p \leq 0.05$) = 0.14), the mobile phosphorus one – between 243 – 252 $mg.kg^{-1}$ (LSD ($p \leq 0.05$) = 7.70), the exchangeable potassium content – between 217 – 221 mg. kg^{-1} (LSD ($p \leq 005$) = 3.42). The content of the nitrate form of nitrogen in the soil layer 0-60 sm did not exceed 0.7 – 1.2 mg. kg^{-1} The chemical analysis showed a significant increase of the mineral elements forms available for plants one year after the application of mineral fertilizers. The mobile phosphorous content was 286 – 308 mg. kg^{-1}, the exchangeable potassium one was 238 – 245 mg. kg^{-1} in the mineral fertilizer application zone.

Table 1 Effect of fertilizers on the content of macronutrients in the leaves of plum, the third decade of may (mg.kg^{-1}).

Variation	N	P	K	Ca	Mg
Rootstock VVA 1					
Control	3.08	0.34	1.72	1.01	0.35
OMF+ foliar application	3.56	0.35	1.76	1.18	0.43
LSD (p ≤0.05)	0.24	0.05	0.07	0.13	0.06
Rootstock Best					
Control	3.16	0.33	1.54	1.26	0.58
OMF+ foliar application	3.75	0.36	1.65	1.48	0.69
LSD (p ≤0.05)	0.10	0.03	0.07	0.11	0.09
Rootstock PK SK 1					
Control	3.11	0.33	1.69	1.18	0.61
OMF+ foliar application	3.45	0.35	1.72	1.23	0.64
LSD (p ≤0.05)	0.15	0.04	0.03	0.17	0.08
Rootstock Pixy					
Control	3.19	0.33	1.66	1.51	0.44
OMF+ foliar application	3.61	0.36	1.73	1.49	0.43
LSD (p ≤0.05)	0.13	0.02	0.05	0.05	0.02
Rootstock cherry plum seedlings					
Control	3.42	0.34	1.97	1.68	0.50
OMF+ foliar application	3.69	0.35	1.95	1.71	0.56
LSD (p ≤0.05)	0.14	0.03	0.07	0.04	0.07

The nitrate-nitrogen content in the soil layer 0 – 40 cm increased 3 – 5 times in spring and 97 – 155% in October compared to the control version (without Organic Mineral Fertilizer application). Against that background the first non-root dressing of trees with water solutions of special fertilizers was conducted in the ratio N:Ph:P = 1:1:1. The treatment was repeated 4 – 5 weeks after flowering (the fruit size is up to 3 cm in diameter) during the stone formatting. The third dressing with water solutions of special fertilizers was conducted in the ratio N:Ph:P = 1:1:2 – 2.5 in summer (in the period of differentiation of buds). The phytoregulator "Novosil" was added in the nutrient solution composition in the ratio at the concentration of 0.02% at each treatment of plants. The changes in the seasonal nutrition mode were checked for the nutrients content in the leaves of growth shoots **(Table 1)**.

Annual systematic application of fertilizers by non-root method during the period of the intensive shoot and ovary growth (in spring) promoted increasing of the total content of nutrients in plum leaves on the rootstocks of various strength of growth. The resulting effect was also noted by several authors who have studied the influence of fertilizers on the plum nutrition mode (Miletić, et al, 2003; Fatma et al, 2018).

The significant increase was detected mainly in the nitrogen and potassium content. However, the increase in potassium content was not always confirmed statistically. Besides, the reliable increase of potassium and magnesium content was noted in the plum on the *VVA 1* dwarf rootstock during that period.

The changes in the plum nutrition mode promoted activation of physiological processes. This corresponds to the data from literature sources reporting about the positive impact of fertilizers on the stone fruit crops **(Wan Yi-zhen, Sheng Bo-biao, Du Hui-fang, 2003; Miletic et al, 2003; Cuque et al, 2011; Milosevic and Milocevic, 2012; Doroshenko, Riazanova, Maksimtsov, 2015; Fatma et al, 2018)**. The increase of several functional pigments (Chla+Chlb) in the plum leaves on rootstocks of various strength of growth was identified by the spectral analysis method in the application of fertilizers. The most significant increase of a number of the main photosynthetic pigment (Chla), an energy donor, was discovered in the leaves of plum on the rootstock *Best.* The high content of the chlorophyll b (Chlb), the activator of the biosynthetic processes, was occurred in the same version annually. The total chlorophyll content (Chla+Chlb) in the leaves exceeded stably the value in the control version by 20.1-25.4% in trees on the rootstock *PK SK 1, rootstock Pixy,* and rootstock *cherry plum seedlings*. At the same time, the lamina area of trees on those rootstocks exceeded the values in the control version by 12.7%, 7.4, and 9.1% respectively. The tendency to increase the nutrient content in the plum leaves against the background of the application of fertilizers revealed mainly in the years with the sufficient water availability on the *VVA 1* dwarf rootstock that had the

