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## Water consumption of sunflower plants under the influence of cultivation technology elements

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**Abstract.** Proper management of the water regime of plants helps to increase yields. Insufficient or excessive water supply can negatively affect their growth and development, reducing final productivity. The purpose of the study was to identify the influence of weather conditions, fertiliser conditions, and the effect of a retardant on the productivity of sunflower hybrids. Field studies were conducted in 2021-2023 on typical low-humus chernozems. Studies have established that the decisive factor determining the level of yield and water consumption is the amount of soil moisture in 0-100 cm of the soil layer for the sowing period and the amount of precipitation for the general growing season. Total water consumption varied over the years of research: it was the lowest in 2022 and amounted to 2,533 m<sup>3</sup>/ha, and the largest – in 2023 – 3,645 m<sup>3</sup>/ha. On average, over three years of research, the total water consumption was 3,095 m<sup>3</sup>/ha. The coefficient of water consumption, which characterised the moisture consumption for the development of 1 tonne of seeds with

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the corresponding amount of by-products, changed under the influence of weather and climatic conditions of the year, morphobiological features of the hybrids that were studied, technological methods, fertiliser optimisation, and in 2021 amounted to 822 to 1,546 m<sup>3</sup>/t; in 2022 – 716 to 1,299, and in 2023 – from 937 to 1,796 m<sup>3</sup>/t. The highest water consumption rate per 1 tonne of sunflower seeds was obtained in 2023. In the RGT Wollf hybrid, it changed as fertilisation rates increased from 1,664 to 996 m<sup>3</sup>/t, Alzan – 1,672-1,108, ES Bella – 1,796-1,187, Lime – 1,727-1,115 m<sup>3</sup>/t. The use of Setar retardant for sunflower cultivation helped to reduce the coefficient of water consumption and ensured more rational use of moisture by plants for the development of a crop unit. Fertiliser showed the greatest impact on reducing the water consumption coefficient. In the most unfavourable years of cultivation for moisture, the efficiency of using moisture by sunflower plants with nutrition optimisation increased significantly, which indicates the effectiveness of using fertilisers and the Setar retardant. The results obtained will be useful for agricultural enterprises in increasing the efficiency of resource use and improving financial results

**Keywords:** moisture; fertilisers; oilseeds; productivity; retardant

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## Introduction

Modern cultivation technologies, especially intensive hybrids, help to increase production volumes, maximising the genetic potential of the crop, which is relevant in the context of climate change. A detailed study of the morphobiological features of sunflower helps to unlock the potential of specific varieties and hybrids. Improving technological methods of cultivation creates optimal conditions for the growth and development of plants, increasing yields. Insufficient soil supply with nutrients and moisture is the main reason for low sunflower yields. Optimal sowing times help to avoid critical periods of humidity requirements. The absorption of nutrients depends on the moisture reserves in the soil: with sufficient moisture, plants better absorb nutrients, and with insufficient moisture, it is impractical to apply high fertilisation rates. Sunflower is very sensitive to fertilisers, which is a key factor in shaping its productivity (Revto & Naboka, 2022).

According to V.V. Gamayunova & V.S. Kudrina (2018), during the period of plant growth and development, a significant role is assigned to the level of water and heat resources. Less attention is paid to the the availability of effective and active temperatures, although at certain stages of plant development, these indicators

have a significant impact on the passage of production processes, and this issue is now a priority and is relevant. However, the moisture supply of plants is of limiting importance in the process of growth and development, the development of productivity not only of sunflower, but also of other crops. Most of all, attention is focused on studying this issue in conditions of insufficient and unstable moisture, in which almost the entire territory of Ukraine is now located (Domaratskyi *et al.*, 2022).

