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SOIL WATER REGIME AND POTATO YIELD UNDER DIFFERENT IRRIGATION METHODS IN THE POLISSYA REGION OF UKRAINE

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Abstract. *In this scientific study, the parameters of irrigation regimes, evapotranspiration (ETc) values, and potato yields were experimentally determined depending on irrigation methods and water supply regimes. To conduct the study, a short-term (2023–2025) field experiment, analytical and statistical methods of experimental data processing were used. It has been proven that the method of laying irrigation pipelines for drip irrigation systems, the method of irrigation, and the water supply regime have a significant impact on evapotranspiration, soil water regime, and potato tuber yield in the Polissya region of Ukraine. Thus, the amount of evapotranspiration of plantings varied depending on the water regime: 2,20–2,51thousand m³/ha in non-irrigated conditions; 4,47–5,31 thousand m³/ha in the case of underground placement of irrigation pipelines (at a depth of 0,30 m), 4,72–5,61 thousand m³/ha for drip irrigation with periodic water supply, and 4,30–5,17 thousand m³/ha for drip irrigation with pulsed water supply. Under sprinkler irrigation, evapotranspiration was highest, ranging from 5,80 to 6,24 thousand m³/ha over the years of the study. It is natural that without irrigation, the lowest yield of marketable tubers was obtained – 43,4 t/ha, and the factor of "irrigation" in combination with fertigation increased this indicator by an average of 1,5 times – to 65,15 t/ha. The increase in tuber yield with drip irrigation with periodic and pulsed water supply was statistically significant: up to 66,4 t/ha and 70,4 t/ha, respectively. Under conditions of sprinkler and subsurface drip irrigation, 60,8 t/ha and 62,7 t/ha were obtained, respectively. The minimum specific irrigation water consumption was obtained with drip irrigation with a pulsed water supply mode – 67,6 m³/t, respectively. The highest water consumption coefficient was for sprinkler irrigation – 100,4 m³/t. Thus, when growing potatoes in the Polissya region of Ukraine, it is more expedient to use drip irrigation, preferably with a pulsed water supply mode, and in conditions of acute water shortage for irrigation, drip irrigation with underground installation of irrigation pipelines.*

Keywords*: irrigation methods, soil water regime, pulsed water supply, evapotranspiration, water consumption coefficient, yield, potatoes*

Relevance of the research. Potato (*Solanum tuberosum L.*) is traditionally one of the main agricultural crops in Ukraine in terms of acreage and consumption. During 2023–2025, the area under this crop ranged from 1,05 to 1,33 million hectares, and the gross annual harvest of tubers ranged from 17,54 to 21,36 million tons. On the one hand, these volumes are sufficient to cover the domestic market, but due to the lack of sufficient modern vegetable storage facilities, Ukraine is forced to import potatoes from EU countries (Poland, Lithuania, Germany, the Netherlands) and Egypt every year [1].

Given the physiological characteristics of potatoes, namely, the cessation of tuber growth at air temperatures above +27–29 °C, the most favorable soil and climatic zones for their cultivation in Ukraine are Polissya and Forest-steppe zone of Ukraine. For example, about 75 % of all potato acreage is located here. Another critically important feature of potato physiology is its demanding water requirements. The average water consumption coefficient of potatoes is over 90–100 m^3/t. At the same time, the amount of effective (over 5 mm) precipitation during the growing season within 200–300 mm ensures a potato yield of no more than 20–30 tons/ha. Therefore, irrigation is a mandatory element in modern technologies for growing this crop in all soil and climatic zones of Ukraine [2]. Practice shows that today, the implementation of various methods of potato irrigation, such as sprinkling and surface drip irrigation, provides relevant efficiency. For Ukrainian conditions, subsurface drip irrigation and drip irrigation with a pulsed water supply mode are relatively new methods of potato irrigation [3, 4]. The principle of pulsed water supply, unlike periodic irrigation, involves the discrete supply of irrigation water to the area of plant root system concentration in short cycles (pulses) of fixed or variable duration in accordance with the actual transpiration of plants.

Thus, applied scientific research on determining the parameters and effectiveness of irrigation methods and water supply modes for potatoes in the Polissya region of Ukraine is new and quite relevant today.

