AGRICULTURAL UNIVERSITY – PLOVDIV

FACULTY OF AGRONOMY
DEPARTMENT OF CROP SCIENCE

BOZHIDAR FRANTSOV TANCHEV

Responses of Bulgarian sunflower hybrids (*Helianthus annuus* L.) to contrasting agroecological conditions.

Abstract

On a PhD thesis for the award of the educational and scientific degree "Doctor"
Scientific specialty: Field crops

Scientific supervisors:
Prof. Dr. Hristofor Kirchev
Assoc. Prof. Dr. Galin Georgiev

Plovdiv
2026

The study was conducted during the period 2023 – 2025. One experiment was conducted in the Plovdiv agro-ecological region - the village of Zhitnitsa, Kaloyanovo municipality, and the other - in the Dobrich agro-ecological region - the village of Petleshkovo, General Toshevo municipality.

The dissertation contains 163 typewritten pages, 26 tables and 27 figures. The list of cited literature includes a total of 167 literary sources, of which 14 are in Cyrillic and 153 in Latin.

The dissertation work was discussed at a departmental council.

The defense of the dissertation will take place on …… 2026 at …….. time at a meeting of the Specialized Scientific Jury at the Agricultural University of Plovdiv,

with members:
Internal members:
Prof. Dr. Nurettin Tahsin
Assoc. Prof. Dr. Zhivko Todorov

External members:
Prof. DSc. Alexander Matev – IPGR, Sadovo
Assoc. Prof. Dr. Daniela Valkova – DAI, Gen. Toshevo
Assoc. Prof. Dr. Galina Mihova – DAI, Gen. Toshevo

INTRODUCTION

The sunflower (*Helianthus annuus* L.) originates from the steppe of North America, where wild forms are still found. Compared historically with other important field crops (wheat, barley, corn, rice, etc.) which have been cultivated by man since the Neolithic period, it is a new agricultural crop, having been brought to Europe in 1510 (16th century), initially grown as an ornamental plant and for seeds. It was not until the 18th century that its widespread cultivation for sunflower oil, which is of high quality, began.

The area under sunflower in the world has grown from 65 million da in the early 1950s to 100 million da in the 1980s, reaching over 295 million da in the 20s of the 21st century . In recent years, intensive work has been done in the field of selection of high-yielding and high-oil hybrids, and considerable success has been achieved. As a result, the rate of area growth lags behind the rate of production of seeds and sunflower oil, which are growing significantly.

The main factors determining the productivity and quality of production in modern intensive sunflower production are the approach to the choice of hybrid, combined with the specific agro-ecological conditions. Over the past 20 years, a trend has emerged in Bulgaria towards the gradual abandonment of Bulgarian sunflower hybrids in favor of foreign ones, and currently the sunflower varietal composition is represented entirely by imported hybrids. In Bulgaria, sunflower breeding has traditions and globally recognized successes, especially in the late 80s and early 90s. And now Bulgarian sunflower hybrids are offered and grown in neighboring European countries - Romania, Moldova and Ukraine.

Based on what has been said so far, it can be concluded that the importance of sunflower for Bulgarian agriculture has undoubtedly increased. Its position as the second most important field crop in terms of area and importance requires detailed research on the agronomic aspects of production, adequate to the selection achievements in this crop.

OBJECTIVES AND TASKS

- Objective: To determine the influence of different agro-ecological conditions on some biological and economic qualities of Bulgarian sunflower hybrids.

- Tasks:

1. To study the phenological development of sunflower in order to establish the duration of the interphase periods depending on the agro-ecological region.
2. To study the productive indicators (seed, oil and meal yields) and plant structure of sunflower hybrids depending on soil and climatic conditions.
3. To investigate the qualities of seeds, oil and meal of sunflower hybrids under contrasting agro-ecological conditions.

4. To establish the stability of sunflower hybrids under genotype-×environment interaction.
5. To establish the correlations between the studied quantitative and qualitative indicators of sunflower hybrids.

MATERIAL AND METHODS.

1. Field experiments

To achieve the goal and objectives of the study, two parallel three-year field trials were conducted during the period 2023-2025.

One experiment was conducted in the Plovdiv agro-ecological region - the village of Zhitnitsa, Kaloyanovo municipality, and the other - in the Dobrich agro-ecological region - the village of Petleshkovo, General Toshevo municipality.

The experiments were conducted using the block method in 4 replications with an experimental area of 28 m^2.

1.1. Factors studied and their levels:

Factor A – Hybrid
- A1 – P64LP170 – Corteva (standard)
- A2 – Dalena CLP – DAI – Gen. Toshevo
- A3 – Deveda – DAI – Gen. Toshevo
- A4 – Enigma CLP – DAI – Gen. Toshevo
- A5 – Krasela – DAI – Gen. Toshevo
- A6 – Sunny IMI CLP – DAI – Gen. Toshevo

Factor B – Agro-ecological region
- B1 – Plovdiv
- B2 – Dobrich

2. Biological indicators

2.1. Phenological development

- Recording the occurrence of the main phenological phases (Schneiter and Miller , 1981):

Sowing (V0), germination (VE), second pair of true leaves (V2), fourth pair of true leaves (V4), budding (R1), beginning of flowering (R5), end of flowering (R6), ripening (R9).

- Duration of interphase periods (number of days).

2.2. Biometric indicators - determined from representative samples of 10 plants as follows:

- stem length, cm (DS)
- stem thickness, mm (DEC)
- stem mass, g (MS)
- stem density, mg /cm^3 (PS)

- leaf mass, g (ML)
- diameter of the disk, cm (DP)
- number of seeds per disk (BSP)
- mass of the disk, g (MP)
- seed mass in the disk, g (SME)
- disk density, number of seeds/cm ^{2} (PP)

2.3. Productivity indicators

- Seed yield, kg/da
- Harvest index of the plant – calculated as the ratio of seed yield to the total biological yield of the plant;
- Harvest index of the disk – calculated as the ratio of seed yield to the total biological yield of the disk;
- Seed harvest index – calculated as the ratio of kernel mass to total seed mass;
- Oil yield, kg / da
- Meal yield, kg / da

2.4. Seed quality:

- oil content in seeds, %
- mass of 1000 seeds, g – by weighing two samples of 500 seeds (BDS 13358-76);
- test weight, kg – by chondrometer (cylinder with a capacity of 1 liter) (BDS ISO 7971-2);

2.5. Oil quality:

- unsaturated fatty acid ratio;
- fatty acid composition of the oil, %

2.6. Quality of meal:

- crude protein content, g/kg dry matter
- amino acid composition of the protein – through a regression equation (Degussa , 2001) of the type y = a + b * x , where:
  y – amino acid, g/kg dry matter
  a – free member,
  b – regression coefficient
  x – crude protein, g/kg dry substance

3. Chemical analyses

3.1. Soil agrochemical analyses – annually before sowing from the 0-60 cm layer, to determine:

- pH (BDS ISO 10390:2022)
- mobile nitrogen content, mg/kg (ISO/TS 14256-1:2003)
- mobile phosphorus (P_2O_5) mg /100g (ISO 22036:2008)
- mobile potassium (K_2O) mg /100g (ISO 22036:2008)
- hummus, g/kg (BDS ISO 14235:2002)

3.2. Plant seed analyses.

- Determination of crude fats – (BDS – 3412);
- Determination of crude protein – (BDS – 13490);
- Fatty acid composition of the oil – by gas chromatography (ISO 12966).

SOIL-CLIMATIC CHARACTERISTICS

1. Soil characteristics

Plovdiv region

The Upper Thracian Plain is the largest lowland in Bulgaria. It is part of the historical and geographical region of Thrace, and in Bulgaria the lowland is often called only Thrace. The morpho- hydrographic and physio-geographical features of the lowland give reason to divide it into two sub-regions - Western (Pazardzhik-Plovdiv Plain) and Eastern (Starozagorsk Plain), with the two fields being separated by the Chirpan Hills. The land of the village of Zhitnitsa is located in the western sub-region of the lowland at an altitude of 232 m above sea level, on the right bank of the Pikla River.

On the unconsolidated Pliocene lake sediments and the impact of the Mediterranean climate have determined the wide distribution of the tar soils in the region (Filcheva, 2007). Unlike the chernozem and gray forest soils, the tar soils were formed in the conditions of the transitional-continental climate on heavy clay materials and grassy-marsh vegetation. Soils of this type are characterized by a relatively thick humus horizon, reaching 50-80 cm in the Zhitnitsa region, where the leached Smolnici . By structure and structure, it is divided into two parts - upper (loose subhorizon) and lower (fused subhorizon). It has a black color and a granular- powdery structure, and the transition between the individual horizons is gradual.

Dobrich region

Dobrudja occupies the northeastern part of the country and borders Romania to the north, the Black Sea to the east, the Ludogorets Plateau to the west, and the Varna-Provadia lowland to the south. Geographically, it represents the southern part of the Dobrudja Plateau, which continues north into Romania to the mouth of the Danube River.

The land of the Dobrudzha Agricultural Institute is located in the eastern flat part of the Dobrudzha Plateau. The altitude of the Institute's land is 236 m.

Studies in the experimental field of the Institute show that it is located on a weakly leached chernozem (Yolevsky et al., 1959). The most characteristic morphological features of these soils are: dark gray with a brown tint of the humus horizon; a relatively thick humus horizon, which ranges on average between 60-80 cm.

Weakly leached chernozems are uniform in mechanical composition - heavy sandy-clay throughout the depth of the profile. They are classified as soils

with good structure. Their mechanical composition determines a favorable water regime. The bulk density characterizes weakly leached chernozems as soils with a loose structure throughout the depth of the entire profile. Weakly leached chernozems do not retain large amounts of water that is not available to plants.

Table 1. Agrochemical analysis of soil before sowing sunflower.

