Physical and mechanical parameters of the soil and yield of tubers of food potato depending on the spacing width

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Abstract. For food potato, one of the important factors in the quality of tubers is the low content of solanine in tubers, determined visually by the presence of green tubers. The purpose of the research was to improve the physical and mechanical parameters of the habitat of potato plants, increase the yield of tubers and reduce the number of green tubers with an increased solanine content during growth by increasing the width of row spacing. The research was carried out in the Moscow region. The main production method for reducing the greening of tubers (increasing the solanine content in tubers) was chosen to grow potato for food purposes in wide ridges or rows chequerwise (110 +30) and (120+30) cm. With such placement, not only a more uniform maintenance of optimal moisture, density, hardness and temperature of the soil is ensured, but also the soil layer around the tuber nest is retained to ensure a decrease in the number of green tubers by 4.4...6.5%. As a result, the cultivation of potato in rows allowed to increase the commercial yield by 1.2...5.5 t/ha (9...19%).

1. Introduction

Potato is one of the main food crops in the life of the world's population. The gross harvest (374 million tons) and the average yield (17.2 t/ha) of potato in the world are growing [1]. The largest potato producers are Russia, China and India [2, 3]. When cultivating food potato and for processing for food purposes, it is necessary to remember that it is unacceptable to reduce the marketability of tubers due to greening [4, 5]. But in recent years there have been changes in climatic conditions: prolonged droughts and heavy rains, which leads to the erosion of the ridges and, as a result, the accumulation of solanine in tubers and a shortage in food potato yield [6, 7]. To solve such emerging problems, it is necessary to study the possibilities of preserving the shape of the ridge and moisture conservation by increasing the width of row spacing [8, 9]; changing the planting period [10]; mulching [11]; using innovations in the form of moisture-retaining superabsorbents [12, 13]; nutrition optimization [14, 15, 16, 17]. Insufficient attention is paid to issues related to the problems of tuber greening in the field. Therefore, research on the development of new elements or improvement of existing potato growing technologies is relevant for national economic needs.

The purpose of the research is to improve the physical and mechanical parameters of the habitat of potato plants, increase the yield of tubers and reduce the number of green tubers with an increased solanine content during growth using a production method - doubling the spacing width.

Research tasks:
1. To identify the dependence of the agrophysical parameters of the soil, such as: humidity, density, hardness, temperature from the row spacing width, as a production method for potato cultivation.
2. To prove the effectiveness of double row spacing on potato productivity due to changes in meteorological conditions.

2. Objects and Methods

The object of research: potato, physical and mechanical parameters of the soil, production method

Research material: potato tubers of varieties with different maturation periods.

Field work was carried out in two farms.

The first experiment was conducted at the experimental field in Korenevo, Lyuberetsky district, Moscow region at the "Potato FRC named after A.G. Lorkh" in 2015-2017 on sod-podzolic medium-reclaimed sandy loam soil (humus content by the Tyurin's method is 1.99%; mobile phosphorus by the Kirsanov's method – 380-473 mg/kg; potassium exchange by the Kirsanov's method – 125-193 mg/kg; pH KCl for Alyamovsky was 5.04) with spacing width in control of 75, in the experiment (120+30) cm with the use of seed tubers average fraction (46...53 mm in cross section) and plant density of 45.0 thousand tubers/ha, varieties: Zhukovsky rannyi (early), Udacha (early), Krepysh (early), Lyubava (medium-early), Ilinsky (medium-early), Kolobok (medium-ripening) in four replications and plots with an area of 21 m².

The second experiment was performed in a SEC "Elite potato", vil. Zavorovo, Moscow region, in 2002-2004 on sod-podzolic medium loamy soil (humus content – 2.49%; mobile phosphorus – 372-551 mg/kg; exchange potassium – 122-259 mg/kg; pH (KCl) – 5.63) with spacing width in control of 70, in the experiment (110+30) cm with the use of seed tubers of average fraction (46...53 mm in cross section) and plant density of 50.0 thousand tubers/ha, varieties: Zhukovsky rannyi (early), Udacha (early) in triplicates and the plots with an area of 50.4 m².

Multifactorial experiments were laid by the method of systematic placement of plots. In both experiments, chemical treatments were performed to combat weeds, against the Colorado potato beetle, against late blight and alternaria leaf spot.

Meteorological conditions for the 6 studied years were different: a dry (2002) year with an average HTC for the growing season of 0.7...1.2; favorable - with optimal moisture supply (2003, 2004) with HTC - 1.3...1.7, as well as years with increased precipitation (2015-2017) HTC - 1.7...2.5 with a climatic norm of 1.3...1.6.

