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IMPACT OF PLANTING DENSITY ON SUNFLOWER YIELD IN EASTERN UKRAINE

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Abstract *Sunflower is a key crop in Ukraine, accounting for over 30% of global sunflower oil production. Recent studies emphasize optimizing cultivation technologies, particularly planting density, to improve sunflower yield and quality under varying climatic conditions.*

Study evaluates the effects of plant density and climate on the yield and quality of two sunflower hybrids, Biloba CLP and SY Daxton, over three growing seasons (2022–2024).

Field trials conducted in the Dnipropetrovsk region revealed that a planting density of 55,000 plants/ha maximized yields for both hybrids across diverse environmental conditions. Lower densities underutilized resources, while higher densities led to excessive competition.

Variability in rainfall and temperature significantly influenced growth stages and yield outcomes. The findings underline the importance of site-specific density optimization and hybrid selection to enhance sunflower production in Ukraine's agro-climatic zones.

Keywords: *Sunflower, plant density, yield, climatic conditions.*

Introduction

In recent years, the sown area under sunflower in Ukraine has reached its maximum level 5.2 million hectares (FAOSTAT, 2023). The sunflower market demands stable, high-yielding hybrids with enhanced adaptability to unfavourable biotic and abiotic factors. Additionally, there is a growing need to revise and improve the cultivation technology for this strategically important crop in Ukraine (Kyrychenko V. V. 2005). Ukraine contributes significantly to global sunflower oil production and exports, accounting for over 30% of the world's sunflower oil supply (UkrAgroConsult, 2022).

Research conducted in Ukraine emphasizes the importance of plant density in optimizing sunflower yield under varying climatic conditions (Kovalenko et al., 2018; Poltavets et al., 2020; NAAS, 2021). This component is necessary for managing soil fertility, tillage practices, hybrid-specific reactions, and regional environmental conditions. Studies have revealed that hybrids have dramatically varied yield potential due to differences in plant density. Soil board practices appropriate for Ukraine's climate zones, as well as hybrid adaptability, influence these differences (Ivanenko and

Honchar, 2019; NAAS, 2021).

This paper presents new findings from field tests conducted in Dnipropetrovsk region of Ukraine to evaluate the impact of climate and plant density on sunflower yield and quality. These findings should help boost sunflower production in Ukraine's varied agro climatic zones (Dobrenkyi O.A., Avramenko S.V. 2024). In today's conditions, sunflower occupies the largest area in the structure of sown areas in the region, significantly surpassing winter wheat. Most likely, this trend will continue until there is a change in the price of winter wheat.

Analysing agrometeorological conditions and studying the links between weather elements and yield allows for the development of prediction models that aid in yield forecasting based on specific growing season circumstances. This would enable effective management of cultivation technologies as well as adaptation of farming strategies, with a focus on hybrids' ecological adaptability and stability.

Sunflower hybrids that can adapt to shifting climatic circumstances can reach their biological potential even with limited moisture and high temperatures, making them effective under such settings. Using predictive models and agronomic technologies, it is possible to dramatically improve production stability and product quality.

Optimizing plant density is crucial for maximizing sunflower (Helianthus annuus L.) yield, as it influences resource utilization, plant growth, and competition. Research indicates that higher plant densities can enhance overall biomass and seed yield, despite reductions in individual plant metrics such as grain weight and 1000-seed weight. For instance, a study in the Hetao Irrigation District of China found that increasing plant density led to taller plants and higher leaf area indices, resulting in greater biomass production and achene yield. However, excessive densities caused dry matter to shift from the head to the stem, potentially limiting yield gains. The study suggests that a plant spacing of 35 cm with 50 cm row spacing is optimal for sunflower cultivation under mulched drip irrigation with saline water at concentrations of 3.0 $g \cdot L^{-1}$. (Li, J., Qu, Z., Chen, J., Yang, B., & Huang, Y. 2019)

In organic farming systems, increasing sunflower density has been shown to improve weed suppression, thereby enhancing crop yield and quality. A study published in the Agronomy Journal reported that higher plant densities in sunflower crops reduced weed biomass, leading to better resource allocation for the sunflowers and improved yields (Mouillon P. 2020)

Additionally, research on planting patterns and densities has demonstrated significant effects on sunflower yield and light interception. A study found that different planting patterns and densities influenced the extinction coefficient, which relates to how efficiently a plant canopy intercepts light. Optimizing these factors can lead to improved photosynthetic efficiency and higher yields (Mohammad J. 2005)

It's important to note that the optimal plant density can vary based on environmental conditions, irrigation practices, and specific sunflower varieties. Therefore, localized studies and field trials are recommended to determine the most effective planting densities for specific regions and farming practices.

