AGRICULTURAL UNIVERSITY - PLOVDIV

FACULTY OF AGRICULTURE
DEPARTMENT OF CROP SCIENCE

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Agronomic characteristics of express tolerant sunflower hybrids (*Helianthus annuus* L.) depending on the soil's nutrient supply.

ABSTRACT

In the scientific specialty 6.1. "Plant Growing"
Specialty Plant Breeding

Supervisor:
Prof. Dr. Hristofor Kirchev

Plovdiv, 2021

The study was conducted in the period 2018 - 2020 in the Experimental field of the Department of Crop Science at the Agricultural University, Plovdiv.

The dissertation contains 174 typewritten pages, 27 tables, 31 figures. The list of cited literature includes a total of 268 literature sources, of which 57 in Cyrillic and 211 in Latin letters.

The dissertation was discussed at the Department council.

The defence of the dissertation will take place on …………… 2021. from. ….... hours of the meeting of the Specialized Scientific Jury at the Agricultural University, Plovdiv,
with members:

Internal members:

Prof. Dr. Ivan Yanchev

Prof. Dr. Tonya Georgieva

External members:

Assoc. Prof. Dr. Petar Yankov

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I. INTRODUCTION

Sunflower (*Helianthus annuus* L.) is the most widespread and important technical crop in Bulgaria. This is not a coincidence, given that sunflower oil is the traditional vegetable oil that has been consumed in Bulgaria over the last 90 years.

Sunflower originated in the steppes of North America, where wild forms are still found. For Europe and other continents, it is a relatively new culture, as it was transferred to Europe in 1510 (16th century), originally grown as an ornamental plant and for seeds. Barely in the 18th century began its mass cultivation for sunflower oil, which is of high quality. The interest in sunflower also comes from its high production capacity. In our country, the sunflower was transferred after the Liberation, initially as an ornamental plant, and later began to be grown as an oil crop, and shortly after that, it became the main one.

The area of sunflowers in the world is growing from 65 to 100 million da. In recent years, hard work has been done in the field of selection of highly productive and high-oil hybrids, and significant success has been achieved. As a result, the growth rate of the areas lags behind the rate of production of seeds and sunflower oil, which increase significantly.

Sunflower has become the main crop for the countries of Southern Europe for the production of biodiesel, and this is one of the main uses of oilseed crops in recent years.

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 largest and most important field crop requires detailed research on the agronomic aspects of production, adequate to the selection achievements of this crop, land ownership and market economy.

II. PURPOSE AND TASKS OF THE RESEARCH

The present study aims to determine the influence of soil nutrient supply on some biological and economic qualities in express tolerant sunflower hybrids.

Tasks:

1. To study the phenological development of express tolerant sunflower hybrids to establish the duration of the interphase periods depending on the variety and content of elements in the soil.

2. To study the yield of seeds and their components in express tolerant sunflower hybrids with different soil nutrition regimes.
3. To study the physical properties of seeds, fat content and their fatty acid composition in conditions of different soil nutrition regimes by express tolerant sunflower hybrids.
4. To establish the correlations between the studied quantitative and qualitative indicators of express tolerant sunflower hybrids.

III. MATERIAL AND METHODS.

1.Field experiment.

To achieve the aim and objectives of the study, three annual field trials were conducted in the period 2018-2020 in the Experimental field of the Department of Crop Science at the Agricultural University of Plovdiv.

The experiments were set by the method of fractional plots (Split-Plot Design) after the predecessor triticale in 4 replications with a size of the experimental area of 21 m^2 and the harvest - 10 m^2 (Box et al., 2005; Jones and Nachtscheim, 2009).

1.1. Factors studied and their levels:

Factor A – Hybrid

A1 – P64LE25 - Pioneer (standard)

A2 – LG 59.580 SX - Limagrain

A3 – Subaro HTS - Syngenta

A4 – ES Arcadia - Euralis

A5 – Magma SU (CSF 17902 SU) - Caussade semences

Factor B - Soil nutritional regime

B1 – Soil nutritional regime 1

B2 – Soil nutritional regime 2

1.2. Soil nutritional regime

The two soil nutritional regimes are due to residual amounts from previous experience with two backgrounds of mineral fertilization of the predecessor triticale (Georgieva, 2020).

