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# Use of pome fruit stock of apple trees for soils bioindication in the North of Central black earth economic region

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# Use of pome fruit stock of apple trees for soils bioindication in the North of Central black earth economic region

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**Abstract.** In the vegetative experience, there is no close correlation between the bonitet of different types of soils and the vegetative productivity of apple seedlings. The most intensive growth on the forest soils of pome fruit stock is a characteristic feature of the biology of its wild-growing relative of the forest apple tree originated and evolved in forest ecosystems. At the same time, poor development of the root system on more fertile black earth, but intensive on forest ones, indicates the adaptation mechanism of roots in the search for nutrients and moisture.

## 1. Introduction

The experience gained in evaluating the degree of soil fatigue in an apple monoculture using 7-week-old apple plants of the McIntosh and Delicious varieties [1]. Under the growing season with annual apple varieties of the Gala variety on the M9 stock, the application of fertilizers into the soil increased the level of chlorophyll and nitrogen in the leaves [2]. In another vegetative experiment with an apple, the application of fertilizers and phosphorus into the soil resulted in an increase in their level in the leaves, without affecting the growth of plants [3]. The frost resistance of the annual shoots of the Topaz apple variety decreased with growing on the soil from old apple orchards [4]. Using the example of Topaz cultivar on the stock M26. it is established that the longer the soil is outside the monoculture of an apple tree, the more nitrogen, phosphorus, potassium and magnesium accumulate in the leaves of an apple tree planted on such soil [5]. With an increase in the level of orchards in the soil in apple leaves of the Cox's Orange variety, the fertilizers level increased from 1.7 to 2.2% and the intensity of photosynthesis increased [2]. The increase in nitrogen level in the leaves of apple varieties Jonagored on the stock M9 continued when the fertilizers level reached in 100 mg / 100 g in alluvial loamy and gray-brown clay soils [6]. With a dose of nitrogen of 50 and 100 kg.d.v./ha in the leaves of this variety, the level of nitrogen increased, and in the fruits remained unchanged [7]. In Iran, in a model experiment, an increase in the phosphorus level in the soil by 4 times did not affect the condition of the leaves of young apple trees of the variety Delicious [8]. Increasing the level of available potassium in the soil from 12 to 20 mg / 100 g did not change the level of potassium, nitrogen, phosphorus, calcium, magnesium, sulfur and chlorine in Golden Delicious apple leaves on the stock M26 during the period of full fruiting [9], and increasing its level from 120 to 200 mg / 100 g led to the decrease in the level of manganese, but it did not change the level of iron, zinc, copper and boron in leaves of the apple tree of this variety [10]. In a and the intensity of photosynthesis in the leaves of 5-year-old apple trees of the Jonagold variety on the M9 stock [11]. It is not advisable to introduce this element into the soil when zinc level in the leaves of this variety on the M26 stock at the level is 17 mg / 100 g in the middle of summer [12].

The purpose of this study is to study the dependence of the mass and height of apple seedlings on the soil type, the nature of the genetic soil horizon and the degree of soil fatigue.

## 2. Objects and research methods

The studies were conducted in 2014-2018. and they continue nowadays. Soil analyzis was carried out in the research agrochemical laboratory of Yelets State University named after I.A. Bunin. The hygroscopic humidity was determined by thermostat-weight method, maximum hygroscopicity was determined similarly after 4-day soil in desiccators with humidity close to 100%, the smallest moisture capacity was evaluated by plaster casts and pouring sites. The agrochemical analysis of the soil was carried out according to the instructions of CINAO [13]: mobile phosphorus and exchangeable potassium was carried out according to the method of F.V. Chirikov [14]. The evaluation of soil availability of possible forms of phosphorus, potassium and magnesium for fruit varieties was carried out according to the method of A. Kondakov [15]. For the growing experiment No. 1. apple seedlings of the variety Renet Kichunova from free crossing were used.

