Comparison of water-physical and microbiological properties of apple orchards soils with indicators in other agricultural lands

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Abstract. The aim of the research is to compare the physical properties and biological activity of the soil in apple orchards with the soils of other lands: strawberry, chokeberry, black currant plantations, field crop rotation, forest plantations, and deposits. In apple orchards, in a layer of 0-40 cm row-spacing, there is a relatively low content of agronomically valuable, water-resistant aggregates, and the lowest moisture capacity. Due to the significant accumulation of snow in the garden and the annual leaf fall of the apple tree in the trunk strips, the same high cellulolytic activity is maintained as in other woody phytocenoses.

1. Introduction
The aisles of most gardens are kept under long-term black steam, which leads to the destruction of the soil structure, reducing the content of humus, reducing the number of soil microbes and worms, falling biological activity [1], washing away the soil in the aisles [2]. In the process of designing intensive gardens, it is necessary to know its microbiological properties [3] and moisture capacity [4]. Apple leaf litter is a valuable source of mineral elements [5] and phytostimulants [6]. Therefore, the soils of some gardens in comparison with forest are more favorable in Ca, P, Mg, K, NO3 [7], organic phosphorus [8] and the number of microorganisms [9].

2. Objects and methods of research
The research was carried out in 2003-2016. The main object of research was the apple orchard (quarter number 130) in OPH VNIIS named after I. V. Michurin, Tambov region, 1987 landing year. Scheme 5×3 m. The prevailing soil type is the meadow-chernozem leached. In SPK "Kochetovsky" apple quarters laid in 1989-1993 according to the scheme of 8 × 4 m. Black currant plantations were represented by varieties Chyornyj zhembchug, Zelenaya dymka and Sozvezdie, placed according to the scheme of 3×1.5 m, strawberries were represented by variety Festivalnyaya placed 1-line rows according to the scheme of 70×30 cm. In SPK "Zelenyi Gaj” apple orchard laid according to the scheme 7×7 m. In SPK "Dubovoe” apple orchards laid in 1993 on typical chernozems and leached according to the scheme 6X4 m. on the rootstock 54-118. In fruit nursery "Zherdevsky” apple orchards laid in 1986-1987 according to the scheme 7×4 m. Varieties: Lobo, Melba, Mentet, Sinap Orlovsky, Pervene, Welsey, Zhigulevskoe, Besseyanka Michurina, Rossoshanskoe polosatoe. Rootstocks: 62-396, 54-118 and pome. Soils of farms are mainly heavy loamy. Row spacing of all gardens were kept
under black steam: spring tooth harrowing for 3-5 cm and 5-6-fold treatment for 10-12 cm during the summer, consisting in alternation of cultivations and disc harrowing; 1 time in 4 years, autumn dump plowing for 30-40 cm was carried out. The intensity of decomposition of fiber was determined by the application method [10]. Agrochemical soil analysis performed according to the instructions of CINAO [11], the smallest capacity (SC) – by casting platforms, capillary moisture capacity (CMC) – using a cylinder with mesh bottom, hygroscopicity (H) and the maximum hygroscopic moisture content (HM) – by thermostatic-weight method, aggregate analysis of soils - by dry sieving [12], accounting of litter and forest floor was carried out at 10 sites a size of 1x1 m [13].

3. Research results

In order to compare the soils in orchards with the soils in field cultivation by structure, in 2007 a structural analysis of the field crop rotation soil was carried out in Kochetovsky SPK (table 1).

**Table 1.** The content of agronomically valuable aggregates in meadow chernozem soil under winter wheat in the tillering phase in the Kochetovsky SPK, %.

| Layer, cm | >10 | 10-7 | 7-5 | 5-3 | 3-2 | 2-1 | 1-0,5 | 0,5-0,25 | <0,25 | Aggregate content 0,25-10 mm, % |
|-----------|-----|------|-----|-----|-----|-----|------|---------|------|-------------------------------|
| 0-30      | 26,76 | 11,45 | 8,44 | 10,94 | 10,79 | 21,80 | 1,65 | 7,19 | 0,98 | 72,26 |

The content of agronomically valuable aggregates in the arable layer (0-30 cm) of meadow-chernozem leached soils in field cultivation was 1.3 times higher than in the same layer of inter-row zones of fruit and berry orchards. If the structural condition of the garden soils is assessed as satisfactory, then in the field the soil structure is good. The field structural coefficient was 2.6, and the row spacing of apple orchards was 0.27.