Matherial and methods

The experimental material included two sunflower hybrids widely grown in Ukraine: Biloba CLP and SY DAXTON. These hybrids were selected for their adaptability to Ukrainian agro-climatic conditions and were developed by leading seed companies. Field trials were conducted during the 2022, 2023, and 2024 growing seasons on typical Ukrainian chernozem soils, on a base of Institute of Grain Crops of NAAS of Ukraine, representative of the Dnipropetrovsk region's agricultural conditions (Kovalenko et al., 2021; NAAS, 2022).

Seven plant densities were tested: 35,000, 40,000, 45,000, 50,000, 55,000, 60,000, and 65,000 plants/ha. The plot size was 60 m² (with 70 cm row spacing). Sunflowers followed wheat in the crop rotation, a common practice in the region (Ivanenko and Honchar, 2020).

The data were analysed using analysis of variance (ANOVA) and response curve methodology (Saulescu and Saulescu, 1967), ensuring robust evaluation of the effects of plant density and environmental conditions on sunflower performance.

Results and discussion The experimental period (2022–2024) showed significant variability in climatic conditions, particularly in the quantity and monthly distribution of rainfall, which directly influenced sunflower growth and yield (Table 1).

Table 1. Average temperature (°C) and monthly distribution of rainfall (mm) during the experimentation

Year	Month					
	April	May	June	July	August	September
Temperature (°C)						
2022	11.8	16.4	21.6	24.3	23.8	17.2
2023	12.0	17.2	22.0	25.0	24.5	18.0
2024	15.5	16.4	23.2	26.6	24.6	21.0
Multi-annual avg.	12.1	16.7	22.3	24.5	23.8	17.4
Rainfall (mm)						
2022	45.3	19.0	29.0	35.0	46.0	35.0
2023	102.0	29.0	29.0	42.0	30.0	14.0
2024	14.0	12.0	29.0	44.0	1.6	11.0
Multi-annual avg.	53.8	20.0	29.0	40.3	39.2	29.7

In 2022, the total amount of rainfall during the growing season (April-September) was 209,3 mm, which significantly below multi-annual average (by 30,2 mm). This deficit was in May (19 mm) and June (29 mm), resulted in water stress during critical growth development stages, such as early vegetative growth, flowering and seed filling. These conditions led to reduced yield and oil content.

In 2023, the amount of precipitation, across same period, was 246 mm. That is closer to the average level. Rainfall during April (102) mm was significantly higher than the average (53,8 mm), providing sufficient moisture for early development of plants. However, in May and June extremely water deficit was experienced. Rainfall in July (42 mm) helped mitigate some water deficit but also let to plant logging in certain areas, potentially affecting yield.

In 2024 amount of precipitation during growing season was 111.6 mm, much lower than the multi-annual average (101 mm). This water deficit was particularly acute in May (12.0 mm) and August (1.6 mm), which are critical for vegetative growth and seed filling. Despite favourable conditions in April (15.5°C) and July (26.6°C), the lack of rainfall significantly impacted sunflower development, leading to reduced yields and lower oil quality.

The analysis of sunflower yields for the hybrid Biloba CLP under varying plant densities at harvest over the years 2022–2024 demonstrates clear trends in yield responses to density (Fig.1). The study revealed that plant densities significantly influence the competitive dynamics among plants and their ability to utilize available resources, including water, nutrients, and light, under Ukraine's agro-climatic conditions.

The highest yields were consistently observed at densities ranging from 45,000 to 55,000 plants/ha, with 55,000 plants/ha providing the most stable performance across the study period (LSD05 year/density-0,42 t/ha). This density range ensures optimal resource utilization while minimizing intra-specific competition. In contrast, lower densities (35,000–40,000 plants/ha) resulted in suboptimal resource utilization, limiting overall yield despite potentially larger individual seed sizes. Conversely, higher densities (60,000–65,000 plants/ha) led to excessive competition, which negatively impacted yield potential, particularly in less favourable climatic conditions.