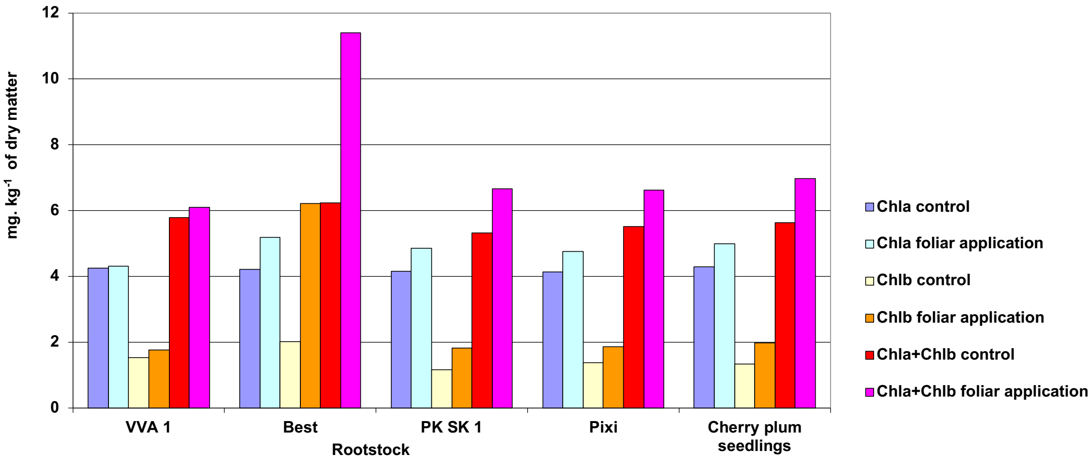

Figure 2 The content of functional pigment in plum leaves in relation to the fertilizers and variety-rootstock. combinations.

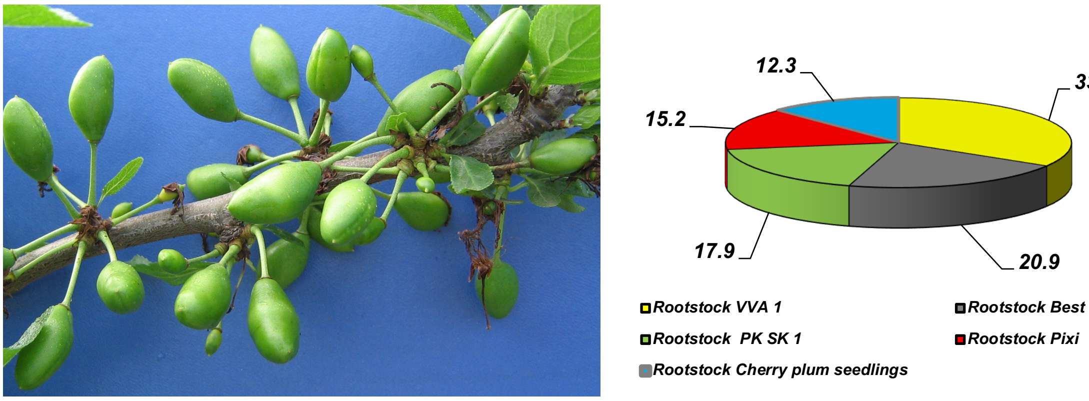

Figure 3 The excess of the number of preserved ovaries in plum plants against the background of application of fertilizers in relation to the control version (with no fertilizers) (the third decade of June),% (2014 – 2017).

surface occurrence of the main part of the root system **(Figure 2)**.

The increase of the intensity of metabolic processes that was probably associated with the activity of photosynthesis and synthetic activity of the root system was confirmed by the analysis of the free amino acid content in the leaves using the method of capillary electrophoresis.

