Fertilizers effect on yield and apples' fruits quality on leached chernozem

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Abstract. In the Central Ciscaucasia, including North Ossetia-Alania, in recent years, new fast-growing, immune, highly-productive varieties of apple trees of an intensive type have become widespread. The effectiveness of the use of fertilizers for growing new varieties of apple trees has not been studied. In this regard, a study was made of the responsiveness of three apple varieties to mineral and organic fertilizers (manure) and their combination. The apple orchard was studied on leached chernozem, covered by pebble from a depth of 50 cm and having a wash water regime. As a result of research, it was found that the use of mineral and organic fertilizers in this type of garden is an effective agrotechnological technique. The use of mineral and organic fertilizers increases the productivity of the fruits of the varieties Aidored, Florina and Stark-Nart by 20.0–130.4 % compared with non-fertilized control. The Florina variety was the most fruitful. Significantly less productive is the Aidored variety and especially Stark-Nart. In the control, respectively, Florin's variety – 22.0 t/ha, Aidored – 12.5 t/ha and Stark-Nart – 11.5 t/ha. Of the fertilized options, the best in all three varieties was N150P150K150: productivity was 40.5, 28.5, and 26.5 t/ha, respectively. The fertilizers under study affected the quality indicators of fruits in different ways. For Aidored variety, there is a tendency toward a decrease in the dry matter content and fruit acidity as the level of mineral nutrition increases, while the content of sugar, vitamin C, P-active substances, sugar-acid index and pectin substances increase. According to these indicators, N150P150K150 stands out as the best of the fertilized options. In relation to the Florin and Stark-Nart varieties, it should be pointed out that the patterns of action of fertilizers on the quality of fruits noted for the Aidored variety are identical, although the quantitative indicators are not the same. In particular, it can be noted that in terms of sugar content, Stark-Nart is inferior to two other varieties. And in terms of acidity, Florin is an advantage (the fruits are less acidic). Vitamin C is more in the fruits of the Aidored variety (9.3 mg / 100 g in the control), Florin is in second place, and Stark-Nart is in third (in the control of 8.0 and 7.1, respectively).

1. Introduction
One of the conditions for effective gardening is the use of high-quality planting material. Mineral nutrition of plants is an important factor affecting the growth and fruiting of fruit plants, increasing the stability and quality of seedlings. The root pathway of mineral elements to plants is the root system [15]. Directional regulation of plant nutrition, taking into account the requirements of the culture and the characteristics of the variety, is the key to obtaining the maximum, genetically determined level of apple productivity. In this regard, the main task of agrochemical science is to increase the effective
soil fertility and create optimal backgrounds for the mineral nutrition of fruit crops under conditions of intensification of the industry. The process of optimizing their nutrition system involves the use of fertilizers in accordance with the biological characteristics of plants and the genetic properties of varieties [14].

The ways to reduce the negative stressful effects during this period can be a selection of drought tolerant varieties, irrigation and agricultural technologies, including the complex use of fertilizers and biologically active substances (BAS): antistressants, immunomodulators, growth regulators, soil improvers according to the phases of fruit development plants [10].

The frequency of fruiting of apple plants is largely the result of many factors, including the insufficient nutrient content in the soil, or their unbalanced elemental composition. Mineral and organic fertilizers contribute to the annual fruiting and development of apple fruit of satisfactory commodity calibers simultaneously with the development of a large crop. Therefore, studies on establishing the effect of various fertilizer systems on the productivity and quality of the fruit-bearing garden are relevant [3].

Despite the extensive experience in using mineral fertilizers, the optimization of the mineral nutrition of fruit trees continues to be a severe problem. Especially the situation has worsened at the present time when the cost of fertilizers has increased significantly, and their effectiveness is unsatisfactory. The low efficiency of the use of fertilizers is due to the lack of evidence-based recommendations in which soil properties, climatic conditions, and, most importantly, biological and varietal features of the cultivated crop must be taken into account. As a result, the use of fertilizers in gardens does not contribute to increasing productivity and product quality. Moreover, the use of fertilizers leads to their irrational consumption, especially nitrogen, and, as a result, environmental pollution [2].

