The study of physical and mechanical parameters of the soil in the cultivation of tubers

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Abstract. In the Russian Federation, due to the variety of conditions for growing tubers, it is important to increase the yield and completeness of the harvest in difficult and extreme conditions of harvesting. The technology, stable in critical weather conditions, based on the cultivation of food potatoes and Jerusalem artichoke of high quality, was developed by specialists of the all-Russian research Institute of potato farming named after Lorkh. Its main elements include growing tubers on broad ridges (110+30) and (120+30) cm. This placement of plants, both on loam and sandy loam provides retention of more moisture in dry periods, and more uniform maintenance of optimal moisture in the event of a significant amount of precipitation. Data on changes in soil moisture show that the value of this index is possible to exert a certain influence through a variety of agrotechnical methods. The difference in soil temperature during hot periods depends on the row spacing: in the variant (110+30) cm it was changing the parameters of the ridge can affect the temperature of the soil in the zone of the tuber nest.

Key words: potatoes, Jerusalem artichoke, crests, ridges, technology, loam, sandy loam, humidity, soil density and temperature.

1. INTRODUCTION

The problem of non-cultivated fields is increasing in the world [1]. With traditional technologies of growing tubers used in the non-chernozem zone, with rows of 70 or 75 cm and planting density – 50...60 thousand tubers per 1 hectare it is impossible to obtain high-quality yields of tubers of especially large fraction, because the plants are too dense, they lack nutrients and moisture [2]. The aim of the work is to make a comparative assessment of soil parameters at the ridge (with row spacing of 70 (75) cm) and ridge (with row spacing (110+30), (120+30)) technologies of cultivation of tubers; to reveal the influence of row spacing on the physical and mechanical parameters of the soil in the zone of the tuber nest (temperature, humidity and density) on the yield of tubers.
2. MATERIALS AND METHODS

Researches of soil parameters in the cultivation of potato tubers and Jerusalem artichoke was carried out in 2002-2004 in Lorch Potato Research Institute of the Moscow region on sod-podzolic medium-loamy soil. At the depth of the arable horizon, the soil is characterized by the following agrochemical indicators of the arable horizon: humus content by the method of Tyurin (OST 4647-76) was 2.49%; mobile phosphorus by Kirsanov was 372-551 mg/kg; exchange potassium by Kirsanov was 122-259 mg/kg; pH (KCl) was 5.63; hydrolytic acidity was 3.43 mg-EQ; maximum field moisture content of the soil (PPV) was 22.5%.

And also in 2015-2017 on the basis of the experimental Lorch Potato Research Institute in Korenevo (Lyuberetskiy district, Moscow region) on sod-podzolic sandy loam soil. At a depth of arable horizon soil was characterized by the following agrochemical indices of arable horizon: the sum of exchange bases was 1.5...2.4 mg-EQ/100 g; the content of humus according to Tyurin method (Gomernent Standard(further named as GOST) 26213-91) was 1.99%; mobile phosphorus according to Kirsanov (GOST 26079-91) was 380-653mg/kg; exchange potassium by Kirsanov (GOST 26207-91) was 223 is 25 mg/kg; pH X, Alyosha (GOST 26483-85) was 5.04; hydrolytic acidity (GOST 26412-91) was 3.46 mg-equiv.; maximum field moisture capacity of soil (PPV) – 13.3%.

The scheme of the experiment involved the study of the influence of row spacing on soil parameters:
– in the 2002-2004 experiment: in the crests was 70 cm (control) between the central axes of the crests; in the ridges (double ridges) was 140 cm between the central axes of the ridges with the placement of tubers in two rows in one ridge with a distance between the rows of 30 cm, which is denoted as (110 + 30) cm;
– in the experience of 2015-2017: in the crests was 75 cm (control) between the Central axes of the crests; in the ridges (double crests) was 150 cm between the Central axes of the ridges with the placement of tubers in two rows in one ridge with a distance between the rows of 30 cm, which is denoted as (120 + 30) cm.

Placement of plots is systematic. Accounting area on loam was 50.4 m²; on sandy loam was 22 m²; planting density was 50.0 and 44.4 thousand PCs. / ha, respectively. Repeat was three times.