The tendency of the predominant increase of arginine in shoot leaves was detected annually during the period of the activity of growth processes in spring when the maximum temperature was up to 28 – 32 ºC and the precipitation fell periodically. The changes in the nutrition mode promoted increasing of the arginine amount in leaves by 42.3% (*Rootstock Best*), 37.4% (*Rootstock PK SK 1*), 29.6% (*Rootstock Pixi*), 12.7% (*Rootstock VVA 1*), and 27.9% (*Rootstock cherry plum seedlings*) at that stage of seasonal plant development. More active protein synthesis was occurred in leaves on the rootstock *Best* in spring and summer annually. Its content was higher by 8-10% compared to the one in the control version (with no fertilizers). Further, the recorded annual increase in air temperature to maximum values of 30 – 35 ºC and the prolonged lack of precipitation promoted increasing of the amino acid Proline content in the leaves. Its content in leaves was 46.4% (*Rootstock PK SK 1*), 39.8% *(Rootstock Pixi*), 32.5% (*Rootstock VVA 1*), 26.2% (*Rootstock cherry plum seedlings*), and more than 80% (*Rootstock Best*) higher in the version with the application of fertilizers. The identified tendency was confirmed by our researches on other fruit crops **(Popova, Yaroshenko, Sergeeva, 2018)**.

The nutrition mode of culture changed by the end of the second decade of June against the background of the growth activity decrease of trees. The total nitrogen and phosphorous content in all versions of experiment was 2.22 – 2.24 and 0.163 – 0.168% respectively. The potassium content went up to 2.12% (*Rootstock VVA 1*) and 2.61 – 2.68% (*Rootstock Best, Rootstock PK SK1, Rootstock Pixi, Rootstock cherry plum seedlings*). Calcium in the leaves of dwarf and medium trees went up to 1.59% (*Rootstock VVA 1*) and 1.70% respectively. There were no changes in the plum on the rootstock *cherry plum seedlings*. The total magnesium content changed insignificantly. The secondary metabolite content in the plum shoot leaves decreased on the rootstocks of various strength of growth. That was probably caused by an outflow of assimilates into the growing fruits. The total number of amino acids was no more than 60.2 -89.6% of the previously established content in all versions of the experiment. In June the accountings for the degree of ovary reduction on the accounting trees showed the advantage of the version with the application of fertilizers: a number of the fully preserved ovary was higher by 12.3 – 33.7% depending on the rootstock **(Figure 3)**.

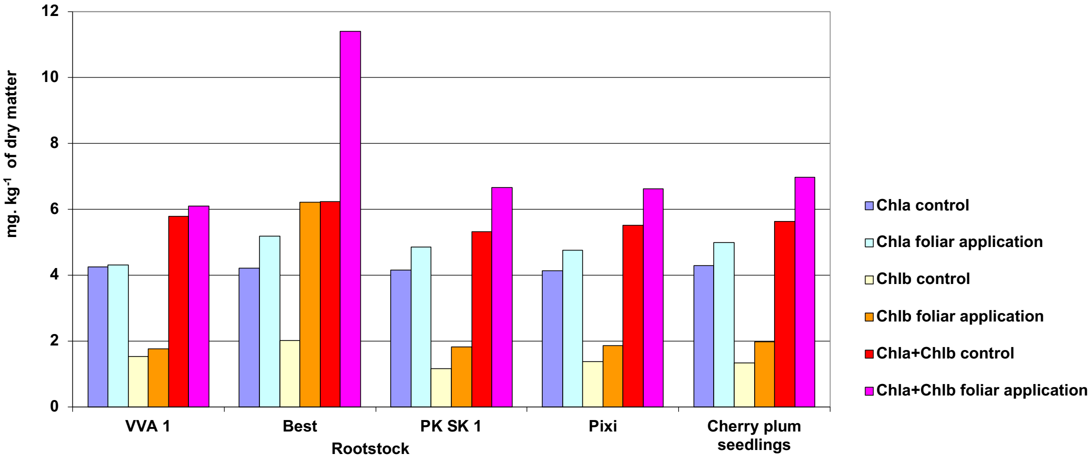

Figure 4 The most common character deformity of plum ovary development on the example of the Stanley variety on the rootstock *Best* (2014 – 2017).