When studying the process of growth and development of sunflower plants, attention is focused not only on the amount of precipitation and its distribution during the growing season of the crop, but also on the presence of moisture that will be available to plants in the soil. In addition, the influence of moisture supply on the growth and development of sunflower plants with various fertiliser options is also relevant. This can be judged by conducting biometric measurements of plants grown under different effects of nutrients and different levels of moisture supply. As noted by L. Chaves *et al.* (2014), the use of nitrogen and potassium does not significantly affect plant height. However, the introduction of phosphorus and ensuring a sufficient level of moisture

have a positive effect on the specified biometric indicator. When determining the diameter of the stem, its parameters increase with the introduction of nitrogen and potassium, while the effect of phosphorus is not observed. An increase in nitrogen application rates contributes to an increase in the diameter of the sunflower stem up to 19.7% compared to options without fertilisers. In turn, the biometric parameters of sunflower plants also increased with an increase in moisture supply indicators. With an increase in productive moisture in the soil against the background of the use of fertilisers, there is also an increase in the number of leaves on the plant and the area of leaves.

In the case of sunflower cultivation, crop rotation is of great importance. Z. Dehtiarova (2023) argued that in the context of an increase in the share of sunflower in the structure of crop rotation, there is a decrease in its yield as a result of a deterioration in the availability of moisture. According to the saturation of the sunflower crop rotation by 60%, moisture consumption is at the level of 2,969 m<sup>3</sup>/ha. When reducing the shares to 40 and 20%, the indicators were 2,713 and 2,824 m<sup>3</sup>/ha. Studies show that with the share of sunflower in crop rotation at the level of 40%, the water consumption coefficient is the lowest.

When growing sunflower seeds, precipitation is the main source of moisture in the soil. Their number is insufficient, with an uneven distribution. The predominant amount of precipitation falls during the spring-summer growing season of crops. Analysis of weather conditions over the past 10 years shows that against the background of close indicators for crop moisture supply, there is a significant decrease in the amount of productive precipitation. Ye.O. Domaratsky *et al.* (2021) noted an increase in the number of heavy rains, which, in turn, leads to the creation of stressful conditions and has a negative impact on the growth and development of plants and their productivity. The level of yield of field crops is significantly determined by the total water consumption, moisture reserves in the 0-100 cm soil layer during sowing and precipitation during the

growing season, and is characterised by a direct relationship between these indicators. Therefore, crops in years with sufficient moisture supply form higher yields.

However, providing sunflower plants with moisture at various stages of their development plays an important role in shaping crop productivity. V.F. Kaminskyi & V.V. Hanhur (2018) emphasised that sunflower is not a crop that removes a large amount of basic nutrients from the soil, as it is characterised by a compensatory return of them to the soil with by-products. However, to form a certain crop, the plant must take these minerals from the soil.

Analysing the water consumption of sunflower plants, A. Kovalenko *et al.* (2020) noted that they take as much moisture from the soil layer of 0-100 cm as it was accumulated during the pre-sowing and growing season. With insufficient precipitation during the growing season, sunflower plants can meet their needs due to the moisture reserves in the soil layer up to 200 cm by 50-60%. However, according to A.V. Panfilova & V.V. Hamaiunova (2019), this can cause problems when growing the next crop. G.V. Pinkovskiy & S.P. Tanchyk (2020) concluded that due to the emergence and introduction of new hybrids of foreign and Ukrainian breeding, which are characterised by a high adaptive potential, sowing using high-quality seed material and the use of modern technologies, it is possible to increase the level of efficiency of growing sunflower seeds due to obtaining an increased crop yield.

Thus, in the conditions of climate change and unstable water supply, increasing sunflower productivity requires a comprehensive approach that considers the interaction of agrotechnical techniques, moisture availability, and fertiliser systems. Improving cultivation technologies, considering the morphobiological features of hybrids, helps to rationalise the use of resources and optimise crop development. The purpose of the study was to determine the influence of weather conditions, fertilisers, and retardants on the productivity of sunflower hybrids.

## Materials and Methods

Field research was conducted at the Agronomic Experimental Station, a separate division of the National University of Life and Environmental Sciences of Ukraine, in 2021-2023. The soils of the experimental field are typical low-humus chernozems. The humus content in the soil of the experimental field was 4.32%. Typical low-humus chernozem was characterised by an average supply of phosphorus and potassium, and low nitrogen.