Year	Area	pH	N, mg / kg	P2O5, mg / 100 g	K2O, mg /100 g	Hummus, g/ kg
2023	Plovdiv	7.45	14.3	5.1	32.4	22.3
	Dobrich	6.95	45.6	6.7	13.8	29.9
2024	Plovdiv	7.78	18.16	9.06	35.8	27.4
	Dobrich	6.93	28.51	12.16	23.41	26.48
2025	Plovdiv	7.01	9.1	5.15	34.41	16.96
	Dobrich	5.93	19.19	6.36	20.99	19.56

2. Climatic characteristics

Plovdiv region

The climate in the area where the experiment was conducted – the village of Zhitnitsa, Kaloyanovo municipality – is transitional continental (Sabev and Stanev, 1963). The foothills of Sredna Gora protect the territory of the municipality from sudden changes in temperature during the seasons, there are no prolonged and cold winds. There are no sudden changes in temperatures during the individual seasons. The climate is characterized by mild winters (the average January temperature is 1°C) and warm and dry summers. The coldest month is January, and the warmest is July. The Maritsa River basin also has a significant influence on the climatic conditions.

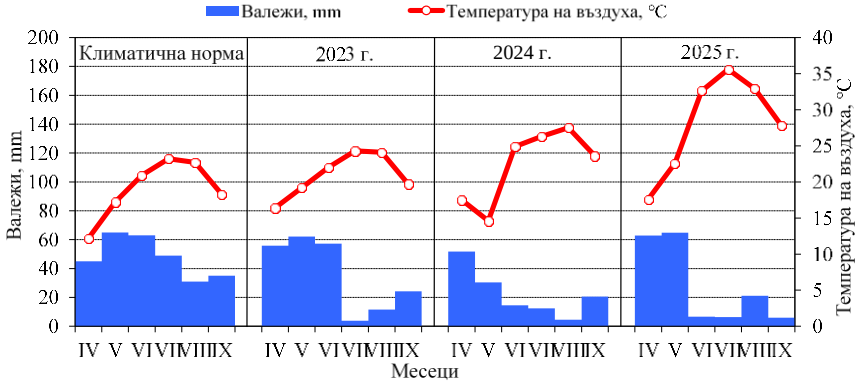

Figure 1. Climatogram of the Plovdiv region.

Dobrich region

In terms of climate, Dobrudja falls into the middle and eastern climatic region of the Danube Hilly Plain, included in the temperate continental climatic subregion and the climatic region of the Northern Black Sea Coast in the Black Sea climatic subregion (Sabev and Stanev, 1963), but most of its territory is located in the eastern climatic region, in which the research was carried out.

The coldest month is January with an average monthly temperature of 0.7 °C. Winter frosts are weaker compared to those of the northern and middle climatic regions and the number of days with negative daily temperatures is 35-45.

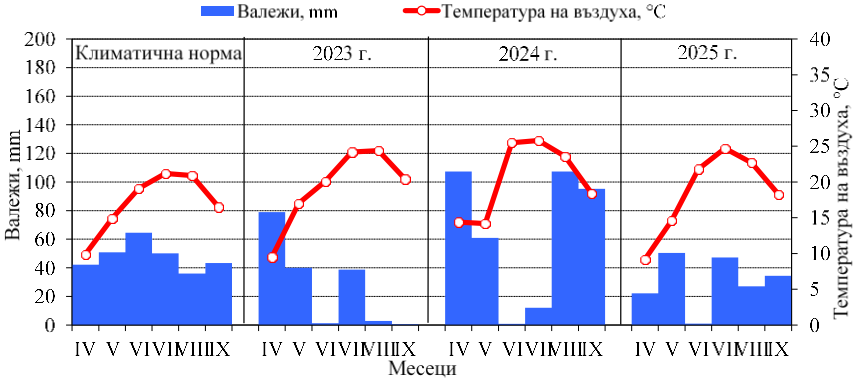

Figure 2. Climatogram of the Dobrich region.

RESULTS AND DISCUSSION

1. Phenological development

In 2023, the interphase period sowing-emergence has a very different duration in the two regions – in Dobrich it lasts 13-15 days, while in the Plovdiv region it lasts 19-28 days. The reason for the prolonged germination period in Southern Bulgaria is the low temperatures in March. The remaining interphase periods do not differ significantly between the two regions, nor between the hybrids. Although the ripening in Plovdiv is about one month earlier than in Dobrich, due to the prolonged germination, the vegetation period in Southern Bulgaria is between 136-138 days, while in Dobrudzha the sunflower vegetation is between 130-134 days.

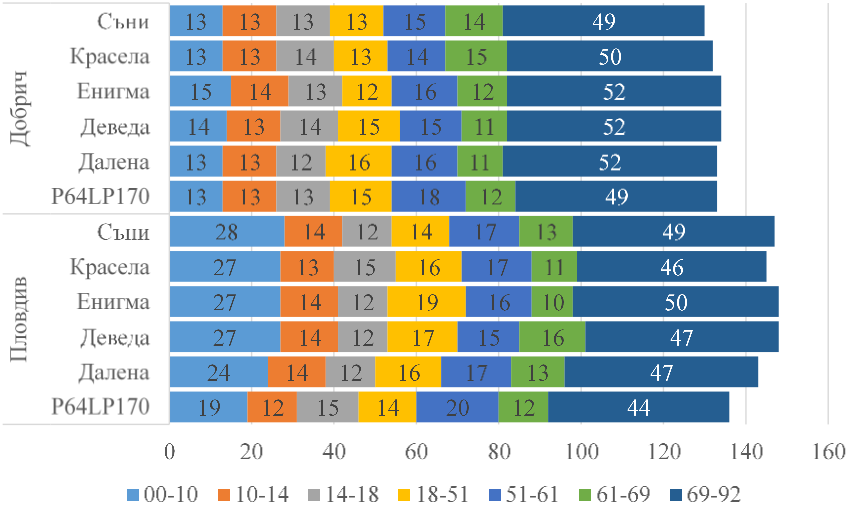

Figure 3. Duration of interphase periods 2023

In the second year of the study, the interphase periods did not differ significantly, both between the two regions and between the hybrids until the moment of the latter. The figure clearly shows that the ripening period in the Plovdiv region is between 12-22 days shorter than that in the Dobrich region, with the largest difference being in the Krasela hybrid and the smallest in Dalena. CLP. This difference is due to the extremely warm summer and the lack of precipitation of economic importance during the period in the Plovdiv region. Last year, the growing season in Southern Bulgaria was between 115-120 days, while in the Dobrudja region it lasted 133-134 days.

In the third year of the study, the interphase periods did not differ significantly, both between the two regions and between the hybrids until the onset of the pre-midday and the last. The figure clearly shows that the end of flowering period in the Plovdiv region is between 4-7 days shorter than that in the Dobrich region, with the largest difference being in the Deveda hybrid, and the smallest in P64LP170 and Sunny IMI CLP. The same thing is observed during the ripening period of the plants. The largest difference is between the hybrids Dalena and Krasela (5 days), and the smallest between P64LP170 and Enigma (2 days). Over the past year, the growing season in Southern Bulgaria was between 126-130 days, while in the Dobrudzha region it lasted 137-141 days.

2. Plant structure

On average for the three years of the study, the stem length (SL) of the hybrids P 64 LP 170, Dalena, Deveda, Krasela and Sunny is greater in the Dobrudja

region. Only the Enigma hybrid forms longer stems in the Southern Bulgaria region. The tallest plants in the Plovdiv region are formed by the Sunny hybrid (149.6 cm), and in the Dobrich region – by the standard P 64 LP 170 (153 cm). In all three harvest years, in both regions, the shortest-stemmed hybrid is Deveda - 123.2 cm in Plovdiv and 127.2 cm in Dobrich. The difference between the tallest and the shortest hybrid in Plovdiv is 26.4 cm, and in Dobrich – 25.8 cm.

In the next stem characteristic – thickness (D E C) at the P 64 LP 170 standard, Delena and Sunny plants form thicker stems in the Thracian region, while Deveda and Krasela have higher results in the Dobrudzha region. Only the Enigma hybrid forms equally thick stems in both regions – 16.77 mm. On average for the three years, the smallest difference between the two regions is for the Krasela hybrid – 0.2 mm, and the largest – for Dalena – 1.84 mm. The thinnest stem in the Plovdiv region is formed by Deveda – 16.63 mm, and in Dobrich by the Dalena hybrid – 15.23 mm .

On average for the three harvest years, the stem mass (SM) has been proven to be higher in the Plovdiv region for all studied hybrids. The smallest difference between the two regions is for the Deveda hybrid – 8.23 g, and the largest difference is for the Sunny hybrid – 22.2 g. In the Plovdiv region, the heaviest stem is formed by the Sunny hybrid – 74.6 g, and in Northern Bulgaria the standard P 64 LP 170 – 60.7 g.

Table 2. Structural elements of the vegetative organs of sunflower on average for the three years.

A Hybrid	In Area	DS	DES	MS	PS	ML
P64LP170	P	147.80	16.83	75.30	2.28	34.77
	D	153.03	16.43	60.70	1.98	35.63
Dalena	P	131.70	17.07	71.77	2.34	45.13
	D	137.03	15.23	50.52	20.1	36.10
Deveda	P	123.23	16.63	57.80	2.07	40.70
	D	127.27	17.07	49.57	1.78	32.57
Enigma	P	142.00	16.77	60.47	1.93	35.50
	D	135.13	16.77	51.57	1.82	35.83
Krasela	P	138.13	16.73	67.40	2.21	40.47
	D	138.77	16.93	47.63	1.58	33.27
Sunny	P	149.63	17.40	76.40	2.15	36.70
	D	152.93	16.73	54.20	1.74	33.57
ANOVA	A	*	*	*	*	*
	In	*	*	*	*	*
	A × B	*	*	*	n.s.	*

*Significant effect at P<0.05, ns – insignificant effect of the factor

Similar to stem mass (MS), the next indicator – stem density (SD) on average for the three years has higher values for all studied hybrids in the Plovdiv region. In both regions, the densest stem is formed by the hybrid Dalena – 2.34 mg /cm ^{3} in Plovdiv and 2.01 mg /cm ^{3} in Dobrich. The lowest stem density in Southern Bulgaria was recorded for the hybrid Enigma – 1.93 mg /cm ^{3} and in Dobrudzha – for the hybrid Sunny – 1.74 mg /cm ^{3}.