Analysis of recent studies and publications. Over the years, the issue of optimizing the water regime of potato soil in Ukraine has been most thoroughly researched at three scientific institutions: the Institute of Irrigated Agriculture of the National Academy of Agrarian Sciences (now the Institute of Climate-Oriented Agriculture of the National Academy of Agrarian Sciences), the Institute of Hydrotechnics and Land Reclamation of the NAAS (now the Institute of Water Problems and Land Reclamation of the NAAS), and the Institute of Southern Vegetable and Melon Growing of the NAAS (currently located on the temporarily occupied territory of the Left Bank of the Kherson Region, in the city of Hola Prystan). At the first stage (1970s-1990s), Ukrainian scientists established the optimal parameters of the water regime for potatoes under sprinkler irrigation. The greatest contribution in this regard was made by scientists from the Institute of Irrigated Agriculture – E.M. Gorbatenko, V.A. Pysarenko, M.S. Boiko, P.V. Matsko, G.S. Balashova, and others [5, 6, 7]. Since the 2000s, domestic scientists (V.A. Pysarenko, I.P. Bugayeva, V.S. Snigovyi, M.I. Chernichenko, Yu.O. Lavrinenko, P.V. Pysarenko, O.I. Golovatskyi, S.M., Romashchenko M.I., Shatkovsky A.P., Yatsyuk Z.F., Kapelyukha T.A., Lymar V.A., Shabunin I.M.) studied both the effectiveness of drip irrigation in potato cultivation and compared different irrigation methods in the conditions of the Ukrainian Steppe [2, 8–14]. The general conclusion of these scientific studies is that drip irrigation (compared to sprinkler and micro-sprinkler irrigation) is proven to be effective for growing potatoes in the southern region of Ukraine.

At the same time, there have been almost no studies on potato irrigation in the Polissya region of Ukraine to date. Against the backdrop of drip irrigation, research was conducted under the leadership of Veremeyenko S.I., but the main subject of study was the effect of fertigation on potato yield [15]. The need for such research is further emphasized, on the one hand, by the increasing aridization of the climate [16] and, on the other hand, by the actual gradual introduction of irrigation in the Polissya region of Ukraine, especially in the Zhytomyr, Kyiv, and Chernihiv regions. In this context, the most relevant are the studies conducted by Polish scientists from the Faculty of Agriculture and Biotechnology at the University of Science and Technology in Bydgoszcz during 2011–2013 [17]. Based on the results of a two-factor experiment, they determined the water requirements of potato plants and found that drip irrigation increased the marketable yield of tubers by 55 %. The effectiveness of fertigation compared to the application of mineral fertilizers was also confirmed. Other comprehensive studies in Poland (2007–2009) have proven the positive effect of drip irrigation and fertigation on the yield and some quality elements of potato tubers [18].

The aim of the study was to prove and evaluate the impact of irrigation methods and water supply regimes on soil water regime, evapotranspiration, and potato yield in the Polissya region of Ukraine.

Materials and methods. Field experiments were conducted under production conditions on irrigated lands of Agrofirma Kyivska LLC (Makovysche village, Bucha district, Makariv territorial community, Kyiv region, Polissya zone of Ukraine, Google maps coordinates 50.465494, 29.855753) during 2023–2025. The two-factor field experiment included the following options: sprinkler irrigation, drip irrigation with periodic water supply, drip irrigation with pulsed water supply, and subsurface drip irrigation with irrigation pipes laid in the center of the ridge at a depth of 0,30 m. The control option was natural moisture supply without irrigation. The study was conducted using standard methods: systematic plot placement, four repetitions, and a plot area of 32 m^2 [19, 20]. The Granada potato variety (early maturing table variety, originator – Solana GmbH & Co. KG, Germany) was used. The planting pattern was 75+75 × 15 cm with irrigation pipes laid in the center of the ridge. The predecessor crop was field peas (*Pisum sativum*).

The soil of the experimental plot was gray podzolized sandy loam on loess. The density of its 40-centimeter layer was 1,49 g/cm^3 , humus content – 0,51 %, pH = 4,1, soil nitrogen content is very low, mobile forms of phosphorus are high, potassium – average. The minimum moisture content of the arable soil layer (0–30 cm) is 20,15 % of the mass of absolutely dry soil, and that of the 0–100 cm soil layer is 18,33 %.

The amount of productive precipitation during the growing season (May-first ten days of September) for potatoes varied over the years of research. In 2023, it was 188 mm, which is 71,8 % of the climate norm, in 2024 – 198,3 mm or 75,0 %, and in 2025 – 211.6 mm or 80,9 % of the climate norm. The pre-irrigation moisture level in a 30 cm layer of soil was −18 kPa. To determine the timing of irrigation, we used the mMetos Base digital internet station with Watermark 200 SS sensors [21], as well as AQUAMETER PRO tensiometric sensors [22]. Statistical analysis of the results was performed using dispersion, correlation, and regression methods with the Statistica 8.0 program.