The analysis of weather conditions during the years of the study shows a significant difference between the indicators, which had a significant impact on the course of sunflower production processes. They were manifested in an increase in the average daily values of air temperature indicators, which was observed in all growing seasons of the research years. The growing season of sunflower was characterised by uneven distribution of precipitation and insufficient amount, which did not allow creating optimal conditions for the passage of production processes and, accordingly, did not contribute to the maximum implementation of the genetic potential of sunflower plants. The amount of precipitation during the growing season of the crop varied by year: in 2021 it was 301.8 mm, in 2022 – 300.5, in 2023 – 441.6 mm, which was reflected in the plant productivity. The study met the requirements of the Convention on Biological Diversity (1992).

The experiment was three-factor. Factor A – sunflower hybrids (RGT Wollf, Alzan, ES Bella, Lime); Factor B – fertiliser (calculation for planned yields by the balance method); Factor C – application of retardant Setar (use in microstages BBCH 30-32, 0.5 l/ha). The experiment consisted of four repetitions. The area of the sown plot was 56 m<sup>2</sup>, accounting – 42 m<sup>2</sup>. The predecessor in the experiment was winter wheat. The density of sunflower plants for the harvest period was 55 thousand plants per hectare. Fertilisers were applied according to the scheme of the experiment: nitrogen – for pre-sowing cultivation, phosphorous and potassium – for main treatment. The content of available moisture in the soil was determined

by the thermostatic-weight method. The total water consumption of sunflower seeds was determined by the water balance using the equation:

$$E = O + (Wn - Wk), \quad (1)$$

where  $E$  – amount of water consumed during the growing season, m<sup>3</sup>/ha;  $Wn$ ,  $Wk$  – indicators of the initial and final moisture reserve in the soil, m<sup>3</sup>/ha;  $O$  – amount of precipitation during the growing season, m<sup>3</sup>/ha. The water consumption coefficient was calculated using the equation:

$$Kw = E : Y, \quad (2)$$

where  $Kw$  – water consumption coefficient, m<sup>3</sup>/t;  $E$  – amount of water consumed by plants during their growing season, m<sup>3</sup>/ha,  $Y$  – sunflower seed yield, t/ha. In the phase of full ripeness of sunflower seeds, the amount of accumulated aboveground biomass was determined (typical plants were selected in each version of the experiment, followed by drying the attachments at temperatures of 105°C to a completely dry state of plant material and calculations were performed per 1 ha.

The sunflower seeds were collected in sections by direct harvesting. The bunker weight of seeds was recalculated for the crop from 1 ha, considering contamination and humidity in terms of 8% (DSTU 7011:2009, 2010). Based on the results of the obtained indicators, a correlation analysis was carried out between yield indicators and productive moisture reserves for the sowing period (Rozhkov *et al.*, 2016).

## Results

The main sunflower crops in Ukraine are concentrated in conditions characterised by insufficient or unstable moisture levels. Under unfavourable weather conditions, the genetic potential of sunflower is only 45-50% realised. In conditions of unstable moisture, the moisture content in the soil is a limiting factor in creating favourable conditions for the growth and development of plants and their productivity. An important role, in this case, is played by the correct selection of varieties

and hybrids of the crop for cultivation. The results of studies conducted in different growing areas indicate that a higher yield is formed by sunflower crops that were better provided with moisture. The amount of precipitation in the autumn-winter period and the first half of the growing season must be considered. Calculations of moisture reserves showed a significant difference in indicators over the years of research. According to them,

during 2021-2023, moisture reserves in the metre-long soil layer during the sunflower growing season changed from 3,217 m<sup>3</sup>/ha (2022) up to 4,402 m<sup>3</sup>/ha (2023) (Table 1). Precipitation was characterised by indicators in 2021 – 2,489 m<sup>3</sup>/ha, 2022 – 1,923, 2023 – 2,963 m<sup>3</sup>/ha. In turn, according to calculations, moisture consumption during the growing season ranged from 2,533 to 3,645 m<sup>3</sup>/ha. The highest indicator was received in 2023.

