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Models of sunflower hybrid productivity in the Right-Bank Forest-Steppe of Ukraine

Abstract. The relevance of this research lies in the need to identify the specific features of productivity formation in sunflower hybrids and to establish the relationship between dry matter accumulation at different growth stages and crop yield under varying nutritional conditions. This study aimed to examine the impact of nutritional regimes on the growth, development, and productivity formation of sunflower hybrid agrocenoses, with the application of mineral fertilisers and the growth regulator Kvadrostym, under specific soil and climatic conditions. The research employed both theoretical (statistical analysis) and practical (descriptive and comparative) methods. The following indicators were assessed: dry matter content in plant samples at defined stages of sunflower hybrid development, yield levels, and the interrelationship between these parameters. It was found that as sunflower plants progressed through their growth stages, dry matter accumulation increased accordingly. The values differed depending on the developmental

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characteristics of the hybrids under study. The highest values were recorded at the BBCH 74-77 growth stage. The indicators varied according to the hybrid and nutritional conditions, ranging from 6.12 to 8.62 t/ha. The highest dry matter accumulation was observed in crops of the hybrid ES Monalisa. The application of the growth regulator Kvadrostym contributed to increased dry matter accumulation and, consequently, to higher yields across all sunflower hybrids. The research results demonstrated a consistent relationship between dry matter accumulation in sunflower plants and crop yield at all stages of development. Analysis of linear regression models indicated a strong correlation between these parameters. At the BBCH 74-77 stage, the coefficient of determination varied by sunflower hybrid from 0.9829 to 0.9934. The findings support conclusions regarding the rational use of mineral fertilisers and growth-regulating products to create optimal nutritional conditions for sunflower hybrids

Keywords: *Helianthus annuus*; weather conditions; regression model; dry matter; fertilisers; yield

INTRODUCTION

The food security challenge and its resolution represent a global priority requiring immediate action. One effective approach involves increasing the productivity of agricultural crops through the intensification of agricultural production processes and the development and introduction of new crop varieties and hybrids adapted to specific soil and climatic conditions. Alongside higher yield indicators, the quality and safety of the resulting produce are gaining increasing importance. Sunflower remains the leading oilseed crop cultivated in Ukraine. The area under sunflower cultivation meets both domestic demand – from the population and industry – and supplies significant export volumes. However, the rapid expansion of sunflower cultivation areas has led to oversaturation in crop rotations, which in turn causes several issues, including soil depletion and desiccation. These challenges negatively affect the physical, chemical, and biological properties of soils. This situation highlights the need to optimise cultivation technologies and assess the adaptability of new varieties and hybrids now entering the market. Such measures would support the more complete realisation of their genetic potential under specific climatic conditions (Drobitko *et al*., 2024; Zhao *et al*., 2024).

A review of the literature indicates that there is considerable experience in studying the effects of environmental factors and cultivation technologies on dry matter accumulation in sunflower plants. However, ongoing climate change presents new challenges for producers (Kalenska *et al*., 2021; Hussain *et al*., 2025). Identifying relationships between production processes – particularly dry matter accumulation and crop yield – requires further attention. According to K. Narayana Rao *et al*. (2020), the majority of essential nutrients (nitrogen, phosphorus, potassium), meso-elements (magnesium, calcium, sulphur), and micronutrients (zinc, molybdenum, copper, cobalt, manganese, etc.) are absorbed by the plant before the flowering stage. This period is marked by a rapid increase in vegetative biomass. Research by S. Li & Z. Liu (2025) shows that the separate application of nitrogen, phosphorus, and potassium can increase yield by 23%, 21%, and 12%, respectively. In contrast, the application of compound fertilisers (NP, NK, PK, NPK) results in even greater yield increases – 30%, 28%, 17%, and 42%, respectively. Sunflower plants have the highest nitrogen demand during the head formation and flowering stages.