Research results and discussion. The study experimentally confirmed the direct influence of the irrigation method, and in fact, the method of distributing irrigation water within the field and the transformation of water flow into soil moisture, on the formation of the soil water regime. In particular, the irrigation method had a significant effect on the irrigation regime (timing, amount, and frequency of irrigation), evapotranspiration, yield, and water consumption coefficient of potatoes (Table 1).

The largest number of vegetative irrigations were carried out using pulse drip irrigation – 237 with an average rate of 10–12 m^3/ha. These parameters correspond to the principle of pulse water supply (discrete irrigation in short cycles (pulses) of fixed or variable duration in accordance with the actual transpiration of plants). Under conditions of periodic water supply, 38 irrigations were carried out using drip irrigation at a rate of 80 m^3/ha. Potatoes required fewer irrigations with sub-soil irrigation – 27 with an average rate of about 100–105 m^3/ha. The smallest number of irrigations was with sprinkler irrigation – 13, but this method resulted in the maximum irrigation rate: 283 m^3/ha due to the need to moisten the entire area and moisture losses due to evaporation during irrigation.

The total volume of irrigation water (irrigation rate) required to maintain the pre-irrigation threshold (−18 kPa) was close in value for subsurface and drip irrigation with a pulsed water supply mode –2,76 thousand m^3/ha and 2,66 thousand m^3/ha, respectively. A significantly higher rate was observed for drip irrigation with periodic watering – 3,05 thousand m^3/ha. In turn, sprinkler irrigation increased the irrigation rate by 1,3–1,5 times – up to 3,96 thousand m^3/ha. The parameters of evapotranspiration (ETc) of potato plants varied similarly. Lower values were characteristic of drip irrigation options (4,77–5,18 thousand m^3/ha), and the maximum ETc was for sprinkler irrigation – 6,08 thousand m^3/ha. On average, irrigation increased evapotranspiration by 2,25 times compared to non-irrigated conditions, where ETs was limited by productive precipitation and soil moisture reserves and amounted to 2,33 thousand m^3/ha.

The minimum specific irrigation water consumption was obtained when implementing the drip irrigation option with a pulsed water supply mode – 67,6 m^3/t, respectively. The relevant water consumption coefficient was for drip irrigation with periodic watering and subsurface drip irrigation – 78,0 m^3/t and 78,2 m^3/t, respectively. The highest water consumption coefficient was for sprinkler irrigation – 100,4 m^3/t. In the control group, this indicator averaged 53,7 m^3/t over three years.

It has been proven that irrigation is a key factor in intensifying potato productivity in the Polissya region of Ukraine. It was found that irrigation combined with fertigation (compared to the control – without irrigation, 43,4 t/ha) increased the yield by an average of 1,5 times – to 65,15 t/ha (Fig. 1).

The yield of tubers in non-irrigated conditions varied greatly over the years of the study, depending on the regime and amount of productive precipitation: from 37,1 t/ha in 2024 to 53,7 t/ha in 2023. In turn, irrigation ensured consistent productivity, and this indicator varied within narrow limits over the years of the study: 57,9–64,3 t/ha for sprinkler irrigation, 61,4–64,5 t/ha for subsurface drip irrigation, 66,3–68,7 t/ha for drip irrigation with periodic water supply, and 68,5–72,25 t/ha for drip irrigation with pulsed water supply.

1. Irrigation regime, evapotranspiration, and water consumption coefficient (WCC) of potatoes depending on the irrigation method (average for 2023–2025)

Irrigation method	Water supply regime	Number of watering	Irrigation rate, m^3/ha	Evapotranspiration (ETc), m^3/ha	WCC, m^3/t
Subsurface drip	Periodic	27	2765	4902	78,2
Drip	Pulse	237	2663	4746	67,4
	Periodic	38	3048	5179	78,0
Sprinkling	Periodic	14	3962	6079	100,0
Control	–	–	–	2329	53,7

