Processing of specific growth of various potato varieties under drip irrigation in Lower Volga region

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Abstract. The analysis of the state of the potato industry in the Lower Volga region is made. The heat and moisture supply and soil conditions of the region and their compliance with the biological characteristics of potato plants are estimated. The object of research is the planting of potatoes of promising varieties under drip irrigation. The aim of the research is the formation of water regimes of the soil and production processes of various varieties of potatoes during drip irrigation in years with different weather conditions for vegetation periods. The patterns of irrigation, water consumption and productivity of summer plantings of seed potatoes are established. The most productive studied variety is Zhuravinka of the Belarusian selection, planting of which forms the tuber yield from 36.07 to 43.10 t/ha, Roko of the Dutch selection with a yield of 32.86–41.13 t/ha and Golubizna of domestic selection with that of 33.06–39.81 t/ha of tubers.

1. Introduction
In the Russian Federation, one of the most important sources of nutrition for humans, animal feed and raw materials for industry is potatoes. The share of the area occupied by potatoes in the world of all categories of farms is 15–17 %, gross production of the total output is only 7–8 %. The possibilities of this culture are far from exhausted. So, the average potato yield in the country over the past five years has been growing, reaching 14.5–15.9 t/ha of tubers. However, this level is 2.8–3.0 times less than that in developed countries [1–2]. As a result of this, there is an annual reduction in acreage sown with potatoes. For instance, from 1990 to the present its harvesting area has decreased by 1.5 million hectares from 3.4 to 1.9 million hectares, including 0.33 million hectares over the past five years. In this regard, the level of Russia's self-sufficiency in potatoes is reduced and, according to the results of 2017, amounts to 90.7 %, which is 4.3 % lower than the minimum indicator established in the country's Food Security Doctrine [2]. One of the many reasons for this situation is the poor quality of planting material and the lack of innovative technologies for seed production of potatoes in the Lower Volga region.

2. Methods and materials
The purpose of the research is to develop water regimes of the soil that provide high quality planting material and maximum yield of tubers of seed fractions of various varieties of potatoes. The object of research is five varieties of potatoes of domestic and foreign selection under drip irrigation. Two-factor field experiments have been carried out on light chestnut soils of the Volga-Don field of the All-
Russian Research Institute for Hunting Husbandry and Livestock Breeding (VNIIOZ) since 2015. The first factor (A) is the water regime of the soil. It includes four variants. The first one consisted of vegetative irrigation at a pre-irrigation humidity of 80 % FMC in a layer of 0.6 m. The second one was at 80 % FMC in the 0.4 m layer. The third one was at 80 % FMC in a layer of 0.4 m from planting to budding, and the rest of the growing season was 0.6 m. The fourth one was without irrigation (control). The second factor (B) included Russian potato varieties (Nevsky and Golubizna), Dutch varieties (Ivan da Marya and Roko) and a Belarusian variety (Zhuravinka).

The agrochemical properties of the soil were characterized by low nitrogen supply, medium supply by mobile phosphorus and exchange potassium. The humus content in the arable layer was 1.82 %, the reaction of the soil solution was slightly alkaline (pH = 7.1–7.4).

Field experiments were carried out using generally accepted methods against the general background of mineral nutrition with the application of fertilizers N190P80K180, designed to produce 40 tons of potato tubers per hectare [3-6]. Watering of summer plantings of potatoes was carried out using drip irrigation systems and the method of its calculation [7]. Agricultural technology in field experiments on potatoes was based on the currently existing elements of the Dutch and Zavorov technologies, as well as the recommendations of the VNIIOZ and other NRIs [8–16].

3. Results
Differing in a complex of biological features and economically valuable traits, the varieties form the basis of potato growing technologies. Potato varietal resources registered in the State Register of the Russian Federation in 2017 are represented by 409 varieties, including 209 varieties of Russian selection and 200 varieties of foreign selection. The adaptation and development of new varieties that have certain advantages over previously created varieties are an important factor in increasing the volume and efficiency of potato production. Therefore, when choosing a variety for seed research in the Lower Volga region, an area with a high infectious load, special attention, along with productivity, plasticity, attractive tubers, universal use, etc., was given to complex resistance to the most common diseases (Table 1).