The leaf mass (LM) of the hybrids Dalena , Deveda , Krasela and Sunny is greater in the Plovdiv region, while the standard P 64 LP 170 and Enigma is greater in the Dobrich region. In the Plovdiv region, the lightest leaves are those of the hybrid P 64 LP 170 – 45.1 g, and in Dobrudzha of the hybrid Deveda – 32.6 g. The highest average values for the three years of the study for this indicator were recorded for the hybrid Dalena – 45.1 g in Plovdiv and 36.1 g in Dobrich.

Similar to all quantitative indicators, the mass of the cake without seeds (MP) is higher in the Dobrich region compared to Plovdiv for all hybrids (Table 4). The lightest in Southern Bulgaria are the cakes of the Dalena and Krasela hybrids – 29 g, and in Dobrudzha – of the Dalena hybrid – 30 g. The heaviest cakes in both regions are formed by the Sunny hybrid – 33.7 g in Plovdiv and 40.5 g in Dobrich. This is the reason why the interaction of the factors "region" and "hybrid" has been proven, as well as the independent action of the two factors.

Table 3. Structural elements of the reproductive organs of sunflower on average for the three years.

A Hybrid	In Area	MP	SMEs	BSP	DP	PP
P64LP170	P	33.6	55.9	1137	93.8	7.4
	D	29.1	62.4	1312	92.6	8.5
Dalena	P	32.8	51.0	1152	90.6	6.8
	D	32.1	51.4	1261	86.9	8.8
Deveda	P	32.6	45.9	1183	105.9	6.5
	D	24.9	45.1	1464	97.6	9.6
Enigma	P	28.6	45.1	1079	86.6	7.0
	D	30.6	53.1	1258	94.1	8.5
Krasela	P	33.2	51.2	1162	103.7	7.0
	D	26.2	51.6	1194	88.6	7.9
Sunny	P	36.2	60.6	993	110.4	5.5
	D	27.3	55.3	1124	90.4	7.7
ANOVA	A	*	*	*	*	*
	In	*	*	*	*	*
	A × B	*	*	*	n.s.	n.s.

* Significant effect at P<0.05, ns – insignificant effect of the factor

On average for the three years studied, the mass of the pit without seeds (MP) is higher in the Dobrich region only for the Enigma hybrid. All the other five hybrids have a higher mass of the pit in the Plovdiv region. The lightest in Southern Bulgaria are the pits of the Enigma hybrid – 28.6 g, and in Dobrudzha – of the Deveda hybrid – 24.9 g. The heaviest pits in the Plovdiv region are formed by the Sunny hybrid – 36.1 g, and in Dobrich the Dalena hybrid – 32.1 g.

On average for the three years of the study, the seed mass in the cob (MSP) of the hybrids P 64 PL 170, Dalena, Enigma and Krasels is higher in the Dobrich region, and for Deveda and Sunny the seed mass in the cob is higher in the Plovdiv region. The largest difference between the two regions was recorded for the Enigma hybrid - 8 g followed by P64LP170 - 6.5 g; Sunny - 5.3 g; Deveda - 0.8 g; Dalena - 0.4 g; and the smallest for Krasela - 0.3 g. In the Plovdiv region, the lowest values of the seed mass in the cob are the Enigma hybrid - 45.1 g, and in Dobrich it is the Deveda hybrid - 45.1 g , and with the highest - the Sunny hybrid - 85.8 g in Thrace, and in Dobrudzha the standard P64LP170 - 62.4 g .

The number of seeds in the cob (BSP) for the three harvest years also has higher values in the Dobrich region for all studied hybrids. The largest difference between the two regions is for the hybrid Deveda – 281 pcs., followed by Enigma – 179 pcs.; P 64 LP 170 – 139 pcs.; Sunny – 131 pcs.; Dalena – 109 pcs. and the smallest for Krasela – 32 seeds. In both regions, the hybrid with the lowest number of seeds in the cob is Sunny – 993 pcs. in the Plovdiv region and 1124 pcs. in Dobrich. The same hybrid also has the most seeds in the cob in both regions – Deveda – 1183 pcs. in Thrace and 1464 pcs. in Dobrudzha.

On average for the three tested years, all studied hybrids formed a larger comb in the Plovdiv region, with the exception of the Enigma hybrid, expressed by the comb diameter (PD) indicator. The largest difference is for the Sunny hybrid – 20.0 mm, followed by Krasela – 15.1 mm; Deveda – 8.3 mm; Enigma – 7.5 mm; Dalena – 3.7 mm, and the smallest difference between the regions is the standard P 64 LP 170 – 1.2 mm. In the Plovdiv region, the largest comb is formed by the Sunny hybrid – 110.4 mm in Plovdiv, and in the conditions of Dobrudzha – the Deveda hybrid – 97.6 mm. The smallest comb in Southern Bulgaria is formed by the Enigma hybrid – 86.6 mm, and in the Dobrich region – the Dalena hybrid – 86.9 mm.

Similar to most quantitative traits of the comb and seeds, in all tested hybrids the comb density is higher in the Dobrich region. The largest difference is in the hybrid Deveda – 3.1 pcs. /cm ^{2} followed by Sunny – 2.2 pcs. /cm ^{2} ; Dalena – 2.0 pcs. /cm ^{2} ; Enigma – 1.5 pcs. /cm^2; P 64 LP 170 – 1.1 pcs. /cm ^{2} and the smallest difference is in Krasela – 0.9 pcs. /cm ^{2} . The densest combs in Thrace were recorded in the standard P64LP170 – 7.4 seeds/cm ^{2} and in Dobrudzha – in the hybrid Deveda – 9.6 pcs. /cm ^{2} . The lowest in both regions is the comb density in the hybrid Sunny – 5.5 pcs. /cm ^{2} in Plovdiv and 7.7 pcs. /cm ^{2} in Dobrich.

On average for the three years of the study, the stem occupies 39% of the plant in the Plovdiv region and 33% in the Dobrich region with the P64LP170 standard.

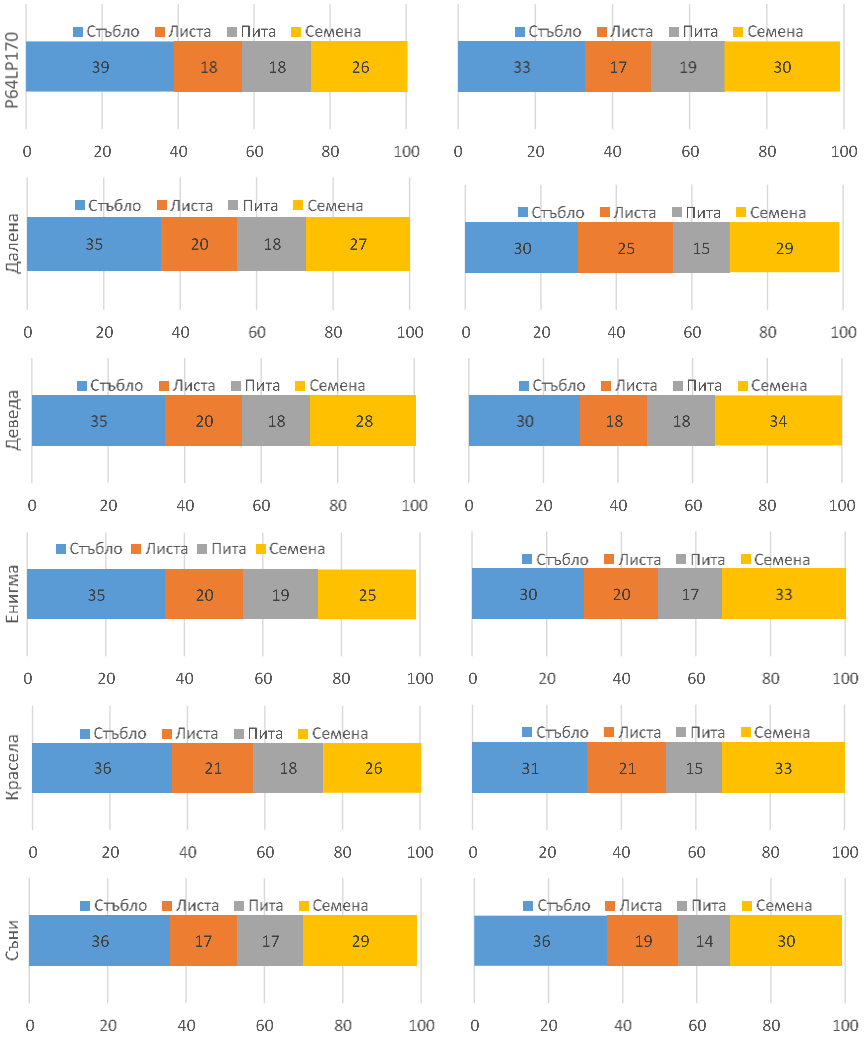

Figure 4. Division of plant organs average for three years

In the Plovdiv region, the share of leaves is 18%, and in the Dobrich region by 1% less. The share of the pith in Plovdiv is 1% less than in Dobrich, and the share of seeds - by 4% more in the Dobrudzha region. In the Dalena hybrid, the stem occupies 35% of the plant in Plovdiv and 30% in Dobrich; the leaves - 20% in Plovdiv and 25% in Dobrich; the pith - 18% in Plovdiv and 15% in Dobrich and the seeds - 27% in Plovdiv and 29% in Dobrich. On average, over the three years

of the study, the Deveda hybrid formed its biomass in Southern Bulgaria at the expense of 35% stem, 20% leaves, 18% pith and 28% seeds.

