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Management of productivity of sunflower plants depending on terms of sowing and density of standing in arid conditions of the Right-bank Steppe of Ukraine

Zarządzanie produktywnością słonecznika w zależności od terminu siewu i obsady roślin w suchych warunkach Prawobrzeżnego Stepu Ukrainy

Summary. The article presents the results of scientific research conducted in 2016–2018, in order to determine the impact of sowing dates and standing density on the growth, development and productivity of sunflower hybrids. The field experiment was performed by the method of splitting plots in three replications in the experimental field of the Institute of Agriculture of the Steppe of NAAS in arid conditions of the Right Bank Steppe of Ukraine. The material for the study were sunflower hybrids of the middle-early maturity group – Forward, LG 56.32, LG 54.85, LG 5582 (Factor A); terms of sowing – the first when warming up the soil at a depth of seed wrapping to 5–6°C, the second when warming up the soil at a depth of seed wrapping to 7–8°C, the third when warming up the soil at a depth of seed wrapping to 9–10°C (Factor B); density of standing plants – 50, 60, 70 thousand per hectare (Factor C).Research found that the productivity of sunflower plants directly depends on the temperature of the soil (sowing dates), optimal water regime, density of standing plants, genetic and morphological characteristics of hybrids. It is also established that by regulating timing of sowing and selecting the optimal density of standing plants can affect the growth and development of sunflower plants, bypassing critical periods during cultivation. The optimal time for sowing sunflower for hybrids LG 55.82 and LG 54.85 is warming the soil at depth of seed wrapping up to 5–6°C, for hybrids Forward and LG 56.32 is warming the soil at a depth of seed wrapping up to 9–10°C. On average, according to the years of research, the highest seed yield of 3.85 t ha^{-1} was formed by the hybrid LG 55.82, which is higher than that of the hybrids Forward, LG 54.85 and LG 56.32 by 19.8%; 5.5% and 6.0%, respectively. It is established that the optimal density of sunflower is 60 thousand plants per hectare. Thus, sunflower productivity varied significantly under the influence of the morphobiological features of the hybrid – factor A (the proportion of impact was 47.5%), density of standing plants (factor C) – 5.4%, sowing time (factor B) – 3.4%.

Key words: sunflower, hybrids, sowing dates, density of standing plants, productive moisture, yield

INTRODUCTION

Sunflower (*Helianthus annuus* L.) is the most important oil crop in Ukraine and Europe. Climatic anomalies, including very high temperatures, are predicted to be the main negative factors affecting plant growth and development, which can lead to catastrophic losses in agricultural production [Craita and Gerats 2013].

Among natural factors holding back growth of sunflower production by increasing yields in steppe, is the lack of moisture in the soil due to the arid climate [Yeremenko 2017]. The use of moisture by sowing sunflowers can be regulated by sowing dates to some extent. Shifting sowing dates to earlier ones makes it possible to change the conditions of growth and development of sunflower plants, namely, the plants are better provided with moisture, and it is possible to avoid critical temperature periods of plant development [Pinkovskyi and Tanchyk 2019a].

In the context of climate change and the emergence of new hybrids in the production, the research to optimize the timing of sowing and density of standing plants of different hybrids is relevant and important for science and production. To increase the productivity of sunflower plants is the search for optimal sowing dates that fall on different calendar dates.

Analysis of literature sources shows the presence of opposing views on determining the timing of sowing sunflower. Some argue that the optimal time for sowing sunflower is the period when the soil temperature at a depth of 10 cm is 8–10°C, at which sunflower plants have formed the highest performance elements and provided the highest yield without additional costs [Kovalenko 2005, Markova 2011, Kocherha and Butiaha 2015]. At the same time, the results of research by other scientists prove that the optimal time for sowing sunflower is the period when the average daily stable soil temperature at a depth of 10 cm reaches 10–12°C. During this sowing period, pre-sowing cultivation can destroy the bulk of early annual weed seedlings, sow sunflower seeds in well-heated, weed-free soil and get friendly seedlings – on the 9th–12th day after sowing [Mynkovskyy and Polyakov 2007, Totskyi 2009].

Also, according to some authors, sunflower is a crop of early sowing, sunflower seeds can germinate at a temperature of 4–5°C, and seedlings can withstand short-term spring frosts – up to minus 4–6°C [Pleshakov 1987, Pustovoit 1990, Andriienko et al. 2016]. Early sowing, when the soil warms up to 6–8°C allows to shift the time of technological maturity of sunflower hybrids to the first or second decade of September, that is to avoid the rainy season during harvest [Trotsenko and Butenko 2002, Andriienko 2013].

However, it is not recommended to sow sunflower at a later date when the seed layer is dried and sunflower seeds do not germinate for a long time. In addition, due to the shift of growing season, ripening of crop falls on the cool period. In this regard, the vegetation of plants is prolonged, seed yield, oil and protein content are reduced [Sydorenko et al. 1990].

Optimal standing density is one of the most important prerequisites for high and good quality sunflower seed yields [Hrabovskyi 2012]. Plant density depends on both climatic conditions and the genotype of the hybrid and in steppe of Ukraine ranges from 40 to 70 thousand plants per hectare [Oleksiuk 2000].

Sowing density, depending on the study region can vary from 40–55 to 70–85 thousand plants per hectare. When thickening crop to 85 thousand pieces per hectare flowering of plants are delayed for 2–4 days, and height of plants increased on average by 10–12 cm. The diameter of the basket (from 15.2 to 12.4 cm) and the weight of 1000 seeds (from 56.6 to 46.0 g) also decreased [Thompson and Fenton 1979]. But in the conditions of India, some varieties responded well to thickening to 85 thousand plants per hectare. The increase in seed yield was 1.3 centner ha^{-1} compared to density of 40 thousand pieces per hectare [Patil et al. 1976].

According to the University of Buenos Aires [All-ukrainian journal of a modern agroindustrialist 2012. Zerno. 7 (76)], the recommended sowing density is 40,000 to 50,000 plants per hectare in arid regions. In areas with high productivity potential, where there are no restrictions on watering, and fertilizers are applied in sufficient quantities, sowing density can be increased to 60–70 thousand plants per hectare. If the sowing density is low, the plants receive more resources (water, sunlight, nutrients) and have more quantity of leaves and seeds in the basket. The seeds are heavier in the basket. At high density the competition between plants increases and the leaves grow more actively, as a result, the basket receives little nutrients [Harsya et al. 2012].

The choice of the optimal sowing period and density of standing plants is a prerequisite for the efficient use of environmental resources for the formation of high yields by crops [Kramarenko et al. 1998].

The aim of research is to increase productivity by optimizing the time of sowing and density of standing sunflower plants in the Right Bank Steppe of Ukraine.

MATERIAL AND METHODS

The field experiment was conducted in 2016–2018 in the experimental field of IAS NAAS Kirovohrad region. The soil cover of the experimental plots is ordinary heavy loam chernozem. The content of humus in the arable soil layer is 4.72%, easily hydrolyzed nitrogen – 104 mg kg^{-1} of soil, mobile phosphorus – 191 mg kg^{-1} of soil and exchangeable potassium – 142 mg kg^{-1} of soil, pH_{KCl} – 5.8.

