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Techniques for increasing potato productivity

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Abstract. This study, conducted at the All-Russian Research Institute of Reclaimed Lands, aimed to investigate the effects of integrated techniques on potato yield and soil microflora. For three years, potatoes were grown in vessels equipped with a water-regulating device, with varying treatments including organic fertilizer, humic preparation, and artificial irrigation. The results show that all techniques, either individually or in combination, significantly increased the number of soil microflora by 15-40% and potato yield by 42-63%. Organic fertilizer provided sustained nutrient supply, while the humic preparation had a stimulating and protective effect on tubers and soil microflora. Additional watering created optimal moisture conditions, enhancing the fertilizer's effect and contributing to the formation of a reserve of productive moisture. These findings highlight the importance of integrated approaches in improving potato production and soil health.

1 Introduction

One of the main tasks when growing crops is to provide the crops with optimal conditions for water and nutritional regimes. Uneven distribution of precipitation during the growing season negatively affects plant development and crop formation. At the same time, to increase the productivity of the cultivated crop, various organic fertilizers and preparations are used. There is a certain relationship between the efficiency of fertilizer use and the moisture supply of plants during the growing season: the higher its level, the greater the effect of using fertilizers [1]. In particular, the result of the combined action of irrigation and fertilizers is significantly higher compared to the experience of their separate use [1, 2]. It should also be noted that one of the connecting elements of the chain soil moisture – organic fertilizers – productivity is the soil microflora, which responds to the level of soil moisture, the application of fertilizers and has an important influence on the formation of the crop [3].

For the Russian Federation, potatoes are a valuable food, feed and strategic crop. Its cultivation is often accompanied by the use of various fertilizers, drugs, and growth stimulants [4]. At the same time, potato plants are quite demanding of moisture. The critical period of water consumption of this crop is the budding phase - the beginning of flowering [1]. Compliance with optimal conditions for moisture supply and nutritional value of plantings during the growing season is an effective comprehensive method for increasing potato productivity [4-6].

The purpose of the work is to study the influence of water and nutritional regime on soil microflora and potato yield.

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2 Materials and methods

At the All-Russian Scientific Research Institute of Reclaimed Lands (VNIIMZ a branch of the Federal Research Center " V.V. Dokuchaev Soil Institute"), a model experiment was carried out for three years (2020-2022) on growing early-ripening potatoes of the Red Scarlet variety. For this purpose, metal vessels measuring 70x70x100 cm were used, equipped with a water control device to maintain a given groundwater level and calculated soil moisture (Fig. 1).

The vessels were filled with a monolith of soddy-podzolic light loamy soil with an undisturbed structure. Based on our own research, as well as literature data, it was determined that the optimal soil moisture when growing potatoes should be at a level not lower than 70% of the maximum field moisture capacity (MPV) [5]. After heavy rains, excess soil moisture was naturally removed through the drainage pipe. When the soil moisture supply in the 0-40 cm layer decreased to 70% of the MPV in the irrigation options, artificial sprinkling irrigation was carried out in such a way that the moisture content of the root-inhabited soil layer was maintained in the optimal range. Other options were left in natural conditions.

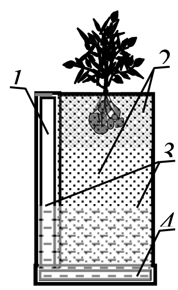

Fig. 1. Design of a tank for regulating groundwater levels: 1 – water regulating device, 2 – soil, 3 – adjustable groundwater level, 4 – drainage tube.

Before planting potatoes in the first year of research, organic fertilizer was added to the soil - multi-purpose compost (KMN - developed by the All-Russian Scientific Research Institute of Reclaimed Lands) at a rate of 15 t/ha. Characteristics of KMN: humidity – 60%; pH_{KCl} 6.08; N_{total} – 2.45%; P_2O_5 – 2.26%; K_2O – 1.93%; C – 21.5% [7]. In subsequent years, KMN was not introduced, but its aftereffect was assessed. Every year, potato tubers were treated with a 10% working solution of the humic preparation BoHum (developed by VNIIMZ) 2 hours before planting. Characteristics of BoHum: pH 8.13, content of humic acids – 10 g/l, dry residue – 23 g/l, total microbial number – 1.3×10^7 CFU/ml [8].

The experiment scheme is presented below.

I Drained soil (drainage work): 1 – without fertilizers (control); 2 – KMN; 3 – KMN + treatment of tubers with BoHum.