In the efficient use of agricultural land, the paramount place is the problem of preserving and improving sufficient soil fertility. Among the methods for increasing adequate soil fertility, the central location belongs to the rational use of fertilizers [4].

According to Tyurin, the humus content in the arable layer of leached chernozem ranges from 3.5 to 7.5 %, but more often makes up 4.5–6.0 %. In leached chernozem, high content of gross forms of nutrients is noted: total nitrogen 0.24–0.45 %, phosphorus 0.2–0.3 %, potassium 1.6–2.3 %. Mobile types of nutrients contain: easily hydrolyzable nitrogen according to Tyurin-Kononova 4–10, mobile phosphorus, and exchange potassium, according to Chirikov, respectively 5–14 and about 15 mg/100 g of soil. That is, the availability of mobile nitrogen and phosphorus is weak and medium, exchange potassium is medium, sometimes increased [5].

Mineral nutrition refers to factors through which it is possible to directly influence the development and productivity of plants [1].

In gardens with intensive technology, much attention is rightly paid to the optimization of plant nutrition processes. It has been established that a lack or excess of nitrogen fertilizers affecting growth processes adversely affects the ripening of fruits, their color, taste, and keeping quality [9].

To successfully grow plants in southern Russia, it is necessary, first of all, to select varieties with high resistance to drought and heat. At the same time, agricultural practices that contribute to the implementation of the noted properties are of great importance [8].

Numerous studies in various regions of our country indicate that the use of complete mineral fertilizers and top dressing in orchards increases fruit yield by 55 % and increases the number of apple-bearing trees annually. Moreover, even on Kuban chernozems rich in nutrients, it is impossible to get regular and high yields in gardens without the use of fertilizers [13].

In recent decades, the cultivation of fruit crops, in particular, apple trees, has been carried out under adverse weather conditions for plants: the effects of annual abiotic and biotic stresses, extreme temperatures during dormancy and vegetation, epiphytes of the leading apple diseases – scab and powdery mildew. A set of unfavorable factors reduces the stability and quality of the products obtained since the protection of plants from viruses involves treatment with chemicals that affect the environmental safety of products [8].
In young high-intensity gardens, the problem of the frequency of fruiting (the alternation of abundant and weak flowering) arises quite early. One of its reasons is the imbalance in growth processes and crop load [11].

2. Statement of the problem
1. To establish the effect of fertilizers on the productivity of various varieties of apple trees.
2. To identify the impact of manure on the quality of apple fruits.

3. Research issues
Appletree is one of the most common fruit crops in Russia. The natural conditions of North Ossetia-Alania are favorable for the cultivation of different varieties of apple trees, mainly varieties of winter ripening. Essential and valuable quality indicators of the apple tree are high productivity, high winter hardiness compared to other fruit species, a wide range of varieties. One of the main elements of the technology of cultivating fruit crops is the fertilizer application system to optimize its mineral nutrition. In current conditions, for this, it is necessary to correctly use the methods of diagnostic control of the mineral nutrition of fruit trees to ensure normative payback.

In the Central Ciscaucasia, including North Ossetia-Alania, in recent years, new fast-growing, immune, highly productive varieties of apple trees of an intensive type have become widespread. The productivity of unique varieties of apple trees very much depends on the exact observance of the recommended technologies for their cultivation, including the correct science-based use of fertilizers. Any violation of the link in this technology can cause a sharp decrease in the fruits’ yield and quality of these varieties. However, they suffer much more than the old types of adaptive gardens. Therefore, in the technology of growing new varieties of fruit crops, it is necessary to strictly observe a scientifically based system of fertilizer application, which allows obtaining high stable yields with good indicators of fruit quality.

4. The purpose of the study
To identify the most useful variants of the fertilizer system for various varieties of fruit crops in the forest-steppe zone of the Central Ciscaucasia on leached chernozems. Leached chernozem characterized by high payback of fertilizers, stably high productivity with good quality fruits, maintaining and improving soil fertility, and the absence of a negative impact on the environment.