By comparing the content of agronomically valuable aggregates in the soil of row-spacings with near-tree strips, one can evaluate the degradation of the structure in fruit and berry orchards. In the Kochetovsky SPK, in the row-spacing of the apple and chokeberry orchards, soil degradation is stronger than in the upper arable layers (0-30 cm) compared to the near-trunk strips than in the arable, currant plantations - on the contrary, it is more noticeable in the arable (30-60 cm) layers.

The structural state of meadow-chernozem soils in the near-trunk bands of apple orchards in the Green Guy SEC was assessed as good, and the inter-row spacing was satisfactory. The soil structural coefficient in the 60 cm row spacing was 2.8 times lower than in the near-trunk strips (table 2).

**Table 2.** The structural coefficient of meadow-chernozem soil of fruit and berry plantings of SPK “Zelenyj Gaj”.

| Area                  | Depth, cm | 0-30  | 30-60 | 0-30  | 30-60 |
|-----------------------|-----------|-------|-------|-------|-------|
| Apple tree            | 5,50      | 1,61  | 1,23  | 1,32  |
| Black currant         | 3,48      | 0,57  | 0,56  | 1,34  |
| Wild strawberry       | 2,87      | 1,17  | 1,35  | 0,73  |

In blackcurrant stands, the similar difference was less and amounted to 2.12 times and even less in strawberry stands - 1.8 times. This can be explained by the fact that the rows of blackcurrant, and especially strawberries, are narrower and, therefore, for their mechanical processing, lighter techniques are used than in apple orchards, to a lesser extent compaction of the arable layers.

In 2007, in the SPK “Zelenyj Gaj”, the soil between the rows of strawberries was better structured in comparison with apple and currant orchards (table 3).
Table 3. The content of agronomically valuable aggregates (0.25-10 mm) in the meadow-chernozem soils of the SPK “Zelenyj Gaj” gardens, %.

| Layer, cm | Apple orchard Barrel strip | Black currant Barrel strip | Wild strawberry Barrel strip |
|-----------|---------------------------|---------------------------|-----------------------------|
| 0-30      | 39,69                     | 81,57                     | 34,12                       | 75,23                       | 59,19 | 74,47 |
| 30-60     | 54,43                     | 65,0                      | 39,40                       | 55,98                       | 52,18 | 54,10 |

SSD_{05} = 4,71  SSD % = 8,25

Differences in the content of agronomically valuable aggregates in the soil between row-spacings and under-cover uncultivated zones of strawberries were significantly smaller than in the above gardens.

As a result of the research, it was found that in the near-stem strips of apple orchards on meadow-chernozem, chernozem-meadow, gray forest and chernozems podzolized, the soil structure is similar to fallow and field crop rotation, that is, better than in other fruit and berry stands. This is due to the stronger structural effect of the root system of the apple tree compared to the roots of currant, chokeberry and strawberry.

In the row-spacing of apple and chokeberry orchards, the content of agronomically valuable aggregates is much lower than in the currant and strawberry plantations, especially in the 30-60 cm layer. This is due to the greater compaction of the subsurface layer because of using of heavier equipment (table 4).

Table 4. The content of agronomically valuable aggregates in meadow chernozem soils of the Tambov region under apple orchards compared to other agricultural lands, %.

| Area         | Layer, cm | Apple tree | Black currant | Wild strawberry |
|--------------|-----------|------------|---------------|-----------------|
|              |           | Barrel strip | Barrel strip | Barrel strip    |
| Barrel strip | 0-30      | 84,60      | 68,90         | 64,80           | 74,18           |
|              | 30-60     | 61,70      | 70,18         | 43,51           | 54,01           |
| Row spacing  | 0-30      | 51,20      | 57,91         | 50,10           | 57,55           | 73,46 | 72,26 |
|              | 30-60     | 47,03      | 55,62         | 45,60           | 52,21           | 71,20 | 69,0  |

Our research showed that with an increase in the proportion of plant debris in the soil, its capillary moisture capacity decreases, dropping to the level of 30-36% in the turf of virgin soils of the Michurinsky district (table 5).

