The number of mini-tubers of potatoes depending on the density of planting micro-plants

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Abstract. The obtained results indicate the influence of the feeding area of potato micro-plants on the number of mini-tubers of promising varieties. In the experiments, micro-plants were placed in pots as follows: one plant in a pot with a nutritional area of 380 cm², two plants in a pot - 190 cm², three plants - 127 cm², plants - 95 cm². It was noted that with a decrease in the area of plant nutrition, the height of plants increased, as well as the number of tubers obtained from one plant. The study of the fractional composition of tubers showed that in order to obtain the maximum number of mini-tubers of potatoes, the most valuable fraction for further planting is not recommended to place one plant in a pot. Varieties reacted differently to the density of micro-plantings. For example, Gulliver and meteor varieties have an optimal feeding area for one plant to form tubers of the optimal fraction of 190 cm², Zumba and Samba – 127 cm², Reggae and Courtney – 95 cm². In the salsa variety, there were no differences in this trait between variants with a feeding area of 95 to 190 cm².

1. Introduction
The profitability of agricultural production is largely determined by the quality and yield properties of seeds and planting material. In potato seed production, a promising direction at the current stage of development of the industry is microclonal propagation, the advantage of which is the ability to get healthy planting material in large quantities in a short time.

Russian breeders have bred a huge number of potato varieties with economically valuable traits and properties. However, the share of domestic varieties in the seed potato market in Russia remains insignificant. The study of new domestic potato varieties will determine the most adapted to the soil and climatic conditions of the Volga region of Russia. The development of recommendations for growing new promising potato varieties will allow them to move to the market.

The amount of potato seed material produced depends on a number of indicators, including the number of mini-tubers obtained from micro-plants. The number of mini-tubers is influenced by various factors, in particular, the number of plants per unit area, the duration of their vegetation, and the genotype [1]. The technology of mini-tubers production requires additional research. Scientists focus on the need to study the methods of planting micro-plants and planting density [2].

In the Central scientific research Institute of potato (India) it was found that the number of mini-tubers per plant depends on the variety, and biometric indicators of plants (plant height, number of compound leaves per plant, number of stems per plant). It was noted that the largest number of tubers on the plant was formed in varieties whose biometric indicators were lower [3].
When growing mini-tubers of potatoes in protected greenhouses, it was found that the most optimal planting scheme in these conditions is 45 cm x 10 cm. In addition, the Kufri potato variety Chipson-1, which was characterized by high growth rates, had the highest yield of mini-tubers from the plant [4]. If the plants are less densely distributed, the area of food increases, while competition for sunlight decreases and the plants are stunted [5]. However, it was found that for potato varieties Kufri Himalini and Kufri Giriraj, the method of planting micro-plants does not significantly affect the number of mini-tubers [6].

In experiments on the study of various micro-plant planting schemes, a dependence was found indicating that a smaller feeding area gives a twofold increase in the number of mini-tubers on the plant [7]. At the same time, a larger number of tubers on the plant was observed with a thicker planting (15 x 10 cm), but the size of the tubers was less than in the 20x10 cm planting scheme. At a smaller distance between plants, smaller tubers were collected (from <3 g to 20 g), and at a larger distance between plants, larger tubers were collected (more than 20 g) [8].

The planting density of potato varieties Spunta and Yayerla had a strong influence on the number of mini-tubers - with increasing planting density, their number on the plant increases [9]. In the Kufri Shaila potato variety, the maximum number of mini-tubers of the seed fraction was obtained at the maximum planting density of microreliefs (166,666 plants / ha), in the Kufri Jyoti variety, the minimum planting density (83,333 plants / ha) negatively affected the number of mini-tubers in the plant [10].

Scientists from the Central Kufri potato research station (Shimla) found that a higher planting density of micro-plants (20 x 10 cm) contributes to the formation of more mini-tubers, but with an increase in the feeding area of micro-plants (30 x 10 cm), large mini-tubers are formed [11].

Studies have revealed a number of contradictions that indicate the need to study the effect of the distance between potato plants on the yield of mini-tubers of various varieties [12].

A comprehensive study of the impact of micro-plant planting methods on the yield of potato mini-tubers will help to develop recommendations for obtaining healthy mini-tubers with maximum reproductive capacity.

The purpose of our research is to study the effect of the micro-plants nutrition area on the number of mini-tubers of promising potato varieties of Russian selection.

2. Methods and materials
To achieve this goal, we correlated the number of mini-tubers of potatoes with the area of leaves, studied the relationship between the number of mini-tubers and the area of plant nutrition. The experiment was carried out in the spring of 2020. The research objects were promising potato varieties of the Russian selection. We provided a two-factor experiment. The first factor studied is the potato variety: Reggae, Salsa, meteor, Gulliver, Courtney, Samba, and Zumba. The second factor is the number of plants in the pot: 1 plant, 2 plants, 3 plants, 4 plants. Potato micro-plants were planted in 5 L plastic pots 220x180x250 mm in size.