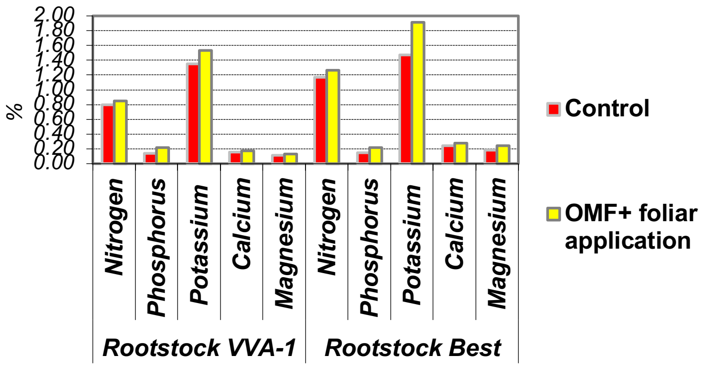

Figure 5 The chemical content of growing fruits in July (2014 – 2017).

The visual analysis and the calculation of the ovary in the control version allowed us to conclude that without the application of fertilizers, the percentage of deformed fruits, that is associated, according to **Semenov (2007)**, with the negative abiotic factors impact, is higher significantly and ranges from 3.3 to 8.7% depending on the variety-rootstock combination. The most common characteristics of ovary deformity are represented in **Figure 4**.

In July the stage of development of generative buds of plum of Stanley variety in the sinuses of side leaves of shoots was diagnosed by the method of microscopy. In the same period, the analysis of the chemical content of growing fruits was conducted with leaf diagnostics. The most significant difference between the versions was identified on the rootstock *VVA*1 and rootstock *Best* **(Figure 5)**. The closest correlation between the nitrogen, potassium, and calcium content in leaves and fruits was determined. The correlation coefficient was 0.68, 0.74, 0.52 (*Rootstock VVA 1*) and 0.75, 0.84, 0.61 (*Rootstock Best*) respectively.

The correlation analysis showed a less close relationship that did not exceed the values of 0.55 – 0.64. Several scientists **(Plich, Wójcik, 2002; Fatma et al, 2018)** pointed to changes in the quality of plum fruits and the increase of calcium content in them against the background of the application of non-root dressings.

The summer and early autumn experimental studies were accompanied by the annual accounting and the analysis of metadata because many authors pointed to the strong influence of the water stress factor on the intensity of plum growth processes **(Li Wen-hua et al, 2003)**. It is necessary to note that the longest stress situations related to hyperthermia, the lack of precipitation, and the decrease of air humidity up to 12 – 14% was observed from the second decade of July to mid-September. The data of the functional state of Prunus domestica plum plants on the rootstocks of various strength of growth was the most informative and allowing to evaluate the effectiveness of fertilizers under these conditions.

Conducted research on green pigment content in leaves identified the seasonal decrease of plant photosynthetic activity. At the same time, despite the negative effect of physical factors the level of green pigment content in plum shoot leaves was higher significantly against the background of the application of fertilizers than one in the control version. It is possibly related to the action of the phytoregulator used as a part of the nutrient solution for non-root dressings and increased the plant protective features. That fact was also pointed by in their study **(Upadysheva, Upadyshev, 2012) (Table 2)**. The difference between the experimental versions was also identified by protein content in plum leaves. The seasonal decrease of protein in shoot leaves an average of 20-24% compared to the spring and the summer period was observed in all versions of the experiment. However, when the fertilizers were applied the decrease of protein amount in leaves of plum on the rootstock *Best* and rootstock *PK SK 1* was minimal and amounted to 25.3 and 23.2 mg. kg^{-1} of dry matter respectively.

