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Economic and biological characteristics and productivity analysis of sunflower hybrids

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Abstract. Evaluation of the biological characteristics of sunflower hybrids and their potential to improve the qualities of the plant under study that are useful for agricultural development is considered relevant. The research aims to carefully and in-depth evaluate the biological characteristics of sunflower hybrids to obtain information on the possibility of improving the qualities of the plant under study that is useful for agricultural development. During the experiment, the properties of such sunflower hybrids as Ukrainian *F1* (control sample), P62LL109 *Pioneer* (Classic), LG5377

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(*Limagrain*), ES Bella (*Euralis Semans*) and NK Rocky (*Syngenta*) were investigated. Each of these plants is listed in the State Register of Plant Varieties of Ukraine. The methods used in this research work include the production method, weighing and measuring, visual, laboratory and chemical, and mathematical. It was determined that the best indicators of productivity and economic characteristics are observed in three hybrid species, namely Ukrainian F1 (the best morphological characteristics, the highest weight of 1000 seeds, and hulling level), NK Rocky (*Syngenta*) (the highest percentage of fat and oil yield per 1 ha) and P62LL109 (*Pioneer*) (the highest weight of seeds per basket and bulk weight, the lowest hulling level, the highest yield). This may be useful for agricultural enterprises that may be interested in growing new sunflower hybrids with improved productivity and economic characteristics. The results of the study may become an impetus for further research of existing and creation of new sunflower hybrids that will be most useful for agricultural development

Keywords: southern chernozems; agriculture; grain profitability; early ripening group; oil content; yield

INTRODUCTION

The development of new varieties and uninterrupted production of sunflower seeds and other oilseeds, both in Ukraine and globally, is still a pressing issue, given the wide range of factors, including the significant demand for raw materials needed for oil production; climate and weather changes; and changes in the structural components of phytocoenoses. It is also important to consider the adaptive capacity of certain varieties or hybrids and, of course, the active spread and development of plant diseases and pests inherent in sunflowers.

Studies on similar issues were analysed to better understand the level of progress in this area of research. O. Andriienko *et al.* (2020) examined the impact of sowing density on sunflower yield in the Zaporizhzhia region. The results of the study showed that in years with favourable weather, yields increased by 8.6% with an increase in sowing density from 40,000 to 70,000 plants per hectare. In years with unfavourable weather, increasing planting density had no significant effect on yield (Tymchyshyn *et al.*, 2021). In addition, it was found that different sunflower varieties respond differently to changes in sowing density.

O. Andriienko and K. Vasylkovska (2020) studied the effect of plant density on sunflower yield in farms in the Kirovohrad region. The results showed that the optimal planting density of sunflowers in the Ukrainian steppe depends on the specific hybrid and year of cultivation. But, in general, 40-45 thousand plants per hectare is optimal.

It is also worth considering the results of a study conducted by S. Kalenska *et al.* (2020) on the morphological characteristics of plants and yields of sunflower hybrids in the northern part of the forest-steppe zone of Ukraine. The results show that rainfall and high temperatures during the growing season had a positive effect on the yield of hybrids. In addition, correlation analysis showed that plant height had a strong positive relationship with yield, while the number of seeds per head had a moderate positive relationship.

V.M. Lukomets *et al.* (2021) studied current trends in sunflower breeding and genetic improvement. Attention was paid to the main achievements in sunflower breeding, in particular high-yielding hybrids, varieties with high resistance to diseases and pests, as well as hybrids with improved seed and oil qualities. Modern breeding methods and the use of genetic engineering to improve sunflower characteristics are also described.

It is also worth considering the study by H.V. Pantsyreva (2020), which investigated the peculiarities of the formation of legume productivity. The results of the data analysis showed that in the Ukrainian right-bank forest-steppe and steppe regions, the highest productivity of legumes can be achieved by using fertilizers and certain cultivation methods. For example, the use of large amounts of nitrogen has a positive effect on crop productivity, while a decrease in the amount of fertilizer leads to a decrease in yield.

The practical significance of the results lies in the fact that high-quality seed has a significant impact on the productivity and personal quality characteristics of a particular sunflower hybrid, which is economically beneficial for every agricultural enterprise in Ukraine (Nesterchuk, 2017; Shahini *et al.*, 2022a). The research subject is the determination of the processes of sunflower productivity formation in the climatic and geochemical conditions of the Kherson region. The research aims to study the influence of hybrids' biological properties on the level of plant quality and yield and the quality of sunflower seeds. To achieve the goal of this study, the following tasks were defined: to evaluate the existing varietal and hybrid composition of sunflowers in terms of compliance with the complex action of biotic and abiotic factors, as well as to determine the potential of their productivity, study the effect of the length of the growing season on the long-term improvement of the technical qualities of sunflower and increase the productivity of this plant; to determine the effect of vegetation density on the duration of the growth and development phases of sunflower; to study the effect of individual biological properties of certain sunflower hybrids on quality indicators and yield.