Field experiments were established by the method of split plots. In three-factor experiment studied sunflower hybrids – Forward selectionist: Institute of Plant Breeding named after V. Ya. Yuriev, LG 56.32, LG 54.85, LG 55.82 selectionist: Limagrain Europe S.A. France. High-yielding hybrids of medium-early maturity group with excellent drought resistance indicators that have not been studied in arid conditions of the Right Bank Steppe of Ukraine. (Factor A); terms of sowing – the first when warming up the soil at a depth of seed wrapping to 5–6°C, the second when warming the soil at a depth of seed wrapping to 7–8°C, the third when warming the soil at a depth of seed wrapping to 9–10°C (Factor B); density of standing plants – 50, 60, 70 thousand per hectare (Factor C). The experiment was repeated three times. The area of sowing plot is 50.4 m^2, the accounting area is 25.2 m^2. The technology of growing sunflower in the experiment is generally acceptable, except for the factors baing studied. The forecrop was spring barley.

The weather conditions of the 2016–2018 research differed from the long-term averages in terms of precipitation and temperature (Fig. 1).

In order to establish the optimal sowing time, sunflower hybrids were sown in time: in 2016, the first sowing period was 5–6°C at a depth of seed wrapping (April 6), the second one was 7–8°C (April 10), and the third was 9–10°C (April 13). In 2017, respectively, the first sowing period – 5–6°C (April 7), the second – 7–8°C (April 12), the third – 9–10°C (April 28). In 2018, respectively, the first sowing period – 5–6°C (April 6), the second – 7–8°C (April 12), the third – 9–10°C (April 24).

To obtain the density of standing sunflower required at the time of harvest, 50, 60, 70 thousand per hectare, sown 3.6; 4.3; 5.0 pieces of seeds per 1 running meter. Sowing of sunflower was carried out in a dotted manner with row spacing of 70 cm.

The content of productive moisture in soil was determined by thermostatic-weight method.

Net productivity of photosynthesis was determined in phases 9–10 pairs of true leaves and flowering (gram $m^2 \times$ day and night) by sampling plants, in which determined the total weight, weight of individual organs and leaf area and was calculated by the formula [Kazakov 2000, Yeshchenko et al. 2014]. Photosynthetic potential (million $m^2 \times$ day ha^{-1}) – by the main interphase periods in phases 4–5 and 9–10 pairs of true leaves, flowering, ripening according to the formula [Kiriziy 2004].

Sampling to determine the yield was carried out in sections in the phase of full maturity (first–second decade of September), threshing baskets was carried out with a combine Sampo.

Statistical analysis of research results was performed by the method of dispersion analysis of three-factor field experiment data with evaluation of the quality of the conducted research and interpretation of their results, calculations were performed using MS Excel Agcstat.

RESULTS AND DISCUSSION

Research found that the productivity of sunflower plants directly depends on the temperature of the soil (sowing dates), optimal water regime, density of standing plants, genetic and morphological characteristics of hybrids.

Agrometeorological indicators of the sunflower vegetation period

One of the decisive factors in achieving high and sustainable crop yields in conditions of unstable moisture of the Right Bank Steppe of Ukraine is the accumulation and rational use of moisture, which is one of the most important unregulated factors that limit yields [Melnyk and Hovorun 2014, Maliyenko 2015, Pinkovskyi and Tanchyk 2020].

The provision of sunflower plants with moisture and heat is evidenced by the hydrothermal coefficient (HTC) both in separate periods of growth and development of sunflower plants, and in general during the vegetation period (Fig. 1).

The average HTC for the sunflower vegetation in 2016 was 1.22 with medium long-term value of 1.05. In the critical period of growth and development of sunflower plants (July), the HTC was 0.2 at the norm of 1.16, which was lower the long-term value by 82.7%. HTC (hydrothermal coefficient) of less than 0.7 indicates a ground-air drought that negatively affects crop formation.

In 2017, the figure was 0.49, with medium long-term of 1.05. In the critical period of growth and development of sunflower seeds, HTC was 0.91 at the norm of 1.16, it was lower than the long-term value by 21.6%, which characterized a substantial shortage of rainfall and drought.

In 2018, this figure was 0.62, with an medium long-term value of 1.05. During the critical period of growth and development of sunflower seeds, HTC was 1.95, at 1.16, it was higher than the long-term value by 40.6%.

Thus, small amount of rainfall and irregular rainfall during critical sunflower periods (June and July) have led to a decrease in sunflower yields. June was characterized by warm and rainfall deficit weather in 2017–2018. In July, the weather was unstable with

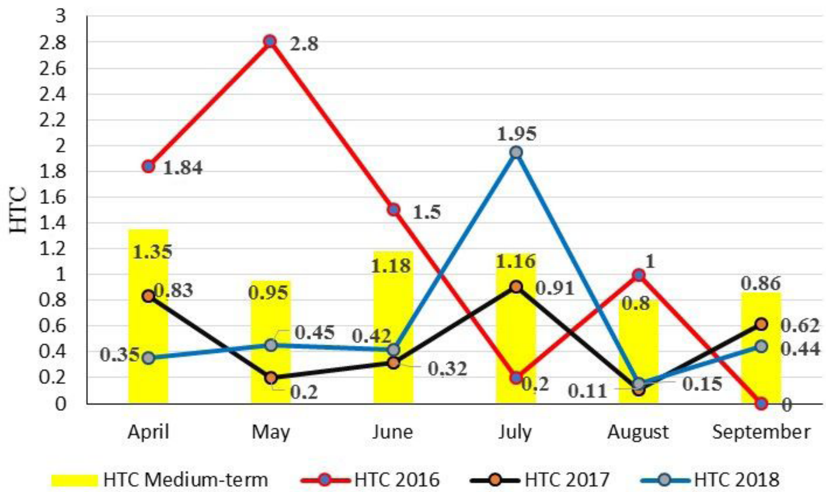

Fig. 1. Degree of moistening of the territory expressed by hydrothermal coefficient HT Selyaninova, 2016–2018

precipitation in 2016. Maturation and termination of vegetation occurred with good heat supply, but with limited soil moisture in the absence of rainfall.

Analyzing the results of the research, it should be noted that in most cases higher seed yield in sunflower hybrids was formed in those variants where the period from the formation of the basket to flowering occurred in June or the first decade of July, regardless of the year of testing just when precipitation is possible on medium long-term indicators.

Sunflower, having long vegetation period, with full supply of nutrients, uses a significant amount of moisture to form a large mass, which thus ensures high productivity of the crop.

Field germination of seeds

An important prerequisite for the formation of high-yield crops is to obtain healthy seedlings of optimal density.

It was established that depending on sowing dates hydrothermal conditions vary and this affects the field germination of seeds, seedling dynamics and subsequent growth and development of sunflower hybrid plants significantly [Markova 2015].

All studied sunflower hybrids provided the highest field germination of seeds due to the reserves of productive moisture. This is one of the advantages of early sowing of sunflower. Insufficient supply of soil with moisture reduces germination, and even more so the longer the dry season. However, excessive moisture in the soil can also cause a decrease in field germination due to insufficient air, as oxygen is required for germination [Pinkovskyi and Tanchyk 2019b].