The laying of field experience, records, observations and data processing were carried out in accordance with the requirements of the methodology of field experience [18], the Methodology of research on potato crop (1967) and the Methodology of conducting agrotechnical experiments, records, observations and analyses on potato [19]. Calculations of economic and bioenergetic efficiency - according to the methodology of VNIIPI (1983) and VNIIKH (2000).

3. Results and discussion

In modern conditions of a changing climate, it is necessary to improve potato cultivation technologies, considering the direction for the formation of mechanical resistance of the soil environment to external and internal actions.

The data obtained from the results of the physical and mechanical parameters of the soil of the experimental plots that affect the growth and development of plants showed that they depend more on the amount and distribution of precipitation. Their dependence on the production method is also noted - the width of the spacings.

The optimal value of soil moisture for potato is 70... 85% of the FMC (the FMC of loams is 22.5%, sandy loams - 13.3%). It was found that when cultivating potatoes with row spacing width (110+30) on loams and (120+30) cm on sandy loams, soil moisture values improved (Table 1), on average increased from 61...67 to 63...70% of the total field moisture capacity (FMC). On average, over the years of research, the soil moisture in the root system location zone at a depth of 10-20 cm with a row spacing width (110(120)+30) cm was higher by 4.8...5.4% of the FMC. At the same time, the volume
of soil in the rows is able to retain more moisture, including during dry periods, and during prolonged heavy rains, the number of tubers with signs of suffocation decreases.

### Table 1. Humidity, density and temperature of the soil in the area of the tuber nest (10-20 cm) depending on the width of the row spacing, the average for the growing season.

| Year | Row spacing width, cm | Humidity (in % of FMC) | Density (g/cm³) | Temperature, °C | Year | Row spacing width, cm | Humidity (in % of FMC) | Density (g/cm³) | Temperature, °C |
|------|-----------------------|------------------------|-----------------|-----------------|------|-----------------------|------------------------|-----------------|-----------------|
| 2002 | 70, control           | 47.4                   | 0.95            | 21.7            | 2015 | 75, control           | 43.2                   | 1.24            | 21.2            |
| 110+30|                        | 53.5                   | 0.94            | 21.2            | 120+30 |                        | 45.6                   | 1.25            | 20.9            |
| 2003 | 70, control           | 67.2                   | 0.90            | 20.0            | 2016 | 75, control           | 52.0                   | 1.34            | 21.9            |
| 110+30|                        | 69.2                   | 0.92            | 19.4            | 120+30 |                        | 58.1                   | 1.33            | 20.8            |
| 2004 | 70, control           | 58.8                   | 0.95            | 17.8            | 2017 | 75, control           | 70.6                   | 1.24            | 16.8            |
| 110+30|                        | 66.7                   | 0.92            | 16.8            | 120+30 |                        | 76.4                   | 1.20            | 16.4            |
| average|                        | 57.8                   | 0.93            | 19.8            | average |                        | 55.3                   | 1.27            | 20.0            |
| 110+30|                        | 63.1                   | 0.93            | 19.1            | 120+30 |                        | 60.0                   | 1.26            | 19.4            |

The increase in row spacing width slightly affected the values of soil density in the center of the ridge. In the area of the tuber nest, the density on average turned out to be 0.90...0.95 g/cm³ on loam at a rate of 1.1...1.2 g/cm³, and 1.20...1.34 g/cm³ on sandy loam at a rate of 1.4...1.5 g/cm³, that is, in all years of research, the soil density was maintained at an optimal level.

The optimal soil temperature for potato tuber formation is 14-18 °C. Changes in soil temperature in the tuber nest location, depending on the production method used, were especially important in research, since during all periods of the growing season of the experiments, quite long periods with high temperatures were noted. In this experiment, the average temperature in the ridges was 0.6...0.7°C lower than in ridges.

In the ridges (110(120) +30) cm in the tuber nest zone, a more favorable environment for plants is created, which is confirmed by a large decomposition of linen cloths in the ridges by 8.7%, and, consequently, an increase in the activity of cellulose-decomposing microorganisms in the soil. The soil hardness before potato harvesting in the center of the ridge in the 2.5 – 20 cm formation ranged from 20 to 750 kPa (Figure 1), while in the variants with ridges (110(120) +30) cm with milling during planting care, the values of soil hardness were lower than in the ridges (70/75 cm).
Figure 1. The values of soil hardness (kPa) along the central row - ridge line in the period before potato harvesting, depending on the depth of measurement.