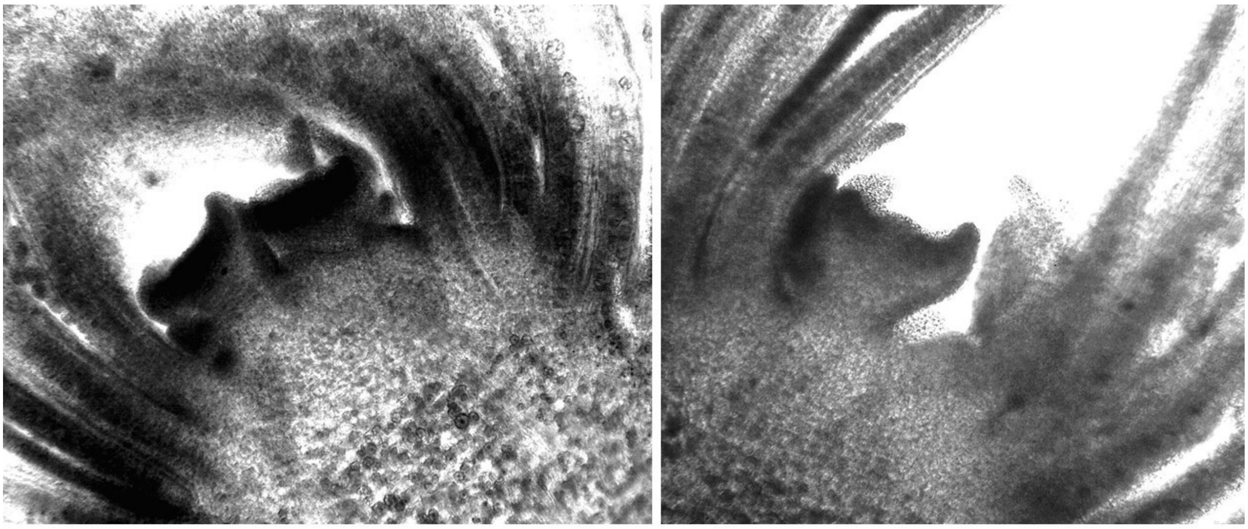

Figure 6 The development of the sepal rudiments in the inflorescence flower (A), the development of the sepal rudiments in the single flower (B) (2014 – 2017).

Table 3 Effect of fertilizers on the content of macronutrients in the leaves of *Prunus domestica* plum, early August (mg.kg^{-1}).

Variation	N	P	K	Ca	Mg
			Rootstock VVA 1		
Control	2.41	0.18	1.87	2.73	0.37
OMF+ foliar application	2.62	0.18	2.80	3.17	0.51
LSD (*p* ≤0.05)	0.11	0.02	0.18	0.14	0.10
			Rootstock Best		
Control	2.52	0.14	2.58	3.19	0.34
OMF+ foliar application	2.58	0.16	2.75	3.48	0.46
LSD (*p* ≤0.05)	0.07	0.02	0.08	0.11	0.05
			Rootstock PK SK 1		
Control	2.64	0.16	2.32	3.12	0.38
OMF+ foliar application	2.86	0.16	2.44	3.17	0.41
LSD (*p* ≤0.05)	0.09	0.01	0.07	0.10	0.05
			Rootstock Pixy		
Control	2.47	0.14	2.49	3.03	0.43
OMF+ foliar application	2.53	0.15	2.57	3.10	0.48
LSD (*p* ≤0.05)	0.05	0.02	0.05	0.09	0.05
			Rootstock cherry plum seedlings		
Control	2.73	0.20	2.48	1.85	0.34
OMF+ foliar application	3.03	0.23	2.97	2.97	0.35
LSD (*p* ≤0.05)	0.13	0.02	0.19	0.23	0.06

That fact characterized higher intensity of reparation processes in trees on those rootstocks.

Under the conditions of the tensity of hydrothermal factors in summer, the water content in leaves was determined depending on the application of fertilizers and the variety-rootstock combinations. Plants on the rootstock cherry plum seedlings had the most significant losses of shared water that was up to 9.3% (Organic Mineral Fertilizer + non-root dressings) and 12.7% (control, with no fertilizers). The minimal water losses were identified in leaves in plum on the rootstock *PK SK 1* that was 5.7 – 8.4% respectively.

The continuation of diagnostic studies of the functional state of the plum plant was accompanied by morphoanatomical observations of the generative buds in the first decade of August. The beginning of the differentiation of the rudimental sepals was detected in the majority of conducted buds **(Figure 6)**.

That stage of plum plant development was characterized by the next change of nutrition mode. The gross content of nitrogen, potassium, and calcium increased in shoot leaves. At the same time, the differences between the versions were significant **(Table 3)**.

According to the morphoanatomical research data, the transition to formatting of petals and stamens began in the majority of rudimental flowers of the plum plant by early September. The periodical precipitation promoted growth activity mainly in trees on the medium rootstocks. The gross content of nitrogen, phosphorous, and magnesium increased up to 18.6%, 7.7, and 29.5% respectively regardless of the version of the experiment **(Figure 7)**.

The most significant increase of amino acid content in leaves was determined in plum plants on the rootstock *Best* in the version with the application of fertilizers against that background. The excess of the sum of amino acids was 26.6 – 30.8% in some years. The correlation coefficient between the nitrogen content in leaves and the total amount of free amino acids was r = 0.56 (Rootstock *VVA 1*), r = 0.67 – 0.71 (Rootstock *PK SK 1*, Rootstock *cherry plum seedlings*), r = 0.81 – 0.83 (Rootstock *Best*).