The reserves of productive moisture in the meter layer of soil at the time of sowing remained high and significantly affected the dynamics of seedling emergence (Fig. 2). This is due to low temperatures, compensation for high relative humidity, low evaporation of moisture from the soil, moisture reserves of the autumn-winter period and precipitation during this period.

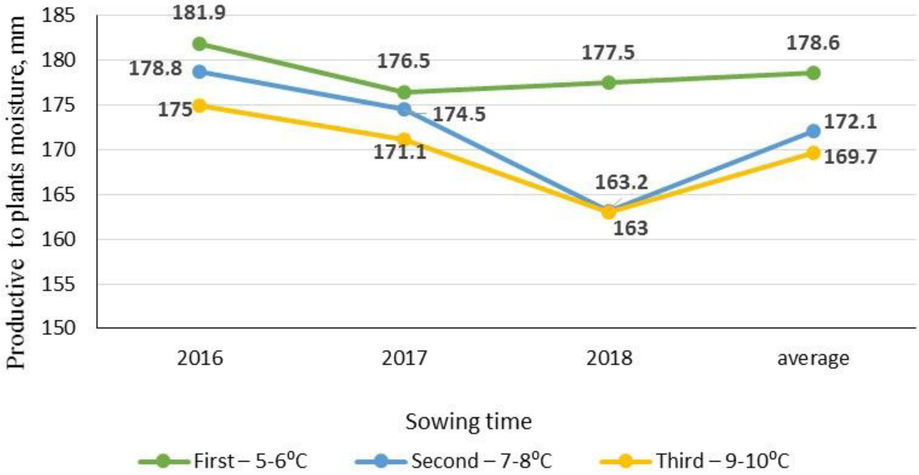

Fig. 2. Content of moisture productive to plants in soil layer 0–100 cm at the time of sunflower sowing

During 2016–2018 years of research, the most productive moisture in the 0–100 cm soil layer, during the first sowing period, when the soil warmed up at a depth of seed 5–6°C, the average moisture reserves were 178.6 mm, which is 5% more than the third term and 3.7% for the second sowing period. During the second sowing period, when the soil warmed up at a depth of seed of 7–8°C, the average moisture reserves amounted to 172.1 mm, which is 1.4% more than in the third period. During the third sowing period, when the soil was heated at 9–10°C, the average moisture reserves amounted to 169.7 mm.

The correlation coefficient between the reserves of productive moisture in the meter layer of soil and seed yield of sunflower is on average 0.85 ±0.12 [Kovalenko et al. 2009].

Table 1. Field germination of sunflower hybrids seeds depending on sowing dates

Hybrid	Sowing period	Field germination of seeds (%)			
		2016	2017	2018	Average
Forward	1	85.6	86.5	86.6	86.2
	2	85.5	87.2	85.0	85.9
	3	85.1	82.0	85.2	84.1
LG 56.32	1	85.8	86.1	89.5	87.1
	2	85.7	85.1	85.5	85.4
	3	85.1	82.3	85.2	84.2
LG 54.85	1	89.2	90.9	93.0	91.0
	2	90.0	90.1	93.0	91.0
	3	87.9	83.0	92.0	87.6
LG 55.82	1	91.2	91.6	94.7	92.5
	2	91.0	90.9	93.7	91.8
	3	92.1	85.0	93.7	90.2
SSD_{05}	factor A 2.17				
	factor B 1.88				

Sowing period: 1 – soil temperature 5–6°C, 2 – soil temperature 7–8°C, 3 – soil temperature 9–10°C; factor A – hybrid, factor B – sowing period. SSD – the smallest significant difference

Table 2. Results of two-factor analysis of dispersion

Source of variation	Sum of squares	Degrees of freedom	Dispersion	F_{fact}	F_{tab095}	Influence (%)
Factor A	773.4	3.0	257.8	46.6	2.7	58.2
Factor B	139.8	2.0	69.9	12.6	3.1	10.5
Factor A*B	16.2	6.0	2.7	0.5	2.2	1.2

The highest indicators of field germination of sunflower seeds were recorded during the first sowing period when the soil temperature at the depth of seed heating warms up to 5–6°C in the hybrid LG 55.82 – 92.5%, in hybrids LG 54.85, LG 56.32, Forward, respectively, 91, 87.1 and 86.2% (Tab. 1). Thus, the field germination of sunflower seeds when sown in the second period, when the soil warms up to 7–8°C, was in hybrids LG 55.82 – 91.8%, LG 54.85 – 91%, LG 56.32 – 85.4%, Forward – 85.9%. When sowing in the third period, when the soil warms up to 9–10°C, the field germination in hybrids LG 55.82 – 90.2%, LG 54.85 – 87.6%, LG 56.32 – 84.2%, Forward – 84.1% were recorded.

Field germination of sunflower seeds when sown in the first term, when the soil warms up to 5–6°C, relative to the second term was higher in hybrids LG 55.82 by 1.5%, LG 56.32 by 1.7%, Forward by 0.3%, in LG 54.85 in both versions was the same, and the third – in hybrids LG 55.82 by 2.3%, LG 54.85 by 3.4%, LG 56.32 by 2.9%, Forward by 2.1%, due to the optimal combination of temperature and water soil regimes.

However, when the third sowing period falls on the third decade of April in dry years, there was rapid drying of the seed layer and field germination decreased by 3.8–7.9%.

Phenology of sunflower

The duration of the interphase periods of sunflower hybrids varied depending on terms of sowing, biological characteristics of cultivated hybrids and weather conditions (Tab. 3).

The duration of the sowing – seedling period depended on the soil temperature regime and reserves of productive moisture in the soil layer 0–100 cm (Fig. 2). During the first sowing period, the duration of the sowing-seedling period was 18 days, during the second sowing period – 16 days and during the third sowing period – 12 days (Tab. 3).

The duration of the period of full germination – the formation of baskets was determined by the temperature regime, in particular, the sum of effective temperatures required for the passage of certain phases of growth and development. Thus, the period of full germination – the formation of baskets at the first and third sowing date was for hybrids: Forward, LG 56.32, LG 54.85, LG 55.82 – 56 days, and in the second period – 54 days.

The duration of the period flowering – the full maturity of the seeds for the first sowing period in the hybrid Forward was 69 days, in hybrids LG 56.32 – 66 days, LG 54.85 and LG 55.82 – 65 days. During the second sowing period, the duration of the period flowering full maturity of seeds was 67 days in the hybrid Forward, in the hybrid LG 56.32 – 63 days, LG 54.85 and LG 55.82 – 62 days, which is 2 and 3 days less than the first term. In the third term sowing duration of the period flowering – the full maturity of the seeds in the hybrid Forward was 63 days, in hybrids LG 56.32, LG 54.85, LG 55.82 – 60 days, which is less by 4; 3 and 2 days compared to the second term and 6 and 5 days compared to the first term. Increasing the standing density of plants from 50 to 70 thousand per hectare did not affect the duration of the interphase periods of sunflower hybrids.