2. Biological indicators

2.1. Phenological development

- Registering the occurrence of the main phenological phases (Ganeva, 1984).
- Duration of the interphase periods.

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

- plant height (cm), stem thickness (cm), leaf area (cm^2), pseudanthium (head) diameter (cm), number of seeds in pseudanthium, the density of the head (Ph), number of seeds/cm^2

2.3. Productive indicators

- The yield of seeds (SY), kg/da. - determined by an indirect method (Zapryanov and Marinkov, 1978)
- Biological yield - total and by organs (stems, leaves, pseudanthiums and seeds), g/plant.
- Head harvest index (HI)
- Seeds harvest index
- Oil extraction, kg/da

2.4. Seed quality indicators:

- mass of 1000 seeds, g - by weighing two samples of 500 seeds (BDS 13358-76);
- hectolitre mass, kg - by chondrometer (cylinder with a capacity of 1 litre) (BDS ISO 7971-2);
- Seed fat content, %
- Fatty acid composition of the oil, %

3. Chemical analysis

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

- pH (BDS ISO 10390: 2005)
- content of mobile nitrogen, mg/kg (ISO / TS 14256-1: 2003)
- mobile phosphorus (P_2O_5) mg/100g (GOST 26209: 1991)
- mobile potassium (K_2O) mg/100g (GOST 26209: 1991)

3.2. Plant seed analyzes.

- Determination of raw fat - (BDS - 3412);
- Fatty acid composition of the oil - by gas chromatography (ISO 12966).

- Unsaturated:	- Saturated:
C18:2 – Linoleum	C16:0 – Palmitic
C18:1 – Oleic	C18:0 – Stearic

IV. SOIL AND CLIMATE CHARACTERISTICS

IV.1. Soil characteristics

According to the FAO international classification, the soil in the Experimental Fiel of the Department of Crop Science is carbonate alluvial-meadow (Mollic Fluvisols). These soils are relatively young, as the process of soil formation is characterized by the accumulation of mature humus and weak chemical weathering of the mineral part of the soil. The soil profile that is formed is of the AC-Go-Gr type (Gyurov and Artinova, 2015).

The agrochemical analysis of the soil before sowing the sunflower determines the conditions of mineral nutrition of the plants depending on the soil nutrients left after two fertilizer norms in the predecessor triticale (Table 1).

Table 1. Agrochemical analysis of the soil before sowing sunflower.

Year	**Soil nutrients**	**pH**	**N, mg/kg**	**P_2O_5, mg/100 g**	**K_2O, mg/100 g**
2018	Sn_1	7,80	29,67	59,54	31,34
	Sn_2	7,87	42,56	71,25	46,73
2019	Sn_1	7,84	28,54	47,85	32,15
	Sn_2	7,91	47,52	69,79	46,84
2020	Sn_1	7,94	24,32	51,23	33,24
	Sn_2	7,98	45,21	70,27	46,62

IV.2. Agrometeorological conditions during the vegetation of the crop

The first year of the study was generally characterized as warmer and wetter compared to the multiannual data for the area (Figure 1).

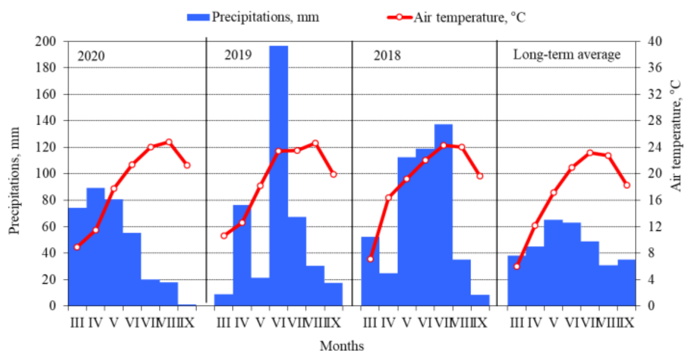

Figure 1. Climatogram of the years of research and average for a multi-year period

Comparing the temperature sum by months, with the climatic norm it is clear that the second harvest year is also warmer. The amount of precipitation for this second year is characterized by drastic differences from the climatic norm. The first month of the vegetation, March, during which the sowing was carried out, is characterized by a very low amount of precipitation (8.8 mm), which is a very low value, considering that it is during this period that the crop needs water to germinate the seeds.