The specified period was also the beginning of fruit ripening of plum of Stanley variety **(Figure 8),** which had an immediate influence on the post-harvest storage of fruits, according to the authors **(Manganaris, Vicente, Crisosto, 2008)**.

The significant impact of the fertilizers applying in the experiment on the content of gross forms of potassium and calcium in fruits on the rootstock *VVA 1*, rootstock *Best*, rootstock *PK SK 1* those content exceeded the amount of the element in fruits of the control version by 12.5 and 23.5%; 24.2 and 11.5%; 17.3 and 19.6% respectively.

The dynamics of plum productivity on the rootstocks of various strength of growth against the background of the application of fertilizers were analyzed depending on the protection area of tree crowns **(Table 4)**. The dimensions of plum tree crowns formed by a spindle-shaped system matched the strength of the growth of the rootstocks. The annual measurement of the protection area of tree crowns in 2014 – 2018 allowed us to establish the highest values in trees on the rootstock *cherry plum seedlings* that were amounted to 3.69 – 3.99 m^2. The smallest protection area of tree crowns was noted in the trees on the rootstock *VVA 1*

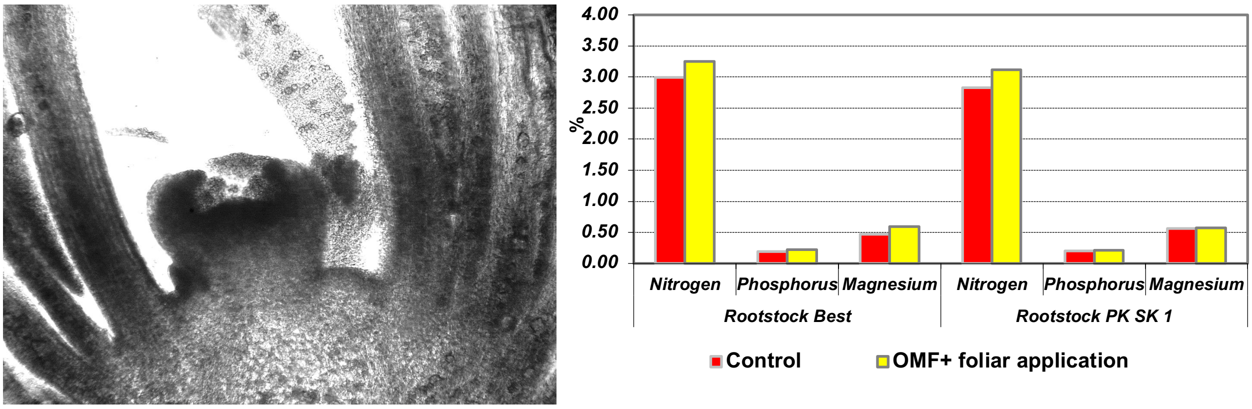

Figure 7 The nitrogen, phosphorous and magnesium content in shoot leaves of plum of Slanley variety in the stage of forming of the petals and stamens in the rudimental flowers, August-September (2014 – 2017).