Table 3. The duration of the interphase periods sunflower hybrids depending on terms of sowing (average for 2016–2018)

Hybrid	Indicator	Soil temperature 5–6°C			Soil temperature 7–8°C			Soil temperature 9–10°C		
		density of standing plants × 1000 × ha^{-1}								
		50	60	70	50	60	70	50	60	70
Forward	sowing – seedlings	18	18	18	16	16	16	12	12	12
	full germination – the formation of a basket	56	56	56	54	54	54	56	56	56
	basket formation – flowering	13	13	13	13	13	13	12	12	12
	flowering – ripening	69	69	69	67	67	67	63	63	63
	full maturity	138	138	138	134	134	134	131	131	131
LG 56.32	sowing – seedlings	18	18	18	16	16	16	12	12	12
	full germination – the formation of a basket	56	56	56	54	54	54	56	56	56
	basket formation – flowering	14	14	14	14	14	14	13	13	13
	flowering – ripening	66	66	66	63	63	63	60	60	60
	full maturity	136	136	136	131	131	131	129	129	129
LG 54.85	sowing – seedlings	18	18	18	16	16	16	12	12	12
	full germination – the formation of a basket	56	56	56	54	54	54	56	56	56
	basket formation – flowering	14	14	14	14	14	14	13	13	13
	flowering – ripening	65	65	65	62	62	62	60	60	60
	full maturity	135	135	135	130	130	130	129	129	129
LG 55.82	sowing – seedlings	18	18	18	16	16	16	12	12	12
	full germination – the formation of a basket	56	56	56	54	54	54	56	56	56
	basket formation – flowering	14	14	14	14	14	14	13	13	13
	flowering – ripening	65	65	65	62	62	62	60	60	60
	full maturity	135	135	135	130	130	130	129	129	129

The shortest vegetation period was recorded during the third sowing period when the soil warmed up to 9–10°C in hybrids LG 56.32, LG 54.85, LG 55.82–129 days, in hybrid Forward – 131 days. During the first period when the soil warmed up to 5–6°C, the duration increased to 135–138 days. When sowing, when the soil warmed up to 7–8°C, the seeds reached full maturity in 130–134 days.

In the Forward hybrid, the vegetation from the first to the third sowing period was reduced from 138 to 131 days. The vegetation period of the LG 56.32 hybrid was reduced from the first to the third sowing period from 136 days to 129 days. Plants of hybrids LG 54.85, LG 55.82 ripened almost simultaneously. The longest vegetation period in the Forward hybrid is 138 days for the first, 134 for the second, 131 days for the third sowing period.

Height of sunflower plants

By the phase of 2–4 pairs of leaves, sunflower grows slowly. Its growth increases during the formation of baskets – flowering growth processes in plants are characterized by the highest rates – up to 5 cm day. With increasing density from 20 to 60 thousand plants per hectare, sunflower growth accelerates by an average of 3 cm day, and up to 80 thousand plants per hectare – is suppressed by 6 cm day [Nykytchyn 1993].

Studies have shown that in dense crops weakens the formation of generative organs, it negatively affects plant productivity. In favorable years for moisture (2016), thickened crops increased the growth of plants in height, and in dry (2017, 2018), on the contrary, the rate of linear growth decreased. The limiting factor in terms of plant height was the amount of precipitation in the first half of the sunflower vegetation.

During the vegetation period, the height of sunflower plants was recorded depending on the studied factors (Tab. 4).

According to the results of research in the initial stages of organogenesis, the linear growth of sunflower plants was influenced by weather conditions, in particular temperature and water regimes, sowing dates and plant density.

The height of sunflower plants of studied hybrids in the phase of 4–5 pairs of true leaves ranged from 28.0 to 31.4 cm (Tab. 4).

The highest plants were in wet 2016. On average, according to the experiment, their height was higher by 0.8–0.7 cm or 2.7–2.4% compared to dry years of 2017–2018. In addition, in the first stages of organogenesis of sunflower, 2017 was characterized by deviations of air temperature from the average long-term data, which caused the slow growth of plants in height.

In the phase of 9–10 pairs of true leaves the height of sunflower plants ranged from 78.1 to 82.9 cm (Tab. 4). During the first sowing period, the plants were the highest, and during the third period, the lowest, which indicates the higher adaptability of medium-early sunflower hybrids to the temperature and optimal water regime during this period. Thus, plants of hybrids Forward, LG 56.32, LG 54.85, LG 55.82 were higher on average by 1.3; 2.0; 1.1; 1.1 cm or 1.6; 2.5; 1.4; 1.4%.

The density of standing plants in the phase of 9–10 pairs of leaves did not significantly affect the linear growth of sunflower plants (the proportion of impact was 18.5%). Thus, during the first sowing period of hybrids Forward, LG 56.32, LG 54.85, LG 55.82, the height with increasing plant density to 70 thousand per hectare was lower by 1.5; 2.0; 2.2; 1.5 cm or 1.9; 2.5; 2.7; 1.9% relative to the option of 50 thousand per hectare.

At the time of flowering, morphobiological differences in the influence of sowing dates and plant density on growth processes were revealed (Tab. 4).

The highest were the plants of the hybrid Forward, growing under the highest plant density – 176.3 cm. Hybrids LG 54.85, LG 55.82 and LG 56.32 had 5, 11.2 and 12.2 cm lower height, due to their biological characteristics. With increasing plant density from 50 to 70 thousand per hectare, the plants were higher, which is explained by their elongation to light.

Table 4. Height of sunflower hybrids plants depending on sowing dates and plant density, cm (average for 2016–2018)

Hybrid	Growth and development phase	Soil temperature 5–6 °C			Soil temperature 7–8 °C			Soil temperature 9–10 °C		
		density of standing plants × 1000 × ha^{-1}								
		50	60	70	50	60	70	50	60	70
Forward	4–5 pairs of leaves	31.4	29.8	29.5	31.1	29.4	29.0	30.1	29.2	28.8
	9–10 pairs of leaves	82.9	82.0	81.4	82.0	81.5	80.9	81.6	80.9	79.5
	flowering	171.7	173.3	176.3	171.1	172.2	173.9	170.5	171.1	172.4
	full maturity	178.3	179.5	181.5	176.5	178.7	180.1	175.3	176.9	178.7
LG 56.32	4–5 pairs of leaves	30.1	29.8	29.6	29.7	28.8	28.8	28.9	28.5	28.6
	9–10 pairs of leaves	82.5	80.9	80.5	82.0	81.0	80.4	80.5	80.0	79.9
	flowering	161.5	162.5	164.1	160.7	161.6	162.9	159.4	160.6	162.0
	full maturity	166.7	167.0	168.6	165.9	166.3	167.5	164.3	165.2	166.4
LG 54.85	4–5 pairs of leaves	30.9	30.0	29.5	30.0	29.5	28.6	29.4	28.5	28.3
	9–10 pairs of leaves	83.0	82.8	80.8	82.2	81.5	79.5	81.9	80.7	80.1
	flowering	167.7	168.5	171.3	166.9	167.4	169.9	166.0	166.7	168.9
	full maturity	172.8	174.0	176.5	172.3	172.9	175.4	171.3	171.9	174.4
LG 55.82	4–5 pairs of leaves	30.1	29.3	29.2	29.5	29.0	28.2	28.8	28.3	28.0
	9–10 pairs of leaves	81.9	81.0	80.4	81.4	80.4	79.8	80.8	79.2	78.1
	flowering	162.6	164.0	165.1	161.8	163.2	164.5	161.1	162.5	163.8
	full maturity	167.3	168.6	169.6	166.8	167.6	169.5	165.9	166.9	168.4
SSD_{05}	4–5 pairs of leaves	factor A 0.29; factor B 0.25; factor C 0.25								
	9–10 pairs of leaves	factor A 0.84; factor B 0.72; factor C 0.71								
	flowering	factor A 3.86; factor B 3.35; factor C 3.35								
	full maturity	factor A 3.81; factor B 3.30; factor C 3.30								

Factor A – Hybrid, factor B – sowing period; soil temperature 5–6°C, 7–8°C, 9–10°C; Factor C – density of standing plants × 1000 × ha^{-1} – 50, 60, 70.