The low values of moisture content of the crop in the third harvest year affected not so much the growth and development of sunflower, but mainly on some quality indicators of the seeds, discussed in the relevant subsections in the section "Results and discussion".

V. RESULTS AND DISCUSSION

V.1. Phenological development

The duration of the vegetation period in the studied sunflower hybrids in the first year of the study varies between 149-160 days.

The longest is in the hybrid Subaro - 160 days, followed by P64LE25 and Magma - 157 days; LG 59.580 SX - 154 days and the shortest in Arcadia - 149 days, which defines it as the earliest compared to other studied sunflower hybrids (Figure 2).

During the second harvest year, the duration of the vegetation period for all studied hybrids varies again as in the first 2018 - from 149 to 160 days. In the hybrids, Subaro and Arcadia, the length of the growing season are the same as in the second year of the study, as in the hybrid Arcadia the growing season is again the shortest (149 days) and it is defined as the earliest one.

In the 2020 harvest year, the length of the growing season for all studied sunflower hybrids is shorter than in the previous two years, varying between 141-152 days. It is the longest in the Magma SU hybrid - 152 days, followed by LG 59.580 SX - 149 days, Subaro - 146 days and P64LE25 - 143 days. The shortest vegetation period is in the EU Arcadia hybrid - 141 days, which for the third year defines this hybrid as the earliest compared with the other studied sunflower hybrids.

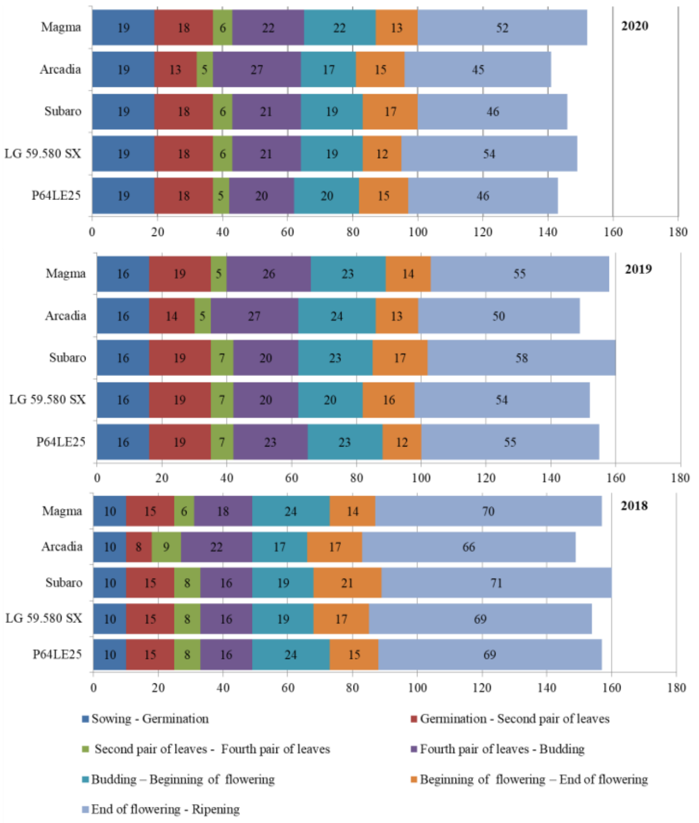

Figure 2. Duration of the interphase periods (number of days)

From the study related to the phenological development of sunflower, it can be concluded that in the conditions of Plovdiv the average vegetation period of the crop is 152 days. The difference between the earliest and the latest hybrid is 10 days. The shortest vegetation period is in the EU Arcadia hybrid - 146 days, and the longest - Magma SU hybrid - 156 days. The longest is the interphase period end of flowering - ripening (57 days) and the shortest - 2nd - 4th pair of leaves (6,5 days). Soil nutritional regime does not affect the phenological development of sunflower.