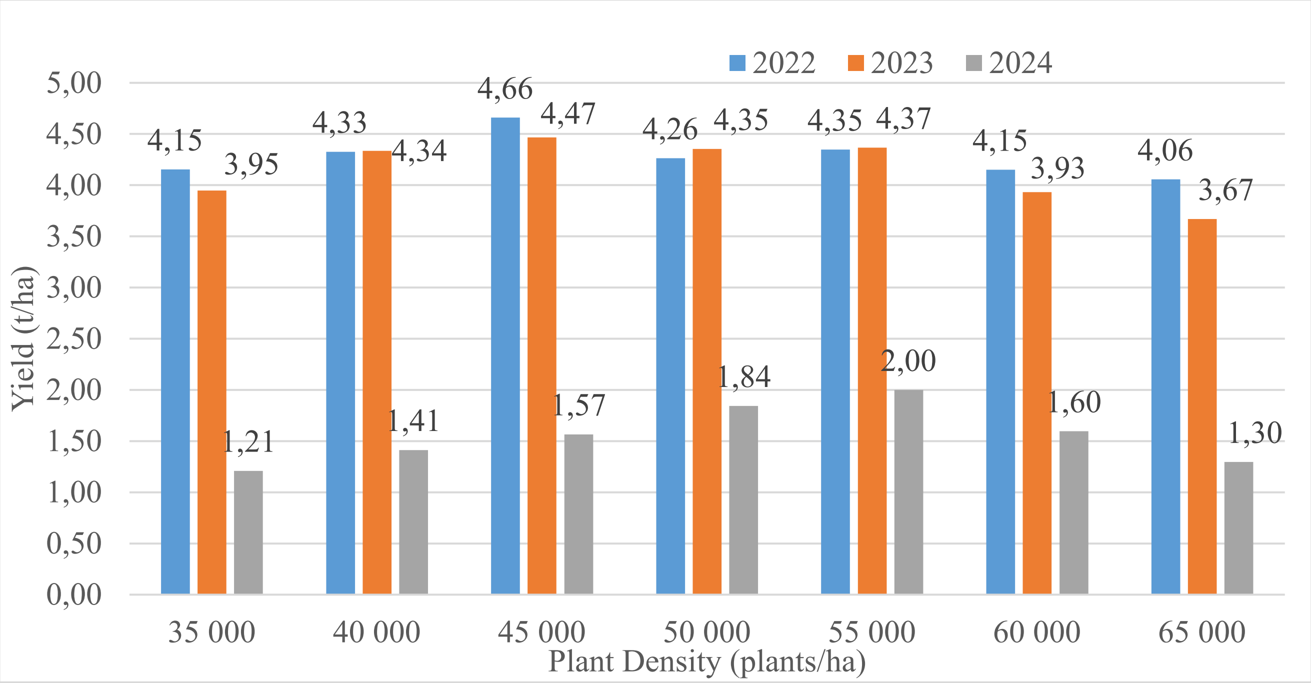

Figure 1 - Yield in sunflower hybrid Biloba CLP with different plant densities during 2022-2024

At 35,000 plants/ha, the yield averaged 3.10 t/ha (LSD05 year – 0,24 t/ha) across the three years, reflecting poor utilization of the available soil and climatic potential. Increasing the density to 45,000 plants/ha improved yields to an average of 3.57 t/ha, representing the peak performance (LSD05 density- 0.17t/ha). Beyond this density, the yield increment diminished, with 60,000 and 65,000 plants/ha averaging 3.23 t/ha and 3.01 t/ha, respectively, indicating the detrimental effects of overcrowding.

The yield performance of the sunflower hybrid SY Daxton under different plant densities over the years 2022–2024 highlights the importance of finding the right balance for optimal productivity (Fig.2).