Table 5. Results of three-factor analysis of dispersion

Source of variation	Sum of squares	Degrees of freedom	Dispersion	F_{fact}	F_{tab095}	Influence (%)
4–5 pairs of leaves						
factor A	11.6	3.0	3.9	12.5	2.7	12.8
factor B	24.3	2.0	12.1	39.3	3.1	26.9
factor C	25.5	2.0	12.7	41.3	3.1	28.2
A*B	0.8	6.0	0.1	0.4	2.2	0.9
A*C	3.9	6.0	0.6	2.1	2.2	4.3
B*C	1.1	4.0	0.3	0.9	2.5	1.2
A*B*C	1.0	12.0	0.1	0.3	1.9	1.1
9–10 pairs of leaves						
factor A	21.6	3.0	7.2	2.9	2.7	7.0
factor B	35.9	2.0	17.9	7.2	3.1	11.7
factor C	56.8	2.0	28.4	11.4	3.1	18.5
A*B	4.1	6.0	0.7	0.3	2.2	1.3
A*C	3.9	6.0	0.7	0.3	2.2	1.3
B*C	0.3	4.0	0.1	0.0	2.5	0.1
A*B*C	6.0	12.0	0.5	0.2	1.9	2.0
flowering						
factor A	1964.0	3.0	654.7	12.4	2.7	32.8
factor B	68.0	2.0	34.0	0.6	3.1	1.1
factor C	148.0	2.0	74.0	1.4	3.1	2.5
A*B	3.3	6.0	0.5	0.0	2.2	0.1
A*C	5.8	6.0	1.0	0.0	2.2	0.1
B*C	2.8	4.0	0.7	0.0	2.5	0.0
A*B*C	4.5	12.0	0.4	0.0	1.9	0.1
full maturity						
factor A	2450.0	3.0	816.7	16.0	2.7	38.5
factor B	77.5	2.0	38.8	0.8	3.1	1.2
factor C	140.5	2.0	70.3	1.4	3.1	2.2
A*B	5.0	6.0	0.8	0.0	2.2	0.1
A*C	9.5	6.0	1.6	0.0	2.2	0.1
B*C	0.5	4.0	0.1	0.0	2.5	0.0
A*B*C	1.5	12.0	0.1	0.0	1.9	0.0

Increasing the density of standing plants from 40 to 80 thousand per hectare contributes to the growth of plant height, due to increased competition between them due to thickening of crops [Zinchenko and Rogalsky 2010].

The hybrid Forward reacted the most to the change in height. Thus, during the first sowing period, its height increased by 4.6 cm with the increase in plant density to 70 thousand per hectare compared to the variant of 50 thousand per hectare. In the sunflower hybrid LG 56.32 plant height increased by 2.6 cm, in hybrids LG 54.85 and LG 55.82, respectively by 3.6 and 2.5 cm. In this period of development, the highest sunflower plants were in the first period of sowing, the lowest - in the third period of sowing. Thus, hybrids Forward, LG 56.32, LG 54.85, LG 55.82 in the first sowing period were higher by 2.4; 1.2; 1.4 and 0.6 cm relative to the second term and 3.9; 2.1; 2.4; and 1.3 cm relative to the third sowing date.

In the phase of full maturity, the highest plants were hybrids in the first sowing period Forward 178.3–181.5 and LG 54.85 172.8–176.5 (Tab. 4). Plants of the LG 56.32 hybrid were the lowest – 168.6–166.7 cm, which was due to genetic and morphological features.

Sowing dates (Factor B) had the greatest impact on plant height in the phase of 4–5 pairs of true leaves (the proportion of impact was 26.9%). Sunflower plants, the seeds of which were sown in the first period (first decade of April), during the entire vegetation were higher in growth compared to plants of other variants. This can be explained primarily by the temperature regime during sowing in the first than in subsequent periods. During the third sowing period, the plants lagged behind in growth due to hotter temperature regime in the initial growth phases than in plants of the first and second sowing periods, which worsened water consumption and other processes that affected their growth and plant development.

Photosynthetic activity of sunflowers

An important indicator of the intensity of sunflower growth is the net productivity of photosynthesis, which shows the ratio of daily growth of dry matter to the area of leaves (Tab. 6). Studies have shown that the net productivity of photosynthesis varies widely depending on the phases of growth and development, the structure of sowing, nutrition and biological characteristics of hybrids.

Table 6. Net productivity of photosynthesis of sunflower hybrids, depending on sowing time and density of plants, gram $m^2 \times$ day and night (average for 2016–2018)

Hybrid	Soil temperature 5–6°C			Soil temperature 7–8°C			Soil temperature 9–10°C		
	density of standing plants × 1000 × ha^{-1}								
	50	60	70	50	60	70	50	60	70
Forward	9.3	9.4	9.0	9.4	9.5	8.9	9.3	9.4	9.2
LG 56.32	9.5	9.8	9.3	9.5	10.0	9.5	9.6	9.9	9.7
LG 54.85	9.8	10.4	9.5	9.9	10.1	9.4	10.0	10.0	9.2
LG 55.82	10.3	11.1	9.7	10.0	10.7	9.9	9.9	10.2	9.9
SSD_{05}	factor A – 0.30;								
	factor B – 0.26;								
	factor C – 0.26;								

Factor A – Hybrid; factor B – sowing period; soil temperature 5–6°C, 7–8°C, 9–10°C; factor C – density of standing plants × 1000 × ha^{-1} – 50, 60, 70.

Table 7. Results of three-factor analysis of dispersion

Source of variation	Sum of squares	Degrees of freedom	Dispersion	F_{fact}	F_{tab095}	Influence (%)
Factor A	11.9	3.0	4.0	12.0	2.7	26.3
Factor B	0.0	2.0	0.0	0.0	3.1	0.1
Factor C	5.9	2.0	2.9	8.9	3.1	13.0
A*B	1.0	6.0	0.2	0.5	2.2	2.2
A*C	1.2	6.0	0.2	0.6	2.2	2.7
B*C	0.3	4.0	0.1	0.2	2.5	0.6
A*B*C	1.1	12.0	0.1	0.3	1.9	2.4

On average, over the years of research, the highest rate of net photosynthesis productivity was observed in the hybrid LG 55.82 for the first sowing period – 11.1 gram $m^2 \times$ day and night, which is 8.2% more for the third period and 3.7% for the second sowing period. The LG 54.85 hybrid provided the highest net productivity of photosynthesis in the first sowing period – 10.4 gram $m^2 \times$ day and night, which is 3.9% more than the third period and 2.9% more than the second sowing period.