Table 5. The moisture content and structure of chernozems typical of apple orchards in the Tambov region compared with field cultivation and the natural state.

| Index, %     | Horizon and depth, cm | Garden aisles | Phytocenosis Field crop rotation | Virgin plots | SSD_{05} | SSD % |
|--------------|-----------------------|---------------|---------------------------------|--------------|----------|-------|
| Hygroscopic  | A_p 0-20              | 5,72          | 6,35                            | 6,04         | 0,47     | 7,78  |
| humidity     | A_r 20-60             | 5,82          | 6,61                            | 7,54         | 0,74     | 11,09 |
|              | AB 60-80              | 5,34          | 6,46                            | 6,91         | 0,48     | 7,75  |
|              | B 80-110              | 4,71          | 5,54                            | 5,26         | 0,15     | 3,04  |
|              | C 110-150             | 4,03          | 5,87                            | 5,88         | 0,53     | 10,11 |
| Maximum      | A_p 0-20              | 11,77         | 12,68                           | 12,03        | 1,52     | 12,54 |
| Hygroscopic  | A_r 20-60             | 11,89         | 12,73                           | 11,54        | 1,37     | 11,38 |
| humidity     | AB 60-80              | 11,55         | 11,67                           | 12,30        | 1,27     | 10,74 |
|              | B 80-110              | 11,18         | 12,01                           | 11,80        | 0,95     | 8,15  |
Such a mulching effect was noted in many virgin soils, especially with a large inflow of leaf litter, which reached a maximum value on forest soils - 7-8 t/ha of dry matter per year. Dark gray forest soils in the virgin state in ZAO “15 let Oktyabrya” have a forest litter ($A_p$) with a thickness of 20 cm with a capillary moisture capacity of 32-33%, while the underlying humus horizon A1 is characterized by a higher capillary moisture capacity - 49%. The hygrosopic humidity of the entire profile of chernozems typical in the aisles of apple orchards in the Tambov region is significantly lower than in field crop and natural state. The indicated differences in the content of agronomically valuable aggregates covered a meter-long layer of chernozem, and in terms of the least moisture capacity - only a layer of 0-20 cm.

The lower soil structure in the rows between apple orchards compared to deposits and fields is explained by frequent cultivations to the same depth (10 cm), as well as more rare plowing (once every 4 years, instead of annual crop cultivation). For example, the content of agronomically valuable aggregates in the arable layer (0-30 cm) of the winter wheat field turned out to be 1.3 times higher than in the same layer of inter-row zones of apple orchards. If the structural condition of the garden soils is assessed as satisfactory, then in the field the soil structure is good.

In the apple and currant orchards of the SPK “Zelenyj Gaj”, the hygrosopic and maximum hygrosopic soil moisture of the row-spacing is significantly lower than in the near-trunk strips, but this difference is less in the strawberry plantations (table 6).

**Table 6. Moisture capacity of meadow-chernozem soil in apple orchards compared to berry orchards in SPK “Zelenyj Gaj”**

| Orchard      | Area         | Moisture absorption,% by weight of dry soil |
|--------------|--------------|--------------------------------------------|
|              |              | Moisture capacity of meadow chernozem soil in apple orchards compared to berry orchards in SPK “Zelenyj Gaj”. |
Table 7. The moisture content of meadow-chernozem leached soil in a layer of 0-60 cm of gardens and field crop rotation SPK “Kochetovsky”.

| Index, %     | Garden aisles | Field crop rotation | SSD05 | SSD % |
|--------------|---------------|---------------------|-------|-------|
|              | Apple orchard | Black currant       | SSD05 | SSD % |
| H            | 3.23          | 4.49                | 5.75  | 0.27  | 6.14  |
| HM           | 7.27          | 6.77                | 8.08  | 0.85  | 11.58 |
| CMC          | 33.28         | 33.19               | 41.46 | 3.19  | 8.86  |

As in apple orchards, the capillary moisture capacity in blackcurrant stands indicates that the mulching effect was provided only in the near-stem bands. A mulching effect was created in strawberry stands on the indicated soil, both in rows and between rows. This is explained by the presence in the arable layer of plant residues of strawberries in the form of whiskers and leaves (table 8).