V.2. Biometric indicators

V.2.1. Plant height

In all hybrids included in the present study, a higher soil nutritional regime has a positive effect on crop height. This is confirmed by the obtained results and the applied two-factor analysis of variance, proving the influence of the "soil nutrients" factor (Table 2).

Table 2. Two-factor dispersion analysis of plant height.

Year	*Source of Variation*	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
2018	Soil nutrients	1863,23	1	1863,22	60,31	0,00*****	4,17
	Hybrids	3299,15	4	824,78	26,69	0,00*****	2,69
	Variance	185,65	4	46,41	1,50	0,23**ns**	2,69
2019	Soil nutrients	2146,22	1	2146,22	147,25	0,00*****	4,17
	Hybrids	7311,25	4	1827,81	125,40	0,00*****	2,69
	Variance	169,65	4	42,41	2,91	0,04*****	2,69
2020	Soil nutrients	2464,90	1	2464,90	107,33	0,00*****	4,17
	Hybrids	3582,00	4	895,50	38,99	0,00*****	2,69
	Variance	251,60	4	62,90	2,74	0,05**ns**	2,69
Average	Soil nutrients	2158,12	1	2158,11	104,97	0,00*****	4,17
	Hybrids	4790,8	4	1170,70	63,70	0,00*****	2,69
	Variance	202,3	4	50,57	2,38	0,11**ns**	2,69

* Proven action at $P<0.05$, **ns** - unproven action of the factor

The influence of the hybrid factor has also been proven, which confirms the thesis of the difference of hybrids due to their remoteness concerning their different origins.

There is no connection between the two factors, which shows that the presence of nutrients in the soil nutritional regimes is not associated with a dependent change in plant height in individual sunflower hybrids because of differences in plant height between the two soil nutritional regimes in each hybrid are different.

Average for the three years of the study, the thesis was confirmed that better soil nutritional regime has a positive effect on plant height in all tested hybrids.
The difference between the two soil nutrients regarding plant height average for the three years of the study and average for all hybrids is 14.6 cm. The lowest plants form the hybrid Magma SU – 170,5 cm and the highest – the hybrid Arcadia – 197,8 cm (Figure 3).

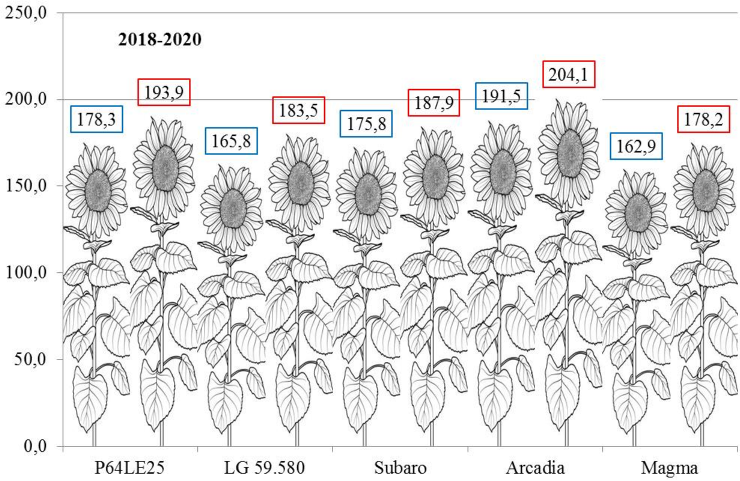

Figure 3. Plant height on average for three years, cm (□ soil nutrients 1 □ soil nutrients 2)

As in the three years of the study, there is no connection between the two factors, which again shows that the presence of nutrients in the soil was not associated with a dependent change in plant height in all of the studied sunflower hybrids.

V.2.2. Stem thickness, cm

Average for the three years of the study, the thesis is confirmed that the better soil nutritional regime has a positive effect on the sign of stem thickness in all five studied sunflower hybrids.

Average for all hybrids, the higher soil nutrients leads to the formation of stems with a diameter of 0.47 cm larger. The thickest stem is formed by the hybrids P64LE25 and Magma SU – 2,57 cm and the thinnest - Hybrid ES Arcadia – 2,50 cm (Figure 4).