According to the findings of T. Wang *et al*. (2021), adequate water availability facilitates the efficient transport of nitrogen compounds to the vegetative and generative organs of sunflower plants. Phosphorus uptake is at its highest during the emergence-to-flowering period, after which its absorption by the plant declines sharply. Potassium is the only element consistently absorbed by sunflower plants throughout the entire growing season. However, a critical period for potassium uptake has been identified – coinciding with the stages from head formation to ripening – during which the plants consume the largest amount of this nutrient. To produce 1 tonne of seed along with the associated vegetative mass, sunflower plants require approximately 60 kg of nitrogen, 26 kg of phosphorus, and 170 kg of potassium. It is worth noting that sunflowers are capable of absorbing forms of potassium unavailable to other crops. Literature sources indicate that even when grown on chernozem soils, sunflower plants have a higher demand for nitrogen and phosphorus than for potassium. In addition, sunflower varieties tend to be less responsive to fertiliser application compared to hybrids.

An analysis of the literature also highlights the issue of soil depletion caused by continuous sunflower cultivation. At the same time, several studies indicate relatively high nutrient return rates via plant residues, which, depending on the level of nutrient removal by the crop, amount to: N – 74%, P_2O_5 – 54%, and K_2O – 94%. For comparison, maize returns are: N – 51%, P_2O_5 – 34%, K_2O – 98%; and for soybean: N – 27%, P_2O_5 – 28%, K_2O – 28%. Research by A. Alves *et al*. (2018), conducted under controlled soil conditions and focused on the impact of macronutrients on dry matter synthesis, demonstrated a significant reduction in the amount of organic matter synthesised by plants in the absence of nutrients. The results showed that in the absence of N, P, K, Ca, and S, dry matter synthesis and accumulation were considerably lower compared with variants treated with a complete nutrient solution. In the absence of K, Ca, and Mg, a nutrient imbalance was observed in the plants, characterised by elevated nitrogen levels compared to plants grown with complete fertilisation.

The study of supplementary elements in crop cultivation technologies has become increasingly relevant, particularly regarding seed treatment, foliar application of micronutrients, growth regulators, biopreparations, and anti-stress agents. These practices contribute to crop productivity by creating favourable conditions at specific stages of plant growth and development, as discussed in the studies of M. Carvalho *et al*. (2016), O. Laslo (2022), R. Mialkovskyi & D. Liubytska (2025). Establishing near-optimal conditions during critical growth periods concerning specific limiting factors can enable crops to realise their full genetic potential. In turn, providing optimal nutritional conditions supports the development of sufficient assimilating surface area, promotes dry matter accumulation, and increases sunflower yield. This study aimed to examine the dynamics of dry matter accumulation in crops of sunflower hybrids Alzan, ES Monalisa, RGT Marllen, and RGT Wollf at specific growth stages under varying nutritional conditions established through different fertiliser treatments.

MATERIALS AND METHODS

The study was conducted during 2020-2022 at the Agronomic Research Station, a separate division of the National University of Life and Environmental Sciences of Ukraine, located in Kyiv Region. The trial was established within the department's long-term field crop rotation system. The soil of the experimental field was typical low-humus chernozem, with a humus content of 4.30%. Nitrogen availability was low (50 mg/kg), while phosphorus (54.3 mg/kg) and potassium (142 mg/kg) levels were moderate.

The field trial was arranged as a three-factor experiment. Factor A included sunflower hybrids – RGT Marllen, RGT Wollf, Alzan, and ES Monalisa. Factor B: application rates of mineral fertilisers, calculated using a balance method based on target yield – $N_{40}P_{20}K_{50}$; $N_{55}P_{50}K_{70}$; $N_{70}P_{80}K_{90}$; $N_{85}P_{110}K_{110.}$ Factor C: foliar application of Kvadrostym against the background of basic fertilisation at BBCH stages 14-15 and 50-52, applied at a rate of 500 mg/ha. Each treatment was replicated four times. The preceding crop was winter wheat. The plant density at harvest was 55,000 plants/ha. Phosphorus and potassium fertilisers were applied in the autumn during primary tillage, while nitrogen fertilisers were incorporated during pre-sowing cultivation. The fertilisers used in the experiment included ammonium nitrate (34.4% N), single superphosphate (19% P), and potassium chloride (60% K). The composition of Kvadrostym was as follows: polyethylene glycol – 400 at 260 g/L, polyethylene glycol – 1,500 at 510 g/L, succinic acid – 0.5 g/L, arachidonic acid – 1.44 mg/L, and potassium (sodium) lignohumate – 3.3 g/L (Kvadrostym, n.d.).