Table 8. Capillary moisture capacity of meadow-chernozem leached soil in blackcurrant and strawberry plantations in 2007, % by weight of dry soil.

| Area               | Layer, cm | SPK “Zelenyj Gaj” | SPK “Kochetovskij” |
|--------------------|-----------|-------------------|--------------------|
|                    |           | Black currant     | Strawberry         | Black currant     |
| Row spacing        | 0-10      | 44.69             | 41.75              | 54.77             |
|                    | 10-60     | 46.86             | 45.64              | 53.58             |
| Barrel strip       | 0-10      | 36.03             | 31.40              | 41.07             |
|                    | 10-60     | 43.57             | 43.82              | 46.33             |
| SSD05              |           | 2.67              | 2.02               | 3.96              |
| SSD%               |           | 6.24              | 4.97               | 8.10              |

In near-stem strips, regardless of the type of soil, a mulching effect is always created due to the arrival of leaf litter of trees, which reduces the value of capillary moisture capacity. During the years of research, the leaf litter of the apple tree was 3-4 t/ha of barrels of dry matter per year. Only in field crop rotation, the capillary moisture capacity of the upper arable soil layer is less than in the subsoil, which indicates a mulching effect (table 9).

Table 9. Capillary moisture capacity (CMC) of chernozems typical of the Tambov region, % by weight of dry soil.

| Nursery “Zherdevsky” | “Dubovoe” apple orchards | Field crop rotation |
|----------------------|--------------------------|---------------------|
| Horizon and depth, cm| CMC                      | Horizon and depth, cm| CMC              |
| A_h 0-10             | 43.46                    | A_h 0-10            | 48.66            |
| 10-53                | 45.48                    | A_1 10-60           | 39.31            |
| 53-73                | 38.43                    | AB 60-94            | 52.70            |
| 73-110               | 32.42                    | B 94-120            | 46.03            |
| C110-150             | 50.76                    | C 120-150           | 53.0             |
| HCP_o5              | 7.59                     | 4.03                | 5.14             |
| HCP%                | 17.04                    | 8.64                | 10.36            |

Thus, unlike field cultivation in apple orchards, the mulching effect is achieved very weakly or is completely absent. It was established that the cellulolytic activity of chernozem soils in the near-trunk bands of apple trees is significantly higher than in virgin meadow areas (table 10).
Table 10. Cellulolytic activity of soils in a layer of 0-30 cm of the near-tree trunks of apple orchards in comparison with other phytocenoses at the I.V. Michurin OPH VNIIS.

| The soil                   | Phytocenosis          | CAS, %          |
|----------------------------|-----------------------|-----------------|
| Meadow chernozem           | Apple orchard         | 94,90 (very strong) |
|                            | Meadow                | 64,61 (strong)  |
|                            | Oak forest belt       | 85,33 (very strong) |
|                            | Birch forest belt     | 85,41 (very strong) |
| Lugovato chernozem         | Apple orchard         | 89,53 (very strong) |
|                            | Meadow                | 78,14 (strong)  |
|                            | Oak forest belt       | 91,70 (very strong) |
|                            | Birch forest belt     | 91,76 (very strong) |
|                            | Pine plantations      | 84,11 (strong)  |
| Chernozem meadow           | Apple orchard         | 81,76 (strong)  |
|                            | Meadow                | 65,0 (strong)   |
| Light gray forest          | Apple orchard         | 77,76 (strong)  |
|                            | Oakery                | 94,73 (very strong) |

SSD₀₅ = 1.79  SSD% = 2.19

This can be explained by higher snow reserves in apple orchards compared to meadow areas (table 11).

Table 11. Snow reserves in the apple orchard compared to other lands in the I.V. Michurin OPH VNIIS (mid-March).

| Soil and phytocenosis         | Density, g/cm³ | Snow index | Reservers, mm |
|-------------------------------|----------------|------------|---------------|
| Lugovato chernozem. Apple orchard | 0.31          | 78.77      | 242.75        |
| Lugovato chernozem. Meadow    | 0.34          | 53.75      | 185.25        |
| Lugovato chernozem. 10 year deposit | 0.35      | 60.0       | 210.0         |
| Lugovato chernozem. Openwork forest belt | 0.33      | 62.32      | 205.50        |
| Gray forest. Oakery           | 0.30          | 50.55      | 151.60        |
| SSD₀₅                         | 0.01          | 4.56       | 13.81         |
| SSD %                         | 3.54          | 7.47       | 6.94          |

In addition, 3 times more dry organic matter is received annually in the near-tree strip of apple trees with leaf litter than in meadow and fallow plots. This, along with large sedimentation, creates more favorable conditions for the breakdown of fiber. Due to the greater annual leaf litter under other tree species, a more significant supply of forest litter is maintained than under the apple tree (table 12).