**Table 1. Moisture availability during the growth and development of sunflower hybrids, m<sup>3</sup>/ha**

Year of research	Reserves of productive moisture in the soil for the sowing period, m <sup>3</sup> /ha	Precipitation during the growing season, m <sup>3</sup> /ha	Moisture reserves, total, m <sup>3</sup> /ha	Moisture balance for the harvesting period, m <sup>3</sup> /ha	Moisture consumption during the growing season, m <sup>3</sup> /ha
2021	1,513	2,489	4,002	895	3,107
2022	1,294	1,923	3,217	684	2,533
2023	1,439	2,963	4,402	757	3,645

**Source:** compiled by the authors

Sunflower plants need different amounts of moisture during the growing season at different stages of development. In the period from the beginning of the development of plants and baskets, plants consume approximately 25% of all the moisture necessary for them. At this stage of development, plants use moisture from the upper layers of the soil. However, at the stages of basket development and flowering, the plant consumes about 60% of the total demand. Insufficient amount of moisture during the specified period leads to the development of underdeveloped baskets and cotyledons.

During the period of physiological ripeness (seed moisture 35-40%), there is a decrease in the intensity and speed of biological processes, physiological evaporation of water, as a result of which seeds lose up to 2.0% of moisture in dry weather conditions. The water supply of sunflower plants depends on the current level of moisture reserves in the soil and weather conditions during the growing season of the crop (precipitation, temperature, relative humidity). In conditions of a high level of soil moisture supply, sunflower plants consume moisture in increasing amplitude.

One of the factors that determines the moisture consumption of sunflower plants for transpiration is the biological characteristics and genotype of the hybrid or variety, which explains the low internal resistance of water in the conducting bundles of the stem, while the low internal resistance of stomata to water vapour.

The amount of water consumed by a plant at different depths depends on the soil's moisture reserves, precipitation, and effective temperatures at a certain stage of plant development. Sunflower seeds with sufficient or excessive moisture can use moisture inefficiently. However, when growing it in arid conditions, there is a more rational use of moisture. An indicator that allows identifying the effectiveness of the impact of a particular technological measure on the use of moisture by plants, together with indicators of total water consumption, is the water consumption coefficient. The indicator shows the consumption of moisture by plants to form a unit of yield (per 1 tonne of sunflower seeds with the corresponding amount of by-products). This indicator depends on the biological characteristics of the variety or hybrid, the availability of nutrients,

technological methods, and weather conditions of the growing season. The findings showed that the reserves of productive moisture during the sowing period depended on the weather characteristics

of the growing year. Sunflower hybrids under study consumed an average of 305 to 495 m<sup>3</sup>/t of water for the development of 1 tonne of dry matter over the years of research (Table 2).

**Table 2.** Indicators of the coefficient of water consumption by sunflower plants per 1 tonne of dry matter of the crop, m<sup>3</sup>/t

Hybrid	Variant	Retardant treatment	2021	2022	2023	Average	
RGT Wolf	N <sub>40</sub> P <sub>20</sub> K <sub>60</sub>	1	502	420	547	492	
		2	463	400	523	464	
	N <sub>60</sub> P <sub>35</sub> K <sub>90</sub>	1	435	401	491	444	
		2	413	350	458	409	
	N <sub>80</sub> P <sub>50</sub> K <sub>120</sub>	1	396	352	459	404	
		2	376	325	423	376	
	N <sub>100</sub> P <sub>65</sub> K <sub>150</sub>	1	321	296	383	335	
		2	310	275	356	315	
	N <sub>120</sub> P <sub>80</sub> K <sub>180</sub>	1	309	271	335	307	
		2	288	251	322	289	
	Alzan	N <sub>40</sub> P <sub>20</sub> K <sub>60</sub>	1	477	398	554	477
			2	458	384	522	456
N <sub>60</sub> P <sub>35</sub> K <sub>90</sub>		1	419	357	494	424	
		2	397	342	454	399	
N <sub>80</sub> P <sub>50</sub> K <sub>120</sub>		1	399	334	473	403	
		2	378	310	417	369	
N <sub>100</sub> P <sub>65</sub> K <sub>150</sub>		1	362	304	420	363	
		2	339	286	392	340	
N <sub>120</sub> P <sub>80</sub> K <sub>180</sub>		1	317	266	369	318	
		2	301	258	353	305	
ES Bella		N <sub>40</sub> P <sub>20</sub> K <sub>60</sub>	1	479	407	562	484
			2	467	386	518	458
	N <sub>60</sub> P <sub>35</sub> K <sub>90</sub>	1	464	381	517	455	
		2	449	371	476	434	
	N <sub>80</sub> P <sub>50</sub> K <sub>120</sub>	1	426	361	464	419	
		2	407	355	445	405	
	N <sub>100</sub> P <sub>65</sub> K <sub>150</sub>	1	380	340	428	385	
		2	366	315	383	357	
	N <sub>120</sub> P <sub>80</sub> K <sub>180</sub>	1	336	291	377	336	
		2	312	273	348	312	
	Lime	N <sub>40</sub> P <sub>20</sub> K <sub>60</sub>	1	507	408	539	486
			2	485	388	518	465
N <sub>60</sub> P <sub>35</sub> K <sub>90</sub>		1	474	386	495	453	
		2	450	381	446	427	
N <sub>80</sub> P <sub>50</sub> K <sub>120</sub>		1	424	358	446	412	
		2	389	343	401	379	
N <sub>100</sub> P <sub>65</sub> K <sub>150</sub>		1	370	325	401	367	
		2	342	304	367	340	
N <sub>120</sub> P <sub>80</sub> K <sub>180</sub>		1	328	288	355	326	
		2	310	269	330	305	