The coefficients of the significance of agrometeorological elements deviations of the current year's from long-term average values were calculated using the following formula:

$$Cs = \frac{(Xi - \bar{X})}{\sigma}, \qquad (1)$$

where *Cs* is the coefficients of the significance of deviation; X_i is the current year weather elements (mean monthly or ten-day period average values of temperature and precipitation); $\bar{X}$ – long-term average value; σ – standard deviation.

The interpretation of these coefficients is as follows:

- *Cs* = 0 ÷ 1 – conditions close to normal;
- *Cs* = 1 ÷ 2 – conditions significantly differ from long-term averages;
- *Cs* > 2 – conditions approaching rare/extreme levels.

The dry matter content in plant samples was determined at specific stages of sunflower hybrid development using a thermostatic-weight method. Plant samples were oven-dried to constant weight at 105°C. Yield data were obtained via combined harvesting from designated plot areas. The actual yield was adjusted to a standard moisture content (8%) and corrected for the presence of impurities, in line with the method described by A. Rozhkov *et al.* (2016). The values for dry matter content and yield are presented as three-year averages, accounting for the mean values across treatments and replications.

Agro-climatic conditions and parameters considered (mean monthly air temperature and precipitation during the growing season) were calculated using average daily values recorded by the Fastiv meteorological station. Based on these data, coefficients of the significance of agrometeorological elements deviations during the sunflower growing season over the study period were calculated. Regression models were developed using correlation-regression analysis, and regression equations were provided. The research was conducted following the Convention on Biological Diversity (1992).

RESULTS AND DISCUSSION

The parameters of key agrometeorological indicators over the research period (2020-2022) demonstrate that the growing seasons differed in both temperature regimes and precipitation levels. An analysis of the temperature data revealed that, across all study years, values exceeded the longterm average (Fig. 1).

Precipitation during the growing seasons of the study years was insufficient and unevenly distributed (Fig. 2).

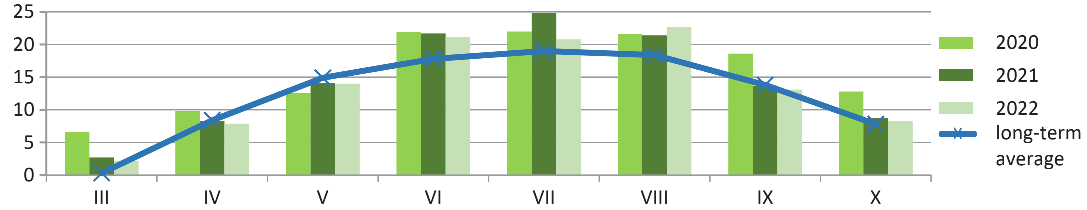

Figure 1. Mean air temperature values, 2020-2022, °C

Source: developed by the authors

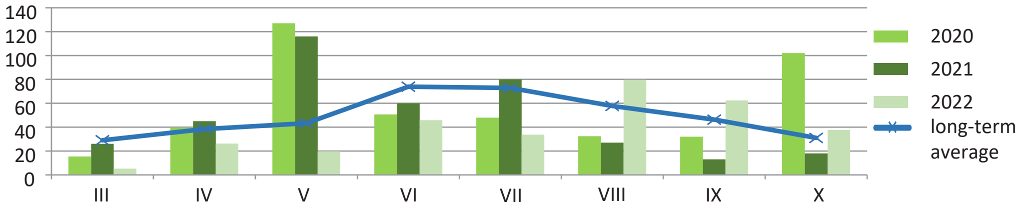

Figure 2. Precipitation levels, 2020-2022, mm

Source: developed by the authors

Calculations and analysis of the coefficients of the significance of average daily temperatures deviation from long-term data indicate that only 58% of the sunflower growing season months fell within the "conditions close to normal" category. In contrast, 25% were categorised as "conditions significantly differ from long-term averages", and 17% were considered "conditions approaching rare/extreme levels" (Fig. 3).