Laying of field experiments, surveys and observations were carried out in accordance with the requirements of the field experience methods (1985 Dospekhov B.A.) and "Potato culture research methods" (Lorch Potato Research Institute 1967).

3. RESULTS AND DISCUSSION

Soil moisture during the growing season is largely due to the amount and distribution of precipitation [3, 4, 5, 6]. The vegetation period of 2002 was characterized by very rare precipitation, much less than the average annual. Soil moisture was low (figure 1). Before harvesting the control (the row sacing was 70 cm) it reached a critical value of 43.6% PPV, in the ridges was 44.6 %. Necessary for the optimal development of plants, the value of this indicator was noted only in May in the ridges. But on 5 June at a depth of 0...10 cm in all variants showed signs of drought. In the beginning of budding the humidity increased slightly in all variants, and in the flowering period (July) signs of drought was again observed at the depth of 0...10 cm (29,0...32,2% of the PPV) and the minimum humidity of 51.7% of the PPV in the ridges (70 cm) and 55.4% of the PPV in the ridges (110+30) cm at the depth of 10...20 cm, which did not contribute to the growth of tubers. 2003 turned out to be more favorable for water supply of potato plants. Soil moisture during tuberization was within 62,2...66.7 % of PPV, which had a positive impact on productivity.
Figure 1. Soil moisture in the zone of the tuber nest (% of PPV) depending on the row spacing, average values.

Tubers grow better on loose soils, this is their biological feature [7]. The optimal density of loamy soil for crops is 1.1...1.2 g/cm³, so all agricultural techniques should be aimed at preserving it during the growing season in this interval [7, 8]. The degree of compaction of the soil depends largely on its moisture content [9, 10, 11]. The results of studies show that from planting to harvesting, soil compaction occurs. But a phenomenon can be noted, when the density of the soil to harvest becomes less, than in the flowering phase. This is explained by the fact that soil particles under the influence of growing tubers and roots are moved apart, and the upper soil layers are loosened [12].

In our experiments, a significant influence of the current conditions of the year on the value of this indicator is not revealed (figure 2). On loam in 2002, the volume mass of soil in the zone of the tuber nest was 0.89...0.99 g/cm³, in 2003 the volume mass of soil was 0.82...0.99 g/cm³, in 2004 the volume mass of soil was 0.87...1.03 g/cm³; sandy loam in 2015 the volume mass of soil was 1.27...1.15 g/cm³, more humid 2016 the volume mass of soil was 1.30...1.38 g/cm³, in very humid 2017 the volume mass of soil was 1.17...1.27 g/cm³. The figure clearly shows that the values of soil density on loam is significantly lower than on sandy loam.

At the same time, there is no significant dependence of soil density on row spacing. In general, it can be noted that in the area of the tuber nest in all years of research, soil density remained within optimal limits due to the timely and quality of soil tillage operations.
Figure 2. Soil density (g/cm³) in the zone of the tuber nest depending on the row spacing.

Normal tuberization of potatoes and Jerusalem artichoke occurs at soil temperature 14...18 °C. When temperature becomes more than 20 °C tuberization is suspended, and when it reaches 29 °C, tuberization stops[3]. High temperatures lead to "climatic degeneration" of tubers. Therefore, the soil temperature in the zone of tuber nest formation has of great practical importance [4, 6]. This is especially actual in years with long periods with high (2002 and 2003) and low (2004 and 2017) temperatures (table 1).

Table 1. The temperature of the soil in the area of tuberous nests, depending on the width of the aisles, °C.