5. Research methods
This article provides a fragment of the research that was carried out in the 1st department of the educational-experimental farm "Gorsky State Agrarian University" in a fruit garden planted in April 2015 on an area of 22.5 hectares. The scheme of planting trees 4x5m at a flow rate of two-year-old seedlings of 500 pcs/ha.

The climate of the forest-steppe zone, in which leached chernozems are familiar, is moderately warm, and humidification is sufficient: an average of 670 mm of precipitation falls annually. The sum of favorable temperatures for the year is 3000–3200 °C.

The soil is leached chernozem, pebbled from a depth of 50–70 cm, while the thickness of the humus horizon is 40–50 cm. The granulometric composition is loamy, with a light-loamy-stony depth.

Humus reserves are in the range of 380–570 t/ha. Humic acids (calcium humates) predominate in humus; the amount of fulvic acids increases with depth. Humus is rich in nitrogen (5–6 %). Actual and exchange acidity are small – pH water = 6.2–6.4, pH salt = 5.8–6.0, hydrolytic acidity = 2.1–2.8 mEq per 100 g of soil. The slightly acidic soil reaction is quite favorable for plants. The degree of saturation with bases is 94–98 %. Calcium predominates in the composition of exchange cations, significantly less than magnesium. Their sum in the arable layer is 33–37 mEq per 100 g of soil.

Our studies on the study of apple trees are designed for the period from 2018 to 2020.

Varietal composition of the apple tree is presented: Florina, Aydored, Stark-Nart.

The studies were carried out in a field experiment in which different doses and combinations of NPK, the comparative effect of mineral, organic fertilizers for the varieties of apple trees Florin, Aydored, Stark-Nart were studied.
Scheme of experience:
1. Control (without fertilizers); 
2. N60P60K60; 
3. N90R90K90; 
4. N120R120K120; 
5. N150R150K150; 
6. N15P35 + manure 10 t/ha is equivalent to N60P60K60; 
7. N30P70 + manure 20 t/ha is equivalent to N120P120K120.

Fertilizers were used: complex fertilizers – in the form of nitroammophoski grades 15-15-15, nitrogen – in the form of ammonium nitrate, phosphoric – simple superphosphate, organic – cow dung, semi-matured (10, 20 t/ha).

Fertilizers were introduced randomly in the spring with subsequent plowing.

In each plot, ten trees of each variety, the repetition is fourfold.

In mature fruits were determined:
1. Sugar content – according to the Bertrand method.
2. The total acidity by 30 minutes of heating the crushed sample with distilled water in a water bath at 80 °C, then in the filtrate by titration of 0.1 N. alkali solution.
3. Vitamin C content – according to the Murray method.
4. Fiber content – according to the method of Hanneberg and Shtoman.
5. The content of NPK according to the method of Kurkayev.
6. The content of the pectin substances carbazole method.
7. The content of nitrates using the device Nitrate – tester.

6. Discussion of the results
Productivity is one of the main factors when evaluating varieties. Productivity is a biological feature of the array. At the same time, the yield also depends on many other factors, namely, soil and climatic conditions, soil care in the garden, the use of fertilizers, pest and disease control, and soil content between rows. The productivity of a variety is the most critical indicator of its biological and economic characteristics and depends on environmental and agricultural practices in horticulture.

Providing a high level of agricultural technology, including the application of fertilizers, contributed to obtaining high yields.

The increase in the number of fruits occurred due to an increase in fruit set on fertilized trees. By increasing the number of fruits and increasing the mass of each fruit, the yield of the studied varieties increased.