MATERIALS AND METHODS

The research was carried out both in the field and in the laboratory on the territory of the Kopani experimental

farm, Kherson region. Field studies were conducted in 2021 in the fields of the northern part of the Kherson region and the area of the sown plot of southern black soil was 100 m^2. The area of the accounting plot was 50 m^2. The studied sunflower hybrids were planted in four rows in a continuous arrangement on one experimental plot. The average seed density was chosen namely 45 thousand units per 1 hectare. The sunflower's predecessor was cereals, in particular winter wheat. Mathematical processing of the results obtained in the course of the work was carried out according to the Student's criterion and using a computer program called Agrostat.

The research objects were selected sowing materials of early ripe hybrids of sunflower plants, namely: ES Bella (*Euralis Semans*), NK Rocky (*Syngenta*), P62GG109 Pioneer (*Classic*), LG5377 (*Limagrain*) and Ukrainian F1 (All-Ukrainian Scientific Institute of Selection). Each of the selected hybrids is listed in the State Register of Plant Varieties of Ukraine and is adapted for active cultivation.

Description of the hybrids used in the study:

Ukrainian F1 (Control). Features: the originator of the variety is VNIS (All-Ukrainian Scientific Institute of Selection). Ukrainian F1 belongs to the early ripe sunflower hybrids. The vegetation period ranges from 103 to 109 days inclusive, which allows farms to grow this hybrid throughout Ukraine. The main advantage of the Ukrainian F1 plant hybrid is its rapid and intensive development in the initial stages of its growth, also known as a quick start. These hybrids can accelerate the development of their root system, while at the same time absorbing the maximum amount of nutrients and moisture dissolved in the soil (Neshev *et al.*, 2022). Subsequently, this provides the plant with increased resistance to stress. Data on the main characteristics of the hybrid are presented in Table 1.

Recommended plant density for sunflower harvesting: 1. Under moderate moisture conditions: from 50 to 55 thousand/ha. 2. Under adequate moisture conditions: from 65 to 70 thousand/ha. Data on the hybrid's resistance to diseases are presented in Table 2.

Table 1. *Main characteristics, morphology, and agronomy*

Origin	**Ukrainian Scientific Institute of Breeding**
Vegetation period	From 103 to 109 days
Crop height	From 172 cm to 180 cm
Oil contents	From 49% to 52%
Ripening group	Early ripening
Capitula diameter	From 21 cm to 25 cm
Capitula angle	Semi-angled
Shedding resistance	High
Drought resistance	High
Yield potential	5.2 t/ha
Hybrid type	Trilinear
Capitula type	Convex

Source: *compiled by the authors*

Table 2. *Disease resistance*

Phomopsis	***Botrytis cinerea Pers.***	***Puccinia helianthi Schw.***	***Sclerotica sclerotiorum***	***Phota oleracea Sass.***	***Plastopara helianthi Hov.***
7 marks	7 marks	9 marks	7 marks	7 marks	7 marks

Source: *compiled by the authors*

These hybrids also can accelerate the development of their root system, while at the same time absorbing the maximum amount of nutrients and moisture dissolved in the soil. Subsequently, this provides the plant with increased resistance to stress. NC Rocky (*Syngenta*). Commercially known as NK Rocky. L-linoleic type of oil content. The highest yields are observed in the early maturity group. This indicator does not decrease in the later stages of sowing (Dosio *et al.*, 2023). Data on the main characteristics of the hybrid are presented in Table 3.

Table 3. *Main characteristics, morphology, and agronomy*

Origin	***Syngenta***
Vegetation period	105 days
Crop height	From 150 to 160 cm
Oil contents	53%
Ripening group	Early ripening
Drought resistance	8 marks
Yield potential	5 t/ha
Herbicide protection system	Traditional
Hybrid type	Simple

Source: *compiled by the authors*

Recommended plant density for sunflower harvesting: 1. Under insufficient moisture conditions: from 35 to 40 thousand/ha. 2. Under adequate moisture conditions: from 45 to 55 thousand/ha. Data on the hybrid's resistance to diseases are presented in Table 4.

It is worth noting that if a farm wants high sunflower yields in the long term, it is necessary to place the plants in rows evenly and take care of the plants according to approved sowing technologies, namely, to observe crop rotation, effectively control weeds and pests and prevent thickening of crops.

LG5377 (*Limagrain*). The originator of LG5377 is the French company "*Limagrain*". It is a hybrid with high yield potential. The high weight of 1000 seeds help to increase yield and product quality (Céccoli *et al.*, 2022). Data on the main characteristics of the hybrid are presented in Table 5.

Table 4. *Disease resistance*

***Sclerotica sclerotiorum* of stem**	***Sclerotica sclerotiorum* of capitula**	***Phomopsis***
8 marks	8 marks	7 marks

Source: *compiled by the authors*

Table 5. *Main characteristics, morphology, and agronomy*

Origin	***Limagrain***
Vegetation period	97 days
Height	From 150 to 160 cm
Oil contents	49%
Ripening group	Early ripening (up to 100 days)
Capitula diameter	From 15 to 19 cm
Mass of 1000 seeds	From 70 to 75 gr
Yield potential	4.9 t/ha
Initial growth energy	9 marks
Herbicide protection system	Traditional
Yield stability	8 marks
Stress resistance	8 marks
Hybrid type	Simple;
Resistance to *Orobanche cumana Wallr.*	None
Cold resistance	9 marks

Source: *compiled by the authors*

Recommended plant density for sunflower harvesting: 1. Under insufficient moisture conditions: from 45 to 55 thousand/ha. 2. Under adequate moisture conditions: from 50 to 60 thousand/ha. Data on the hybrid's resistance to diseases are presented in Table 6.