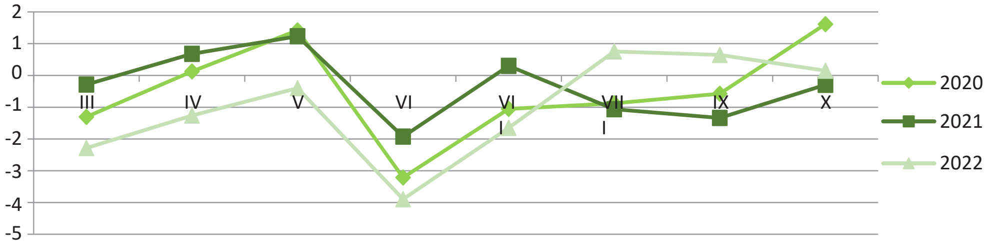

Figure 3. Coefficients of the significance of precipitation deviation from long-term averages, 2020-2022, mm

Source: developed by the authors

Calculations of the coefficients of the significance of average daily temperatures deviation from long-term data (Fig. 4) show that only 46% of the growing season months during 2020-2022 fell within the "conditions close to normal" category. Meanwhile, 42% of the months were classified as "conditions significantly differ from long-term averages", and 13% as "conditions approaching rare/extreme levels".

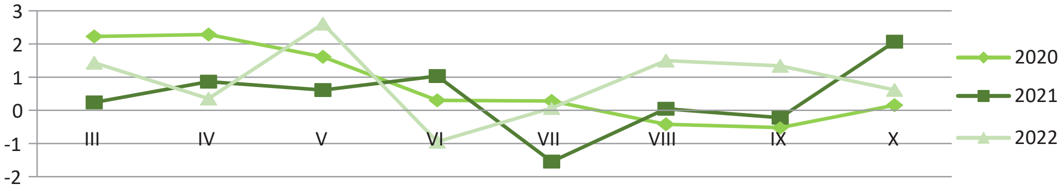

Figure 4. Coefficients of the significance of average daily temperatures deviation from long-term data

Source: developed by the authors

The weather conditions during the years of the study were not favourable for sunflower cultivation, as they did not meet the crop's biological requirements. This adversely affected crop productivity. The synthesis and transformation of organic matter rely on the absorption of solar energy by the assimilating surface of the plant through the process of photosynthesis, which accounts for up to 90% of the dry matter produced. The remaining dry matter is formed through the uptake of mineral nutrients by the plant organism (Hamaiunova & Kudrina, 2020).

The productivity of crops is regulated by two key physiological processes in plants: the development of the assimilating surface and the process of photosynthesis. The photosynthetic activity of crops is influenced by several exogenous factors, including light intensity, temperature regime, atmospheric carbon dioxide concentration, and regional weather conditions. Equally important is the availability of nutrients, which is a controllable factor. These elements, along with the specific characteristics of the variety or hybrid, play a crucial role in the formation and accumulation of dry matter in sunflower plants (Domaratskiy *et al.*, 2018).

According to the research findings, the accumulation of dry matter in sunflower plants occurred gradually as the plants grew and developed. The highest values were observed at the BBCH 74-77 stage (Table 1). At this stage, greater variation in dry matter accumulation was recorded across fertiliser treatments than at earlier stages of development. For instance, the RGT Marllen hybrid accumulated dry matter ranging from 6.21 to 7.31 t/ha, depending on the fertilisation treatment, RGT Wolff from 6.63 to 7.82 t/ha, Alzan from 6.12 to 7.04 t/ha, and ES Monalisa from 6.92 to 8.31 t/ha.