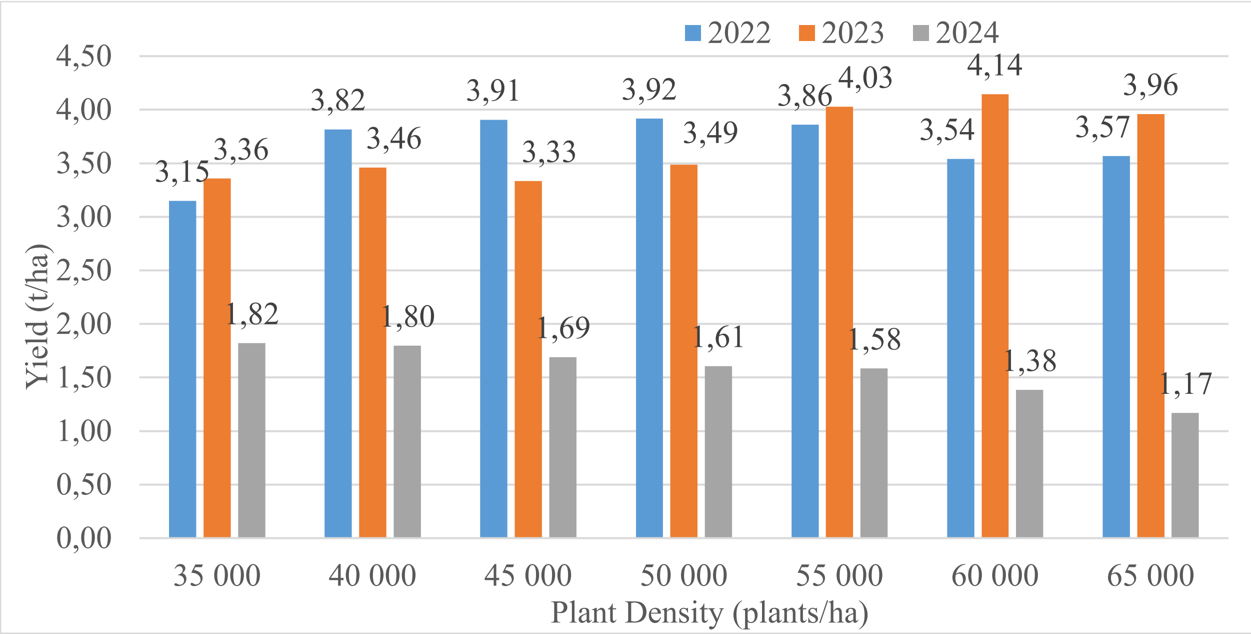

Figure 2.- Yield in sunflower hybrid SY Daxton with different plant densities during 2022-2024

At lower densities, such as 35,000 plants/ha, the yields were lower (averaging 2.78 t/ha across the three years (LSD05 year – 0,25 t/ha)) due to insufficient plant numbers to fully utilize the available resources. As density increased to 40,000 and 45,000 plants/ha, yields improved (averaging 3.03 t/ha and 2.98 t/ha, respectively (LSD05 density- 0.17 t/ha), indicating better resource capture. The highest and most consistent yield was observed at 55,000 plants/ha, averaging 3.16 t/ha ((LSD05 density/ year – 0,51 t/ha). Beyond this point, at higher densities of 60,000 and 65,000 plants/ha, yields started to decline (averaging 2.99 t/ha and 2.90 t/ha, respectively) due to increased competition, which likely hindered seed development.

The results also varied by year. In 2022, the highest yield was recorded at 40,000 plants/ha (3.82 t/ha), with similar performance at 55,000 plants/ha (3.86 t/ha). In 2023, 60,000 plants/ha produced the highest yield (4.14 t/ha), suggesting the hybrid's ability to perform well under beneficial conditions with higher plant populations. However, in 2024, when conditions were less convenient, the best yield occurred at 35,000 plants/ha (1.82 t/ha), reflecting reduced stress from overcrowding during a challenging growing season.

Summary and conclusions.

The findings indicated that a planting density of 55,000 plants/ha was optimal for sunflower hybrid Biloba CLP cultivation in Dnipropetrovsk region, offering a robust compromise between productivity and resilience under varying environmental conditions. The data suggest that the best yields for sunflower hybrid SY Daxton was achieved at densities ranging from 40,000 to 55,000 plants/ha, with 55,000 plants/ha showed the most stable performance across the three years. This density provided a balance where resources are effectively utilized without excessive competition among plants. Production densities exceeding 60,000 plants/ha should be avoided due to their negative impact on yield potential.

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