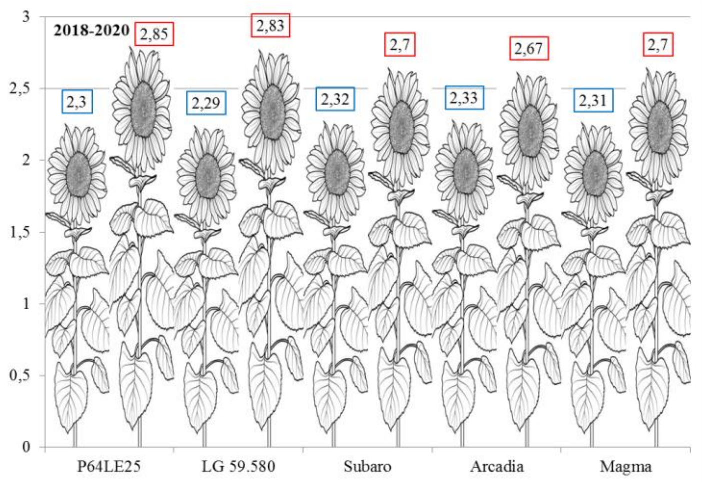

Figure 4. Stem thickness averaged over three years, cm (□ soil nutrients1 □ soil nutrients2)

As in the third harvest year, the influence of the hybrid factor is not proven, because the difference between the maximum and minimum values is only 0,07 cm.

V.2.3. Leaf area

Average for the three years of the study, the positive effect of soil nutritional regime on leaf area was confirmed in all studied hybrids (Table 3).

This positive influence can be seen both from the direct results and from the two-factor analysis of variance, where the influence of the soil nutrients factor and the influence of the hybrid factor is proved.

Average for the three years, the interaction between the two factors is not confirmed, similar to the 2020 harvest.

Table 3. Two-factor dispersion analysis of leaf area

Year	Source of Variation	SS	df	MS	F	P-value	F crit
2018	Soil nutrients	29918898	1	29918898	212,69	0,00*	4,17
	Hybrids	41004875	4	1025121	7,28	0,00*	2,69
	Variance	33669142	4	841728	5,98	0,00*	2,69
2019	Soil nutrients	16780451	1	16780451	94,31	0,00*	4,17
	Hybrids	81345913	4	2033647	11,43	0,00*	2,69
	Variance	39437951	4	985948	5,54	0,00*	2,69
2020	Soil nutrients	17137285	1	17137285	45,49	0,00*	4,17
	Hybrids	41318198	4	1032955	2,74	0,05^{ns}	2,69
	Variance	15168137	4	379203	1,01	0,42^{ns}	2,69
Average	Soil nutrients	21278878	1	21278878	117,5	0,00*	4,17
	Hybrids	54556328	4	1363908	7,15	0,02*	2,69
	Variance	29425076	4	735626	4,17	0,14^{ns}	2,69

* Proven action at $P<0.05$, **ns** - unproven action of the factor

V.2.4. Pseudanthium (head) diameter, cm

Average for the three years of the study, the thesis was confirmed that better soil fertility has a positive effect on the pseudanthium diameter (Figure 5).

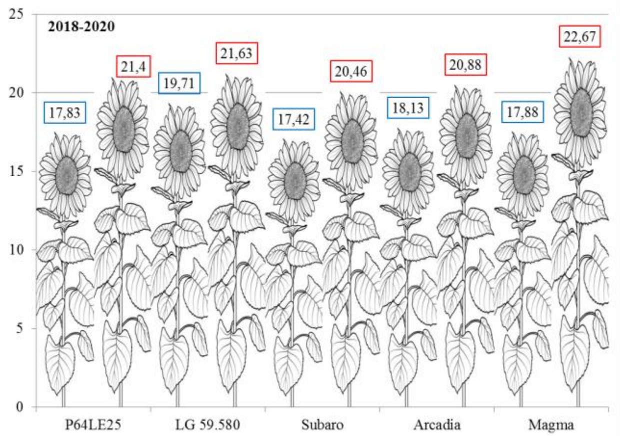

Figure 5. Diameter of the pie on average for three years, cm (□ soil nutrients 1 □ soil nutrients 2)

This is seen from the direct average results, where the increased soil fertility leads to an increase in the size of the head by 3,22 cm.