Table 1. Dynamics of dry matter accumulation in sunflower crops, average for 2020-2022, t/ha

Fertiliser treatments	Microstage (BBCH scale)	ES Monalisa		RGT Wolff		RGT Marllen		Alzan	
		1	2	1	2	1	2	1	2
$N_{40}P_{20}K_{50}$	16-20	0.43	0.45	0.41	0.44	0.37	0.41	0.36	0.39
$N_{55}P_{50}K_{70}$		0.59	0.65	0.55	0.51	0.46	0.52	0.42	0.51
$N_{70}P_{80}K_{90}$		0.71	0.78	0.64	0.71	0.59	0.66	0.49	0.56
$N_{85}P_{110}K_{110}$		0.83	0.93	0.77	0.87	0.75	0.83	0.61	0.74
V, %		**26.70**	**28.97**	**25.57**	**30.88**	**30.45**	**30.01**	**22.85**	**26.43**
$N_{40}P_{20}K_{50}$	54-58	3.19	3.33	3.09	3.18	2.87	2.98	2.81	3.01
$N_{55}P_{50}K_{70}$		3.41	3.64	3.27	3.41	3.03	3.22	3.01	3.19
$N_{70}P_{80}K_{90}$		3.72	4.07	3.45	3.60	3.28	3.54	3.26	3.48
$N_{85}P_{110}K_{110}$		3.97	4.29	3.81	4.02	3.61	3.79	3.54	3.68
V, %		**9.59**	**11.23**	**9.03**	**10.02**	**10.09**	**10.51**	**10.01**	**8.93**
$N_{40}P_{20}K_{50}$	64-68	4.15	4.28	4.01	4.15	3.86	3.99	3.81	3.94
$N_{55}P_{50}K_{70}$		4.39	4.67	4.12	4.39	4.10	4.27	3.96	4.17
$N_{70}P_{80}K_{90}$		4.89	5.05	4.65	4.88	4.52	4.79	4.25	4.59
$N_{85}P_{110}K_{110}$		5.27	5.61	4.94	5.28	4.81	5.01	4.51	4.71
V, %		**10.75**	**11.56**	**9.93**	**10.80**	**9.82**	**10.36**	**7.52**	**8.26**
$N_{40}P_{20}K_{50}$	74-77	6.92	7.21	6.63	6.89	6.21	6.42	6.12	6.39
$N_{55}P_{50}K_{70}$		7.39	7.59	6.97	7.21	6.43	6.71	6.29	6.56
$N_{70}P_{80}K_{90}$		7.85	7.98	7.43	7.69	6.74	6.97	6.62	6.82
$N_{85}P_{110}K_{110}$		8.31	8.62	7.82	8.02	7.31	7.49	7.04	7.17
V, %		**7.85**	**7.67**	**7.22**	**6.73**	**7.15**	**6.59**	**6.22**	**5.04**

Note: 1 – without treatment control; 2 – foliar application of Kvadrostym alongside base fertilisation at BBCH stages 14-15 and 50-52 at a rate of 500 mg/ha
Source: developed by the authors

The application of Kvadrostym increased dry matter accumulation in the RGT Marllen hybrid to 6.42-7.49 t/ha, in RGT Wolff to 6.89-8.02 t/ha, in Alzan to 6.39-7.17 t/ha, and in ES Monalisa to 7.21-8.62 t/ha. Fertiliser application created favourable conditions for the formation and accumulation of dry matter in sunflower plants. A direct correlation was observed between the amount of fertiliser applied and the resulting crop productivity. The relationships between dry matter accumulation at specific growth stages and the yield of sunflower hybrids, under different nutrient supply conditions, are presented in Table 2 in the form of linear regression models. The coefficients of determination obtained from these models indicate a strong association between accumulated dry matter and the yield of sunflower hybrids. At early growth stages, the coefficients of determination were slightly lower compared to those observed at BBCH stage 74-77. Similar patterns were observed in treatments where foliar applications of Kvadrostym were conducted twice during the growing season.

Table 2. Regression models of sunflower hybrid yield depending on dry matter accumulation, average for 2020-2022