Table 6. *Disease resistance*

Phoma betae Frank.	*Sclerotium bataticola Taub.*	*Phota oleracea Sass.*	*Sclerotica sclerotiorum* of stem	*Sclerotica sclerotiorum* of capitula	*Phomopsis*	*Plastopara helianthi Hov.*
7 marks	8 marks	8 marks	8 marks	9 marks	9 marks	9 marks

Source: *compiled by the authors*

Hybrid LG5377 is characterized by resistance to stress and moisture deficit, which makes it popular among farmers who grow sunflowers in conditions of water shortage. LG5377 is also highly resistant to lodging and disease. P62LL109 (*Pioneer*). The P62LL109 sunflower hybrid is high-yielding and disease resistant. In addition, the high oil content of this hybrid makes it suitable for growing for use in the food industry (Ahmed *et al.*, 2021a). Data on the main characteristics of the hybrid are presented in Table 7.

Table 7. *Main characteristics, morphology, and agronomy*

Origin	*Pioneer*
Crop height	From 150 to 160 cm
Oil contents	50%
Ripening group	Average-ripening
Mass of 1000 seeds	From 40 to 60 grams
Vegetation period	From 95 to 105 days
Drought resistance	8 marks
Yield potential	5 t/ha
Resistance to *Orobanche cumana Wallr.*	A-E
Growth technology	Traditional
Hybrid type	Simple

Source: *compiled by the authors*

Recommended plant density for sunflower harvesting: 1. Under insufficient moisture conditions: from 45 to 55 thousand/ha. 2. Under adequate moisture conditions: from 50 to 60 thousand/ha. Data on the hybrid's resistance to diseases are presented in Table 8.

Table 8. *Disease resistance*

Phota oleracea Sass.	*Phomopsis*	*Sclerotica sclerotiorum dBy.*
6 marks	7 marks	7 marks

Source: *compiled by the authors*

Excellent adaptability to different soil and weather conditions allows this hybrid to perform well in any region, and the low number of leaves on the P62LL109 plant allows for a higher sowing density. ES BELLA (*Euralis Semans*). ES Bella hybrid is one of the most productive sunflower hybrids on the market. It has high resistance to *Orobanche cumana Wallr* and diseases, making it the best option for growing in the southern regions of Ukraine (Andriienko *et al.*, 2020). Data on the main characteristics of the hybrid are presented in Table 9.

Table 9. *Main characteristics, morphology, and agronomy*

Origin	*Euralis Semans*
Vegetation period	From 100 to 105 days
Crop height	From 150 to 160 cm
Oil contents	From 49% to 51%
Ripening group	Early ripening
Capitula diameter	22 cm
Capitula angle	Downwards
Drought resistance	8 marks

Table 9, Continued

Origin	*Euralis Semans*
Yield potential	5.3 t/ha
Resistance to *Orobanche cumana Wallr.*	Highest in the early-ripening segment (A-G++)
Hybrid type	Moderately intense

Source: *compiled by the authors*

Recommended plant density for sunflower harvesting: 1. Under insufficient moisture conditions: from 55 to 60 thousand/ha. 2. Under adequate moisture conditions: from 60 to 65 thousand/ha. Data on the hybrid's resistance to diseases are presented in Table 10.

Table 10. *Disease resistance*

Sclerotinia sclerotiorum	*Phomopsis*	*Phota oleracea Sass.*
8 marks	8 marks	9 marks

Source: *compiled by the authors*

The ES Bella hybrid is of interest for oil production due to its high oil content. It is characterized by maximum yield potential and a quick start.

A biochemical soil analysis was conducted on a 100-hectare plot at the Kopani Research Farm in Kherson Oblast. The results of the analysis showed that the site has chernozem soils, which differ from chernozem soils in other areas of the Kherson region. A high nitrogen (N) content of 190 mg/kg was found in the soil of the experimental site. This indicates that the use of nitrogen fertilizers may be necessary, but there is a risk of weathering of the humus layer and groundwater contamination if the norm is exceeded.

In general, the soils of the experimental plot have sufficient nutritional value, average biochemical composition, and favourable conditions for growing various crops.

However, additional fertilization and soil fertility improvement measures may be required to improve sunflower cultivation at this site.

The following fertilizers were used to grow sunflowers on southern black soil:

1. Ammonium. They contain a large amount of nitrogen, which is essential for plant growth. Ammonium fertilizers can be used in granular or powdered form, and they dissolve quickly in the soil. In this case, ammonium nitrate was used.