However, a variety may not show its economically valuable properties or may not show them enough if the planting material is of poor quality. The quality of the planting (seed) material of potatoes depends on the varietal properties, the state of "health" and the physiological state (age) of the tubers. The health status of tubers is determined by the degree of damage by fungal (late blight, alternariosis, rhizoctonie, fusarium, phomosis), bacterial (black leg, ring rot, wet rot of tubers), viral (curl of leaves, mosaic, motility), viroid and other diseases, including a quarantine one. When planting potatoes, diseases reduce the yield and specifically the seed properties of tubers. If the first two can be controlled by chemical and other means, then the rest are uncontrollable, since their pathogens are intracellular pathogens. Most of these diseases are transmitted through tubers, which become reservoirs of infection and spread rapidly during reproduction. Without proper measures to improve and protect the seed from reinfection, the number of affected plants progressively increases, the variety gradually loses its original productivity and degenerates [13]. In this regard, in order to create optimal conditions for the functioning of the production process, the protection of plants from infection must begin with the preparation of tubers (as per GOST 33996-2016 [14]) for planting consisting of autumn hardening, spring dressing and germination aimed at reducing the pathogenic beginning potatoes. The physiological condition of tubers, determined by low and high age, also characterizes the level of health of planting material. This effect on its quality is determined through origin, soil and climatic conditions, provision with food and water elements, storage conditions and others.

In our studies aim at obtaining the maximum yield of tubers of seed fractions, a high physiological age due to apical dominance is undesirable, since large tubers are formed with a simultaneous decrease in yield.
Table 1. Integral assessment of potato varieties (according to originators)

| Potato variety | Tuber productivity [t/ha] | Average tuber weight [g] | Starch content [%] | Tuber marketability [%] | Resistance to viral diseases, etc. |
|----------------|--------------------------|--------------------------|-------------------|-------------------------|-----------------------------------|
| Roko           | 40–45                    | 95–105                   | 15–18             | 95                      | high                              |
| Ivan-da-Marya  | 40–45                    | 110–115                  | 8–14              | 94                      | average                           |
| Nevsky         | 60                       | 120                      | 10–15             | 97                      | high                              |
| Golubizna      | 45–50                    | 90–100                   | 18–20             | 97                      | high                              |
| Zhuravinka     | 75                       | 130                      | 14–19             | 90                      | average                           |

High physiological age shortens the period from planting to the emergence of seedlings, which contributes to the earlier achievement of age-related resistance of plants to viral diseases and late blight. Also, a reduction in the period of germination to 11–12 days in varieties Roko and Nevsky was provided by pre-emergence irrigation with a norm of 100 m³/ha or according to A.A. Navitney [9] of “forcing” irrigation, since on the date of planting potatoes the soil moisture in the layer of 0.0–0.1 m, according to years of research, varied within 64.3–66.4 % FMC. Potato seedlings of Ivan da Marya and Zhuravinka varieties appeared 2–3 days, and Golubizna varieties 3–4 days later than Roko and Nevsky. In the variant without irrigation, the emergence of seedlings by years of research occurred 17–21 days after planting. Further intensive growth of tops and development of potato plants was carried out due to the water regime of the soil varying within 80–100 % of FMC in layers of 0.6, 0.4 and 0.4–0.6 m, respectively. So, in the variant with 80 % FMC in a layer of 0.6 m, maintaining the water regime of the soil within the specified limits was ensured over the years of research by conducting 9–12 vegetation irrigation with a norm of 210 m³/ha, and an average of 10.7 irrigation with an irrigation norm of 2340 m³/ha (Table 2).

At the same time, the total water consumption of potatoes amounted to 3242 m³/ha. With a decrease in the estimated soil moisture layer to 0.4 m, the number of irrigations increased to 16–21, and the irrigation rate and potato water consumption increased to 2340–3040 and 3315–3720 m³/ha, respectively. In the variant with differentiation of the calculated soil moistening layer of 0.4–0.6 m, the water regime of the soil was ensured by conducting from 5 to 10 irrigations with a norm of 140 m³/ha and 5–7 irrigations with a norm of 210 m³/ha each. According to the years of research, the moisture consumption for evaporation and transpiration by potato plants in this variant varied from 3109 to 3527 m³/ha, including irrigation water being 66.3–80.2 % or 2060–2830 m³/ha. In the variant without irrigation, the water consumption of potatoes varied from 1173 to 1662 m³/ha.