In Dobrudzha, 30% of the biomass of the Deveda hybrid is taken up by the stem, 18% by the leaves, 18% by the pith and 34% by the seeds. In the Enigma hybrid, the stem in Plovdiv occupies 35% of the plant, and in Dobrich – 30%. The share of leaves in both regions is 20%. The share of pith in the Plovdiv region is 19%, and in the Dobrich region it is 2% less, and the share of seeds – 25% in Plovdiv and 33% in Dobrich. The Krasela hybrid forms its biomass in Southern Bulgaria at the expense of 36% stems, 21% leaves, 18% pith and 26% seeds. In Dobrudzha, the ratio of plant organs is 31% stems, 21% leaves, 15% pith and 33% seeds. In the Sunny hybrid, the stem occupies 36% of the plant biomass in both regions. The leaves in Plovdiv occupy 17%, and in Dobrich 2% more. The pit in Southern Bulgaria occupies 17%, and in Northern Bulgaria 3% less. In the Plovdiv region, the seeds occupy 29%, 1% less compared to those in Dobrudzha.

3. Productivity indicators

3. 1. Seed production

Table 4. Seed yield, kg / da

A Hybrid	In Area	2023	2024	2025	MEDIUM
P64LP170	P	257	152	93	167.3
	D	294	140	127	187.0
Dalena	P	216	177	75	156.0
	D	226	121	114	153.7
Deveda	P	211	144	92	149.0
	D	220	136	185	180.3
Enigma	P	203	154	76	144.3
	D	216	127	134	159.0
Krasela	P	195	141	166	167.3
	D	205	134	157	165.3
Sunny	P	233	148	160	180.3
	D	238	140	120	166.0
ANOVA	A	*	*	*	*
	In	*	*	*	*
	A ×B	*	n.s.	*	*

* Significant effect at P<0.05, ns – insignificant effect of the factor

On average for the three years of the study, seed yield of hybrids P 64 LP 170, Deveda, and Enigma is higher in the Dobrich region, and Dalena, Krasela and Sunny form a higher seed yield in the Plovdiv region. (Table 4). The difference in yields between the two regions for each of the hybrids is different. For the hybrid

Deveda the difference is the largest – 31.3 kg/da; for the standard P64LP170 – 19.7 kg/da; for Enigma – 14.7 kg/da; for Sunny – 14.3 kg/da; for Dalena – 2.3kg/da and for Krasela it is the smallest – 2 kg/da. In the region of Southern Bulgaria the highest yields were recorded for the hybrid Sunny – 180.3 kg/da, and in Dobrudzha the highest yield was the standard P64LP170 – 187 kg/da, and the lowest seed yield was recorded for the hybrid Enigma – 144.3 kg/da in Plovdiv, and in Dobrich the hybrid Dalena – 153.7 kg/da .

3.2. Oil extraction

On average for the three years of the study, the oil yield of 5 of the tested hybrids was higher in the conditions of Dobrich, and in Plovdiv only the Sunny hybrid had a higher oil yield. The highest amount of oil per unit area in the Plovdiv region was obtained from the Sunny hybrid – 89.7 kg/da , and in the Dobrich region from the Deveda hybrid – 100.3 kg/da . (Table 5). With the P 64 PL 170 standard, the oil obtained in Northern Bulgaria was 11.3 kg / da. more than that in Southern Bulgaria (74 kg/da). With the Dalena hybrid , the oil yield in Northern Bulgaria is 5.7 kg/da more than that obtained in Thrace (72 kg/da). With the Deveda hybrid , the oil yield in Dobrich is 31 kg/da more than that obtained in Plovdiv. The Enigma hybrid is the lowest oil-yielding hybrid in both regions, with the oil yield in Dobrudzha being 12.4 kg/da more than that obtained in Thrace (63.3 kg/da). With the Krasela hybrid , the oil yield in Dobrich is 9.7 kg / da compared to that obtained in Plovdiv (74 kg/da). With the Sunny hybrid, the difference between the two regions is 1 kg / da .

Table 5. Oil yield, kg / da

A Hybrid	In Area	2023	2024	2025	MEDIUM
P64LP170	P	108	71	43	74.0
	D	131	66	59	85.3
Dalena	P	74	100	42	72.0
	D	108	64	61	77.7
Deveda	P	72	83	53	69.3
	D	112	80	109	100.3
Enigma	P	67	82	41	63.3
	D	91	66	70	75.7
Krasela	P	71	69	82	74.0
	D	95	72	84	83.7
Sunny	P	96	83	90	89.7
	D	114	82	70	88.7
ANOVA	A	*	*	*	*
	In	*	*	*	*
	A ×B	n.s.	*	n.s.	n.s.

* Significant effect at P<0.05, ns – insignificant effect of the factor

3.3.Meal production

Sunflower meal is a by-product of the extraction of oil from sunflower seeds, with sunflower meal being the fourth largest in world production after soybean, rapeseed and cottonseed oil. Since sunflower is a temperate crop, Russia and Ukraine are the two main producers and exporters of sunflower meal, with the EU in third place in the world. In countries where sunflower is grown as a major oilseed crop, such as Bulgaria, sunflower meal as a high-protein feed component can be an alternative to imported soybean meal.

On average for the three tested years in the Thrace region, the meal yield is higher for the hybrids Dalena , Krasela and Sunny , and in the Dobrudzha region, the standards P64LP170, Deveda and Enigma show higher results . In both regions, the highest meal yield is for the standard P 64 PL 170 and Krasela – 93.3 kg/da in Plovdiv and 101.7 kg/da in Dobrich. On average for the three years, the lowest meal yield is in Plovdiv for the Deveda hybrid – 79.7 kg/da , and in Dobrich – for the Sunny hybrid – 77.3 kg/da .

Table 6. Meal yield, kg / da

A Hybrid	In Area	2023	2024	2025	MEDIUM
P64LP170	P	149	81	50	93.3
	D	163	74	68	101.7
Dalena	P	142	77	33	84.0
	D	118	57	53	76.0
Deveda	P	139	61	39	79.7
	D	108	56	76	80.0
Enigma	P	136	72	35	81.0
	D	125	61	64	83.3
Krasela	P	124	72	84	93.3
	D	110	62	73	87.7
Sunny	P	137	65	70	90.7
	D	124	58	50	77.3
ANOVA	A	*	*	*	*
	In	n.s.	*	n.s.	n.s.
	A ×B	n.s.	*	n.s.	n.s.

* Significant effect at P<0.05, ns – insignificant effect of the factor

3.4. Harvest index

On average for the three years of the study, the harvest index of the plant for all the studied hybrids is higher in the Dobrich region, with the exception of

the Sunny hybrid . In the Plovdiv region, the harvest index of the plant (HI) is highest for the Sunny hybrid – 0.28 in Plovdiv, and in Dobrich for the Deveda hybrid – 0.30. The ratio of seeds to the total biological yield and for the P64LP170 standard – 0.26 in Plovdiv versus 0.28 in Dobrich (0.02 more). The same difference is observed for the Dalena hybrid – 0.25 in Plovdiv versus 0.27 in Dobrich. For the Enigma hybrid, the harvest index in the conditions of the Dobrudzha region is 0.27, and in the Plovdiv region it is 0.22 (0.05 lower). The largest difference in this indicator is for the Krasela hybrid – 0.22 in Plovdiv versus 0.29 in Dobrich (0.07 higher).

On average for the three harvest years in the Plovdiv region, the highest seed ratio in the pod was recorded for the Sunny hybrid – 0.66 , while in Dobrich it was the standard P64LP170, again with the same result (0.66). The lowest values of the pod harvest index in the Plovdiv region were recorded for the Dalena hybrid – 0.54, and in Dobrich for the Enigma hybrid – 0.59.

On average for the three years of the study, the kernel content in the seeds of the hybrids P64LP170 and Enigma is higher in the Plovdiv region. The kernel content in the seeds of the remaining four hybrids – Dalena , Deveda , Krasela and Sunny is higher in the Dobrich region. In the Plovdiv region, the highest harvest index of the seed was recorded for the hybrids Dalena and Krasela – 0.71, and in Dobrich – for the hybrid Krasela – 0.73. The lowest percentage of the kernel in the Plovdiv region (67%) is formed by the hybrids P64LP170 and Deveda , and in Dobrudzha – hybrid P64LP170 – 61%.

Table 7. Harvest index of the plant (HI), the cob (DHI) and the seed (SHI)

A Hybrid	In Area	HI	DHI	SHI
P64LP170	P	0.26	0.60	0.67
	D	0.28	0.66	0.61
Dalena	P	0.25	0.54	0.71
	D	0.27	0.65	0.71
Deveda	P	0.25	0.57	0.67
	D	0.30	0.65	0.70
0.69Enigma	P	0.22	0.63	0.69
	D	0.274	0.59	0.68
Krasela	P	0.22	0.61	0.71
	D	0.29	0.62	0.73
Sunny	P	0.28	0.66	0.69
	D	0.27	0.64	0.71
ANOVA	A	n.s.	*	*
	In	*	*	*
	A ×B	*	*	*

* Significant effect at P<0.05, ns – insignificant effect of the factor

4. Qualitative indicators

4.1. Seed quality

On average for the three tested years, the seed oil content of the hybrids P64LP170, Dalena , Enigma and Krasela is higher in the Plovdiv region than in Dobrich, and vice versa for Deveda , with the difference being the largest for the Deveda hybrid - 5.4% more, followed by Krasela (3.1%); the standard P64LP170 (0.9%); Enigma (0.5%); Dalena (0.4%), and for the Sunny hybrid there is no difference between the two regions . The lowest oil content in the Plovdiv region is for the Deveda hybrid - 43.4%, and in Dobrich for the Krasela hybrid - 42.6%. The highest oil content in both regions is the Sunny hybrid - 48.9%.

On average for the three years of the experiment, the mass of 1000 seeds in the hybrids P64LP170, Dalena , Krasela and Sunny is higher in the Plovdiv region compared to that in Dobrich, and in Deveda and Enigma - the opposite (Table 10). In the standard P64LP170 the difference is 4.1 g; in Dalena by 3.1 g; in Deveda by 0.6 g; in Enigma by 1.1 g; in Krasela by 2.0 g; and the largest difference is in Sunny - by 12.2 g more.