2. Potash. Potassium is necessary to maintain plant resistance to stressful conditions and increase yields. Potassium chloride was used in this study.

3. Phosphorus. Phosphorus is an essential element for plant root growth. In this experiment, superphosphate was used.

It is worth noting that sunflower's need for fertilizer can vary depending on weather conditions (Shahini *et al.*, 2022b). For example, if the soil is wet, the amount of certain macro- and microelements available to the plant may decrease, so more fertilizer may be needed in this case. Also, if there is a drought during the sunflower growing season, the plants may need additional irrigation to ensure normal growth and development (Aslam *et al.*, 2021).

As for the fertilization scheme, fertilizers were applied according to the needs of the plant and its growth stage, by hand. During this study, three fertilizations were carried out. The first application of fertilizer was made 21 days after planting. Nitrogen fertilizers, such as ammonium nitrate, are most effective at this stage. The second fertilization is carried out at the stage of tassel formation (early July). Potash and phosphorus fertilizers were applied. The third feeding was carried out at the stage of seed growth (early August). In this case, potash fertilizers were used. The fertilizer application rates per hectare of sunflower that were used during this research are presented in Table 11.

Table 11. *Fertilizer application rates per hectare of sunflower*

Nitrogen	Phosphorus	Potassium
90 kg/ha	70 kg/ha	90 kg/ha

Source: *compiled by the authors*

It is worth noting that during this study, a variety of farming equipment was used for sunflower cultivation, including cultivators, rakes, and ridged seeders. In the case of southern soils, where drought is a problem, work was sometimes carried out at night when the soil was moister. The frequency of mechanical work depended on the stage of sunflower development and weather conditions (Zhang *et al.*, 2021). The first treatment was carried out after sowing, and the subsequent treatments were carried out 14-21 days after planting.

As for climate and weather conditions, all data is presented in Table 12.

Table 12. *Climatic conditions of the region*

Climate type	Temperate continental
Moisture	Low
Winter	Soft and low snow
Summer	Hot and dry
Precipitation during the year	Uneven
Average annual rainfall	In the north of the right bank, from 400 mm to 430 mm per year, and in the coastal zone from 300 mm to 325 mm per year
Humidification coefficient	0.3, which means that the evaporation rate is higher than the precipitation rate
Average wind speed	From 3.5 to 5 m/s
Average annual temperature	9.8°C
Annual rainfall	From 355 mm to 440 mm

Source: *compiled by the authors*

As for the sunflower harvest, the key aspects of its cultivation were the weight of 1000 seeds, the weight of seeds per basket, the volume weight of seeds, oil content and husk.

RESULTS AND DISCUSSION

During the experiment, significant variability in sowing and yield properties was recorded among the early maturing sunflower hybrids selected for the study. During the study period, the field germination rate of the seed material reached 94.9%, which depended on the viability and weather conditions during the period limited to sowing to germination. In addition, field germination also depended on biological characteristics.

The lowest rates of plant survival and germination at the end of the growing season were recorded in the early maturing sunflower hybrid ES Bella (*Euralis Semans*). These indicators amounted to 93.6% and 94%, respectively. In the early maturing sunflower hybrids P62LL109 (*Pioneer*) and NK Rocky (*Syngenta*), the lowest number of plants that fell out after sowing and at the end of the growing season was found, namely 2.5% and 2.7%. Also, as of 2021, the largest number of plants after sowing and at the end of the growing season survived in the early ripe sunflower hybrid P62LL109 (*Pioneer*), namely 95.4%. Somewhat fewer plants survived for the same period in the early maturing sunflower hybrid NK Rocky (*Syngenta*), namely 95.2%, but compared to the results of other hybrids, these figures are still high. The reason for the different germination rates of seeds of early maturing sunflower hybrids is the influence of various factors on the seed during harvesting, drying and storage. Based on the results of all these factors, varietal, sowing and yield properties of seeds of early ripe sunflower hybrids are formed. The survival of the hybrids at the end of the growing season depended on the soil and climatic conditions of the area where these plants were grown. Also, weather conditions had a significant impact on such criteria as germination and survival of early ripe sunflower hybrids at the end of the growing season.

The phase of the emergence of the 8th pair of true leaves occurred with a slight difference: in the hybrid LG5377 (*Limagrain*) – on the twenty-first day, Ukrainian F1 (control) and ES Bella (*Euralis Semans*) – on the twenty-second day, and in sunflower hybrids P62LL109 (*Pioneer*) and NK Rocky (*Syngenta*) on the twenty-third day after emergence.

The hybrid LG5377 (*Limagrain*) entered the bud stage the fastest, namely on the 52nd day after germination. In the studied plots, the buds of sunflower hybrids Ukrainian F1 (control) and ES Bella (*Euralis Semans*) appeared on the 53rd day, and the buds of hybrids P62LL109 (*Pioneer*) and NK Rocky (*Syngenta*) appeared the latest, on the 54th and 55th day after germination, respectively.