**Note:** 1 – water treatment; 2 – application of Setar retardant

**Source:** compiled by the authors

Determination of water consumption coefficients for the development of 1 tonne of seeds showed that the indicator depended on the conditions

of moisture availability of the year of research and the yield of sunflower hybrids under study. Indicators varied over the years in a fairly wide range (Table 3).

**Table 3. Indicators of the coefficient of water consumption of sunflower per 1 tonne of seeds, m<sup>3</sup>/t**

Year	Fertiliser variants	RGT Wolf		Alzan		ES Bella		Lime	
		1	2	1	2	1	2	1	2
2021	N <sub>40</sub> P <sub>20</sub> K <sub>60</sub>	1,466	1,345	1,494	1,406	1,501	1,432	1,546	1,459
	N <sub>60</sub> P <sub>35</sub> K <sub>90</sub>	1,233	1,155	1,273	1,186	1,406	1,328	1,381	1,289
	N <sub>80</sub> P <sub>50</sub> K <sub>120</sub>	1,118	1,046	1,159	1,068	1,238	1,159	1,214	1,106
	N <sub>100</sub> P <sub>65</sub> K <sub>150</sub>	893	861	1,015	942	1,079	996	1,046	959
	N <sub>120</sub> P <sub>80</sub> K <sub>180</sub>	885	822	974	901	1,050	968	999	933
2022	N <sub>40</sub> P <sub>20</sub> K <sub>60</sub>	1,212	1,141	1,248	1,184	1,299	1,212	1,254	1,173
	N <sub>60</sub> P <sub>35</sub> K <sub>90</sub>	1,141	989	1,097	1,038	1,178	1,131	1,162	1,131
	N <sub>80</sub> P <sub>50</sub> K <sub>120</sub>	993	911	1,009	938	1,026	989	1,055	1,005
	N <sub>100</sub> P <sub>65</sub> K <sub>150</sub>	828	763	870	812	938	859	918	839
	N <sub>120</sub> P <sub>80</sub> K <sub>180</sub>	789	716	836	787	898	833	876	817
2023	N <sub>40</sub> P <sub>20</sub> K <sub>60</sub>	1,664	1,558	1,672	1,544	1,796	1,599	1,727	1,613
	N <sub>60</sub> P <sub>35</sub> K <sub>90</sub>	1,413	1,306	1,424	1,306	1,592	1,464	1,525	1,370
	N <sub>80</sub> P <sub>50</sub> K <sub>120</sub>	1,261	1,157	1,316	1,146	1,397	1,302	1,365	1,207
	N <sub>100</sub> P <sub>65</sub> K <sub>150</sub>	1,044	967	1,157	1,050	1,223	1,088	1,176	1,057
	N <sub>120</sub> P <sub>80</sub> K <sub>180</sub>	996	937	1,108	1,033	1,187	1,063	1,115	1,038
Average	N <sub>40</sub> P <sub>20</sub> K <sub>60</sub>	1,446	1,352	1,481	1,382	1,502	1,420	1,525	1,420
	N <sub>60</sub> P <sub>35</sub> K <sub>90</sub>	1,268	1,155	1,268	1,181	1,394	1,311	1,363	1,268
	N <sub>80</sub> P <sub>50</sub> K <sub>120</sub>	1,130	1,042	1,168	1,056	1,223	1,155	1,219	1,113
	N <sub>100</sub> P <sub>65</sub> K <sub>150</sub>	927	867	1,018	938	1,086	986	1,053	955
	N <sub>120</sub> P <sub>80</sub> K <sub>180</sub>	895	828	976	910	1,049	958	1,002	935