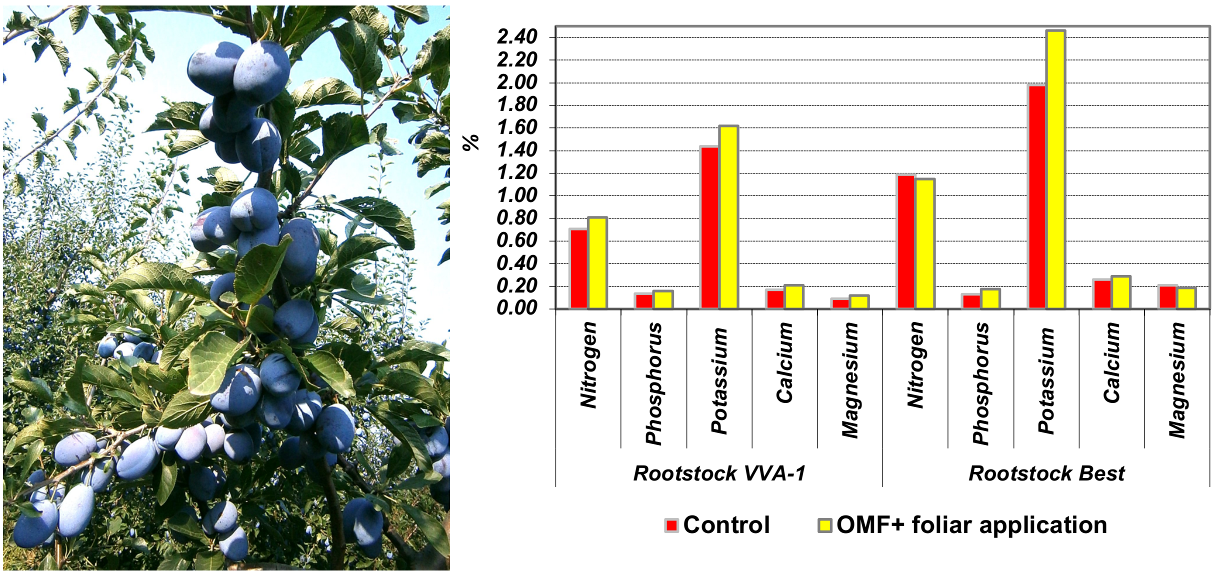

Figure 8 The chemical content of fruits in the ripening period, August-September (2014 – 2017).

Table 4 The productivity of plum of Stanley variety depending on the habitus of the crown and the application of fertilizers.

	The number of fruits per 1 m^2 of the crown projection area, piece.			
Variation	2014	2015	2016	2017
		Rootstock VVA 1		
Control	245	237	288	307
OMF+ foliar application	334	354	345	352
LSD (*p* ≤0.05)	21.42	20.48	21.87	11.78
		Rootstock Best		
Control	210	259	295	286
OMF+ foliar application	240	267	338	321
LSD (*p* ≤0.05)	8.22	5.44	16.98	7.52
		Rootstock PK SK 1		
Control	173	212	225	200
OMF+ foliar application	197	255	241	236
LSD (*p* ≤0.05)	22.41	42.47	13.39	27.28
		Rootstock Pixy		
Control	192	229	237	256
OMF+ foliar application	231	261	258	278
LSD (*p* ≤0.05)	25.01	20.68	24.08	25.76
		Rootstock cherry plum seedlings		
Control	257	248	261	254
OMF+ foliar application	266	274	279	283
LSD (*p* ≤0.05)	22.81	12.04	15.63	7.28

that was 2.02 – 2.52 m^2. The average indicators were determined on the rootstock *Best*, rootstock *PK SK 1*, and rootstock *Pixi* that are 3.07-3.13; 3.53-3.75 and 3.36-3.64 m^2 respectively. The highest stable indicators of plum productivity were identified on the dwarf rootstock *VVA 1* that matched the data of **(Provorchenko et al, 2015)**.

The applied fertilizer system promoted significant excess of reproductive function of plants. Meanwhile, the slopes of trees on the rootstock *VVA 1* caused by harvest load were observed. That indicated the need for installation of supports by using the rootstock *VVA 1*. At the same time, that crown design and the dimensions of the trees allowed us to decrease significantly the plant nutrition area without a decline of the light regime that is also pointed by **Upadysheva, 2015** in her research. The productivity of plum on the medium rootstocks was less significant, but the advantage of the version with the application of fertilizers was saved. The most significant and stable indicators of growth of productivity were received in the versions on the rootstock *Best* (*LSD* (p ≤0.05) – 8.22 (2014); 5.44 (2015); 16.98 (2016); 7.52 (2017)) against the background of the application of fertilizers in those soil and climate conditions. At the same time, it is necessary to note that the values of indicators in the limits of the version were changeable significantly in trees on the rootstock *PK SK 1*, rootstock *Pixi* and rootstock *cherry plum seedlings.*

The classification of plum fruits by quality was conducted according to GOST standard 21920-76 in all versions of the experiment. Such indicators as the color of the fruit, the appearance, the presence of the damages on the surface, the turgescence, and the homogeneity were identified on the level of standard that is common for the feature of plum of European varieties **(Ionica et al, 2013).** The significant differences in the dry matter content in fruits on the rootstocks of various strength of growth were not determined that was accorded with the data of the next scientists **(Meland and Froynes, 2006)**. The sort (calibration) of fruits allowed us to identify the advantages of the version with the application of fertilizers by the criterion "the weight of fruit". The optimization of the nutrition mode of plum of Stanley variety promoted a significant increase in the fruit weight no depending on the strength of growth of the rootstock. That fact matched the data of literature sources **(Kaufmane et al, 2007, Vetrova and Roeva, 2019) (Table 5)**.

Table 5 The weight of plum fruit of Stanley variety depending on the application of fertilizers.