II Drained soil (drainage work) + artificial irrigation: 1 – without fertilizers (control); 2 – KMN; 3 – KMN + treatment of tubers with BoHum.

The experiment was carried out in quadruple repetition.

The number of physiological groups of soil microorganisms was determined by the classical method of limiting dilutions with inoculation on solid nutrient media: microorganisms using organic nitrogen - on the nutrient medium meat peptone agar, using mineral nitrogen - on starch-ammonia agar and mobilizing organophosphorus compounds - on the Menkina nutrient medium.

Statistical processing of experimental data was carried out using Microsoft Excel 2019 computer programs. The number of microorganisms is presented as arithmetic averages with

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a confidence interval. The statistical significance of differences in potato yields was assessed by LSD values (least significant difference) at a 5% significance level.

3 Results and discussion

The amount of precipitation during the growing seasons of the three years of research was slightly different: in 2020 – 244 mm, in 2021 – 270 mm, in 2022 – 290 mm. Frequent rains in 2021 and 2022 helped maintain soil moisture in the 0-40 cm layer at a high level (75-90% of the MPV), as a result of which additional irrigation was not required. Figure 2 shows hydrothermal conditions for 2020. It can be seen that the soil moisture under potatoes from the end of June until harvesting dropped below 70% of the MPV, which required artificial irrigation in vessels corresponding to the experimental design. As a result, during the first year of the experiment, three irrigations were carried out at rates from 340 to 500 m3/ha, with the last irrigation carried out at the critical phase of potato water consumption.

In general, the use of organic fertilizer KMN and humic preparation BoHum had a positive effect on the number of studied soil microorganisms. The most significant changes occurred in 2020. In particular, on drained soil, a statistically significant difference between the variants was observed: compared to the control, the increase in the number of soil microflora in the variant using KMN was 15%, and with additional treatment of tubers with BoHum - 31% (Fig. 3).

Maintaining optimal soil moisture supply (in vessels with additional watering) also had a beneficial effect on the state of soil biota. In the soil of the control variant and the variant with the addition of KMN, the number of studied microorganisms was significantly higher compared to the same variants in vessels without additional watering - by 11.0 and 12.5%, respectively (Fig. 3). In the variant with the combined use of KMN and BoHum, the amount of microflora increased, but not statistically significant (by 8.1%). In other words, the effect of the humic preparation BoHum was higher under the conditions of the dry growing season of 2020 (in vessels without irrigation, where soil moisture dropped below 70% of the MPV). This confirms the ability of humic preparations to reduce the influence of abiotic factors [9].

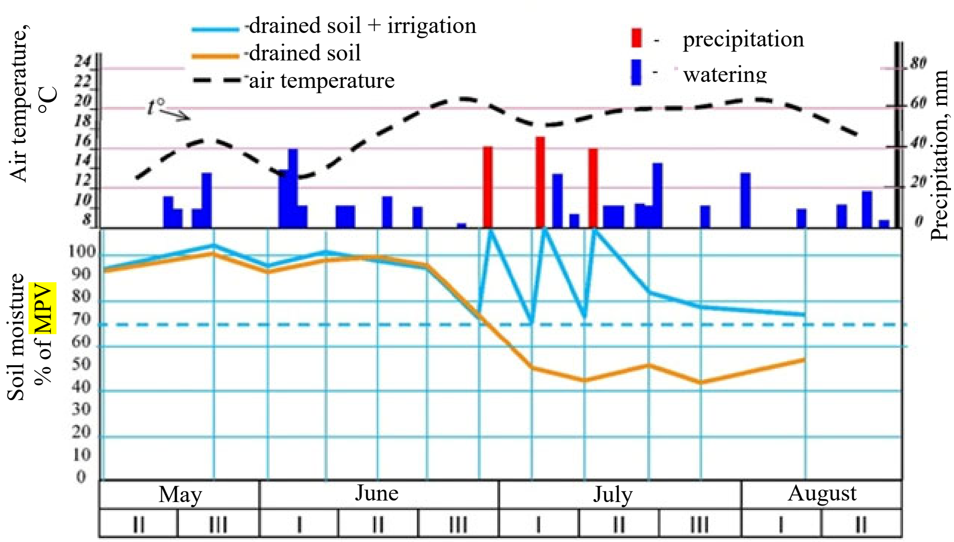

Fig. 2. Hydrothermal regime of the growing season 2020.