Table 2. Indicators of the regime of irrigation and water consumption of seed potatoes (average over 2015–2017)

| Soil watering variants | Number of irrigations | Irrigation rate [m³/ha] | Total water consumption [m³/ha] |
|------------------------|-----------------------|-------------------------|--------------------------------|
| 80 % FMC, h = 0.6 m    | 10.7                  | 2340                    | 3242                           |
| 80 % FMC, h = 0.4 m    | 18.7                  | 2713                    | 3559                           |
| 80 % FMC, h = 0.4–0.6 m| 8/6                   | 2480                    | 3359                           |
| No irrigation          | –                     | –                       | 1382                           |

A feature of water consumption by potato plants is that the indicators of irrigation norms and total moisture consumption in the options with the irrigation regime in dry 2015 were maximum, and under the average humidity of 2016, they were minimal. In the variant without irrigation, the total moisture consumption by planting potatoes was characterized by an inverse relationship, i.e. in the dry year it was minimum, and in the average humidity year it was maximum.

The phenological periods of growth and development and the water regime of the soil (Fig. 1) had a decisive influence on the amount of water consumption by plants in the process of forming a potato crop.

The potato consumes the maximum amount of water during the flowering period. Depending on the water regime of the soil, it varies within 794–1178 m³/ha, and on average for three years from
953.0 to 1069.3 m³/ha or 29.9–30.0 % of the total water consumption. During the planting-seedling period, the potato consumes a minimum amount of water in the range of 285–313 m³/ha, and on average 296–302.7 m³/ha, which makes 8.5–9.1 % of the total potato water requirement. In the period from planting to plant budding, potatoes consume moisture in the range of 1099–1143 m³/ha or 32.1–34.0 % of the total consumption. With the formation of tubers and before the maturation of potatoes, the need for moisture increases to 2142.6–2416.3 m³/ha, which is 66.0–67.9 % of the total plant water demand.

Processing these data obtained in the studies made it possible to establish the dependence of the change in potato water consumption during the growing season, which is described by the equation of curvilinear regression (Fig. 2):

\[ E = aT^2 + bT + c, \]

where \( E \) is the water consumption of seed potatoes, m³/ha; \( T \) is the duration from the beginning of the vegetation, days; \( a, b, c \) are constants.

In our studies, the maximum potato yield was obtained in the variant with 80 % FMC in the soil layer of 0.4 m and according to the years of research, depending on the varieties studied, it varied from 34.88 to 46.03 t/ha, averaging 36.23–43.10 t/ha over the three years. An increase in the calculated soil moisture layer to 0.6 m was accompanied by a significant decrease in the yield of potato tubers to 28.62–37.92 t/ha, and in the variant with 80 % FMC in the soil layer 0.4 and 0.6 m from 31.72 to 42.94 t/ha. The minimum yield of potato tubers was obtained in the variant without irrigation, which, depending on the varieties, varied from 1.72 to 7.56 t/ha over the years, and on average from 4.54 to 5.20 t/ha (Table 3).

The highest productivity from 34.86 to 46.03 t/ha and a significant increase are characteristic of the Zhuravinka variety. The tuber yield increase between the Golubizna and Roko varieties is insignificant, but in relation to the Ivan da Marya and Nevsky varieties, they are characterized by a
reliable increase. Thus, the tuber yield for Golubizna and Roko varieties varied from 31.33 to 42.26 t/ha over the years, and from 31.68 to 43.63 t/ha, respectively, while for Ivan da Marya and Nevsky varieties it varied between 29.46–37.44 and 28.62–38.68 t/ha, respectively. In the variant without irrigation, the increase in yield by variety is insignificant.