	The mass of one fruit (g).			
Variation	2014	2015	2016	2017
		Rootstock VVA 1		
Control	41.7	40.9	34.8	38.8
OMF+ foliar application	42.5	42.7	36.7	40.6
LSD (p ≤0.05)	0.59	1.05	1.34	0.97
		Rootstock Best		
Control	40.3	41.1	32.6	35.7
OMF+ foliar application	40.8	41.9	33.6	37.8
LSD (p ≤0.05)	0.56	0.71	1.02	1.35
		Rootstock PK SK 1		
Control	39.2	40.1	37.5	40.1
OMF+ foliar application	40.6	41.8	37.9	40.7
LSD (p ≤0.05)	1.04	0.43	1.42	0.78
		Rootstock Pixy		
Control	38.8	37.2	35.5	38.9
OMF+ foliar application	39.4	40.5	36.7	39.6
LSD (p ≤0.05)	0.63	0.77	0.68	0.80
		Rootstock cherry plum seedlings		
Control	37.9	39.6	33.2	38.1
OMF+ foliar application	38.6	40.3	33.3	38.7
LSD (p ≤0.05)	0.37	0.56	0.38	0.77

CONCLUSION

The impact of the rootstock and the systematic application of intra-soil and leaf dressings in combination with the phytoregulator on the physiological resistance of plum plants of Stanley variety to the negative effect of annually repeated abiotic factors in summer was investigated according to the criterion of functional state, productivity, and quality of fruits.

As a result of the analysis of experimental data, we identified that the application of fertilizers promoted a significant increase of total content of biologically essential elements and enhanced the synthesis of functional pigments (Chla+Chlb) in spring during the period of the intensive shoot and ovary growth in the plum tree on rootstocks of various strength of growth. The total chlorophyll content (Chla+Chlb) in the leaves exceeded stably the value in the control version by 20.1 – 25.4% in trees on the rootstock *PK SK 1*, rootstock *Pixy*, rootstock *cherry plum seedlings*. The effectiveness of the influence of the nutrition mode revealed mostly in the years with the sufficient water availability on the dwarf rootstock *VVA 1* that has the surface occurrence of the main part of the root system. The increase of the growth process activity was confirmed by the increase of the content of free amino acids that were the most active participants in metabolism in the leaves.

The conditions of mineral nutrition mode influenced the chlorophyll synthesis in plum leaves on the rootstock *VVA 1*, rootstock *Best*, rootstock *PK SK 1*and rootstock *cherry plum seedlings* in summer against the background of hyperthermia, the lack of precipitation, and the decrease of air humidity up to 12 – 14%. The specific to these conditions decline of protein content in the trees on the rootstock *Best* and rootstock *PK SK 1* was minimal. That fact characterized higher intensity of reparation processes. Plants on the rootstock *cherry plum seedlings* had the most significant losses of shared water that were up to 9.3% (Organic Mineral Fertilizer + non-root dressings) and 12.7% (control, with no fertilizers). The minimal water losses were identified in leaves in plum on the rootstock *PK SK 1* that was 5.7 – 8.4% respectively.

The periodical precipitation in early September promoted growth activity mainly in trees on the medium rootstocks. The period of growth activity was accompanied by the increase of gross content of nitrogen, phosphorous, and magnesium that was up to 18.6%, 7.7, and 29.5% respectively. The most significant increase of amino acid content in leaves was determined in plum plants on the rootstock *Best* against the background of the application of fertilizers. The excess of the sum of amino acids was 26.6 – 30.8% in some years.

The period of the beginning of fruit ripening was characterized by the accumulation of gross forms of potassium and calcium in them. The potassium and calcium content in fruits in the version with the application of fertilizers exceeded the amount of the elements in fruits of control version by 12.5 and 23.5%; 24.2 and 11.5%; 17.3 and 19.6% on the rootstock *VVA 1*, rootstock *Best*, rootstock *PK SK 1* respectively. At the same time, the harvest accountings revealed the advantage of the versions with the application of fertilizers: there was an increase in productivity due to a decline of ovary reduction in spring and summer. The number of the fully preserved ovary was higher by 12.3-33.7% depending on the rootstock.

The commercial quality analysis by the criterion "the weight of fruit" that identified the level of economic feasibility of the adoption of optimization of culture's mineral nutrition mode showed the advantages of the version with the application of fertilizers. The largest fruits were obtained from the trees on the rootstock *VVA 1* and rootstock *Best.*

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