Hybrid	Sunflower growth stage	Foliar application of PGR Kvadrostym	Regression model (linear)	Coefficient of determination, R^2
ES Monalisa	BBCH 16-20	–	$y = 0.3917x - 0.5301$	0.9069
		+	$y = 0.4131x - 0.6277$	0.9086
	BBCH 54-58	–	$y = 0.7936x + 1.2016$	0.9568
		+	$y = 0.883x + 0.9891$	0.9606
	BBCH 64-68	–	$y = 1.162x + 1.2035$	0.9749
		+	$y = 1.1578x + 1.1744$	0.9817
	BBCH 74-77	–	$y = 1.3813x + 3.491$	0.9931
		+	$y = 1.2248x + 3.906$	0.9936
RGT Wollf	BBCH 16-20	–	$y = 0.4764x - 0.739$	0.9141
		+	$y = 0.5415x - 1.011$	0.9224
	BBCH 54-58	–	$y = 0.9661x + 0.7047$	0.9706
		+	$y = 0.9911x + 0.5446$	0.9715
	BBCH 64-68	–	$y = 1.3383x + 0.6894$	0.9776
		+	$y = 1.4112x + 0.3919$	0.9782
	BBCH 74-77	–	$y = 1.6316x + 2.6522$	0.9835
		+	$y = 1.4079x + 3.1795$	0.9906
RGT Marllen	BBCH 16-20	–	$y = 0.4505x - 0.6637$	0.9323
		+	$y = 0.451x - 0.7064$	0.9371
	BBCH 54-58	–	$y = 0.8766x + 0.8504$	0.9701
		+	$y = 0.8929x + 0.7865$	0.9752
	BBCH 64-68	–	$y = 1.1531x + 1.2352$	0.9785
		+	$y = 1.1642x + 1.1302$	0.9608
	BBCH 74-77	–	$y = 1.1148x + 3.6563$	0.9834
		+	$y = 1.2858x + 3.2298$	0.9883
Alzan	BBCH 16-20	–	$y = 0.3394x - 0.4066$	0.9472
		+	$y = 0.3814x - 0.5151$	0.9487
	BBCH 54-58	–	$y = 1.0013x + 0.5692$	0.9651
		+	$y = 0.7952x + 1.119$	0.9707
	BBCH 64-68	–	$y = 0.9725x + 1.621$	0.9790
		+	$y = 0.9468x + 1.7086$	0.9761
	BBCH 74-77	–	$y = 1.2668x + 3.2461$	0.9829
		+	$y = 0.8947x + 4.2365$	0.9864

Source: developed by the authors

The results of the study demonstrated that fertiliser application had a positive effect on the productivity of sunflower hybrids. Yields varied depending on nutrient supply and, on average across the study years, ranged from 2.08 to 2.86 t/ha for RGT Marllen, 2.29-3.19 t/ha for RGT Wollf, 2.09-2.87 t/ha for Alzan, and 2.35-3.42 t/ha for ES Monalisa (Fig. 5).

Figure 5. Yield of sunflower hybrids, t/ha, average for 2020-2022
Note: 1 – water treatment; 2 – Kvadrostym treatment at BBCH stages 14-15 and 50-52 at a rate of 500 mg/ha
Source: developed by the authors

In the treatments where foliar application of Kvadrostym was performed at BBCH microstages 14-15 and 50-51, yields were higher and reached 2.23-3.12 t/ha for RGT Marllen, 2.42-3.24 t/ha for RGT Wolff, 2.24-3.11 t/ha for Alzan, and 2.51-3.68 t/ha for ES Monalisa. A direct correlation between fertiliser rates and hybrid yield was identified, with a strong positive correlation observed. Correlation coefficients varied depending on hybrid characteristics and ranged from 0.975 to 0.986. The results of the study showed that, as the plants grew and developed, the biomass of sunflower plants increased. An intensive accumulation of dry matter was observed up to the end of the flowering stage. During this period, plants accumulated the highest amounts of both fresh biomass and dry matter. Further plant development was characterised by a decline in above-ground biomass. Similar findings were reported in studies by V. Hamaiunova & V. Kudrina (2020), which investigated the effects of foliar feeding with modern plant growth regulators (Fresh Energy, Fresh Florid, Retardyn) on sunflowers. The application of these products led to an increased rate of dry matter accumulation, with the amount depending on the type of biopreparation, its dosage, and the growth stage at which it was applied.