Table 3. Yield structure structure of seed plants of potatoes (average over 2015-2017)

| Soil watering variants | Potato variety | Total [t/ha] | Marketabilit [ %] | Productivity [t/ha] |
|------------------------|----------------|-------------|-------------------|---------------------|
| 80 % FMC, h = 0.4 m | Roko          | 32.86       | 93.5              | 23.77               | 6.96           |
| Ivan-da-Marya      | 30.63         | 90.5        | 20.55             | 7.17                |
| Nevskey           | 30.68         | 91.2        | 20.74             | 7.24                |
| Golubizna         | 33.06         | 93.0        | 23.58             | 7.16                |
| Zhuravinka        | 36.07         | 94.5        | 23.69             | 10.40               |
| 80 % FMC, h = 0.6 m | Roko          | 41.13       | 96.5              | 30.66               | 9.03           |
| Ivan-da-Marya      | 36.23         | 92.0        | 21.52             | 11.82               |
| Nevskey           | 36.88         | 93.2        | 22.14             | 12.25               |
| Golubizna         | 39.81         | 96.2        | 29.56             | 8.74                |
| Zhuravinka        | 43.10         | 96.7        | 25.31             | 16.42               |
| 80 % FMC, h = 0.4–0.6 m | Roko        | 39.06       | 95.7              | 28.99               | 8.41           |
| Ivan-da-Marya      | 33.05         | 90.9        | 22.51             | 7.53                |
| Nevskey           | 34.37         | 91.7        | 23.92             | 7.89                |
| Golubizna         | 37.37         | 95.3        | 27.51             | 8.12                |
| Zhuravinka        | 40.39         | 96.5        | 26.13             | 12.85               |
| No irrigation (control) | Roko          | 4.54        | 73.8              | 1.19                | –              |
| Ivan-da-Marya      | 4.86          | 71.1        | 1.40              | –                   |
| Nevskey           | 5.20          | 68.1        | 1.66              | –                   |
| Golubizna         | 4.60          | 74.4        | 1.18              | –                   |
| Zhuravinka        | 4.87          | 73.3        | 1.30              | –                   |

In the structure of the seed crop, the share of non-marketable tubers varied from 3.3 to 9.5 %. The seed fraction of potato with a tuber mass from 30 to 100 g in varieties with water regime of the soil varied from 58.7 to 74.5 % by varieties, and in the variant without irrigation – from 25.6 to 31.9 %. The yield of potato seed tubers was 20.55–30.66 t/ha and 1.18–1.66 t/ha, respectively. The harvest of food potatoes with a tuber mass of more than 100 g by variety, depending on the soil water regime, was 6.96–16.42 t/ha or 21.2–38.1 % of the total crop.

The maximum share of tubers of the seed fraction was formed by varieties Roko (72.3–74.5 % or 23.77–30.66 t/ha) and Golubizna (71.3–74.2 % or 23.58–29.56 t/ha). The Zhuravinka variety was characterized by a low seed fraction of 58.7–65.7 % or 23.69–26.13 t/ha. At the same time, the share of marketable potatoes in this variety was the highest (28.8–38.1 % or 10.40–16.42 t/ha). In the Nevskey and Ivan da Marya varieties, the yield of food potatoes was 7.17–12.25 t/ha, which was higher than for the Roko and Golubizna varieties (6.96–9.03 t/ha). Varieties Ivan da Marya and Nevskey formed the largest share of seed tubers in the variant with 80 % FMC in the layer of 0.4–0.6 m, varieties Roco and Golubizna – with 80 % FMC in the layer of 0.4 m, and Zhuravinka – with 80 % FMC in the layer of 0.6 m.

4. Conclusion
The results obtained in the studies substantiated the need for growing potatoes by summer planting in the Lower Volga region only on irrigated lands, since this territory in terms of heat and moisture supply during the growing season (hydrothermal index = 0.28) refers to the dry zone of mandatory irrigation.

Obtaining 40 t/ha of potato tubers on light chestnut soils of the Lower Volga region is provided by using improved ridge cultivation technology, applying N$_{190}$P$_{80}$K$_{180}$ fertilizers and maintaining the soil at least 80 % FMC in the 0.4 m layer during pre-growing irrigation and vegetation irrigation.
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