Table 8. Oil content in seeds, %

A Hybrid	In Area	2023	2024	2025	MEDIUM
P64LP170	P	41.9	46.4	47.7	45.3
	D	44.6	46.8	42.5	44.6
Dalena	P	34.3	56.5	50.7	47.2
	D	47.6	53.2	39.6	46.8
Deveda	P	34.3	57.5	38.4	43.4
	D	50.9	58.7	36.8	48.8
Enigma	P	32.8	53.3	46.6	44.2
	D	42.2	52 .0	37.0	43.7
Krasela	P	36.4	49.1	51.5	45.7
	D	46.3	53.7	38.7	46.2
Sunny	P	41.0	56.3	49.3	48.9
	D	47.7	58.4	40.7	48.9
ANOVA	A	*	*	*	*
	In	*	*	*	*
	A ×B	n.s.	n.s.	*	n.s.

In both regions, the mass of 1000 seeds is highest in hybrid Sunny – 70.5 g in Plovdiv and 58.3 g in Dobrich, and the lowest – in the Deveda hybrid – 44.7 g in Thrace and 45.9 g in Dobrudzha.

, the mass of seeds in 100 l volume for all hybrids is greater in the Dobrich region. On average for the three years since planting, the mass of seeds in 100 l volume is lowest in both regions for the P64LP170 standard – 30.7 kg /100 l in Plovdiv, and

in Dobrich – 32.6 kg /100 l. The test weight is highest in both regions for the Krasela hybrid – 35.7 kg /100 l in Plovdiv, and in Dobrich – 35.9 kg/100 l.

Table 9. Mass of 1000 seeds, g

A Hybrid	In Area	2023	2024	2025	MEDIUM
P64LP170	P	67.5	58.7	36.5	54.2
	D	65.5	48.4	36.4	50.1
Dalena	P	59.8	55.0	33.2	49.3
	D	58.0	48.9	31.6	46.2
Deveda	P	55.3	46.9	32.0	44.7
	D	54.0	48.8	35.0	45.9
Enigma	P	57.3	54.2	30.9	47.5
	D	56.5	54.4	34.9	48.6
Krasela	P	59.5	57.7	44.2	53.8
	D	56.3	55.0	44.2	51.8
Sunny	P	67.4	68.0	76.2	70.5
	D	63.2	69.8	42.0	53.8
ANOVA	A	*	*	*	*
	In	*	*	*	*
	A ×B	*	*	n.s.	*

Table 10. Test weight, kg /100 l

A Hybrid	In Area	20 23	2024	2025	MEDIUM
P64LP170	P	29.1	33.2	29.8	30.7
	D	34.0	31.7	32.1	32.6
Dalena	P	26.5	38.2	32.6	32.4
	D	38.1	34.4	29.3	33.9
Deveda	P	30.3	33.5	33.1	32.3
	D	37.8	32.9	30.0	33.6
Enigma	P	33.1	36.3	33.5	34.3
	D	39.9	35.4	30.3	35.2
Krasela	P	35.3	33.4	38.5	35.7
	D	37.5	35.8	34.3	35.9
Sunny	P	35.6	34.9	33.4	34.6
	D	36.7	35.3	34.2	35.4
ANOVA	A	*	*	*	*
	In	*	*	*	*
	A ×B	n.s.	*	n.s.	n.s.

* Significant effect at P<0.05, ns – insignifivant effect of the factor

4.2. Oil quality

In addition to the oil content in the seeds, a key quality indicator for sunflower is the composition of the oil. One of the main valuable qualities of sunflower oil is the predominant amount of unsaturated fatty acids compared to saturated ones.

On average for the three years of the study, the content of saturated fatty acids in all hybrids is again higher in the Plovdiv region. In the hybrids Dalena and Enigma by 2%, in the standard P64LP170 and Deveda by 4%, in Krasela by 3%, and in Sunny by 1% . On average for the three years, the content of saturated fatty acids in both regions is highest in the hybrid Deveda – 18.1% in Plovdiv, and in the conditions of Dobrich – 14.2%. The smallest amount of saturated fatty acids in both regions accumulates in the seeds of the hybrid Sunnis – 12% in Thrace, and in Dobrudja – 11.2%.

On average for the three years, again for all studied hybrids, the content of unsaturated fatty acids is higher in the conditions of Dobrudzha, compared to those in Thrace (Fig. 5). The largest difference is in the hybrid Deveda – 5.2%, and the smallest – in the hybrid Sunny – 0.3% more in Dobrich compared to Plovdiv. The largest amount of unsaturated fatty acids in both regions accumulate in the seeds of the hybrid Sunny – 89.4% (40.1% polyunsaturated + 49.3% monounsaturated) in Dobrudzha, and in the region of Thrace – 89.1% (33% polyunsaturated + 56.1% monounsaturated). The lowest amount of unsaturated fatty acids is in the Deveda hybrid in both regions - in the conditions of Plovdiv - 82.2% (59.1% polyunsaturated + 23.1% monounsaturated), and in Dobrich - 87%, of which 67% polyunsaturated and 20% monounsaturated.

In addition to the ratio of saturated: unsaturated fatty acids, another main quality indicator of sunflower oil is the ratio of the two main unsaturated fatty acids (linoleic and oleic), which determines the respective batch of oil as linoleic or oleic type. According to the standards adopted for oil, standard sunflower oil is linoleic type. High-oleic is considered to be one in which the oleic acid content is above 75%, (Codex Stan ., 2017).

On average for the three years of the study, all hybrids accumulated more linoleic acid in the Dobrich region. The highest content of linoleic acid in both regions was observed in the hybrid Deveda – 60.6% in Plovdiv and 67.6% in Dobrich. The lowest content of linoleic acid in both regions was observed in the hybrid Sunny – 38.2% in Plovdiv and 43.3% in Dobrich.

Contrary to linoleic acid, all hybrids accumulate more oleic acid in the Plovdiv region. On average for the three years of the study, the highest oleic acid in both regions is the Sunny hybrid - 49.4% in Plovdiv and 46.5% in Dobrich. The only hybrid that has a higher oleic acid content in the conditions of Northern Bulgaria is Dalena - 28.7% in Plovdiv and 29.9% in Dobrich. The lowest oleic acid in both regions is the Deveda hybrid - 22.7% in Povdiv and 19.4% in Dobrich . And during the three years of the study, none of the hybrids can be classified as high-oleic .

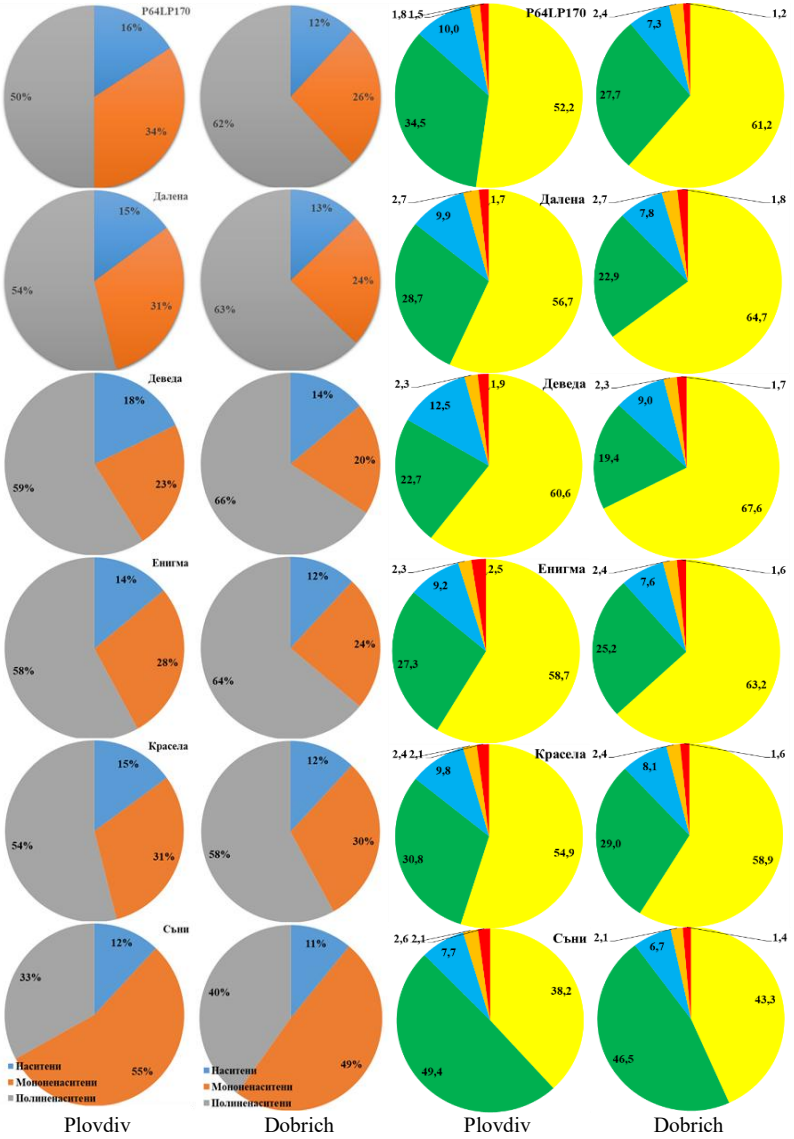

Figure 5. Ratio between saturated and unsaturated fatty acids and fatty acid composition of the oil

On average for the three years of the study, the palmitic acid content of all studied hybrids was higher in the conditions of Plovdiv compared to that in Dobrich.