Flowering in the hybrid LG5377 (*Limagrain*) began on the 68th day after germination, and in plants of the early maturing sunflower hybrid Ukrainian F1 (control) flowering began on the 69th day. Plants of hybrids P62LL109 (*Pioneer*) and ES Bella (*Euralis Semans*) were characterized by an even later flowering period with the beginning of flowering on the 70th day. The later period was observed in the sunflower hybrid NK Rocky (*Syngenta*), the beginning of flowering which occurred on the 71st day after germination.

The shortest period from germination to full ripeness was recorded in the hybrid LG5377 (*Limagrain*), which was 102 days. Plants of hybrids ES Bella (*Euralis Semans*) and P62LL109 (*Pioneer*) were characterized by a slightly shorter period, namely 104 and 106 days, respectively. The longest period was in sunflower hybrids Ukrainian F1 (control) and NK Rocky (*Syngenta*), namely 107 and 109 days, respectively.

Thus, considering all the above, it can be established that in the early stages of the life cycle of early maturing sunflower hybrids, namely before the flowering phase, the highest growth intensity was in the

hybrids Ukrainian F1 (control) and LG5377 (*Limagrain*). In other hybrids, the growth rate was average at the initial stage of development.

In the case of crops, it is necessary to have information about the elements that make up the crop to have a balanced impact on plant productivity. Some of the most important morphobiological signs of any plant growth are stem height, leaf area, number of leaves, and head diameter. Observing them provides information on the state of plant development.

Table 13 presents the data obtained during the survey.

Table 13. *Biometric parameters of sunflower hybrids were obtained during the experiment*

Sunflower hybrids	Stem height, cm	Stem diameter, mm	Capitula diameter, cm	Leaf count, pcs.
Ukrainian F1 (control)	172.7	23.6	23.9	33.7
NK Rocky *(Syngenta)*	162.8	22.2	23.5	32.4
LG5377 *(Limagrain)*	159.5	20.8	19.8	29.9
P62LL109 *(Pioneer)*	160.6	23.1	22.6	33.1
ES Bella *(Euralis Semans)*	158.1	21.7	21.3	28.9

Source: *compiled by the authors*

Following the results, among all hybrids, the tallest plants were recorded in the Ukrainian F1 (control) hybrid (172.7 cm). This hybrid is also characterized by the largest diameter of the basket (23.9 cm), stem diameter (23.6 mm) and the largest number of leaves (33.7 pcs). The shortest plants were recorded in sunflower hybrids LG5377 (*Limagrain*) and ES Bella (*Euralis Semans*), 159.5 cm and 158.1 cm, respectively. It was also found that they have the smallest basket diameter (19.8 cm and 21.3 cm), stem diameter (20.8 mm and 21.7 mm), and the lowest number of leaves (29.9 pcs and 28.9 pcs). The sunflower hybrids NK Rocky (*Syngenta*) and P62LL109 (*Pioneer*) showed average biometric parameters. All the results are presented in Table 14.

Table 14. *Data on crop structure and seed quality were obtained*

Sunflower hybrids	Mass of 1000 seeds, g	Mass of seeds from one capitula, g	Volume weight of grain, g	Huskiness, %	Oil content, %
Ukrainian F1 (control)	71.7	83.4	384.8	23.9	49.9
NK Rocky *(Syngenta)*	66.5	84.2	392.1	21.8	52.6
LG5377 *(Limagrain)*	71.0	78.1	385.7	23.2	49.2
P62LL109 *(Pioneer)*	66.2	84.8	393.9	21.4	50.8
ES Bella *(Euralis Semans)*	69.0	81.3	389.0	22.4	50.5

Source: *compiled by the authors*

The weight of 1000 grains is one of the most important aspects of sunflower yield formation and has a wide range of fluctuations, depending on the biological characteristics of a particular hybrid. In the hybrid Ukrainian F1 (control), this indicator is the highest and reached an average of 71.7 g. Also, this indicator was high in the hybrid LG5377 (*Limagrain*) (71.0 g). Plants of hybrids NK Rocky (*Syngenta*) and P62LL109 (*Pioneer*) had the lowest performance in this aspect – 66.5 g and 66.2 g, respectively. As for the weight of seeds per basket, this indicator was the highest in hybrids NK Rocky (*Syngenta*) and P62LL109 (*Pioneer*), namely 84.2 g and 84.8 g. The lowest result was found in the hybrids ES Bella (*Euralis Semans*) and LG5377 (*Limagrain*) (81.3 g and 78.1 g). All results are presented in Table 15.