The data obtained indicate that increasing the width of the row spacing can affect the soil temperature and moisture.

It was found that in rows, potato yield (Table 2) increased on average by varieties by 0.3...1.2 t/ha (2...6%) on loam and by 1.4...3.8 t/ha (4...12%) on sandy loam soil. At the same time, the LSD05 for the Zhukovsky ranniy variety was 0.10; 0.95; 1.30 t/ha (2015, 2016, 2017); for variants of the Udacha variety – 0.10, 0.25, 1.75 t/ha; for variants of the Krepysh variety – 1.25, 0.95, 0.60 t/ha; for variants of the Lyubava variety it was 1.25, 1.45, 0.95 t/ha; for variants of the Ilyinsky variety – 1.15, 0.35, 4.25 t/ha; for variants of the Kolobok variety – 1.45 (2015), 0.70 (2016), 2.30 (2017) t/ha.

Table 2. Commercial yield, considering green tubers (t/ha), depending on the width of row spacing and potato variety

| Years of research | Variety    | Row spacing width, cm | Green tubers with high content of solanine, % | Yield of commercial tubers after separation of green ones, t/ha | ± to the control variant, t/ha | % |
|-------------------|------------|-----------------------|---------------------------------------------|----------------------------------------------------------------|-----------------------------|----|
| 2002-2004         | Udacha     | 70 (110+30)           | 5.1                                         | 0.94                                                           | 17.5                        | 0  | 0  |
|                   |            | 70                    | 5.8                                         | 0.88                                                           | 14.2                        | 0  | 0  |
|                   | Zhukovsky  | ranniy (110+30)       | 0.3                                         | 0.05                                                           | 15.5                        | 1.2 | 9  |
|                   | Average for varieties (110+30) | 70 | 5.5                                          | 0.91                                                           | 15.8                        | 0  | 0  |
|                   |            | (110+30)              | 0.3                                         | 0.04                                                           | 17.4                        | 1.5 | 10 |
| 2015-2017         | Udacha     | 75 (120+30)           | 7.1                                         | 2.73                                                           | 35.1                        | 0  | 0  |
|                   |            | 75                    | 5.3                                         | 1.87                                                           | 33.1                        | 0  | 0  |
|                   | Zhukovsky  | ranniy (120+30)       | 0.2                                         | 0.07                                                           | 36.5                        | 3.5 | 11 |
|                   | Krepysh    | (120+30)              | 6.5                                         | 2.33                                                           | 32.5                        | 0  | 0  |
|                   |            | (120+30)              | 0.2                                         | 0.07                                                           | 36.6                        | 4.19| 13 |
Tubers of potato grown by technology with a row spacing width of 70(75) cm are often insufficiently covered by the soil, due to the effects of heavy rains, winds, and are exposed to sunlight. This can increase the solanine content in tubers and their greening. Tubers with a high content of solanine are dangerous for use in food for both humans and animals. When calculating the yield of tubers of the food commodity fraction, minus those planted in the field (Table 2), it turned out that, when growing in the ridges, the number of green tubers is 4.4...6.5%, and in the rows – 0.1 ...0.4%. As a result, the commodity yield of potato when grown in rows (110(120)+30) cm was higher than in ridges 70(75) cm by 1.2...5.5 t/ha (9...19%).

When cultivating potato using ridge technology, on average, a conditional net income of 29.8 thousand rubles/ha was obtained for all varieties, with an increase in labor and money costs, a decrease in cost from 5.56 to 5.00 rubles/kg was noted, an increase in profitability by 6.3%, an increase in the energy efficiency coefficient from 1.15 to 1.27.

4. Conclusions
- To ensure the stable development of potato production, especially for food needs and processing, it is necessary to improve the cultivation technology under changing climatic conditions and thereby increase the production of high-quality potato. The rows (double ridges) are more promising when cultivating potato. It was found that: on average, the soil temperature in the rows was 0.4...1.1°C lower than in conventional ridges; in rows, the average moisture was higher by 4.8...5.4% (of FMC).
- With an increase in the width of spacings, the total number of tubers of the commodity food fraction increased by 1.2...5.5 t/ha (9...19%), since the number of tubers that turned green in the field in the ridges was 4.4...6.5%, while in the rows – 0.1...0.4%.
- The use of wide spacings (rows) proved to be an effective production method and provided a conditional net income of 29.8 thousand rubles/ha; the energy efficiency coefficient increased by 0.12.

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