In the P64LP170 standard grown in Plovdiv, the palmitic acid content is higher by 2.7% compared to that in Dobrich; In Dalena – by 2.1%; in Deveda – by 3.5%; in Enigma – by 1.6%; in Krasela – by 1.7% and in Sunny – by 1%. In both regions, the highest palmitic acid content is again in the Deveda hybrid – 12.5% in Plovdiv and 9% in Dobrich. The lowest palmitic acid content in both regions is in the Sunny hybrid – 7.7% in Plovdiv and 6.7% in Dobrich.

On average for the three years of the study, the stearic acid content in Plovdiv under the P64LP170 standard was 1.8%, and in Dobrich – 2.4%. The hybrids Dalena and Deveda in both regions accumulated 2.7% and 2.3%, respectively. The hybrid Enigma accumulated 2.3% in Plovdiv and 2.4% in Northern Bulgaria. The hybrid Krasela accumulated 0.2% more stearic acid in the Dobrich region, and the hybrid Sunny 0.5% more in the Plovdiv region.

4.3. Quality of meal

On average for the three years of the study, the crude protein content in sunflower seeds is higher in the Plovdiv region for all studied hybrids (Table 11). In both regions, the highest protein accumulation is observed in the P64LP170 standard – 352.2 g/ kg dry matter in Plovdiv, and 316.3 g/ kg in the conditions of Dobrudzha. The lowest protein content is in Plovdiv in the seeds of the Enigma hybrid – 321.4 g/ kg , and in Dobrich – in the Sunny hybrid – 287.8 g/ kg dry matter.

Table 11. Crude protein content, g/ kg d.m.

A Hybrid	In Area	2023	2024	2025	MEDIUM
P64LP170	P	395.1	344.7	316.7	352.2
	D	279.8	344.6	324.4	316.3
Dalena	P	382.6	324.5	317.6	341.6
	D	263.6	325.1	305.0	297.9
Deveda	P	391.0	311.9	305.6	336.2
	D	239.8	309.5	335.5	294.9
Enigma	P	370.5	287.6	306.2	321.4
	D	284.8	298.2	295.9	293.0
Krasela	P	376.1	344.2	294.6	338.3
	D	326.8	290.5	303.9	307.1
Sunny	P	369.8	300.0	304.8	324.9
	D	271.1	299.6	292.6	287.8
ANOVA	A	*	*	*	*
	In	*	*	*	*
	A ×B	n.s.	*	*	*

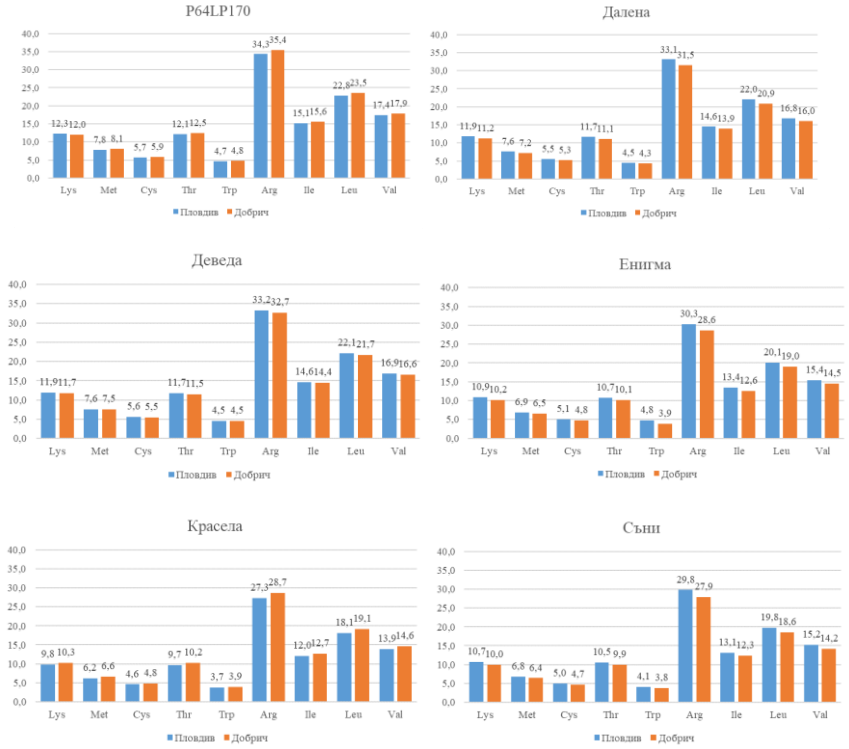

Figure 6. Amino acid composition of sunflower seed protein averaged over the three years, g / kg d.m.

Determining the amino acid composition is useful in formulating feed rations and is also an important parameter in assessing protein quality.

On average over the three years of the study, of the three limiting amino acids (lysine, methionine and cystine) in sunflower, all hybrids had the highest amount of lysine, followed by methionine, and the lowest content of cystine. The highest amount of lysine in both regions was accumulated in the seeds of the standard P64LP170. – 12.3 g/ kg in Plovdiv, and in Dobrich – 12 g/ kg In the conditions of Thrace, the least lysine is synthesized in the seeds of the Krasella hybrid. – 9.8 g/ kg d.m., and in Dobrich the least – in the Sunny hybrid – 10. g/ kg The highest amount of methionine in both regions was again accumulated in the seeds of hybrid P64LP170 - 7.8 g/ kg . d.m., and in Dobrich – 8.1 g/ kg In the conditions of Plovdiv , the least methionine is synthesized again in the seeds of the Krasela hybrid – 6.2 g/ kg. d.m., and in Dobrich the least – again in the Sunny hybrid – 6.4 g/ kg The highest amount of cystine in both regions is accumulated in the seeds of the

standard P64LP170 – 5.7 g/ kg d.m. in Plovdiv, and in Dobrich – 5.9 g/ kg In the conditions of Plovdiv, the least cystine is synthesized in the seeds of the Krasela hybrid – 4.6 g/ kg. d.m., and in Dobrich – for the Sunny hybrid – 4.7 g/ kg d.m.

5. Stability of sunflower hybrids in genotype- ×environment interaction.

At study on the influence on the environment on the hybrid at mining The presence of seeds has a great influence on complex and unpredictable interactions , especially at use on contrasting conditions on the middle. A number authors they believe that the increase on mining by principle is related with low stability and plasticity.

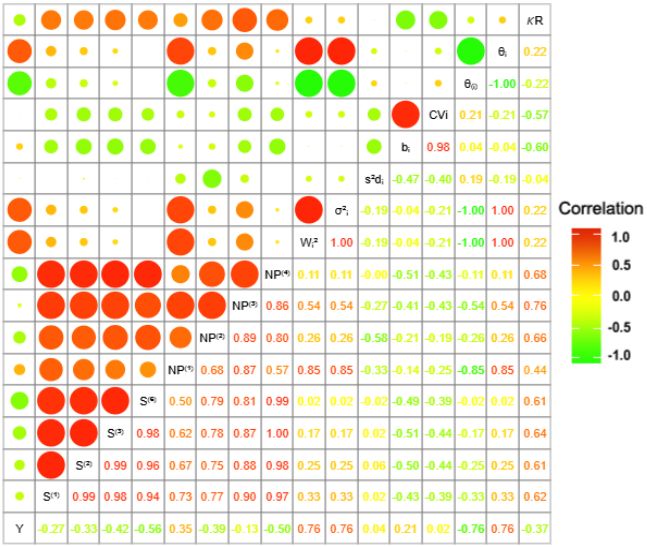

Figure 7. Correlation analysis between yield (Y) and stability coefficients.

There are many models for determining yield stability in agricultural crops. In the online program Stabilitysoft, used for calculating stability, there is an opportunity to make a relationship between yield (Y) and all 16 provided models through a correlation analysis between yield (Y) and the obtained coefficients. In the present study, the Wricke covalence (W_i^2) variation was used to determine and rank the stability of the studied sunflower hybrids. on the stability (σ^2_i) of Shukla and the parameter on stability (θ i) of Plaisted and Peterson precisely

because of their high positive correlation (0.760) with yield compared to the other 13 (Fig. 7).

The ecovalence (W_i^2) measures the contribution on everyone genotype to the general amount from squares on the interaction genotype × environment. Genotypes with low values on ecovalence is consider for more stable, so as show smaller deviations from the average you presentation in the different ones environments. Similar to ecovalence, the low value of the variation (σ^2_i) and the parameter (θ i) of stability n shows t also high stability. The genotype reacts on the environment environment by the same way , in a way which reacts and the average value on all remaining genotypes . She 's tall value n shows low stability (instability) and big sensitivity to the changes in the environment.

All three methods used give similar results. The Enigma hybrid has the lowest values, which can be defined as the most stable. The Dalena hybrid is ranked second, Sunny third, Deveda fourth, and the last places as the most unstable in terms of yield are the P64LP170 and Krasela hybrids, although the highest average yield (177 kg / da) was obtained from the P64LP170 hybrid (Table 12).

Table 12. Equivalence and variation on stability in sunflower hybrids .

No.	Hybrid	SD	W_i^2	σ^2_i	θi	Rank
G 1	P64LP170	177	4696.5	1229.6	1012.0	5
G2	Dalena	155	2119.3	456.4	702.8	2
G 3	Deveda	165	2730.5	639.8	776.1	4
G 4	Enigma	152	793.2	58.6	543.6	1
G5	Krasela	166	4902.3	1291.3	1036.7	6
G 6	Sunny	173	2696.2	629.5	772.0	3

The analysis on stability through AMMI (Additive Manufacturing Model) Main Effects and Multiplicative Interaction) is statistically method used in the rural farm for assessment on the presentation on different genotypes in multitude He combines dispersion analysis (ANOVA) for additive effects and analysis on the main ones components (PCA) for the multiplicative interaction between genotype and environment .

According to the location on the points on the individual hybrids in the space , as much as are by to the right , that much the yield is higher (the abscissa) shows the yield). Certain hybrid is more stable on background on the whole experiment if the point his on the figure is closer to the beginning (0,0) of the interaction on genotype × environment .