**Note:** 1 – water treatment; 2 – application of Setar retardant

**Source:** compiled by the authors

According to the calculations, the coefficient of water consumption by sunflower plants for the development of 1 tonne of seeds in 2021 ranged from 822 to 1,546 m<sup>3</sup>/t under the influence of experimental factors and unregulated factors. Indicators for 2022 varied from 716 to 1,299 m<sup>3</sup>/t, and in 2023 – from 937 to 1,796 m<sup>3</sup>/t. Thus, the water consumption coefficient was influenced by the norms of fertilisers applied, morphobiological features of hybrids, the Setar preparation, and environmental factors. The highest water consumption rate per 1 tonne of sunflower seeds was obtained in 2023. In the RGT Wolf hybrid, it changed as fertilisation rates increased from 1,664 to 996 m<sup>3</sup>/t, Alzan – 1,672-1,108, ES Bella – 1,796-1,187, Lime – 1,727-1,115 m<sup>3</sup>/t. Notably, with the

increase in fertiliser application rates, the sunflower yield increased, while simultaneously, there was a decrease in the water consumption coefficient. The use of the Setar preparation also provided a decrease in this indicator. The correlation coefficient between sunflower yield and productive moisture reserves in the metre-long soil layer for the sowing period was  $r = 0.8624$ , which indicates a strong correlation between the indicators.

## Discussion

The findings showed that the yield of sunflower hybrids depended on the weather conditions of the growing year, in particular, water availability. At different stages of growth and development, sunflower plants require different amounts of

moisture, which ensures optimal conditions for the flow of production processes in plants. According to S.M. Kalenska *et al.* (2019), during the sowing-flowering period of baskets, sunflower plants use 70-85 mm of moisture from the soil. While in the period of sowing-full shoots, sunflower crops evaporate 2-4 mm/ha per day. This is due to the lack of vegetation covering the soil during the specified period. Closing the rows reduces evaporation from the soil surface. In addition, there is an increase in water absorption by plants. Sunflower plants absorb 100-120 mm of water during the basket-maturation period.

When assessing the moisture availability of crops, the availability of moisture in the soil at the time of sowing, the amount of precipitation during the growing season and the remaining moisture in the soil at the time of harvest are considered. F. Filho *et al.* (2013) investigated that soil type affects water use by sunflower plants. The use of organic fertilisers (manure) ensures the growth of elements of the crop structure (weight of 1,000 seeds, number of seeds in the basket) and contributed to the efficient use of water from the soil.

As a result of the conducted studies, it was established that the reserves of soil moisture in the context of the years of research were quite different and ranged from 129.4 to 151.3 mm. However, according to A.V. Melnyk & S.A. Hovorun (2014), optimal humidity is considered to be humidity in the root layer at the level of 60-70% in relation to the lowest field moisture capacity, which implies the presence of 160-180 mm in the soil in the meter layer with a value of productive moisture reserves of at least 100 mm. In turn, the findings of S.V. Kokovikhin *et al.* (2015) indicate an improvement in the effectiveness of fertiliser exposure and an increase in the yield of sunflower seeds with higher precipitation during the growing season of the crop. According to the results of current studies, the coefficient of water consumption of sunflower per 1 tonne of seeds decreased with increasing yield (due to the influence of increasing fertilisation rates).

Research by V.V. Nesterchuk (2015) pointed out that the total water consumption of sunflower crops in some years of research varied depending on the amount of precipitation and soil moisture reserves, while the total water consumption ranged from 3,386 to 4,644 m<sup>3</sup>/ha. However, when growing individual sunflower hybrids, the indicator under study varied in a wider range – from 3,682 to 4,119 m<sup>3</sup>/ha.

