

Influence of climatic parameters on potatoe yield under irrigated conditions of the steppe zone of the Southern Urals

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Abstract. The article presents the results of a study of we analyzed the relationship between the yield of potatoes of 10 different varieties and the air temperature during the growing season: Nevsky (1 St), Spiridon (2 St), Kavaler, Zakhar, Sapfir, Ariel, Kashtak, Krepysh, Lekar', Fioletik. Our studies have shown that potatoes have specific requirements for irrigation in order to obtain good and high-quality tuber productivity. As a result of the analysis, it was revealed that the yield of potatoes directly depends on water regime, on the amount of precipitation during the growing season. High air temperatures adversely affect the yield of potatoes, but varietal specificity must be taken into account. We analyzed the relationship between the yield of potatoes of 10 different varieties and the air temperature during the growing season. As a result of the analysis, it was found that in most cases, the relationship between potato productivity and air temperature (r_2) during the growing season has a negative relationship, with the exception of the varieties "Kashtak", "Krepysh", "Fioletik". The relationship (r_2) of potato varieties "Kashtak", "Krepysh", "Fioletik" with air temperature during the growing season has a strong significant positive correlation.

1 Introduction

The potato (*Solanum tuberosum* L.) is a tuber that is largely used for food and is a source of different bioactive compounds such as starch, dietary fiber, amino acids, minerals, vitamins, and phenolic compounds. The potato is the world's fourth-most important crop after rice, wheat and maize, and plays an important role in food security [1]. Potato growing is one of the priority areas for agricultural development. In recent decades the Russian Federation has been among the leaders in gross production of potatoes and their consumption [1]. Today our country accounts for 17 % of the sown area of potatoes and 11% of the global gross harvest [2].

The potato (*Solanum tuberosum*) is herbaceous annual, its tubers are very rich in starch.

By 2050, the world's population will be about 10 billion people. It will lead to an increase in demand for agricultural products by at least 50% compared to 2019 [2].

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Climate change is exacerbating the frequency of abiotic and biotic plant stress, which creates another challenge for agricultural production. Stress conditions lead to significant economic losses in agricultural production [3]. According to Chuyan O.G. [4] the interaction of climatic conditions, soil quality and the level of agricultural technology determine 68 - 74% of the yield dispersion. The Orenburg region is an agricultural region, the issue of climate change, as the main factor affecting agriculture, is relevant. Food security is one of the main areas for ensuring national security. According to researchers [4], average global temperatures have increased and will continue to increase along with a greater frequency of extremely hot days.

Growing demands for the newly created potato varieties, primarily in their resistance to widespread and adaptable disease populations, as well as their ability resist the effects abiotic and biotic stressors, contribute to the continuous expansion of the potato assortment. Varieties of foreign selection prevailed in the Southern Urals are not sufficiently adapted to local conditions. Due to the high cost of agricultural machinery, protective equipment and mineral fertilizers, the manufacturer cannot influence the potato yield, which over the past five years not exceeded 20 t/ha on average and is subject to significant falls over the years [3].

Potato (*Solanum tuberosum* L.) is an annual herbaceous plant, its tubers are very rich in starch. It is known that *Solanum tuberosum* L. is sensitive to water deficiency, therefore, to obtain high yields, soil moisture should be at least 50 % of the maximum available water in the root zone [2, 6]. In conditions of climate aridity, especially in the transboundary region of the Southern Urals, potatoes grown for production are especially sensitive to water stress, so irrigation is an important tool to achieve high yields [3, 7]. In different regions of Russia, including Orenburg region, the availability of irrigation water is becoming a very expensive way to get good potato yields. Therefore, it is crucial to adopt optimal economic strategies for irrigating potatoes [5, 8-12].

One way to reduce irrigation and optimize yields is economic irrigation, which is to limit the use of water during the growth stages, this use of water in irrigation requires an accurate knowledge of the main stages of plant growth during the growing season. The biological feature of potatoes is an underdeveloped root system, and therefore, potatoes need sufficient water to accumulate.

The optimal selection of the assortment of potatoes for each specific region is one of the main factors determining the increase in yield and quality of both food and seed potatoes. To do this, varieties should be used in production that combine high adaptability to abiotic environmental factors with resistance or immunity to pathogenic organisms. Currently, the number of national potato varieties with similar characteristics is not enough. The article considers the influence of meteorological conditions on the growing season of potatoes [13].