Table 15. *Yields of early ripe sunflower hybrids, as of 2021*

Sunflower hybrids	Mass of 1000 seeds, g	Mass of seeds from one capitula, g	Yield, t/ha	± to control, t/ha
Ukrainian F1 (control)	71.7	83.4	3.89	-
NK Rocky *(Syngenta)*	66.5	84.2	4.05	+0.16
LG5377 *(Limagrain)*	71.0	78.1	3.47	=0.42
P62LL109 *(Pioneer)*	66.2	84.8	4.14	+0.27

Table 15, Continued

Sunflower hybrids	Mass of 1000 seeds, g	Mass of seeds from one capitula, g	Yield, t/ha	± to control, t/ha
ES Bella *(Euralis Semans)*	69.0	81.3	3.64	-0.25

Source: *compiled by the authors*

The volumetric weight of the grain characterizes the weight of seeds in each volume (in Ukraine – the weight of seeds per 1 litre). This indicator was the highest in the hybrids NK Rocky (*Syngenta*) and P62LL109 (*Pioneer*) and amounted to 392.1 g and 393.9 g, respectively. The lowest grain weight was in the hybrids Ukrainian F1 (control) and LG5377 (*Limagrain*) (384.8 g and 385.7 g). The highest index of seed hulling was observed in two hybrids, namely Ukrainian F1 (control) and LG5377 (*Limagrain*) (23.9% and 23.3%, respectively). The lowest index was observed in hybrids NK Rocky (*Syngenta*) and P62LL109 (*Pioneer*), namely 21.8% and 21.4%.

The oil content in the presented hybrids ranged from 49.2% to 52.6% inclusive. The highest oil content was recorded in the plants of hybrids NK Rocky (*Syngenta*) and P62LL109 (*Pioneer*) and it was 52.6% and 51.8%. The lowest index was recorded in hybrids LG5377 (*Limagrain*) and Ukrainian F1 (control), 49.2% and 49.9%, respectively. All results are presented in Table 16.

Table 16. *Oil yields from 1 hectare of early ripe sunflower hybrids*

Sunflower hybrids	Yield, t/ha	Oil contents, %	Oil yield per 1 ha, t/ha	± to control, t/ha
Ukrainian F1 (control)	3.89	49.9	1.67	-
NK Rocky *(Syngenta)*	4.05	52.6	1.83	+0.16
LG5377 *(Limagrain)*	3.47	49.2	1.47	=0.20
P62LL109 *(Pioneer)*	4.14	50.8	1.80	+0.13
ES Bella *(Euralis Semans)*	3.64	50.5	1.59	-0.08

Source: *compiled by the authors*

Following the results of the biochemical analysis of the southern chernozem soil at the experimental site, the soil pH is 6.8, which is optimal for most cultivated plants. The humus content was 4.2%, which is quite high and indicates that the soil is in good condition. The P_2O_5 and K_2O content in the soil is 150 mg/kg and 210 mg/kg, respectively, which are also good indicators for the growth of various cultivated plants. It was also found that the soil of the site contains enough macro- and microelements necessary for plant growth, such as calcium (Ca), magnesium (Mg), iron (Fe), copper (Cu), zinc (Zn) and manganese (Mn). The presence of these elements in the soil is sufficient for growing a wide range of crops. All the results of the biochemical analysis are presented in Table 17.

Table 17. *Results of biochemical soil analysis*

pH	Humus	N	P_2O_5	K_2O	O_2	CO_2	H_2CO_3	Fe	Mn	Cu	Zn	B
6.8	3.5%	0.11%	0.15%	0.19%	0.3 mg/kg	0.05 mg/kg	0.2 mg/kg	40 mg/kg	4 mg/kg	2 mg/kg	10 mg/kg	0.5 mg/kg

Source: *compiled by the authors*

These indicators indicate that the soils in the study area have an average level of humus, nitrogen, and phosphorus, with a high level of potassium. Dissolved oxygen, CO_2 and H_2CO_3 have low values. The content of trace elements in the soil is at a satisfactory level, with particularly high levels of iron and zinc. The effect of ammonium, potassium and phosphorus fertilizers on sunflower growth and productivity was studied on all five hybrids selected for this research (Giannini *et al*., 2022).

The results showed that the application of ammonium fertilizers had a positive effect on the growth and productivity of all sunflower hybrids, except for P62GG109 *Pioneer* (Classic). The hybrids ES Bella (*Euralis Semans*) and LG5377 (*Limagrain*) showed the best results compared to the control group. The application of phosphate fertilizers had a positive effect on the formation of the sunflower root system. The best effect was seen in the hybrids NK Rocky (*Syngenta*) and P62GG109 *Pioneer* (Classic). The least pronounced effect of phosphorus fertilizers was in hybrids LG5377 (*Limagrain*) and Ukrainian F1 (control).

Potash fertilizers had a positive effect on all sunflower hybrids, except for Ukrainian F1, where the effect was less pronounced. The greatest improvement in plant health and resistance to stressful conditions was observed in hybrids ES Bella (*Euralis Semans*) and NK Rocky (*Syngenta*). Thus, the results of the study indicate that the application of ammonium, potassium and phosphorus fertilizers had a positive effect on the growth and productivity of the plants under study.

However, in addition to fertilizers, the development of sunflower hybrids in 2021 was also influenced by early autumn after a dry summer. Such conditions contributed to the early formation of the root system and stimulated plant growth. However, in late summer, the weather became wet, leading to disease and pest outbreaks. All hybrids developed fungal diseases on the leaves when the optimum amount of precipitation was exceeded: hybrids ES Bella (*Euralis Semans*) and LG5377 (*Limagrain*) were the most resistant to these diseases, while hybrid P62GG109 *Pioneer* (Classic) was the least resistant to them.