The weight of the soil in the plastic growing pot for seedlings was 750 g. The repetition is 4-fold. As the drainage at the bottom of the vessels, pure quartz sand was placed with a layer of 1 cm, amounted to 100 g. From above, the soil surface was mulched and stabilized in the hydrothermal regime in the vessels and was also covered with a centimeter layer of sand [16]. The humus horizon upper (0-30 cm) soil type Tambov plain was used such as alluvial sod sandy loam (1), sod podzolic deep glue of medium (2), sod podzolic medium loamy (3), meadow-black earth strongly podzolized heavy loam (4), meadow –black earth medium-podzolized heavy loam (5), alluvial sod light loamy (6), alluvial sod sandy loam (7), alluvial sod medium loamy (8), gray forest medium loamy (9), light gray woody forest medium loamy (8), gray forest medium loamy (9), light gray forest medium loamy (8) I (10). Genetic horizons of the most typical soil in the Central black earth economic region, black earth medium loamy, selected from the meadow of Dolgorukovsky district of the Lipetsk region were used for the vegetation experiment No 2.

## 3. Research results

Humic ($A_1$), transitional ($AB_1$), alluvial ($B_2$) types of soil and tape clay in the soil-forming rock ($C_2$) were characterized by the highest moisture capacity. The lowest moisture index was noted in bags of iron-rich gravel in the alluvial horizon and sand of the soil-forming rock ($C_3$). The actual acidity of the soil ($pH_{H2O}$) in the horizon s to the depth of carbonates is neutral, in the carbonate horizon and band clay it is slightly alkaline, in deep sand it is alkaline. The exchange acidity of the soil ($pH_{KCl}$) to the depth of the carbonate horizon it is slightly acidic, in the clay it is neutral, and in the carbonate horizon and sand it is slightly alkaline. The hydrolytic acidity of the genetic horizon s of leached black earth is high only in the humus horizon. The sum of exchange bases in the sandy, transitional, alluvial horizon and band clay is low, in the humus horizon it is medium, in the carbonate horizon it is high. The level of nitrate nitrogen in the soil to a depth of carbonates is very low, in the carbonate horizon and band clay it is low. In the sand, there are also no nitrates and mobile phosphorus, and in other horizons its content is from low to very low. The level of exchangeable potassium in the sand is very low, and in other horizons it is medium.

In experiment No. 1. the reaction of the apple tree to different soil conditions began to be traced only 5 months after germination. The slowest growth and lowest plant height are observed on alluvial sod soils. On sandy soils of this type, the apex of shoots and upper leaves of the apple tree were drying out and dying out, as well as a very weak development of the root system was noted. It indicates a lack of boron and calcium on this soil. On the gray, light gray forest and sod-podzolic sandy loam soil, the most rapid growth of the root system was pointed out. Long and thick strands of roots, covering the entire volume of the growing plant were formed. On gray forest soils, the highest plant height (up to 40 cm) with the maximum number of leaves on the shoot (22-24 leaves) is also noted. On the black-earth soils, on the contrary, a root system of the apple tree was much less developed. The root mass of the seedlings was very weakly dependent on the quality of the black earth soils (r = 0.57). However, it has been established that the higher the bonitet of black earth soils, the greater the above-ground weight of the apple tree (on average, r = 0.81) and the higher the water-holding capacity (WHC) of the shoots (r = 0.63) (table 1).

**Table 1.** The above-ground mass of an apple tree depending on the quality of the black earth soils.

| Type of soil / bonitet in points | Leaf weight, g / vessel | | Shoot weight, g / vessel | | Raw mass g / vessel | | WHC of shoots, % |
|---|---|---|---|---|---|---|---|
| | green | dried | green | dried | roots | total | |
| Black earth typical / 80.1 | 0.51 | 0.15 | 0.35 | 0.14 | 0.30 | 1.16 | 7.14 |
| Black earth leached / 86.1 | 0.91 | 0.31 | 0.47 | 0.17 | 0.71 | 2.09 | 4.92 |
| Black earth leached/ 88.3 | 1.55 | 0.50 | 0.85 | 0.33 | 1.01 | 3.40 | 1.18 |
| Black earth leached / 84.5 | 0.89 | 0.25 | 0.38 | 0.12 | 1.0 | 2.28 | 7.70 |
| Meadow - black earth / 76.8 | 0.26 | 0.10 | 0.11 | 0.03 | 0.31 | 0.70 | 9.16 |
| Meadow - black earth / 84.8 | 1.34 | 0.45 | 0.68 | 0.30 | 1.08 | 3.11 | 2.13 |
| Black earth - Meadow / 80.3 | 0.93 | 0.32 | 0.52 | 0.20 | 1.18 | 2.63 | 2.80 |
| Regression coefficient (r) | 0.86 | 0.82 | 0.81 | 0.75 | 0.57 | 0.80 | -0.63 |

Within the group of forest soils, a weak correlation was established only between bonitet and the mass of apple shoots (r = 0.55-0.6) (table 2).