The objective of the study is the influence of climatic factors on the yield of potato varieties under irrigation.

2 Materials and methods

2.1 Location, soil and climate

Field experiments were carried out in KFK Khomutsky, Perevolotsky district, Orenburg region (Orenburg oblast, Russia) with coordinates 51°78'72"N-55°28'80"E, which is located in the central part of the region on the left bank of Samara River and borders: with Aleksandrovsky, Sakmarsky, Orenburgsky, Ileksky and Novosergievsky districts of the region. The area of the territory is 2,756 square kilometers. The study area is located in a

zone with a semi-desert (semi-arid) climate of temperate latitudes. The average monthly air temperature ranges from - 24,3 to -27,4 °C in January, to +19,9...+22,4 °C in July, the average annual temperature is +5,3 °C. The average annual rainfall is 350-450 mm. The soil is southern heavy loamy chernozem on red-brown calcareous loams. A 30-cm soil layer contains: humus - 4.1%, readily hydrolysable nitrogen (N) - 8.4 mg, mobile phosphorus (P_2O_5) - 3.25 mg, exchangeable potassium (K_2O) - 27 mg and exchangeable calcium (CaO) - 39,0 mg per 100 g of soil. The high content of carbonates determines the alkaline reaction of the soil pH 7,6-8,0. Data on weather conditions during the study period were obtained at the Orenburg weather station (51°73'93"N-55°9'57"E), as well as on the Internet portal (<http://aisori.meteo.ru/>).

2.2 Experimental design

Field experiments were carried out on 10 varieties of potatoes (*Solanum tuberosum L.*) - Kavalier, Zakhar, Sapfir, Krepysh, Kashtak, Ariel, Lekar, Fioletik, Nevsky (standard), Spiridon (standard), in a randomized scheme with divided plots with four repetitions.

Irrigation: during the growing season - 4 irrigations, with an irrigation rate of 450-600 m³/ha. Option I and Option II as main plots, four irrigation regimes: [watering only during sprouting-dry control (I), watering throughout the cycle (II), watering from tuber setting to 50 % tuber growth (I2), watering from 50 % of tuber growth until the end of tuber growth (I3)].

Healthy pathogen-free tubers with an average weight of about 100 g per Variant I (Spunta) and 50 g per Variant II (Sieglinde) were planted 0,3 m apart in rows spaced 0,7 m apart (equivalent to planting density 4,76 plants per m² Experimental plot size 4,2 m × 4,5 m, 90 plants, border width between irrigations was 2 m. All plants sprouted 20 days after planting.

When planting, the tank mixture was added: Prestige (protectant) 1l/t; Borogum (complex) 1l/ha; Fitosporin AS 1l/ha.

2.3 Statistical processing of the material

Statistical data processing was performed using the Statistica 10,0 software package (StatSoftInc, USA). The results obtained were subjected to statistical processing with the determination of the arithmetic mean (M), the mean error of the mean (m) and the standard deviation (σ). The analysis of regressions was carried out by the least squares method, the strength of the influence of signs was estimated using the procedure of analysis of variance. The collected and calculated data were first subjected to Shapiro-Wilk and Levene's test to test for normal distribution and homoscedasticity, respectively. Multiple correlation analysis was performed by calculating partial correlation coefficients for pairs of features in all possible combinations, followed by correction of the obtained values taking into account the sample size (Pearson's correction for the number of observations). In statistical procedures, the level of significance of hypotheses was considered to be the level providing the probability of an error of less than 5 % ($P<0,05$).

3 Obtained results

3.1 Weather conditions

An analysis of long-term data on the amount of precipitation in the study area showed that for the period of 72 years: 17 years (23 %) were very dry, when less than 280 mm of precipitation

fell, 26 years (36 %) were dry, when 281-380 mm fell in a year precipitation, 23 years (32 %) were wet, with a total precipitation of 381-480 mm, and only 6 years (9 %) were very wet with a total precipitation of more than 480 mm. This assessment of long-term data demonstrates that agricultural products are cultivated in conditions of insufficient moisture and require irrigation. During the growing season of 2022, 46,12 mm of precipitation fell, which is 1,4 times more than the long-term average, with an average daily temperature of +19,6 0C.