Similar results were obtained by V.V. Gamayunova & V.S. Kudrina, (2018) in studies conducted in the Southern Steppe of Ukraine, which show that the use of biologics had an impact on the yield and water consumption of sunflower plants. On average, crop gains, depending on fertiliser options, ranged from 8.8 to 50.2%. For foliar top dressing, a decrease in the water consumption coefficient was noted, which amounted to 1,320 m<sup>3</sup>/t in the control variant and 873.4 m<sup>3</sup>/t in the variant with two fertilisations, which indicated a more efficient use of moisture for the development of a crop unit. That is, it decreased by 51.1%.

The same results were obtained by O.I. Polyakov & A.D. Shcherbak (2022), according to which the water consumption of sunflower varieties and hybrids was determined by the level of crop yield. The yield level was influenced by additional mineral fertiliser. The lowest total water consumption by the crop yield was observed in the version without the use of fertilisers and, depending on the genetic characteristics of the variety and hybrid, they ranged from 359.2 to 372.8 mm. Moisture was most effectively used against the background of applying N<sub>60</sub>P<sub>90</sub>, as evidenced by the lowest coefficient of water consumption, which depended on the application of the growth regulator and varied in the cross-section of hybrids from 1,039 to 1,177 m<sup>3</sup>/t and grades from 1,217 to 1,246 m<sup>3</sup>/t.

The positive impact of fertilisation and foliar treatments on the growth of regulatory preparations of biological origin and optimisation of water consumption of sunflower crops is also evidenced by Yu. Domaratskyi *et al.* (2022). The researchers found that growth-regulating

preparations provide a more rational use of soil moisture for the development of a unit of dry matter. The lowest water consumption coefficient was obtained by using Helavit Combi on the P64GE133 hybrid, which was 1283 m<sup>3</sup>/t of sunflower seeds. In turn, studies conducted in 2015-2016 in the Yelanets district of the Mykolaiv Oblast are aimed at studying the elements of the water balance of sunflower under the influence of fertiliser options and growth-regulating drugs, indicate a decrease in the specific water consumption of the crop (up to 30%) for their action, which indicates the economy of water consumption, despite the increase in total water consumption by 7%.

O.L. Zhygailo *et al.* (2021) analysed the impact of climate change on sunflower yields in the Northern Steppe of Ukraine, focusing on the need to adapt growing technologies to new weather conditions. In turn, V.M. Totsky (2014) focused on the impact of fertiliser and tillage systems on crop productivity, which allows evaluating the effectiveness of various agrotechnical approaches. Research by H.V. Pinkovskiy & S.P. Tanchyk (2019) showed that the timing of sowing and the density of standing plants significantly affect the productivity and water consumption of medium-early sunflower hybrids, which is important for optimising the water regime. A.V. Kokhan (2016) investigated sunflower water consumption depending on technological elements, emphasising the importance of synergy between fertiliser, tillage, and water supply systems to achieve high yields. Thus, previous studies indicate the importance of considering a complex of agroecological factors in sunflower cultivation, which ensures the realisation of the potential of modern hybrids in the context of climate change.

Thus, the results of the study confirmed a close relationship between weather conditions, the level of moisture availability, fertiliser standards, treatment with retardants, and the efficiency of sunflower water consumption. The increase in yield occurred against the background of a decrease in the coefficient of water consumption, which indicates a more rational use of moisture

in conditions of optimal mineral nutrition. The obtained data allow identifying the most effective agrotechnological solutions for increasing the productivity of sunflower hybrids in conditions of unstable moisture.

## Conclusions

Analysis of the weather conditions of the years of research indicates a significant difference between the indicators, which was reflected in the course of production processes of sunflower plants. They were manifested in an increase in the average daily values of air temperature indicators, which was observed in all growing seasons of the years of research and insufficient precipitation with an uneven distribution. Modern sunflower hybrids have different reactions to moisture conditions. During 2021-2023, moisture reserves in the meter-long soil layer for the sunflower growing season ranged from 3,217 m<sup>3</sup>/ha (2022) up to 4,402 m<sup>3</sup>/ha (2023). According to calculations, moisture consumption during the growing season ranged from 2,533 to 3,645 m<sup>3</sup>/ha.