For sowing in the second term, the highest productivity of photosynthesis was formed by hybrids LG 56.32 and Forward – 10.0 and 9.5 gram $m^2 \times$ day and night, which is higher by 1.0% and 1.1% for the third term, 2.0% and 1.1% for the first term.

The net productivity of photosynthesis in all variants increases to 60 thousand per hectare, after which it decreases in the Forward hybrids by 2.2–6.4%, LG 56.32 by 2.1–5.2%, LG 54.85 by 8.0–8.7%, LG 55.82 by 3.0–12.7%, due to the features of their architectonics, in particular, greater number of leaves.

Studied LG 55.82 and LG 54.85 sunflower hybrids provided the highest net productivity in the first sowing period, and the Forward, LG 56.32 sunflower hybrids in the second sowing period contributed primarily to appropriate moisture supply conditions. In the third sowing period, net productivity decreased by 3.9–8.2% and 1.0–2.0% respectively, according to the first and second sowing periods. Such decrease was caused by increase in air temperatures and lack of soil moisture.

The most objective indicator that allows to determine the possibility of using photosynthetically active radiation by crops during vegetation period is photosynthetic potential. It means the total leaf surface that participated in photosynthesis from the beginning of vegetation to the end of photosynthesis.

During the vegetative period of sunflower, the crops of hybrids produced photosynthetic potential at the level of 2.04 – 2.55 million m^2 day ha^{-1}. This gives grounds to affirm that the sunflower crops in the experiment were in good condition.

Increasing plant standing density from 50 to 60 thousand per hectare provided growth of photosynthetic potential. In Forward hybrids, LG 56.32, LG 54.85, LG 55.82 it increased by 12.2–12.9%. At plant density of 70 thousand per hectare, the photosynthetic potential decreased by 4.1–5.0% compared to the density of 60 thousand per hectare. Sunflower sowing at soil temperature 5–6 and 7–8°C contributed to its higher performance in comparison with the third term by 4.1–1.8%. The largest photosynthetic potential was found in the LG 55.82 hybrid during the first sowing period at density of 60 thousand per hectare – 2.55 million m^2 day ha^{-1}. The LG 54.85 hybrid is slightly smaller – 2.51 million m^2 day ha^{-1}. It was the smallest in the hybrids of Forward and LG 56.32 for the third sowing period with the placement of 50 thousand plants per hectare – 2.07 and 2.04 million m^2 day ha^{-1}, respectively.

Sunflower productivity depending on sowing time and plant standing density

Research established significant dependence of yield of sunflower hybrids on the density of plants, biological features of hybrids and sowing time (Tab. 8).

Table 8. Yield of sunflower hybrids, depending on sowing time and density of plants, t ha^{-1} (average for 2016–2018)

Hybrid	Year	Soil temperature 5–6°C			Soil temperature 7–8°C			Soil temperature 9–10°C		
		density of standing plants × 1000 × ha^{-1}								
		50	60	70	50	60	70	50	60	70
Forward	2016	2.70	2.62	2.65	2.87	2.74	2.41	2.79	2.73	2.70
	2017	3.02	2.91	2.66	3.27	3.29	2.79	3.21	3.37	3.27
	2018	3.12	3.29	2.99	2.82	2.93	3.06	2.87	3.17	2.81
	average	2.94	2.94	2.76	2.98	2.98	2.75	2.95	3.09	2.92
LG 56.32	2016	2.79	2.75	2.68	3.06	3.62	3.29	3.24	3.41	3.35
	2017	3.11	3.42	3.56	3.19	3.47	3.23	3.30	3.55	3.70
	2018	3.46	3.76	3.46	3.28	3.,51	3.33	3.53	3.90	3.30
	average	3.12	3.30	3.23	3.17	3.50	3.28	3.35	3.62	3.45
LG 54.85	2016	3.26	3.50	3.00	3.33	3.33	3.18	3.23	3.12	2.93
	2017	3.49	3.69	3.62	3.70	3.99	3.52	3.98	4.10	3.58
	2018	3.53	3.74	3.41	3.37	3.24	3.27	3.58	3.63	3.15
	average	3.42	3.64	3.34	3.46	3.51	3.32	3.59	3.61	3.22
LG 55.82	2016	3.22	3.27	2.70	3.26	3.21	3.38	3.28	2.96	3.38
	2017	3.95	4.04	3.74	3.91	4.16	3.54	3.69	3.98	3.59
	2018	3.74	4.24	3.58	3.47	3.83	3.84	3.86	3.99	3.79
	average	3.63	3.85	3.33	3.54	3.73	3.58	3.60	3.64	3.58
SSD_{05}	factor A 0.13									
	factor B 0.11									
	factor C 0.11									

Factor A – hybrid; factor B – sowing period; soil temperature 5–6°C, 7–8°C, 9–10°C; factor C – density of standing plants × 1000 × ha^{-1} – 50, 60, 70.

In general, over the three years of research, the highest yields of the hybrids LG 55.82, LG 54.85, LG 56.32, Forward was obtained at a density of 60 thousand plants per hectare. In the first sowing period, the highest seed yield of 3.85 t ha^{-1} was provided by the LG 55.82 hybrid, which was 5.5% more than in the third term and 3.2% than in the second sowing period. The plants of the LG 54.85 hybrid formed a seed yield of 3.64 t ha^{-1} for sowing in the first term, which is 0.9% more for the third term and 3.6% for the second sowing period. For the sowing in the third term, the highest seed yields were formed by hybrids of Forward and LG 56.32, respectively – 3.09 and 3.62 t ha^{-1}, which is higher by 3.6 and 3.4% for the second term, 4.9 and 8.9%, respectively first term. Hybrids of sunflower LG 56.32, LG 54.85 and LG 55.82 by seed yield significantly exceeded the Forward hybrid. Thus, the LG 55.82 sunflower hybrid exceeded the Forward hybrid yield by 0.91 t ha^{-1} (23.7%); LG 54.85 at 0.7 t ha^{-1} (19.3%); LG 56.32 – up 0.53 t ha^{-1} (14.7%).

Table 9. Results of three-factor analysis of dispersion (average for 2016–2018)

Source of variation	Sum of squares	Degrees of freedom	Dispersion	F_{fact}	F_{tab095}	Influence (%)
factor A	8.0	3.0	2.6	44.9	2.7	47.5
factor B	0.6	2.0	0.3	4.7	3.1	3.4
factor C	1.0	2.0	0.4	8.4	3.1	5.4
A*B	0.9	6.0	0.1	2.2	2.2	5.5
A*C	0.7	6.0	0.1	1.8	2.2	3.9
B*C	0.4	4.0	0.1	1.8	2.5	2.5
A*B*C	0.6	12.0	0.0	0.7	1.9	3.7
SSD_{05}	factor					
	Year	A	B	C	ABC	
	2016	0.15	0.13	0.13	0.45	
	2017	0.12	0.10	0.10	0.36	
	2018	0.13	0.11	0.11	0.39	

Thus, sunflower productivity varied significantly under the influence of the morphobiological features of the hybrid – factor A (the proportion of impact was 47.5%), density of standing plants (factor C) 5.4%, sowing time (factor B) 3.4% (Tab. 9).