Table 1. Statistical analysis of climatic parameters for the growing season in the study area (2022)

Parameters	Valid N	Mean	Minimum	Maximum	Std.Dev.
Average daily temperature (T, °C)	12	19,65	11,00	25,80	5,07
Average long-term temperature (T, °C)	12	19,45	13,70	22,30	2,86
Average rainfall during the growing season	12	15,37	0,00	77,00	23,09
Average long-term precipitation, mm	12	11,25	9,00	13,00	1,66

Statistical analysis of climatic parameters for the growing season in the research area showed that daily average temperature exceeded the long-term average temperature 1,01 times, the average rainfall for the growing season in 2022 exceeded the long-term average rainfall 1,4 times (Table 1). Moreover, the minimum and maximum parameters are shown in Table 1.

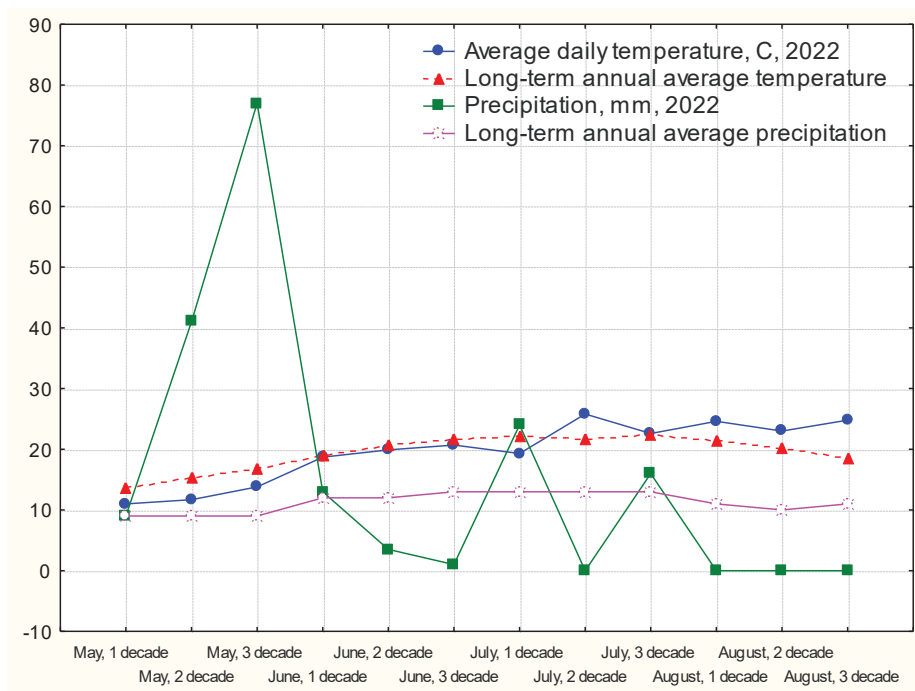


Fig. 1. Decadal parameters of temperatures ($T^{\circ}\text{C}$) and precipitation during the growing season of plants

Figure 1 shows the ten-day course of temperatures and precipitation recorded during the experiment. It can be noted that there was an increase in the amount of precipitation in the 3rd decade of May, when the plants needed the greatest amount of moisture for germination and, as a result, no watering was required during this period of time when laying and forming tubers.

3.2 Potato yield

The yield of potatoes directly depends on weather and climatic conditions (see Table 2), since potatoes are a plant of the cool summer season. Potatoes were grown in a sharply continental climate, and it was concluded after over 3 years of study that even in the 1st decade of May heat and light was sufficient for plants. We analyzed the relationship between the yield of potatoes of 10 different varieties and the air temperature during the growing season. As a result of the analysis, it was found that in most cases, the relationship between potato productivity and air temperature (r^2) during the growing season has a negative relationship, with the exception of the varieties "Kashtak", "Krepysh", "Fioletik". The relationship (r^2) of potato varieties "Kashtak", "Krepysh", "Fioletik" with air temperature during the growing season has a strong significant positive correlation. According to the data obtained, these varieties are classified as the most drought-resistant, that is, when exposed to positive air temperatures, these potato varieties have a good yield.

Thus, the analysis of long-term temperature data during the growing season with potato yield in most cases showed a negative relationship, that is, the plant is very sensitive to high positive temperatures.