Each variant consisted of 250 plant pots. The experiment was repeated four times. The plants were planted in greenhouses 22 m long and 6 m wide. The experiment was conducted in four greenhouses. The options in the greenhouse were placed randomly. For minituber growing, the medium was high-moor peat with low decomposition degree. This peat had standard pH of the growing medium (5.5). The substrate for growing mini – plants was riding peat of a low degree of decomposition. The peat substrate had the pH of 5.5 normalized by lime materials (dolomite and limestone flour). In addition, peat was initially enriched with the main nutrients: - NH4NO3*CaCO3 - 150 mg/l; P2O5-150 mg/l; K2O-250 mg/l; Mg — 30 mg/l; Ca — 120 mg/l + trace elements. The organic matter content was about 80%. The substrate had a highly porous structure, which allowed the root system of potato micro-plants to grow freely and build up mini-tubers. Peat did not contain pathogens or weed seeds.

The prepared peat was supplemented with a complex mineral fertilizer "Nitroammofoska" (NH4H2PO4 + NH4NO3 + KCL) produced by Uralchem. It contains three main components that are necessary for the normal growth and development of plants at different stages - nitrogen, phosphorus and potassium (NPK). Nitrogen, phosphates (assimilable) and potassium are equally divided here, 16%
each. In total, the total share of active ingredients is 48%. Fertilizers were well mixed with the medium. During planting, the pots were filled with peat 2/3 high of the total volume. Later, as potato plants grew, peat was added until planting pot was full.

Potato micro-plants were planted on 18 June. Before planting potato micro-plants, the soil in the pots was moistened with a drip irrigation system. Plants were removed from test tubes using anatomical tweezers and immediately planted in pots with a substrate. The nutrient medium in which the plants were located was not washed off the root system. When planted in pots, micro-plants were buried to the second internode. Greenhouse air temperature was maintained at +25 °C. To ensure automatic adjustment of the main parameters (temperature, humidity soil), a microclimate system is installed in greenhouses. Soil moisture was regulated by a drip irrigation system, and air humidity was maintained by a sprinkler system. Irrigation was carried out from a 10 m³ container. Water intake for irrigation was carried out from the well. The irrigation rate varied depending on the soil humidity, which was maintained at 65-70 %. During the growing season, potato plants were fed with YaraTera Kristalon special 18-18-18 +3MgO + micro fertilizers at the rate of 2 kg per 1 hectare. Fertilizers were applied together with drip irrigation. As potato plants were growing and developing, leaf surface area was measured and recorded for control and experimental plants. The punching/cutting out method was used, where the weight of a leaf of the selected plants is measured, cutouts are made, weighted, and the leaf area of each plant is identified. An average sample of plants was taken, the leaves were quickly cut off, and their weight was calculated. Then, from the central part of the leaf blade of each leaf of the plants with a drill with a diameter of 1.1 cm, several punches were knocked out, combined and their weighing weight was set, with an accuracy of 0.01 g (in the experiment, a Sartorius Entris 423i-1SRU balance was used). The place where the cut is taken characterizes the average sheet density. The leaf area was determined by the formula:

\[ SL = \frac{M_l \times S_v}{M_v}, \]

SL – area of plant leaves, cm²; Ml – mass of raw leaves, g; Mv – mass of raw die – cuts, g; Sv - area of die-cuts, cm².

The most preferred size of potato mini-tubers is from 25 to 35 cm in diameter. When placing 1 plant in a pot, the nutritional area of one plant is 380 cm², when placing two plants in a pot - 190 cm², three plants - 127 cm², four - 95 cm². The MC Excel software was used to identify the relationship between the studied traits.

3. Results and discussion

With a decrease in the area of plant nutrition, the height of the plants in the pot increases. The exception was the varieties Samba and Zumba (Table 1). In the Samba potato variety, the tallest plants were obtained in the variant with two and three plants - 32.9 and 31.4 cm, respectively. The Zumba variety has the strongest plants in a pot - 32.1 cm.

| Variety | Feeding area of a single plant, cm² |
|---------|-------------------------------------|
|         | 380 | 190 | 127 | 95  |
| Meteor  | 29.4| 33.1| 35.3| 36.8|
| Courtney| 12.5| 13.3| 18.3| 20.4|
| Gulliver| 18.1| 20.8| 22.7| 25.0|
| Zumba   | 20.5| 28.9| 32.1| 26.0|
| Samba   | 25.0| 32.9| 31.4| 30.2|
| Reggae  | 14.3| 19.1| 20.6| 20.7|
| Salsa   | 17.4| 24.1| 25.7| 26.7|
All varieties reacted differently to changes in feeding area. In all varieties, placing one plant in a pot did not affect the increase in the mass of tubers per plant. For varieties Meteor, Gulliver, Zumba and Salsa, the optimal placement in a pot of two plants with a nutritional area of each 190 cm² (table 2). In this variant, the mass of tubers per plant in these varieties was in the range of 156.4 - 169.6 g. Tighter planting of Samba and Courtney plants resulted in an increase in tuber mass per plant. Thus, with a feeding area of 127 cm², it was 194.0 and 158.9 g, respectively. Of all the cultivars studied for Reggae, a decrease in the feeding area to 95 cm² promoted an increase in the mass of tubers per plant by 76% compared to a single placement of plants.