Table 12. The mass of leaf litter of apple compared with other tree species in the I.V. Michurin OPH VNIIS, t/ha dry matter.

| Phytocenosis       | Oakery | Apple orchard | Birch forest belt | Oak forest belt | Pine plantations | SSD₀₅ | SSD % |
|--------------------|--------|---------------|-------------------|-----------------|------------------|-------|-------|
| Annual litter      | 7.18   | 3.85          | -                 | -               | -                | 0.19  | 3.57  |
| Litter stock       | 16.95  | 4.00          | 11.0              | 10.05           | 27.0             | 0.50  | 3.50  |

Contrary to this, the degree of cellulose decomposition in chernozem soils under an apple tree is equivalent or even higher than under other artificially planted tree species. Only on gray forest soils cellulolytic activity (CAS) is higher than under an apple tree. On these soils, formed under broad-leaved, mainly oak forest, the stock of forest litter is 4 times greater than under the apple tree. To
quickly decompose such an amount of organic matter, the DAC must be very significant. Under the apple tree, as well as under the rest of the indicated breeds, a layer of 0-30 cm is not affected by the eluvial podzolic process. Under the pine stands from the depth of 20 cm, the first signs of the podzolic process are noted, and from the depth of 25 cm a pronounced eluvial horizon $A_2$ begins, which is poorly populated by microbes. Therefore, despite the most significant reserves of forest litter beneath the pine, its CAS, although high [14], is still lower than that of the apple tree and other species.

4. Conclusion
1. Perennial cultivation of the apple orchard negatively affects soil fertility. With its regular processing in a layer of 0-40 cm row-spacing, the content of agronomically valuable, water-resistant aggregates, and the lowest moisture capacity, are reduced.
2. Soils in apple orchards in comparison with other fruit and berry plantations, field crop rotations, fallow lands and virgin lands have less water resistance and moisture capacity.
3. Due to the significant accumulation of snowfall in the garden and the annual leaf litter of the apple tree in the near-trunk strips, the same high cellulolytic activity is maintained as in other woody phytocenoses.

References
[1] Sedov E N 1998 Some problems of adaptive gardening Horticulture and viticulture 4 2-4
[2] Kabelka D, Kincel D, Janecek M, Vopravil J and Vrablik P 2019 Soil and water research 14(3) 172-82
[3] Hong G, Geronimo F K, Choi H and Kim L H 2018 Impacts of nonpoint source pollutants on microbial community in rain gardens Chemosphere 209 20-7
[4] Lan T, Guo S W, et al. 2019 Evaluation of physical properties of typical urban green space soils in Binhai Area, Tianjin, China Urban forestry & urban greening 44 UNSP 126430
[5] Chen M L, Huang Y M, et al 2019 Impact of different nitrogen source on the compost quality and greenhouse gas emissions during composting of garden waste Process safety and environmental protection 124 326-35
[6] Mertoglu K, Ileri O and Altay Y 2018 Aqueous leaf extracts effect of some apple cultivars on growth characteristics of the green manure legumes via allelopathy Fresenius environmental bulletin 27(6) 4052-60
[7] Kukla J, Whitfeld T, et al. 2019 Land degradation and development 30(2) 166-77
[8] Paul R, Singh R D, et al. 2018 Phosphorus dynamics and solubilizing microorganisms in acid soils under different land uses of Lesser Himalayas of India Agroforestry systems 92(2) 449-61
[9] Wartman P C, Dunfield K E, et al. 2017 The establishment of apple orchards as temperate forest garden systems and their impact on indigenous bacterial and fungal population abundance in Southern Ontario, Canada Renewable agriculture and food systems 32(2) 157-68
[10] Zvyagincev D G, Aseeva I V, et al. 1980 Methods of soil microbiology and biochemistry (Moscow: Publication of MSU)
[11] 1973 CINAO instruction for conducting mass analysis of soils in zonal agrochemical laboratories (M.: Kolos)
[12] Revut I B 1964 Soil physics (L.: Kolos)
[13] Grishina L A and Samojlova E M 1971 Biomass accounting and chemical analysis of plants (Moscow: Publication of MSU)
[14] Perez-Izuquierdo L, Saint-Andre L, et al. 2018 Tree genotype and seasonal effects on soil properties and biogeochemical functioning in Mediterranean pine forests European journal of soil science 69(6) 1087-97