Weather conditions play an important role in sunflower cultivation, as the crop requires sufficiently high temperatures and precipitation to produce a rich harvest (Chandrashekar and Krishnadoss, 2022). Low temperatures and frequent frosts in March and April 2021 resulted in delayed sowing and germination. In addition, high precipitation in March and April resulted in flooding of some ploughed fields and delayed ploughing. In May and June, high temperatures and sufficient rainfall provided favourable conditions for sunflower growth. However, in early July, the region was hit by a severe drought, which negatively affected plant development and productivity. Nevertheless, despite the negative factors, as of 2021, the amount of precipitation required for plant growth and development was generally sufficient. Temperature conditions were also favourable for the crops. All early maturing sunflower hybrids emerged on the fourteenth day after sowing and did not depend on any biological characteristics of the hybrids.

In the studies of sunflower hybrids ES Bella (*Euralis Semans*), NK Rocky (*Syngenta*), P62GG109 *Pioneer* (Classic), LG5377 (*Limagrain*) and Ukrainian F1 (All-Ukrainian Scientific Institute of Selection), some changes in growth and yield related to weather conditions were recorded. The most vulnerable to drought were hybrids P62GG109 *Pioneer* (Classic) and Ukrainian F1 (control). At the same time, the hybrids ES Bella (*Euralis Semans*), NK Rocky (*Syngenta*) and LG5377 (*Limagrain*) showed increased resistance to drought and slight yield losses compared to the first two hybrids.

Considering the results obtained, it can be concluded that the hybrids ES Bella (*Euralis Semans*), NK Rocky (*Syngenta*) and LG5377 (*Limagrain*) showed the most stable productivity when growing sunflowers in this experimental plot. Since it was found that the application of ammonium, potassium and phosphorus fertilizers has a significant impact on the growth and productivity of sunflowers, it is necessary to calculate the optimal amount of fertilizer for each hybrid individually, considering its characteristics and requirements for soil and climate.

Based on the data obtained, it can be concluded that there is an inverse relationship between the weight of 1000 seeds and the bulk weight and size of the seeds: larger seeds had a lower bulk weight and weight of 1000 seeds, and smaller seeds had a higher bulk weight. In addition, small seeds had a lower hulling index and higher oil content.

The results of other studies are also worth considering. M.A. Ahmed *et al.* (2021b) considered the heterosis of sunflower seeds. Seed yields were higher in hybrids with dominant or superdominant genes. As for the oil content, it had a positive and significant heterosis for all hybrids when compared to plants with mothers of better genetic structure. Significant differences between genotypes were also observed in terms of average seed yield and fatty acid traits. Heterosis indices for the studied aspects were significant in almost all hybrids. It was determined that the non-additive and additive effects of genes are actively involved in the inheritance of all traits. Dominant variances ($\sigma 2D$) were higher for oil quality and grain yield of sunflower compared to additive variances ($\sigma 2A$).

Another study that deals with the genetic aspect is the research work of H.G.M.D. Ahmed *et al.* (2022), who examined the molecular characteristics of hybrid sunflower varieties and their authenticity. The results showed that 10 hybrids are authentic, i.e., their genetic characteristics match the description provided by the manufacturer. In addition, the molecular characterization, using SSR markers, allowed us to identify different alleles present in the hybrids, which can be useful for further improvement of breeding programs.

It is also worth mentioning the results of a study conducted by A. Radanović *et al.* (2018). They examine the genetic structure of sunflowers from ancestors to modern hybrids. The genetic characteristics of sunflowers, including genomes, chromosomes, genetic markers, physiological and biochemical characteristics, and factors affecting the development of sunflowers are described in detail. The mechanisms of formation of new combinations of genes used in breeding to create new, more productive sunflower hybrids were analysed.

A. Sher *et al.* (2022) focused on studying the effects of different irrigation sources on sunflower yield and oil quality. The study was conducted using different sunflower hybrids and three irrigation sources (rainfall, ordinary water, and saltwater). The results showed that using ordinary water for irrigation increased yields and improved oil quality. In contrast, the use of salt water reduced yields and oil quality. The amount of precipitation did not have a significant effect on yield and oil quality.

It is also worth considering the study by V. Tyagi *et al.* (2020), which determined the heterotic effects of different combinations of cytoplasm in sunflower hybrids grown under different irrigation conditions. The results showed that hybrids combining corn and pea cytoplasm were the most productive. It was also found that hybrids with corn cytoplasm were less sensitive to water deficit, while hybrids with sunflower cytoplasm were more sensitive.

M. Ghaffari *et al.* (2021) evaluated the resistance and yield of sunflower hybrids using genotypic analysis. The results showed that sunflower hybrids planted in different regions of Iran had different yields. The analysis of genotype-environment interaction also helped to identify the most stable and productive sunflower genotypes under different conditions. In general, the study by M. Ghaffari *et al.* (2021) showed that the stability and yield of an average sunflower hybrid vary widely in different conditions but can be predicted by analyzing the genotype and environment.