Our data show that the use of fertilizers in the orchard helped to improve the growth and development of trees and fruits, and, ultimately, increase productivity. In all cases, the fruit yield of all varieties was higher than in control by 2.5–18.0 t/ha. It can be noted that it consistently increased with increasing doses of NPK 60 to 150 kg/ha a.v. (Table 1).

| Option          | Florina yield t/ha | Florina increase % | Aidored yield t/ha | Aidored increase % | Stark-Nart yield t/ha | Stark-Nart increase % |
|-----------------|--------------------|--------------------|--------------------|--------------------|------------------------|------------------------|
| Control         | 22.0               | -                  | 12.5               | -                  | 11.5                   | -                      |
| N60P60K60       | 26.5               | 4.5                | 20.5               | 15.0               | 20.0                   | 4.5                    |
| N90P90K90       | 31.5               | 9.5                | 43.2               | 18.5               | 40.0                   | 9.5                    |
| N120P120K120    | 34.5               | 12.5               | 56.8               | 23.5               | 88.0                   | 13.0                   |
| N150P150K150    | 40.5               | 18.0               | 81.8               | 28.5               | 128.0                  | 15.0                   |
| N15P35 + manure 10 t/ha | 28.0           | 6.0                | 27.3               | 16.0               | 28.0                   | 5.5                    |
| N30P70 + manure 20 t/ha | 33.5           | 11.5               | 52.3               | 21.5               | 72.0                   | 10.5                   |
| HCP05           | 0.07               | 0.12               | 0.10               |                    |                        |                        |
The combination of low doses of mineral fertilizers and manure was slightly more effective than N60P60K60 (an increase of 6 t/ha versus 4.5 t/ha). Doubling the treatments in this combination increased the yield increase by almost two times (from 6.0 to 11.5 t/ha) for the Florin variety. A similar picture was observed for other types.

An important criterion in assessing the reaction of an apple tree to the application of mineral fertilizers is the fruit quality indicators [6]. Our data indicate that the fertilizers studied had different effects on the quality of the fruit. For Aidored variety (Table 2), one can note a tendency to a decrease in the dry matter content and acidity of the grains as the level of mineral nutrition increases. In contrast, the content of sugar, vitamin C, P-active substances, sugar-acid index, and pectin substances increase. According to these indicators, N150P150K150 stands out as the best of the fertilized options.

| Option          | Dry matter, % | Sugar, % | Acidity, % | Vitamin C, mg/100g | P-active substances, mg/100g | Sugar-acid index | Pectin substances, % |
|-----------------|---------------|---------|------------|------------------|-----------------------------|-----------------|----------------------|
| Control         | 14.6          | 10.5    | 0.75       | 9.3              | 120.6                       | 14.0            | 0.5                  |
| N60P60K60       | 14.2          | 10.9    | 0.68       | 9.9              | 126.4                       | 16.0            | 0.7                  |
| N90P90K90       | 13.5          | 11.3    | 0.61       | 10.6             | 135.2                       | 18.5            | 0.7                  |
| N120P120K120    | 13.2          | 11.7    | 0.50       | 11.1             | 139.1                       | 23.4            | 0.8                  |
| N150P150K150    | 12.7          | 12.2    | 0.48       | 12.0             | 147.3                       | 25.4            | 0.9                  |
| N15P35 + manure 10 t/ha | 13.1          | 11.9    | 0.56       | 11.4             | 140.0                       | 21.3            | 0.6                  |
| N30P70 + manure 20 t/ha | 14.3          | 12.0    | 0.54       | 11.8             | 142.8                       | 22.2            | 0.8                  |

Concerning Florin and Stark-Nart varieties (Table 3 and Table 4), it should be pointed out that the patterns of action of fertilizers on the quality of fruits noted for the Aidored variety are identical. However, quantitative indicators are not the same. In particular, it can be noted that in terms of sugar content, Stark-Nart is inferior to the other two varieties. In terms of acidity, Florin is superior to the variety (fruits are less acidic). Vitamin C is more in the fruits of the Aidored variety (9.3 mg/100 g on the control). In second place is Florina. On the third – Stark-Nart (on the control of 8.0 and 7.1, respectively).