The application of fertilisers created conditions that promoted the formation and accumulation of dry matter in sunflower plants. Studies conducted by A. Mahapatra *et al.* (2020; 2021) indicate a gradual accumulation of dry matter in sunflowers, reaching a peak during the ripening stage, which supports the findings of the present research. According to F. Villalobos *et al.* (1994), the distribution of dry matter and yield formation are critical factors for the successful modelling of crop productivity. The genetic characteristics of sunflower hybrids influenced the synthesis, accumulation, and distribution of dry matter within the plants, as evidenced by the results obtained. Field studies by O. Polyakov & S. Litoshko (2022) demonstrated that the highest dry matter accumulation in sunflowers was achieved with the application of a complete mineral fertiliser at a rate of $N_{60}P_{60}K_{60}$. The use of plant growth regulators promoted increased dry matter accumulation at all stages of plant growth and development, regardless of the mineral fertiliser background.

According to the findings of H. Pinkovskyi (2019) and H. Pinkovskyi & Yu. Mashchenka (2019), the development of high sunflower productivity depends on the genetic characteristics of the hybrid, weather conditions during the growing season and the availability of essential nutrients. The most favourable conditions for sunflower growth and development were observed with the application of a complete mineral fertiliser at a rate of $N_{40}P_{40}K_{40}$, combined with fertilisation using the by-products of the preceding crop. Three-year research conducted by O. Polyakov & A. Shcherbak (2022) under the conditions of the Southern Steppe of Ukraine confirmed the positive impact of mineral fertilisers and growth regulators on the dynamics of dry matter accumulation in sunflower plants. The highest increase in dry matter was recorded during the grain-filling to maturity stages with the application of a complete mineral fertiliser at a rate of $N_{60}P_{60}K_{60}$. The use of growth regulators enhanced the accumulation of dry matter at all stages of plant growth and development, regardless of the mineral nutrition background under investigation.

According to the findings of V. Hanhur *et al*. (2020; 2022), which focused on the effects of fertilisation and the application of biopreparations under the conditions of the Poltava Region, the highest yield was achieved when the Kameniar hybrid was cultivated with the application of $N_{32}P_{32}K_{32}$ and foliar treatments using the biopreparations Organic-Balance (0.5 L/ha) and Liposam (0.5 L/ha), resulting in a yield of 3.02 t/ha. A direct relationship was identified between the amount of fertiliser applied and the resulting crop productivity. In field experiments conducted by V. Sendetskyi *et al*. (2022), it was established that the use of the growth regulators Vermymah and Vermyiodis influenced the intensity of sunflower plant growth processes, contributing to an increase in leaf surface area, the accumulation of dry matter, and improvements in yield structure elements. Based on a mathematical and statistical analysis, structural indicator models were proposed, revealing a direct correlation between the experimental factors and yield outcomes.

The study by O. Sakharchuk & L. Harbar (2018) demonstrated an increase in dry matter accumulation and yield of sunflower hybrids as a result of applying fertilisers and micronutrients. However, findings from research conducted by E. Domaratskiy *et al*. (2018) under Steppe conditions indicate that optimising the nutritional regime for sunflower plants depends not solely on fertiliser application. During the early stages of development, sunflower plants are exposed to stress due to herbicide application or lack of moisture. The adverse effects of such stress conditions can be mitigated, and nutrient uptake can be enhanced, through the use of growth regulators in combination with mineral fertilisation. The application of growth regulators was found to increase yield by 11.0-13.6%. Research by W. Nasim *et al*. (2016), which investigated the effects of different nitrogen fertiliser rates on the growth, development, and productivity of sunflower hybrids under varying climatic conditions, yielded somewhat different results. Their findings indicated that nitrogen fertilisers directly affect the synthesis and accumulation of dry matter in sunflower plants, and consequently, their yield. The highest dry matter accumulation and yield were recorded under the treatment with the highest nitrogen dose (N_{180}). Thus, both the research findings and the literature evidence strongly suggest that optimising mineral nutrition in combination with the use of biopreparations and growth regulators is a key factor in enhancing biomass accumulation and achieving high productivity in sunflower crops, which is reflected in increased yield.