In general, considering the above studies and comparing them with this research, similarities in the final results can be seen. This can be useful for breeding to grow more productive sunflower hybrids in Ukraine, as well as for increasing the efficiency of growing this crop in this region.

CONCLUSIONS

Based on the research results, it can be concluded that each of the presented early maturing sunflower hybrids produced a grain yield that largely depended on the biological characteristics of a particular hybrid. It is also worth noting that the weather conditions favourable for the research made it possible to study the genetic potential of the experimental objects, giving the plants everything, they needed for intensive growth and development. As a result of the research, it was found that the highest yields among early maturing sunflower hybrids were shown by P62LL109 (*Pioneer*) and NK Rocky (*Syngenta*) (4.14 t/ha and 4.05 t/ha). During the study, it was also found that the field germination rate of the seed of early-ripening sunflower hybrids is within 94.9%. As for the morphological parameters, they are the highest in the Ukrainian F1 hybrid (control) (height – 172.7 cm; stem diameter – 23.6 mm; basket diameter – 23.9 cm; the number of leaves per stem – 33.7 pcs).

Regarding the characteristics of seeds, the weight of 1000 grains is also the highest in this hybrid (71.7 g). However, the weight of seeds from one basket was the highest in hybrids P62LL109 (*Pioneer*) and NK Rocky (*Syngenta*), namely 84.8 g and 84.3 g. The volumetric weight of grain was also the highest in these two hybrids (P62LL109 (*Pioneer*) – 393.9 g; NK Rocky (*Syngenta*) – 392.1 g). The highest level of huskiness is inherent in the sunflower hybrid of the early maturing group Ukrainian F1 (control) and hybrid LH5377 (*Limagrain*), namely 23.9% and 23.2%, respectively. The lowest indicators in this aspect were recorded for hybrids P62LL109 (*Pioneer*) and NK Rocky (*Syngenta*) (21.4% and 21.8%). Regarding fat content, the highest percentage was observed in hybrids P62LL109 (*Pioneer*) and NK Rocky (*Syngenta*), namely 50.8% and 52.6%, and the lowest – in hybrids Ukrainian F1 (control) and LG5377 (*Limagrain*) (49.9% and 49.2%).

The hybrids P62LL109 (*Pioneer*) and NK Rocky (*Syngenta*) yielded the highest yields of 4.14 t/ha and 4.05 t/ha. The oil yield per 1 ha was also the highest in these two hybrids: P62LL109 (*Pioneer*) – 1.80 t/ha; NK Rocky (*Syngenta*) – 1.83 t/ha. The highest indicators of profitability and economic efficiency were also presented by sunflower hybrids NK Rocky (*Syngenta*) and P62LL109 (*Pioneer*).

Considering all the results obtained in the course of writing this paper, to improve seed quality and increase the yield of sowing material, it is worth sowing certified seeds of high-quality sunflower hybrids Ukrainian F1 (control), NK Rocky (*Syngenta*) and P62LL109 (*Pioneer*) at the optimal sowing density of 45 thousand units per 1 hectare and regularly and timely carry out all necessary agronomic measures, which will increase the quality of the final product and increase the final net profit for the agricultural enterprise.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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Аналіз господарсько-біологічних особливостей та продуктивності гібридів соняшнику

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Анотація. Оцінювання біологічних особливостей гібридів соняшникута їх потенційні можливості для підвищення корисних для розвитку сільського господарства якостей досліджуваної рослини вважається актуальним. Метою даної наукової роботи є уважне та поглиблене оцінювання біологічних особливостей гібридів соняшнику задля отримання інформації, що стосується можливості підвищення корисних для розвитку сільського господарства якостей досліджуваної рослини. В ході експерименту було досліджено властивості таких гібридів соняшнику, як Український *F1* (він же контрольна проба), П62ЛЛ109 *Pioneer* (Класичний), ЛГ5377 (*Limagrain*), ЕС Белла (*Euralis Semans*) та НК Роккі (*Syngenta*). Кожна з перерахованих рослин занесена у Державний реєстр сортів рослин України. Серед методів, які були використані в даній науковій роботі, є виробничий метод, вимірювально-ваговий, візуальний, лабораторно-хімічний, а також математичний. Було визначено, що найкращі показники продуктивності та господарських особливостей спостерігаються у трьох гібридних видах, а саме Український F1 (найкращі морфологічні показники, найвища маса 1000 насінин та рівень лушпинності), НК Роккі (*Syngenta*) (найвищий відсоток жиру та вихід олії з 1 га) і П62ЛЛ109 (*Pioneer*) (найвища маса насінин з одного кошика та об'ємна маса, найнижчий рівень лушпинності, найвищий рівень врожаю). Це може бути корисно для сільськогосподарських підприємств, які можуть зацікавитися у вирощуванні нових гібридів соняшнику з покращеними показниками продуктивності та господарських особливостей. Результати дослідження можуть стати поштовхом для подальшого дослідження наявних і створення нових гібридів соняшника, які будуть максимально корисні для розвитку сільського господарства

Ключові слова: південні чорноземи; сільське господарство; рентабельність зерна; ранньостигла група; олійність; врожайність