CONCLUSIONS

The ability to form high level of productivity of sunflower plants significantly depends on their ability to adapt to growing conditions that are not stable. Based on specific soil and climatic conditions, sowing dates can be differentiated.

By shifting sowing dates to earlier ones, it is possible to purposefully influence the growth and development of sunflower plants. Depending on sowing dates and temperature regime, the level of productive moisture, the duration of vegetation period and the yield as a whole changed.

At the time of sowing, reserves of productive moisture in the 0–100 cm layer of soil were the largest during the first sowing period and amounted to 178.6 mm, during the second sowing period – 172.1 mm, the third sowing period – 169.7 mm. Such moisture reserves create quite favorable conditions for moistening the seed layer of soil to obtain healthy and full seedlings when sowing in the first – second decade of April. However, at the end of the third decade of April there is a significant decrease in gross moisture reserves in the seed and deeper soil layers, which limits the productivity of crops.

The choice of sowing dates for sunflower hybrids should be based on the temperature of soil warming at the depth of seed wrapping, and it do not on the calendar term, taking into account the weather conditions of spring period and plant density.

The optimal time for sowing sunflower for hybrids LG 55.82 and LG 54.85 is warming the soil at depth of seed wrapping up to 5–6°C, for hybrids Forward and LG 56.32 is warming the soil at a depth of seed wrapping up to 9–10°C.

On average, according to the years of research, the highest seed yield of 3.85 t ha^{-1} was formed by the hybrid LG 55.82, which is higher than that of the hybrids Forward, LG 54.85 and LG 56.32 by 19.8%; 5.5% and 6.0%, respectively.

It is established that the optimal density of sunflower is 60 thousand plants per hectare.

In recent years, there have been significant changes in weather conditions during the growth and development of sunflower. The obtained results are of great practical importance for the continuation of research on the optimization of sowing dates and density of plants of different hybrids in the conditions of climate change.

REFERENCES

Andriienko A.L., 2013. Yak virno vybraty strok sivby soniashnyku? [How to choose the right time of sunflower sowing]. Ahronom 1, 178–184. [in Ukrainian]

Andriienko O., Zhuzha O., Andriienko A., 2016. Prychyny nevypovnenosti nasinnia ta koshyka soniashnyku [Causes of incomplete seeds and baskets of sunflower]. Propozytsya 3, 60–68. [in Ukrainian]

Craita E.B., Gerats T., 2013. Plant tolerance to high temperature in a changing environment: scientific fundamental sand production of heat stress-tolerant crops. Front. Plant Sci. 4(273), 1–18.

Harsya F., Fabrytstsy K., Andrade F., 2012. All about growing sunflower – developed by the University of Buenos Aires, Zerno 7, 26–37, 68–78.

Hrabovskyi M.B., 2012. Vplyv hustoty stoiannia roslyn na proiav hospodarsko-tsinnykh oznak ta produktyvnist soniashnyku v umovakh Tsentralnoho Lisostepu Ukrainy [The influence of plant density on the detection of economically valuable features and productivity of sunflower in the Central Forest-Steppe of Ukraine]. Ahronom 1, 135–138. [in Ukrainian]

Kiriziy D.A., 2004. Fotosyntez y rost rastenyi v aspekte donorno-aktseptornykh otnoshenyi.[Photosynthesis and plant growth in terms of donor-acceptor relationships]. Logos, Kyiv, pp. 191. [in Ukrainian]

Kocherha A.A., Butiaha Ya.V., 2015. Vplyv strokiv sivby na urozhainist soniashnyku.[Influence of sowing time on sunflower yield]. Material of the scientific-practical internet conference “Innovative aspects of technology of cultivation, preservation and processing of crop products”. Poltava State Agrarian Academy, 52–56. [in Ukrainian]

Kovalenko O.O., 2005. Produktyvnist hibrydiv soniashnyku zalezhno vid strokiv sivby ta hustoty stoiannia roslyn u pivnichnii pidzoni Stepu Ukrainy [Productivity of sunflower hybrids depending on sowing time and plant standing density in the Northern Sub-steppe of Ukraine]. Abstract of the dissertation. Dnipropetrovsk. pp. 19. [in Ukrainian]

Kovalenko A.M., Taran V.H., Kovalenko O.A., 2009. Vyroshchuvannia soniashnyku v sivozminakh v umovakh Stepu [Sunflower cultivation in rotation in the Steppe]. Sci. Techn. Bull. Instit. Oilseeds UAAS 14, 157–161. [in Ukrainian]

Kramarenko N., Hlushchenko A., Dudiak Y., Fedorchuk M., 1998. Hustota posevov y urozhai. [Density of planting and harvest]. Zemledelye 12, 23. [in Ukrainian]

Maliyenko A.M., 2015. Deiaki shliakhy optymizatsii rezhymu volohosti gruntu u posivakh polovykh kultur. [Some ways to optimize soil moisture in field crops]. Zemlerobstvo 1, 68–76. [in Ukrainian]

Markova N.V., 2011. Formuvannia produktyvnosti hibrydiv soniashnyku zalezhno vid strokiv sivby ta zakhodiv borotby z burianamy v umovakh Pivdennoho Stepu Ukrainy. Formation of productivity of sunflower hybrids depending on terms of sowing and measures of control of weeds in the conditions of the Southern Steppe of Ukraine. Bull. Agric. Sci. 4(61), 170–175. [in Ukrainian]

Markova N.V., 2015. Polova skhozhist nasinnia i produktyvnist hibrydiv soniashnyku zalezhno vid strokiv sivby i zakhodiv borotby z burianamy [Field germination of seed and productivity of sunflower hybrids dependingon the timing of sowing and measures to control weeds]. Taurian Sci. Bull. 92, 79–84. [in Ukrainian]

Melnyk A.V., Hovorun S.O., 2014. Vodospozhyvannia ta urozhainist soniashnyku zalezhno vid sortovykh osoblyvostei ta poperednykiv v umovakh pivnichno-skhidnoho Livoberezhnoho Lisostepu Ukrainy [Water consumption and sunflower yield depending on varietalcharacteristics and predecessors in the conditions of the northeastern Left Bank Forest Steppeof Ukraine]. Bull. Sumy National Agrarian Univ. 3(27), 173–175. [in Ukrainian]

Mynkovskyy A.E., Polyakov A.Y., 2007. Produktyvnost hybryda Zaporozhskyi 28 v zavysymosty ot strokov seva y hustoty stoianyia rastenyi [The productivity of Zaporizhzhya 28 hybrid, dependingon terms of sowing and plant standing density]. Sci. Tech. Bull. Inst. Oilseeds NAAS 12, 225–229. [in Ukrainian]

Nykytchyn D.Y., 1993. Soniashnyk. [Sunflower]. Urozhay, Kyiv, pp. 192. [in Ukrainian]

Oleksiuk O.M., 2000. Vplyv sposobiv sivby i hustoty stoiannia roslyn na urozhainist hibrydiv soniashnyka v Pivnichnii chastyni Stepu Ukrainy [Influence of sowing methods and plant density on yield of sunflower hybrids in the Northern part of the Steppe of Ukraine]. Abstract of the dissertation. Dnipropetrovsk, pp. 16. [in Ukrainian]

Patil V.A., Bangal D.B., Goswami P.B., 1976. A note on inter-floret competition in sunflower. Indian J. Plant Physiol. 19(1), 28–31.