As much as the value of the hybrid is closer to the horizontal line , so much his/her variation is less , and stability higher (Fig . 23) . In our case most stable is hybrid Enigma (G 4), followed by by Sunny (G 6), Dalena (G 2) and Deveda (G 4). The P64LP170 standard (G 1) is farthest to the right due to the

high yield, but also furthest from the origin of the coordinate system, indicating low stability.

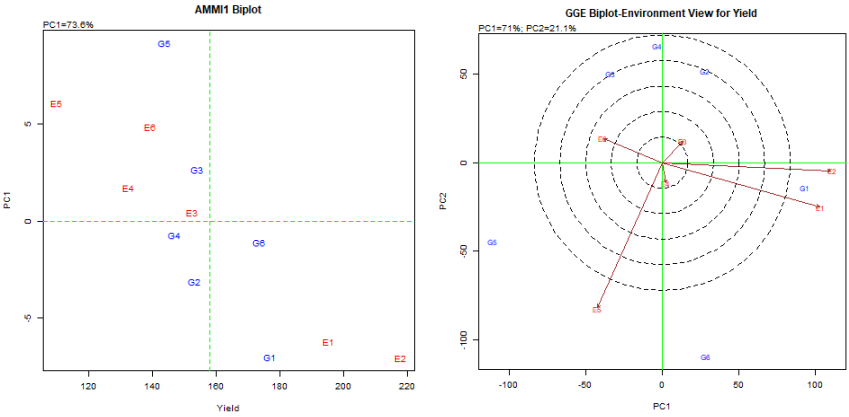

Figure 8. Grouping on hybrids by seed yield and stability through AMMI and GGE Biplot models

Similar results are obtained with another graphical analysis – GGE Biplot - powerful graphic tool used in plant breeding for simultaneous analysis on genotype and the interaction between genotype and the environment environment . The hybrids closest to the center are the most stable, and those outside the circle are unstable (Fig. 8).

For simultaneously viewing on mining and stability is used the biplot with medium coordinates on the middle (CKC) (Fig . 8). It shows the ranking of hybrids by attitude on their average yield and stability . The average Average Env .) is determines from the PC1 and PC2 estimates on The line passing through through the beginning on biplot and the average Wednesday , is calls axis on the average environment and serves as abscissa of SCCC. The projections on the hybrids on this one axis show their approximate average yield . The Horde of the CCC is the line that passes through the beginning on the coordinate system and is perpendicular on the abscissa of the CCC. For difference from the abscissa of the CCC, which there is one direction to the bigger one average effect on genotype , ordinate of the CCC is marked with double arrows , like each direction , distant from the beginning on biplot , shows bigger effect on genotype and reduced stability (Yan , 2002). Hybrid P64LP170 (G1) is the genotype with highest yield , since it is at the end of the abscissa of the CCC. In addition to this , the biplot shows that Sunny (G6) is with tall average yield and is strongly stable , so as is positioned close to the abscissa of the CCC. For difference from this , Krasela (G5)

is the most unstable hybrid, so as is far away from the abscissa of AEC. Hybrid Deveda (G3) is the most stable genotype .

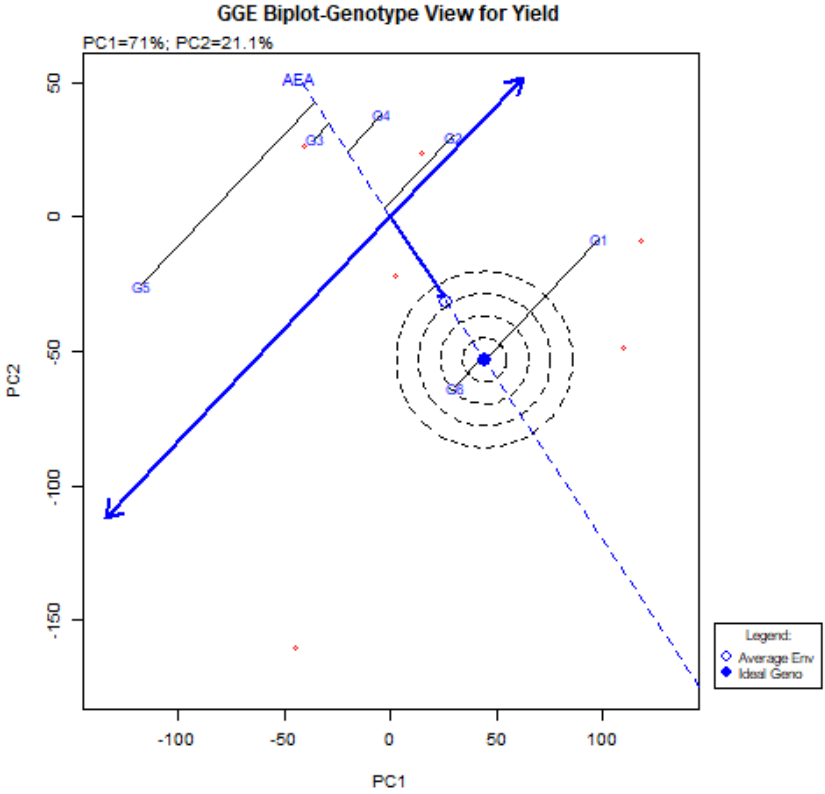

Figure 9. Spatial presentation on hybrids by the magnitude and stability on mining through principled component analysis on the GGE Biplot program

The ideal genotype (Ideal Geno .) is determines as one who is with highest yield in all test environments and is absolutely stable by attitude on productivity. Despite that such ideal hybrid can yes no exists in reality, he can yes is uses as reference landmark for evaluation. In the present study, the closest to the ideal genotype is the hybrid Sunny (G 6).

6. Correlations between quantitative and qualitative indicators in sunflower.

In order to establish a relationship between the variables (quantitative and qualitative traits) in sunflower, a correlation analysis was performed, in which the

correlation coefficients between each of the variables were expressed in terms of value, as well as visually through a graphical representation of the dependence between the main quantitative (seed yield) and qualitative (seed oil content) indicators.

Quantitative characteristics are those that are measured in absolute quantities – a specific numerical expression presented in natural units of measure – fractions (kg/da), meter (m), number and etc. Qualitative characteristics are measured in relative quantities – they represent attitude on two absolute or two medium magnitudes - (%, index, etc.). Positive and negative correlations have been reported, and according to the adopted methodological scheme (Zapryanov and Marinkov, 1978) the correlations are weak (<0.333), medium (0.333-0.666) and strong (> 0.666).

6.1. Correlations between quantitative indicators in sunflower.

Seed yield is related in different ways and in different directions (positive or negative) to the other quantitative indicators, with the values of the correlation coefficients varying widely. Strong positive correlations (> 0.666) with seed yield were reported with oil yield (0.847) , and of the structural elements of the plant, the mass of seeds in the cob (0.919) and the number of seeds in the cob (0.815) have the strongest influence on seed yield. In addition to the high positive correlation coefficients, the absolute values of these traits have a very low correlation dispersion, which further proves the strong effect of the traits on seed yield (Fig. 10). Medium positive correlations with yield were reported with cob diameter (0.412), stem length (0.482), stem thickness (0.450) – all reliable at a significance level $\alpha = 0.05$. A significant average negative correlation with yield was found only with
stem density (-0.351). The relationship of yield with the other structural elements (PP, MS, ML and MP) is weak and unproven.

Stem length was positively correlated with seed mass in the cob (0.574), oil yield (0.447) and stem mass (0.379). There was a negative correlation between stem length and cob density (-0.432).

Stem thickness is strongly positively correlated with several traits - panicle diameter (0.724), stem mass (0.709), panicle mass (0.678), moderately positively correlated with leaf mass (0.602), number of seeds in a panicle (0.513), oil yield (0.507) and mass of seeds in a panicle (0.391). There is a proven negative correlation between stem thickness and its density (-0.567).

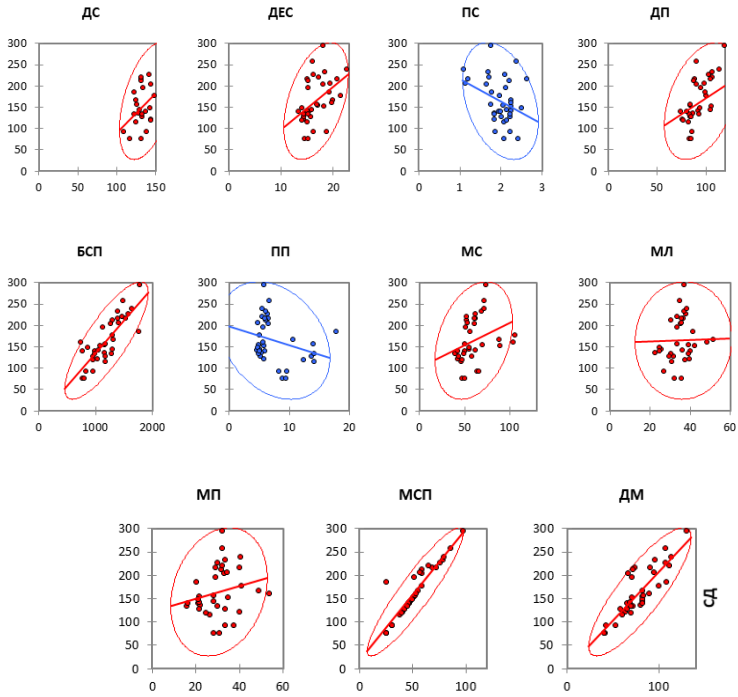

Figure 10 . Correlationally distraction between seed yield and quantitative indicators in sunflower.

With most structural elements, the relationship with stem density is either negative or not significant. Proven negative relationships were reported with oil yield (-0.412) and number of seeds per cob (-0.446). The diameter of the pith is most strongly correlated with the mass of the stem (0.684). There is also a strong positive correlation with the mass of the pith (0.660), which is logical. There are also positive and reliable correlations with the mass of the leaves (0.531), the yield of oil (0.492) and the mass of the seeds in the pith (0.403).