**Table 2.** Ground mass of an apple tree depending on the strength of forest soils.

| Type of soil / bonitet in points | Leaf weight, g / vessel | | Shoot weight, g / vessel | | Raw mass g / vessel | | WHC of shoots, % |
|---|---|---|---|---|---|---|---|
| | green | dried | green | dried | roots | total | |
| Gray Forest / 68.2 | 1.11 | 0.40 | 0.71 | 0.30 | 1.98 | 3.81 | 4.84 |
| Light gray forest / 66.7 | 1.31 | 0.43 | 0.58 | 0.20 | 0.63 | 2.52 | 1.78 |
| Sod-podzolic / light loamy deep glue / 75.7 | 1.17 | 0.43 | 0.84 | 0.36 | 1.68 | 3.69 | 1.20 |
| Light loamy / deep glue 75.9 | 1.85 | 0.49 | 0.89 | 0.48 | 0.90 | 3.65 | 1.75 |
| Sod-podzolic sandy / 76.2 | 0.86 | 0.30 | 0.63 | 0.24 | 1.55 | 3.05 | 5.70 |
| Regression coefficient (r) | 0.27 | 0.18 | 0.55 | 0.60 | 0.10 | 0.46 | -0.16 |

Apple seedlings on leached black earth, selected from 4-year-old gardens, developed well, but their growth was strongly inhibited on the soil from 16-20-year-old apple orchards. The total raw biomass (r = 0.62) and the water level in the shoots (r = 0.75) increase within a group of soils formed on alluvium. But plants lost their turgor and dried out first of all in creating an artificial water deficiency on soils with sandy and sandy sand granulometric structure. It is noted on sod-podzolic, alluvial turf and gray forest soils. The soil bonitet did not affect the dry matter content in the leaves and shoots of the apple tree (table 3).

**Table 3.** Vegetative productivity of an apple tree depending on the quality of the soil underlain by alluvium.

| Type of soil / bonitet in points | Leaf weight, g / vessel | | Shoot weight, g / vessel | | Raw mass g / vessel | | WHC of shoots, % |
|---|---|---|---|---|---|---|---|
| | green | dried | green | dried | roots | total | |
| Gray Forest /66.64 | 1.30 | 0.41 | 0.60 | 0.22 | 0.62 | 2.50 | 1.80 |
| Sod-podzolic medium loamy /76.05 | 1.83 | 0.50 | 0.90 | 0.46 | 0.90 | 3.66 | 0.74 |
| Sod-podzolic light-loamy /76.52 | 0.87 | 0.31 | 0.62 | 0.23 | 1.54 | 3.03 | 5.62 |
| Alluvial sod sandy / 69.5 | 0.37 | 0.12 | 0.28 | 0.11 | 1.58 | 2.26 | 4.05 |
| Alluvial sod light loamy / 72.54 | 0.62 | 0.20 | 0.46 | 0.18 | 0.96 | 2.05 | 5.93 |
| Alluvial sod medium loamy /73.15 | 1.05 | 0.48 | 1.07 | 0.52 | 1.12 | 3.40 | 1.95 |
| Regression coefficient (r) | 0.26 | 0.19 | 0.47 | 0.53 | 0.33 | 0.63 | 0.15 |

On the soil taken from virgin and fallow lands of apple seedlings, the aerial part and roots developed normally (table 4).