Pinkovskyi H.V., Tanchyk S.P., 2019a. Produktyvnist ta vodospozhyvannia serednorannikh hibrydiv soniashnyka zalezhno vid strokiv sivby ta hustoty stoiannia roslyn u Pravoberezhnomu Stepu Ukrainy [Productivity and water consumption of mid-early sunflower hybrids depending on the sowing time and plant standing density in the Right-Bank Steppe of Ukraine. Irrigated agriculture]. Kherson. 72, 47–52. [in Ukrainian] https://doi.org/10.32848/0135-2369.2019.72.11

Pinkovskyi H.V., Tanchyk S.P., 2019b. Polova skhozhist nasinnia soniashnyku zalezhno vid strokiv sivby ta hustoty stoiannia roslyn u Pravoberezhnomu Stepu Ukrainy [Field germination of sunflower seeds depending on sowing dates and density of standing plants in the Right Bank Steppe of Ukraine]. Scientific reports of the National University of Life and Environmental Sciences of Ukraine 1(77). [in Ukrainian] http://dx.doi.org/10.31548/dopovidi2019.01.018

Pinkovskyi H., Tanchyk S., 2020. Dynamics of the availability of available moisture in soil byoptimization of sowing time and density of statement of sunflower plants in the Right-Bank Steppe of Ukraine. Technium: Rom. J. Appl. Sci. Technol. 2(3), 68–77. https://doi.org/10.47577/technium.v2i3.556

Pleshakov N.A., 1987. Vlyianye srokov poseva na prorastanye semian y urozhai podsolnechnyka. [Impact of planting dates on seed germination and sunflower harvest]. Bull. Sci. Techn. Inform. Oilseeds. Krasnodar 1, 21–24. [in Russian]

Pustovoit V.S., 1990. Yzbrannye Trudy. [Selected Works]. Agropromizdat, Moscow, pp. 367. [in Russian]

Sydorenko Yu.Ya., Turchyn V.V., Vasylenko Y.A., Kharchenko N.L., 1990. Po yntensyvnoy tekhnolohy [By intensive technology]. Ind. Crops 2, 20. [in Ukrainian]

Thompson J.A., Fenton I.G., 1979. Influence of plant population on yield and yield components ofirrigated sunflower in Southern New South Walles. Austral. J. Exp. Agr. Anim. Hasbandry 19(100), 570–574.

Totskyi V.M., 2009. Vplyv strokiv sivby na formuvannia elementiv produktyvnosti ta vrozhainosti soniashnyku [Influence of sowing dates on the formation of elements of productivity andyield of sunflower]. Bull. Poltava State Agrar. Acad. 1, 122–124. [in Ukrainian]

Trotsenko V.I., Butenko A.O., 2002. Osoblyvosti nasinnytstva sortiv soniashnyku v Lisostepovii zoni Ukrainy [Peculiarities of sunflower seed production in the Forest-Steppe zone of Ukraine]. Scientific works of the Crimean NAU. Simferopol 72, 163–166. [in Ukrainian]

Yeremenko O.A., 2017. Produktyvnist hibrydiv soniashnyku (Helianthus annuus L.) u Pivdennomu Stepu [Productivity of sunflower hybrids (Helianthus annuus L.) in the Southern Steppe]. Collection of Scientific Works of the National Research Center. Institute of Agriculture NAAS 1, 127–139. [in Ukrainian] http://nbuv.gov.ua/UJRN/znpzeml_2017_1_14

Yeshchenko V.O., Kopytko P.H., Kostohryz P.V., Opryshko V.P., 2014. Osnovy naukovykh doslidzhen v ahronomii [Fundamentals of scientific researches in agronomy]. Vinnytsya, pp. 332. [in Ukrainian]

Zinchenko O.I., Rogalsky S.V., 2010. Rist i vrozhainist soniashnyku zalezhno vid strokiv sivby i hustoty roslyn [Growth and yield of sunflower depending on the timing of sowing and plant density]. Collection of Scientific Works of Uman National University of Horticulture 73(1), 234–239. [in Ukrainian]

Streszczenie. W artykule przedstawiono wyniki badań naukowych przeprowadzonych w latach 2016–2018 w celu określenia wpływu terminów siewu i obsady roślin na wzrost, rozwój i produktywność mieszańców słonecznika. Doświadczenie polowe przeprowadzono metodą podziału poletek w trzech powtórzeniach na polu doświadczalnym Instytutu Rolnictwa Stepowego NAAS w suchych warunkach Prawobrzeżnego Stepu Ukrainy. Materiał do badań stanowiły mieszańce słonecznika z średniowczesnej grupy dojrzałości – Forward, LG 56.32, LG 54. 85, LG 5582 (czynnik A); terminy siewu – pierwszy, gdy gleba na głębokości nasion ogrzała się do temperatury 5–6°C, drugi, gdy gleba na głębokości nasion ogrzała się do temperatury 7–8°C, trzeci, gdy gleba na głębokości nasion ogrzała się do temperatury 9–10°C (czynnik B); obsada roślin – 50, 60, 70 tys. szt. na hektar (czynnik C). Badania wykazały, że wydajność roślin słonecznika zależy bezpośrednio od temperatury gleby (terminy siewu), optymalnego reżimu wodnego, obsady roślin oraz cech genetycznych i morfologicznych mieszańców. Ustalono również, że regulując termin siewu i dobierając optymalną obsadę, można wpłynąć na wzrost i rozwój roślin słonecznika, z pominięciem krytycznych okresów podczas uprawy. Optymalny termin siewu słonecznika dla mieszańców LG 55.82 i LG 54.85 jest wówczas, gdy gleba na głębokości nasion ogrzewa się do 5–6°C, a dla mieszańców Forward i LG 56.32 – do 9–10°C. Średnio z lat badań najwyższy plon nasion wynoszący 3,85 t ha^{-1} uzyskał mieszaniec LG 55,82 i był on wyższy od plonu mieszańców Forward, LG 54,85 i LG 56,32 odpowiednio o 19,8%; 5,5% i 6,0%. Stwierdzono, że optymalna obsada słonecznika wynosi 60 tys. roślin na hektar. Zatem wydajność słonecznika zmieniała się istotnie pod wpływem cech morfobiologicznych mieszańca: czynnika A (udział wpływu wynosił 47,5%), obsady roślin (czynnik C) – 5,4% oraz terminu wysiewu (czynnik B) – 3,4%.

Słowa kluczowe: słonecznik, mieszańce, terminy siewu, obsada roślin, wilgotność produkcyjna, plon

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