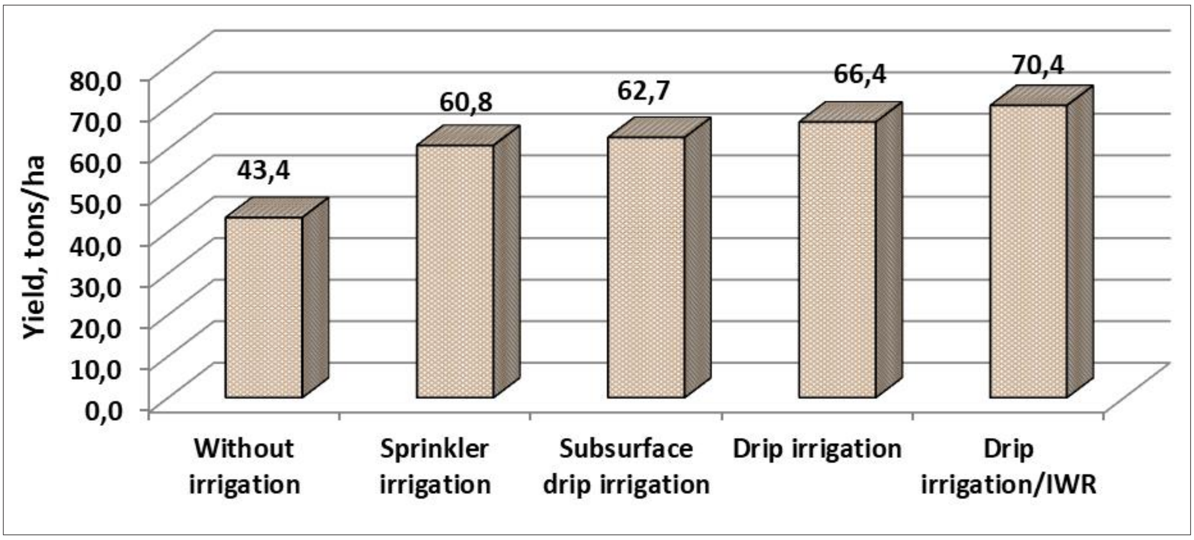

Fig. 1. Yield of marketable potato tubers depending on the irrigation method (average for 2023–2025) $MDD_{.5}$ = 3,15 t/ha

A statistically significant ($MDD_{.5}$ = 3,15 t/ha) increase in tuber yield was observed with drip irrigation with periodic and pulsed water supply: up to 66,4 t/ha and 70,4 t/ha, respectively. Under conditions of sprinkler and subsurface drip irrigation, 60,8 t/ha and 62,7 t/ha were obtained, respectively.

Based on averaged experimental data on evapotranspiration and potato yield, a statistical relationship between evapotranspiration and yield was obtained. This relationship is actually a response curve to a single-factor field experiment and consists of three parts: limiting, stationary (optimal), and inhibitory (excessive). The coefficient of determination R^2 = 0,764 indicates a stable relationship between these values. It has been established that the limiting area of the curve corresponds to the control variant of the experiment – without irrigation; the stationary part (optimum zone) corresponds to three variants with drip irrigation (subsoil, surface, and impulse drip), and the inhibitory part (excess zone) corresponds to sprinkler irrigation (Fig. 2).

The established statistical dependence between evapotranspiration and yield is not

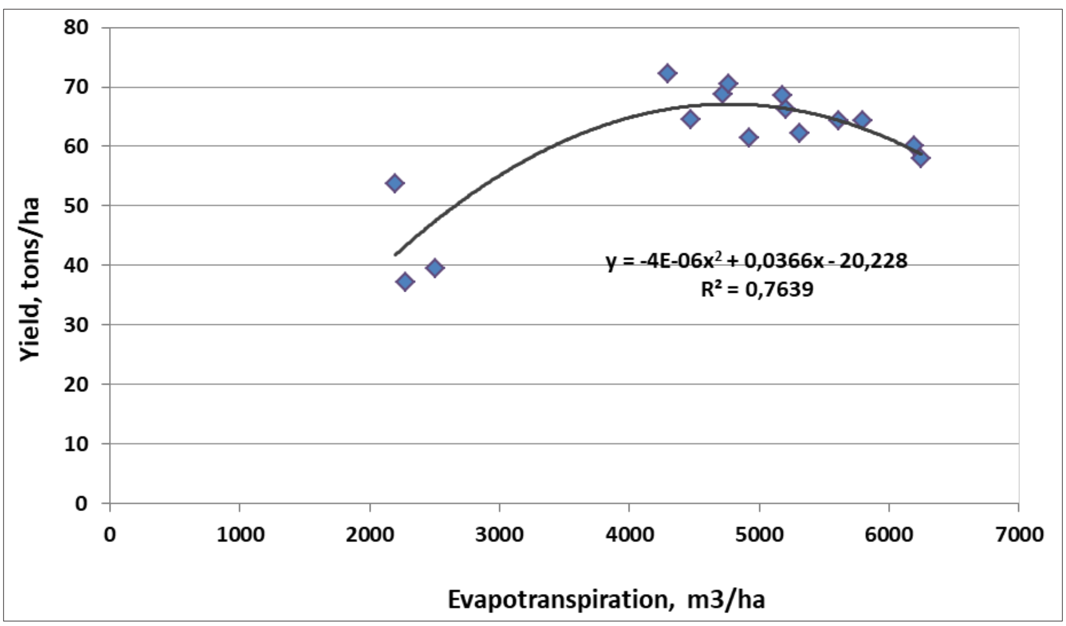

Fig. 2. Dependence of “Evapotranspiration – Yield” for potato cultivation in the Polissya region of Ukraine