| Year     | Row spacing, cm | Landing | Shoots | Budding | Flowering | Before harvesting | Average |
|----------|-----------------|---------|--------|---------|-----------|-------------------|---------|
|          |                 |         |        |         |           |                   |         |
| 2002     | 70 (110+30)     | 14,1    | 14,5   | 31,1    | 26,9      | 22,1              | 21,7    |
|          |                 | 14,1    | 14,9   | 30,3    | 26,2      | 20,4              | 21,2    |
| 2003     | 70 (110+30)     | 16,0    | 17,0   | 24,9    | 23,8      | 18,5              | 20,0    |
|          |                 | 16,0    | 15,8   | 24,2    | 23,5      | 17,5              | 19,4    |
| 2004     | 70 (110+30)     | 13,8    | 19,1   | 21,8    | 19,4      | 14,9              | 17,8    |
|          |                 | 13,8    | 16,4   | 21,2    | 19,0      | 13,7              | 16,8    |
| Average  | 2002–2004 (tt.) |         |        |         |           |                   |         |
| 70 (110+30) | 14,6    | 14,6    | 16,9   | 25,7    | 23,4      | 18,5              | 19,8    |
| 14,6    | 14,7    | 15,7    | 25,2    | 22,9    | 17,2      | 19,1    |
|          |         |         |         |         |           |                   |         |
| 2015     | 75 (120+30)     | 11,0    | 23,0   | 24,0    | 22,24     | 26,0              | 21,2    |
|          |                 | 11,0    | 22,0   | 23,7    | 22,20     | 25,6              | 20,9    |
| 2016     | 75 (120+30)     | 17,5    | 21,3   | 25,8    | 25,0      | 19,2              | 21,8    |
|          |                 | 16,4    | 20,6   | 23,8    | 23,5      | 19,5              | 20,8    |
| 2017     | 75 (120+30)     | 12,4    | 16,8   | 13,8    | 21,9      | 19,3              | 16,8    |
|          |                 | 11,7    | 16,4   | 13,8    | 21,1      | 18,9              | 16,4    |
| Average  | 2015–2017 (tt.)|         |        |         |           |                   |         |
| 75      | 13,6    | 20,4    | 21,2    | 23,0    | 21,5      | 19,9    |

In our experiments in 2002-2004, the maximum soil temperatures were recorded in the budding phase. In 2002, soil was heated to 31.1 °C, in 2003 to 24.9 °C, in 2004 to 21.8 °C. When the width
of the row spacing (110+30) cm the size of this parameter was 0.6...0.8 °C lower than when row spacing was 70 cm.

In 2015, during the budding phase, the soil in the crests was heated to 24.0 °C, in the ridges soil was heated to 23.7 °C. However, its highest temperature was recorded before harvesting temperature was 26.0 and 25.6 °C, respectively. The average temperature in the ridges was 0.35 °C lower than in the crests. In 2016, the maximum soil warming in the experiment was noted in the second half of June (the budding phase of potatoes), the temperature was 25.8 °C in crests and 23.8 °C in ridges. The average temperature in the ridges was 1.00 °C lower than in the crests. In 2017 the highest value of this indicator was observed in early July (flowering phase in potatoes and the beginning of the budding phase in Jerusalem artichoke), temperature was 21.9 °C in crests and 21.1 °C in ridges. The average temperature in the ridges was 0.4 °C lower than in the crests. On average for 3 years, average temperatures in the crests (120+30) cm were 0.5 °C lower than in crests of 75 cm. This confirms that changes in the parameters of the crest can influence the temperature of the soil in the area of tuberous nests.

Yields of potatoes and Jerusalem artichoke on ridges (110+30) cm and (120+30) cm in almost all years of research was higher than on crests (70 and 75 cm). The average increase for 2002-2004 was 0.3 ... 11.1 t / ha, or 2...26 %. For 2015-2017, their yield on the ridges was higher than on the crests, respectively, by 2.3 ... 14.4 t / ha, or 6...33 %.

The most time-consuming operation in the cultivation of tubers is harvesting. When it is carried out, the traction resistance of the combine is determined by the cross-sectional area of the tuber layer of the soil. Milling crest formation allows you to form the largest volume of the crest (ridge) with a cross – sectional area between rows 70 cm is 818...911 cm², 90 cm is 1230...1250 cm², 110 + 30 cm is 2325...2444 cm²[13]. In adverse conditions, the ridge method of cultivation makes it easier to combine harvesting by reducing the volume of separable soil by 44...38 % [14, 15].

4. SUMMARY

Soil in the row spacing (110 + 30) and (120+30) cm retains more moisture in dry periods, and when a large amount of precipitation with this placement of plants decreases "suffocation" of tubers. The soil temperature during hot periods when the width of the row spacing (110+30) cm reduced compared with the row spacing of 70 cm, 0.6...0.8 °C, and with the ridges (120+30) cm, in comparison with crests 75 cm, by 0.5 °C. Such changes indicate that the humidity and temperature of the soil can be influenced by using different techniques.

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