| Option          | Dry matter, % | Sugar, % | Acidity, % | Vitamin C, mg/100g | P-active substances, mg/100g | Sugar-acid index | Pectin substances, % |
|-----------------|---------------|---------|------------|------------------|-----------------------------|-----------------|----------------------|
| Control         | 13.7          | 10.4    | 0.60       | 8.0              | 96.0                        | 18.1            | 0.7                  |
| N60P60K60       | 13.5          | 10.9    | 0.52       | 8.6              | 102.5                       | 21.0            | 0.8                  |
| N90P90K90       | 13.2          | 11.5    | 0.50       | 9.2              | 105.6                       | 23.0            | 0.9                  |
| N120P120K120    | 12.8          | 12.1    | 0.47       | 9.7              | 108.4                       | 25.7            | 1.0                  |
| N150P150K150    | 12.5          | 12.8    | 0.45       | 10.1             | 111.9                       | 28.4            | 1.1                  |
| N15P35 + manure 10 t/ha | 13.4          | 11.3    | 0.56       | 8.8              | 109.3                       | 20.2            | 0.8                  |
| N30P70 + manure 20 t/ha | 12.9          | 11.7    | 0.54       | 9.5              | 110.2                       | 21.7            | 0.9                  |

| Option          | Dry matter, % | Sugar, % | Acidity, % | Vitamin C, mg/100g | P-active substances, mg/100g | Sugar-acid index | Pectin substances, % |
|-----------------|---------------|---------|------------|------------------|-----------------------------|-----------------|----------------------|
| Control         | 14.7          | 9.9     | 0.67       | 7.1              | 89                          | 14.8            | 0.8                  |
| N60P60K60       | 14.5          | 10.1    | 0.64       | 7.3              | 91                          | 15.8            | 0.9                  |
| N90P90K90       | 14.3          | 10.4    | 0.60       | 7.6              | 93                          | 17.3            | 1.0                  |
| N120P120K120    | 14.1          | 10.8    | 0.58       | 7.8              | 96                          | 18.6            | 1.1                  |
| N150P150K150    | 13.9          | 11.2    | 0.56       | 8.0              | 98                          | 20.0            | 1.2                  |
| N15P35 + manure 10 t/ha | 14.6          | 10.2    | 0.65       | 7.4              | 92                          | 15.7            | 0.9                  |
| N30P70 + manure 20 t/ha | 14.0          | 11.0    | 0.59       | 7.7              | 97                          | 18.6            | 1.1                  |
Pectin substances play a significant role in the medical nutrition of humans. In the control, the content of pectin substances in apples of the Florin variety reached 0.71%. On the fertilized version N150P150K150, the pectin content was 0.41% higher than on the control.

7. Conclusions
1. In the apple orchard on leached chernozem, lined with pebbles from a depth of 50 cm and having a wash water regime, the use of mineral and organic fertilizers is an effective agrotechnological technique. This technique increases the yield of the fruits of the varieties Aidored, Florin, and Stark-Nart by 20.0–130.4% compared with non-fertilized control.

2. The Florin variety was the most fruitful, the Aydored range and especially Stark-Nart were significantly less productive: 22.0, 12.5 and 11.5 t/ha, respectively, were controlled. Of the fertilized options, the best in all three varieties were N150P150K150: productivity was 40.5, 28.5, and 26.5 t/ha, respectively.

3. The data obtained indicate that the fertilizers studied had different effects on the quality indicators of the fruit. For Aidored variety, there is a tendency toward a decrease in the dry matter content and fruit acidity as the level of mineral nutrition increases. In contrast, the content of sugar, vitamin C, P-active substances, sugar-acid index, and pectin substances increase. According to these indicators, N150P150K150 stands out as the best of the fertilized options.

4. Concerning the Florin and Stark-Nart varieties, it should be pointed out that the patterns of action of fertilizers on the quality of fruits noted for the Aidored array are identical. However, quantitative indicators are not the same. In terms of sugar content, Stark-Nart is inferior to two other types, and in terms of acidity, the advantage is in Florin's variety (fruits are less acidic). Vitamin C is more in the fruits of the Aidored variety (9.3 mg / 100 g in control), Florin is in second place, and Stark-Nart is in third (in the power of 8.0 and 7.1, respectively).

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