**Table 4.** The effect of soil fatigue on the vegetative productivity of apple seedlings of the variety Renet Kichunova.

| Type of soil | Farmland | Productivity, g / vessel | | | | WHC of shoots, % |
|---|---|---|---|---|---|---|
| | | weight of green leaves | weight of green shoots | weight of roots | total biomass | |
| Black earth typical | Orchards | 0.51 | 0.35 | 0.30 | 1.16 | 7.14 |
| | Fallow | 1.90 | 0.70 | 0.71 | 3.31 | 4.50 |
| Meadow – black earth | Garden | 0.26 | 0.11 | 0.31 | 0.69 | 9.16 |
| | Meadow | 1.34 | 0.68 | 1.08 | 3.11 | 2.13 |
| Black earth - meadow | Garden | 1.80 | 0.97 | 1.35 | 4.13 | 3.62 |
| | Meadow | 0.93 | 0.52 | 1.18 | 2.63 | 2.80 |

The plant height in average is 30–40 cm. There were 12–18 leaves with an average area of 22 $cm^2$ on the shoot. Leaves and shoots were characterized by a higher water-holding capacity compared to plants on the soil from old apple orchards. The growth of apple seedlings was strongly oppressed on the soil of 16-20-year-old apple orchards: the average height of plants was 8 cm, a number of leaves on the shoot was no more than 7. with an average plate area of 10 $cm^{2.}$ and on soils from old gardens of light loamy and sandy-sandy granulometric structure the edges of the lower leaves 2/3 of the leaf area were dry and painted red (“marginal burn”), indicating a lack of potassium. The water-holding capacity of the leaves and shoots of the oppressed apple plants was significantly lower than on the soils of natural lands, and the total vegetative mass was in 2-4 times less. The suppression of apple growth under the influence of soil exhaustion was clearly visible on meadow-black earth soil, black earth-meadow soil, typical and leached black earth.

The differences in the biomass of apple seedlings depending on the genetic horizon were distinguished in the vegetation experiment No. 2. on the 142nd day. Apple trees on gravel and sand due to nitrogen deficiency formed the smallest leaves, and due to the lack of phosphorus it had the weakest root system. The lowest plant height is marked on the alluvial horizon, gravel and sand. At $B_2$. this is caused by too heavy a grain-size structure, compaction and swimming of this horizon during irrigation, and on sand and gravel due to the poverty by mineral elements. On the $B_{3Ca}$ horizon in apple trees, due to root burns from carbonates, a change in leaf color is observed: the lower ones turn red completely, and the upper ones are chlorotic. Chloroticity (interstitial yellowing) is a consequence of iron deficiency, the mobility of which is blocked by a weak alkaline reaction. The highest growth, a number and size of leaves, a large above-ground and root biomass of apple seedlings were marked on the humus horizon. Rather good indicators of biometrics of apple seedlings were obtained on the transition horizon and band clay (table 5).

The beneficial effect on the growth of apple clay band is due to the almost neutral reaction, medium loamy granulometric structure, moderate carbonate content and the presence of a sufficient amount of mineral elements.

**Table 5.** Biomass of apple seedlings on different horizons of leached black earth per vegetation vessel.

| Horizon | Plant height, cm | Total dried biomass, g | Dried weight, g | | |
|---|---|---|---|---|---|
| | | | leaves | shoots | roots |
| $A_1$ | 15.4 | 2.2 | 1.05 | 0.65 | 0.5 |
| $AB_1$ | 10.3 | 1.24 | 0.52 | 0.42 | 0.3 |
| $B_2$ | 5.0 | 0.75 | 0.32 | 0.23 | 0.2 |
| $B_{2f}$ | 8.4 | 0.6 | 0.3 | 0.2 | 0.1 |
| $B_{3Ca}$ | 9.5 | 1.22 | 0.5 | 0.32 | 0.4 |
| $C_2$ | 9.3 | 1.42 | 0.62 | 0.45 | 0.35 |
| $C_3$ | 3.8 | 0.77 | 0.37 | 0.2 | 0.2 |

## 4. Conclusion

1. An increase in bonitet within the black earth soils and soils on alluvium contributes to an increase in the above-ground mass, while in the limits of forest soils, the dried weight of the shoots, and the gleying inhibits the growth of seedlings.

2. The optimal particle size of the soil for apple seedlings is medium loamy.

3. The most favorable soil types for the growth of apple seedlings are gray forest soils; the most unfavorable ones are heavy loamy black earth and sandy alluvial sod soils.

4. As a degree of suitability for apple seedlings decreases, the leached black earth horizons are placed as follows: humus $A_1$> transitional $AB_1$ or band clay $C_2$> carbonate $B_{3Ca}$ > alluvial $B_2$ or $B_{2f}$ > sand $C_3$.

5. The adverse parameters for apple seedlings in leached black earth are too heavy or light grain size distribution, an excess of carbonates or poverty with mineral elements.

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