Table 2. The relationship between potato productivity by variety (2020-2022) and average annual temperature and precipitation during the growing season

Variety	R ² temperature	R ² precipitation
Nevsky (1 St)	-0,78	0,83*
Spiridon (2 St)	-0,81	0,72*
Kavaler	-0,04	0,91*
Zakhar	-0,91	-0,14
Sapfir	-0,84	0,91*
Ariel	-0,95	0,95**
Kashtak	0,84*	-0,59
Krepysh	0,54 **	-0,67
Lekar'	-0,69	0,81**
Fioletik	0,69*	-0,73

Note: *- P<0,01; ** P<0,05

Potatoes are demanding to soil moisture. At the beginning of the formation of sprouts, the need for moisture is almost entirely covered by the mother tuber. When sprouts appear and in the first periods of leaf formation, plants need little moisture. Precipitation plays an important role in the period of tuber formation, especially in the 1st decade of May, that is, during the period of planting and the beginning of plant germination (Fig. 1, 2). The presence of water during the formation and growth of tubers is especially important for potatoes. In this regard, we analyzed the amount of precipitation during the growing season and their relationship with potato productivity by variety. As a result of the research, we found that the following varieties have a significant positive correlation relationship: "Nevsky (1 St)" $r^2=0,83$ (P<0.01), "Spiridon (2 St)" $r^2=0,72$ (P<0,01), "Cavalier" $r^2=0,91$

($P < 0,01$), “Sapphire” $r^2 = 0,91$ ($P < 0,01$), “Ariel” $r^2 = 0,95$ ($P < 0,05$), “Healer” $r^2 = 0,81$ ($P < 0,05$), that is, with an increase in precipitation, the productivity of potatoes increases accordingly.

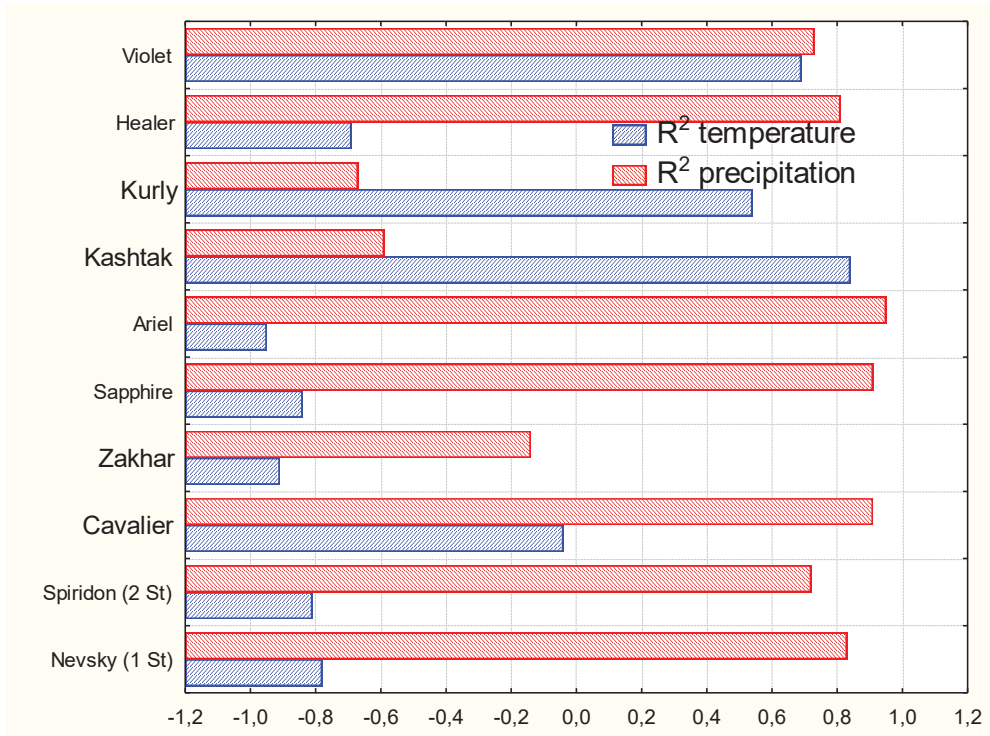


Fig. 2. Effect of temperature and precipitation during the growing season on potato productivity.

Thus, despite the natural and climatic conditions of the region and the presence of an irrigation system, the correct choice of a potato variety is of great importance, taking into account the characteristics of its cultivation. Potato varieties vary significantly in yield depending on soil and climatic conditions.

4 Conclusions

Our studies have shown that potatoes have specific requirements for irrigation in order to obtain good and high-quality tuber productivity.

As a result of the analysis, it was revealed that the yield of potatoes directly depends on water regime, on the amount of precipitation during the growing season.

High air temperatures adversely affect the yield of potatoes, but varietal specificity must be taken into account.

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