| №  | Variety | Feeding area of a single plant, cm² | 380 | 190 | 127 | 95 |
|----|---------|------------------------------------|-----|-----|-----|----|
| 1  | Meteor  | 106.0                             | 158.6| 126.2| 120.8|
| 2  | Courtney| 54.5                              | 109.5| 158.9| 147.8|
| 3  | Gulliver| 124.4                             | 157.7| 90.7 | 132.9|
| 4  | Zumba   | 104.6                             | 156.4| 141.9| 141.4|
| 5  | Samba   | 84.4                              | 150.0| 194.0| 174.6|
| 6  | Reggae  | 79.2                              | 106.1| 101.9| 139.5|
| 7  | Salsa   | 120.9                             | 169.6| 157.8| 176.1|

Single placement of potato micro-plants in a pot with a nutritional area of 380 cm² had a negative effect on the number of minitubers per plant (table 3). This pattern was observed for all studied varieties. The number of tubers in this variant in all varieties was 60-154% less in comparison with the best variants.

| №  | Variety | Feeding area of a single plant, cm² | 380 | 190 | 127 | 95 |
|----|---------|------------------------------------|-----|-----|-----|----|
| 1  | Meteor  | 5.1                                | 8.7 | 9.1 | 11.3|
| 2  | Courtney| 5.9                                | 9.1 | 15.0| 13.8|
| 3  | Gulliver| 8.8                                | 14.3| 14.0| 20.1|
| 4  | Zumba   | 5.3                                | 9.6 | 10.0| 8.5 |
| 5  | Samba   | 5.1                                | 9.8 | 15.8| 13.6|
| 6  | Reggae  | 7.5                                | 10.2| 15.4| 18.0|
| 7  | Salsa   | 6.8                                | 9.3 | 10.3| 10.9|

The maximum yield of potato tubers of fraction Ø >35 was observed with a feeding area of one plant of 190 cm², the smallest one with a feeding area of 95 cm². The largest number of tubers with a diameter of Ø <25 was obtained in variants with a feeding area of 95 - 127 cm². In order to achieve the maximum number of potato minitubers of the optimal fraction, it is not advisable to place one plant in a pot. For varieties Gulliver and Meteor, the optimal nutritional area for one plant according to this indicator is 190 cm², for Zumba and Samba - 127 cm², for varieties Reggae and Courtney - 95 cm². For the Salsa potato variety, there are no differences between the variants with a feeding area of 95 to 190 cm².

| №  | Variety | Fraction | Ø <25 | Ø 25-28 | Ø 28-30 | Ø 30-35 | Ø >35 |
|----|---------|----------|-------|---------|---------|---------|-------|
|    | Meteor  |          | 1.1   | 0.3     | 0.7     | 1.0     | 2.3   |
| 2  | Courtney|          | 3.0   | 1.2     | 0.8     | 0.4     | 0.6   |
| 3  | Gulliver|          | 5.1   | 1.4     | 0.6     | 1.2     | 0.6   |
| 4  | Zumba   |          | 1.8   | 0.5     | 0.5     | 0.6     | 1.9   |
In the conditions of a greenhouse complex with insufficient natural light (without artificial additional illumination), the main influence on the formation of tubers was exerted by the introduction of mineral fertilizers, which include macro and microelements. The leaf area did not affect the number of tubers per plant (figure 1). In the conditions of 2020, we noted an inverse relationship between the area of leaves and the number of potato tubers. In variants with a minimum feeding area, the leaf area decreased to 510 cm² in the Reggi variety to 925 cm² in the Salsa variety. But at the same time there was an increase in the number of tubers per plant 18 - 10.9 pcs. respectively. An increase in the feeding area of one plant led to an increase in the leaf area. However, this did not affect the number of tubers obtained.

![Figure 1](image_url)
4. Conclusion
The feeding area of micro plants planted in pots has influenced the growth and development of potato plants, as well as the formation of mini tubers. When one plant with a feeding area of 380 cm² was placed in a pot, the number of mini tubers from the plant decreased in all the studied varieties. Two plants in a pot with a feeding area of 190 cm² in the meteor, Gulliver, Zumba and Salsa varieties allowed obtaining a mass of tubers from the plant from 156.4 to 169.6 g, and in this variant the highest number of potato tubers of the Ø 35 fraction was observed. When the feeding area of Samba and Courtney varieties was 127 cm², the mass of tubers per plant was 194.0 and 158.9 g, respectively, and the maximum number of potato mini-tubers of the optimal planting fraction was also noted for Zumba and Samba varieties. Reducing the feeding area to 95 cm² for the Reggae variety contributed to an increase in the mass of tubers from the plant, as well as the yield of the most valuable fractions of mini tubers. Thus, for Gulliver and meteor varieties, the optimal feeding area of one plant is 190 cm², Zumba and Samba – 127 cm², for Reggae and Courtney varieties – 95 cm² and the Salsa variety can be placed on 2, 3 or 4 plants in a pot.

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