The coefficient of water consumption for the development of 1 tonne of sunflower seeds under the influence of the factors under study varied depending on the year of research: in 2021, it ranged from 822 to 1,546 m<sup>3</sup>/t; in 2022 – from 716 to 1,299, and in 2023 – from 937 to 1,796 m<sup>3</sup>/t. The highest coefficient of water consumption per 1 tonne of sunflower seeds was obtained in 2023: in the RGT Wollf hybrid, it changed as fertiliser doses and retardant action increased from 1,664 to 996 m<sup>3</sup>/t, Alzan – 1,672-1,108, ES Bella – 1,796-1,187, Lime – 1,727-1,115 m<sup>3</sup>/t. The data obtained confirm that increasing the level of fertiliser and the use of retardants not only increases yields, but also increases the efficiency of using soil moisture, which is critical in arid regions. A strong positive correlation was established between the reserves of productive moisture in the soil for the sowing period and the yield of hybrids ( $r = 0.8624$ ), which indicates the importance of considering water supply when planning

agricultural technologies. In the experiment, high doses of mineral fertilisers in combination with retarding treatment were more effective, which helped to reduce the specific water consumption for the development of 1 tonne of seeds.

The prospect of further research is the possibility of a multidimensional study and identification of the degree of influence of fertilisers, trace elements, new preparations, an increase of regulatory substances and technological methods of growing field crops on their water consumption,

and further application in cultivation technologies in difficult climatic conditions.

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## Водоспоживання рослин соняшнику за впливу елементів технології вирощування

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**Анотація.** Правильне управління водним режимом рослин сприяє підвищенню врожайності. Недостатнє або надмірне вологозабезпечення може негативно вплинути на їх ріст і розвиток, знижуючи кінцеву продуктивність. Метою дослідження було виявити вплив погодних, умов удобрення та дії ретарданту на формування продуктивності гібридів соняшнику. Польові дослідження були проведені у 2021-2023 рр. на чорноземах типових малогумусних. Дослідженнями встановлено, що вирішальним фактором, який визначає рівень урожайності і водоспоживання, є кількість ґрунтової вологи в 0–100 см шарі ґрунту на період сівби та кількість опадів за загальний період вегетації. Сумарне водоспоживання різнилося за роками досліджень: найнижчим воно було в 2022 році і склало 2533 м<sup>3</sup>/га, а найбільшим – у 2023 році – 3645 м<sup>3</sup>/га. У середньому за три роки досліджень сумарне водоспоживання склало 3095 м<sup>3</sup>/га. Коефіцієнт водоспоживання, що характеризував витрати вологи на формування 1 т насіння з відповідною кількістю побічної продукції, змінювався за впливу погодно-кліматичних умов року, морфобіологічних особливостей гібридів, які вивчали, технологічних прийомів, оптимізації удобрення та становив у 2021 р. від 822 до 1546 м<sup>3</sup>/т; у 2022 р. – 716 до 1299, а в 2023 р. – від 937 до 1796 м<sup>3</sup>/т. Найвищий коефіцієнт водоспоживання на 1 т насіння соняшнику було отримано у 2023 році. У гібрида РЖТ Вольф він змінювався у міру зростання норм добрив від 1664 до 996 м<sup>3</sup>/т, Альзан – 1672–1108, ЕС Белла – 1796–1187, Лайм – 1727–1115 м<sup>3</sup>/т. Застосування ретарданту Сетар за вирощування соняшнику сприяло зменшенню коефіцієнту водоспоживання та забезпечувало більш раціональне використання вологи рослинами на формування одиниці врожаю. Найбільший вплив на зменшення коефіцієнту водоспоживання показало удобрення. У найбільш несприятливі за зволоженням роки вирощування ефективність використання вологи рослинами соняшнику за оптимізації живлення істотно підвищується, що свідчить про ефективність застосування добрив і ретарданту Сетар. Отримані результати будуть корисними для аграрних підприємств у підвищенні ефективності використання ресурсів і покращенні фінансових результатів

**Ключові слова:** волога; добрива; олійні культури; продуктивність; ретардант