stable from an agrobiological point of view, since there are agrotechnological and breeding-genetic possibilities for increasing potato yield with the same plant evapotranspiration values. Therefore, the main task of future research on evapotranspiration processes is to reduce unproductive water consumption (for physical evaporation and infiltration into lower soil horizons) while increasing the productivity of potato plants.

The results obtained are generally consistent with the data obtained in a study by Polish scientists [17]. In particular, drip irrigation increased the marketable yield of potato tubers by 55 %, and the water requirement for irrigation during the growing season was 2,2 thousand m^3/ha.

Conclusions. It has been proven that the method of laying irrigation pipelines for drip irrigation systems, the method of irrigation, and the water supply regime have a significant impact on evapotranspiration, soil water regime, and potato tuber yield in the Polissya region of Ukraine. The most optimal for potatoes in these conditions is the introduction of drip irrigation with a pulsed water supply regime. This ensures minimum specific irrigation water consumption and a yield of marketable tubers of over 70 t/ha. The option with underground irrigation pipelines provided almost identical irrigation water consumption parameters during the growing season, but the yield decreased by 10,9 % or 7,7 t/ha. This irrigation method is advisable to implement as a strategy for integrating potatoes into field crop rotation.

Conflicts of interest: the authors declare no conflict of interest.

Use of artificial intelligence: the authors confirm that they did not use artificial intelligence technologies during the creation of this work.

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ВОДНИЙ РЕЖИМ ҐРУНТУ І ВРОЖАЙНІСТЬ КАРТОПЛІ ЗА РІЗНИХ СПОСОБІВ ЗРОШЕННЯ В УМОВАХ ПОЛІССЯ УКРАЇНИ

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Анотація. *У науковому дослідженні експериментально визначено параметри режимів зрошення, величини евапотранспірації (ETc) та врожайність картоплі залежно від способів зрошення та режиму водоподачі. З метою реалізації дослідження використано короткотерміновий (2023–2025 рр.) польовий дослід, аналітичні і статистичні методи обробки експериментальних даних. Доведено, що спосіб укладання поливних трубопроводів систем краплинного зрошення, спосіб зрошення та режим водоподачі достовірно впливають на евапотранспірацію, водний режим ґрунту та врожайність бульб картоплі в умовах Полісся України. Так, величина евапотранспірації насаджень варіювала залежно від водного режиму: 2,20–2,51 тис. м^3/га у незрошуваних умовах; 4,47–5,31 тис. м^3/га у разі внутрішньоґрунтового розміщення поливних трубопроводів (на глибині 0,30 м), 4,72–5,61 тис. м^3/га за краплинного зрошення з періодичним режимом водоподачі та 4,30–5,17 тис. м^3/га – за краплинного зрошення з імпульсним режимом водоподачі. За умови зрошення дощуванням евапотранспірація була найвищою і становила від 5,80–6,24 тис. м^3/га за роками дослідження. Закономірно, що без зрошення отримано найнижчий рівень врожайності товарних бульб – 43,4 т/га, а фактор «зрошення» у поєднанні з фертигацією збільшував цей показник в середньому у 1,5 рази – до 65,15 т/га. Статистично достовірним було збільшення врожайності бульб за краплинного зрошення з періодичним та імпульсним режимом водоподачі: до 66,4 т/га і 70,4 т/га відповідно. За умов дощування та внутрішньоґрунтового краплинного зрошення отримано 60,8 т/га і 62,7 т/га відповідно. Мінімальні питомі витрати зрошувальної води отримано за реалізації варіанту краплинного зрошення з імпульсним режимом водоподачі – 67,6 м^3/т відповідно. Найвищим коефіцієнт водоспоживання був для умов дощування – 100,4 м^3/т. Таким чином, за вирощування картоплі в умовах Полісся України доцільніше впроваджувати краплинне зрошення, переважно – з імпульсним режимом водоподачі, а за умови гострого дефіциту водних ресурсів для зрошення – краплинне зрошення з внутрішньоґрунтовим укладанням поливних трубопроводів.*

Ключові слова: *способи зрошення, водний режим ґрунту, імпульсний режим водоподачі, евапотранспірація, коефіцієнт водоспоживання, врожайність, картопля*