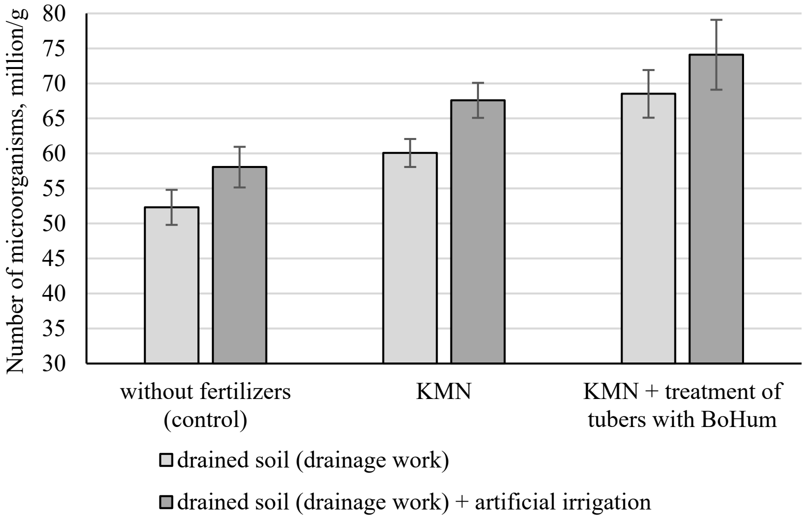

Fig. 3. Average number of soil microorganisms in the growing season of 2020.

In other years, the prolonged effect of the previously applied organic fertilizer was noted: the number of microflora in the variants with KMN was 15-40% higher (depending on the growth phase of the potato) compared to the control variant. In the variant of joint use of KMN and BoHum, the number of microflora was even higher, but without significant differences. It should be noted that in 2022, the number of microflora in general was slightly higher, which affected the formation of the harvest.

The maximum yield in the experimental options was determined in 2020, in particular, in the options with maintaining optimal soil moisture and with a richer nutrient regime (Table 1). A similar trend was observed throughout all three years of research.

Treatment of tubers with BoHum against the background of KMN contributed to a statistically significant increase in yield compared to the KMN variant: in 2020, on drained soil, the increase in yield was 14%, on drained soil with irrigation – 9%. This is consistent with data on the number of soil microorganisms. In general, according to experience, the dependence of potato yield (y) on the number of studied microorganisms (x) in the first year of research is described by the linear equation $y = -1355.93 + 35.842*x$, correlation coefficient $r = 0.95$. On average over three years, this dependence is weaker - the correlation coefficient is $r = 0.81$.

Table 1. Potato harvest.

Variant	**2020**		**2021**		**2022**		**On average for 2020-2022**	
	g/ bush	**increase in control, %**	**g/ bush**	**increase in control, %**	**g/ bush**	**increase in control, %**	**g/ bush**	**increase in control, %**
Drained soil								
Without fertilizers (control)	516	-	314	-	628	-	486	-
KMN	912	77	422	34	733	17	689	42
KMN + BoHum	1036	101	464	48	813	30	771	59

Drained soil + artificial irrigation								
Without fertilizers (control)	613	-	338	-	640	-	530	-
KMN	1164	90	430	27	780	22	791	49
KMN + BoHum	1269	107	482	43	839	31	863	63
HCP_{05}	81.3		40.5		66.0			

Despite the fact that no additional irrigation was carried out in 2021 and 2022, the potato yield in the "drained soil + artificial irrigation" experimental options was higher than in the corresponding options with drained soil. This can be explained by the reserve of productive moisture that was preserved in these vessels as a result of maintaining optimal soil moisture over several growing seasons. The difference in the yield of the control options (without fertilizers) confirms this: with artificial irrigation, the yield in 2020 is higher by 18.8%, in 2021 – by 7.6%, in 2022 – by 2.0%.

4 Conclusion

Providing plants with optimal conditions for moisture and nutrition is an effective way to increase potato yields. It was established that all the considered potato cultivation methods (the use of organic fertilizer KMN, treatment of tubers before planting with the humic preparation BoHum and timely additional watering) collectively or separately, on average over three years of research, contributed to an increase in the number of soil microflora up to 40%, and the yield - up to 63%.

Over the course of three years of research, the maximum potato yield was observed with the simultaneous use of all the techniques considered, since each of them performed its own function, was characterized by its own characteristics and complemented the action of the others. KMN, having a prolonged effect, provided potato plants with nutrients, the humic preparation BoHum had a stimulating and protective effect on tubers and soil microflora, and additional watering created optimal conditions for potatoes in terms of moisture supply, enhanced the effect of KMN and contributed to the formation of a reserve of productive moisture.

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