The number of seeds in the cob is positively and reliably correlated with oil yield (0.770) and seed mass in the cob (0.670). The results are unproven with the other traits. The density of the cob is negatively correlated with almost all traits, except for leaf mass. A reliable negative correlation exists with the mass of seeds in the cob (-0.426). The mass of the stem is positively correlated with the mass of the stalk (0.650), the mass of the pod (0.691), the mass of seeds in the cob (0.382) and oil yield (0.354).

The mass of the leaves is in a positive and reliable correlation with the mass of the pith (0.691), and the mass of the seeds in the pith – with the oil yield (0.768).

6.2. Correlations between quality indicators in sunflower.

As an oilseed crop, oil content is a key quality indicator for sunflower. This is the reason why this quality indicator was adopted as the main parameter when comparing with the other variables in this study.

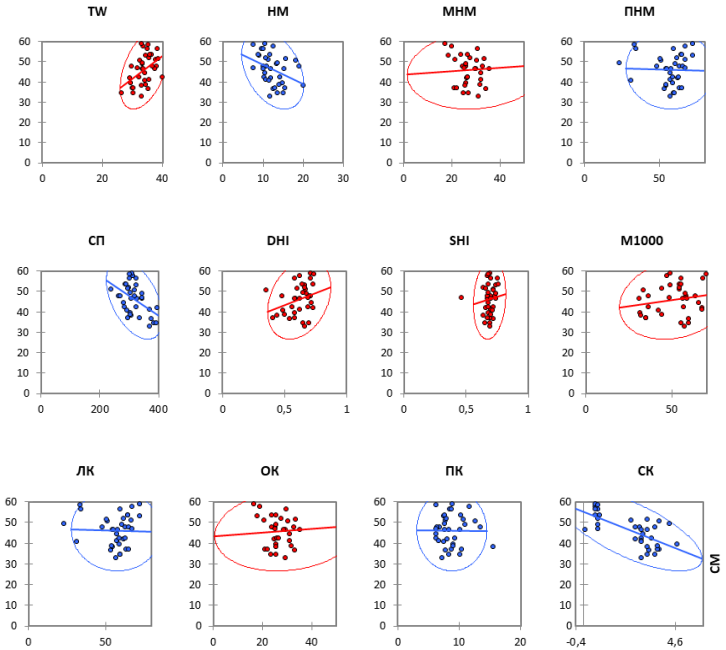

Figure 11 . Correlationally distraction between oil content and quality indicators in sunflower.

A positive and proven relationship between oil content and hectoliter weight was reported only (0.457). The remaining reliable correlations were negative:

-0.474 with the crude protein content, -0.380 with the saturated fatty acid content, which is mostly related to stearic acid (-0.690) for which the correction scatter is the lowest (Fig. 11).

In addition to oil content, crude protein content has been shown to be negatively correlated with hectoliter weight (-0.547). For both harvest indices, positive relationships exist between the harvest index of the kernel and the mass

of 100 seeds (0.712), as well as between the harvest index of the seeds and hectoliter weight (0.390). Negative significant correlations have been reported between the harvest index of the kernel and the content of saturated fatty acids (-0.682) – for palmitic -0.608 and stearic -0.467, respectively. The mass of 1000 seeds has a positive proven correlation with monounsaturated fatty acids (0.401) mainly at the expense of oleic acid (0.378) and a negative correlation with saturated fatty acids (-0.620) mainly at the expense of palmitic acid (-0.624). The hectoliter weight has a reliable negative correlation with saturated fatty acids (-0.400).

Saturated fatty acids are in a proven positive relationship with the other saturated ones – palmitic (0.845) and stearic (0.652). Monounsaturated fatty acids have a very strong positive correlation with oleic acid (0.999) as well as a very strong negative correlation with linoleic acid (-0.964). With polyunsaturated fatty acids it is the opposite – a strong positive correlation (1.000) with linoleic and negative (-0.967) with oleic acids.

CONCLUSIONS

1. The growing season of sunflower in the Plovdiv region is about 120 days, and in the Dobrich region – 135 days. The first year of the study is an exception due to the sudden cold snap after sowing and the prolonged germination, which extended the growing season in the Plovdiv region.
2. On average for all hybrids in the Plovdiv region, plants are formed by 36% stems, 19% leaves, 18% pistil and 27% seeds. In the Dobrich region, the stem occupies 33%, leaves – 20%, pistil – 16% and seeds 31%.
3. Seed yield from the hybrids P64LP170, Deveda , and Enigma is higher in the Dobrich region, and from Dalena , Krasela , and Sunny - in the Plovdiv region. In the region of Southern Bulgaria, the highest yield was recorded for the Sunny hybrid - 180.3 kg / da , and in Dobrudzha from the standard P64LP170 - 187 kg / da .
4. The oil yield is higher in the conditions of Dobrich, with the exception of the Sunny hybrid, which forms a higher oil yield in Plovdiv. In the Dobrich region, the most oil per unit area is obtained from the Deveda hybrid . In both regions, the highest meal yield is with the P 64 PL 170 standard .
5. The harvest index of the plants is higher in the Dobrich region, with the exception of the Sunny hybrid . In the Plovdiv region, the highest share of seeds in the pod is for the Sunny hybrid, and in Dobrich for the P64LP170 standard . In both regions, the highest harvest index of seeds is recorded for the Krasela hybrid .
6. In the hybrids P64LP170, Dalena , Enigma and Krasela, the oil content in the seeds is higher in the Plovdiv region than in Dobrich. The highest oil content in both regions is the hybrid Sunny.
7. The mass of 1000 seeds in the hybrids P64LP170, Dalena , Krasela and Sunny is higher in the Plovdiv region compared to that in Dobrich, and in the case of Deveda and E nigma – the opposite. In both regions, the mass of 1000 seeds is highest in the hybrid Sunny . For all hybrids, the mass of seeds per 100 l volume is greater in the Dobrich region. The hectoliter weight is highest in both regions for the Krasela hybrid .
8. The content of saturated fatty acids in all hybrids is higher in the Plovdiv region and of unsaturated fatty acids in the conditions of Dobrudzha. The highest content of saturated fatty acids in both regions is in the Deveda hybrid , and the highest content of unsaturated fatty acids is in the Sunny hybrid.
9. All hybrids accumulate more linoleic acid in the Dobrich region. The highest content of linoleic acid in both regions is observed in the hybrid Deveda . The lowest content of linoleic acid in both regions is observed in the hybrid Sunny, which is also the most high-oleic .
10. The crude protein content in the seeds is higher in the Plovdiv region for all studied hybrids. In both regions, the highest protein accumulation is

observed in the P64LP170 standard, which also has the highest content of the three limiting amino acids (lysine , methionine and cystine).

11. With the lowest values The most stable hybrid in terms of covalency , variation and stability parameter is the Enigma hybrid, which can be defined as the most stable. The second in rank was the Dalena hybrid , the third - Sunny , the fourth Deveda and in the last places as the most unstable in terms of yield are the P64LP170 and Krasela hybrids . This is largely confirmed by the grouping of the hybrids using the AMMI and GGE Biplot models .
12. Strong positive correlations between seed yield and oil yield were observed, and among the structural elements of the plant, the mass and number of seeds in the cob had the strongest influence on yield. The absolute values of these traits also have very low correlation dispersion, which further proves the strong effect of the traits on seed yield.
13. A positive and proven relationship of oil content was reported only with hectoliter weight. The remaining reliable correlations are negative – with crude protein content and saturated fatty acid content, which is mostly related to stearic acid, for which the correction dispersion is the lowest.

CONTRIBUTIONS

1. Scientific and theoretical contributions:

1. It has been established that the growing season of sunflowers in the Plovdiv region is shorter than that in Dobrich by an average of 15 days, except in cases where there is a cold snap after sowing and prolonged germination, which prolongs the growing season.
2. The proportion of plant organs has been determined. The proportion of stems and pistils is greater in the Plovdiv region, and in the Dobrich region – leaves and seeds.
3. The study distinguished the Enigma hybrid as the most stable. The Dalena hybrid ranked second, Sunny third , Deveda fourth , and in last place as the most unstable in terms of yield were the P64LP170 and Krasela hybrids .
4. A positive correlation was found between seed yield and oil yield, mass and number of seeds in the kernel. A positive correlation was found between oil content and hectoliter weight, and a negative correlation was found between oil content and crude protein content.

2. Scientific and applied contributions:

1. The combination of climatic conditions in the individual regions is specific and allows for differentiation of the tested hybrids at different

levels of abiotic stress during the individual phenological phases. The accumulated information is suitable for refining the cultivation technology under the conditions of Southern and Northern Bulgaria in a risky environment.

2. It has been studied that in the region of Southern Bulgaria the highest seed yields were recorded for the Sunny hybrid, and in Dobrudzha for the P64LP170 standard. In the region of Dobrich the most oil was obtained from the Deveda hybrid , and in Plovdiv – from the Sunny hybrid. In both regions the highest meal yield was obtained from the P 64 PL 170 standard .
3. It was found that the highest oil content in both regions is the Sunny hybrid, which also recorded the highest mass per 1000 seeds. For all hybrids, the mass of seeds in 100 l volume is greater in the Dobrich region. The hectoliter weight is highest in both regions for the Krasela hybrid .
4. It has been studied that in both regions the highest linoleic is the hybrid Deveda , and the highest oleic is the hybrid Sunny , and the crude protein content in the seeds is higher in the Plovdiv region. In both regions, the highest protein, lysine , methionine and cystine accumulate in the standard P64LP170.

Scientific publications related to the dissertation:

Tanchev, B., G. Georgiev. 2025. Productivity of sunflower hybrids grown under extreme drought in two different ecological regions . Research Journal of Agricultural Science, 57 (1), 2 40-245 . ISSN: 2668-926X

Tanchev , B., H. Kirchev . 2025. Phenological development of sunflower hybrids grown under contrasting agroecological conditions . Research Journal of Agricultural Science, 57 (2), 254-259. ISSN: 2668-926X