CONCLUSIONS

An analysis of the key agrometeorological indicators during the growing seasons of the study years (2020-2022) revealed significant variation in both temperature patterns and precipitation levels. Temperature readings were consistently higher during the study period compared with long-term averages. Precipitation was insufficient and unevenly distributed throughout the growing seasons. Overall, the weather conditions were not favourable for sunflower cultivation, as they did not meet the biological requirements of the crop. The findings indicated that the highest accumulation of dry matter occurred at the BBCH growth stage 74-77. During this stage, the following levels were recorded: for the RGT Marllen hybrid, 6.21-7.31 t/ha; RGT Wollf, 6.63-7.82 t/ha; Alzan, 6.12-7.04 t/ha; and ES Monalisa, 6.92-8.31 t/ha. The application of Kvadrostym contributed to further increases in dry matter accumulation, raising values to 6.42-7.49 t/ha for RGT Marllen, 6.89-8.02 t/ha for RGT Wollf, 6.39-7.17 t/ha for Alzan, and 7.21-8.62 t/ha for ES Monalisa. The highest dry matter accumulation across all sunflower plots was observed under the treatment with $N_{85}P_{110}K_{110}$ fertiliser during the cultivation of the ES Monalisa hybrid, reaching 8.31 t/ha. Foliar application of Kvadrostym further increased this value to 8.62 t/ha. The maximum seed yield was also recorded for the ES Monalisa hybrid under the $N_{85}P_{110}K_{110}$ fertiliser regime, at 3.42 t/ha, with Kvadrostym treatment contributing to an increase in yield to 3.68 t/ha.

The research findings demonstrated a clear relationship between dry matter accumulation in sunflower plants and crop yield at all stages of development. Analysis of linear regression models indicated a strong association between these parameters. At the BBCH 74-77 growth stage, the coefficient of determination varied by hybrid, ranging from 0.9829 to 0.9934. Regression models describing yield as a function of dry matter accumulation at different developmental stages confirmed the strength of this relationship. A direct correlation was also established between fertilisation treatments and yield indicators, with correlation coefficients ranging from 0.975 to 0.986. These results highlight the potential for further comprehensive investigation into the influence of nutrient elements, novel bioproducts, growth regulators, and cultivation technologies on the growth, development, and productivity of sunflowers under conditions of climate change.

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CONFLICT OF INTEREST

None.

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Моделі продуктивності гібридів соняшнику в умовах Правобережного Лісостепу України

Анотація. Актуальність досліджень полягає у необхідності виявлення особливостей формування продуктивності гібридів соняшнику та встановлення взаємозв'язку між накопиченням сухої речовини на окремих стадіях росту та розвитку культури і її урожайністю за впливу різних умов живлення. Мета досліджень полягала у вивченні впливу умов живлення на ріст, розвиток, формування продуктивності агроценозів гібридів соняшнику за внесення мінеральних добрив і ріст регулюючого препарату «Квадростим» за впливу конкретних ґрунтово-кліматичних умов. У процесі проведення досліджень використовували такі методи: теоретичні (статистична обробка) та практичні (описові, порівняльні). Проводили оцінку наступних показників: вмісту сухої речовини у рослинних зразках у певні періоди розвитку гібридів соняшнику, урожайності та взаємозв'язку між ними. Встановлено, що по мірі росту та розвитку рослин соняшнику спостерігалося збільшення показників накопичення сухої речовини. Значення різнилися залежно від особливостей розвитку гібридів, які вивчали. Максимального значення показники сягали на стадії ВВСН 74-77. Показники варіювали залежно від гібриду та умов живлення від 6,12 до 8,62 т/га. Максимальне значення сухої речовини накопичували посіви гібриду ЕС Моналіза. Застосування препарату «Квадростим» сприяло накопиченню сухої речовини посівами та, відповідно, зростанню урожайності всіх гібридів культури. Результати досліджень засвідчили залежність між накопиченням сухої речовини рослинами соняшнику та урожайністю культури на всіх етапах їх розвитку. Аналіз регресійних моделей лінійного типу вказував на сильний зв'язок між зазначеними показниками. На стадії ВВСН 74-77 коефіцієнт детермінації змінювався залежно від гібриду соняшника від 0,9829 до 0,9934. Результати досліджень дозволяють зробити висновки щодо раціонального використання мінеральних добрив та ріст регулюючих препаратів для створення оптимальних умов живлення гібридів соняшнику

Ключові слова: *Helianthus annuus*; погодні умови; регресійна модель; суха речовина; добрива; урожайність