The largest difference between the two soil nutritional regime is observed in the Magma SU hybrid – 4,79 cm larger head compared to the lower soil nutrients, and the smallest - in the LG 59.580 SX hybrid – 1,92 cm. The stronger influence of the "soil nutrients" factor on the "hybrid" factor is established by comparing the differences between the higher and lower values - the difference between the two soil nutrients is 3,22 cm, while the difference between the hybrids that formed the smallest (Arcadia) – 19,50 cm) and the largest pie (LG 59.580 SX – 20,67cm) is 1,17 cm.

V.2.5. Number of seeds in the pseudanthium

Average for the three harvest years, the number of seeds in the head is positively affected by increasing the soil's nutrient supply (Table 4).

Table 4. Number of seeds in the pseudanthium

Year	**Soil nutrient**	**Hybrids**				
		P64LE25	**LG 59.580**	**Subaro**	**Arcadia**	**Magma**
2018	Sn_1	1347	1757	1383	1157	1339
	Sn_2	1659	2094	1584	1435	1588
	±D	312	337	201	278	249
2019	Sn_1	1092	1215	995	913	932
	Sn_2	1409	1459	1258	1004	972
	±D	317	244	263	91	40
2020	Sn_1	1478	1353	1193	998	1287
	Sn_2	1559	1421	1248	1084	1388
	±D	81	68	55	86	101
Avarege	Sn_1	1305	1441	1190	1022	1186
	Sn_2	1542	1658	1351	1174	1316
	±D	237	217	161	152	130

The average results show the largest difference between the two soil nutrients in the P64LE25 hybrid - 237 seeds more at the higher soil nutrients, and the smallest - in the Magma hybrid - 130 seeds.

Contrary to the previous indication connected with the head (diameter of the head), with this indication, the influence of the "hybrid" factor is more significant than the "soil nutrients" factor, because the difference between the hybrid with the smallest and largest number of seeds in the pseudanthium is 452, and between the two soil nutrients - 179 seeds.

V.2.6. The density of the head, number of seeds/cm^2

The increased level of macronutrients in the soil leads to a proven effect of the factor on the density of the pseudanthium (Table 5).

Table 5. Two-factor dispersion analysis of the density of the head

Year	*Source of Variation*	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
2018	Soil nutrients	1,89	1	1,89	9,86	0,00*	4,17
	Hybrids	10,42	4	2,60	13,62	0,00*	2,69
	Variance	3,32	4	0,83	4,34	0,01*	2,69
2019	Soil nutrients	30,695	1	30,695	8,366	0,01*	4,17
	Hybrids	354,77	4	88,693	24,17	0,00*	2,69
	Variance	56,652	4	14,163	3,860	0,01*	2,69
2020	Soil nutrients	15,18	1	15,18	23,61	0,00*	4,17
	Hybrids	12,38	4	3,10	4,81	0,00*	2,69
	Variance	0,86	4	0,22	0,34	0,85^{ns}	2,69
Avarage	Soil nutrients	15,91	1	15,92	13,95	0,00*	4,17
	Hybrids	125,86	4	31,46	14,20	0,00*	2,69
	Variance	20,30	4	5,07	2,85	0,29^{ns}	2,69

* Proven action at $P<0.05$, **ns** - unproven action of the factor

In all of the studied hybrids, the higher soil nutritional regime leads to a lower density of the pseudanthium, especially in the P64LE25 hybrid, in which the higher soil nutritional regime leads to 1,8 fewer seeds located in the head.

Considering the indicator of density of the head and the two-factor analysis of variance, average for the three studied years, the higher soil fertility has a proven influence on the indicator as well as the hybrid factor, but the interaction of the two factors is not proved (Table 5).

In all five studied hybrids, the higher soil nutritional regime leads to a lower density of the head. The biggest difference between the two soil nutrients is in the Magma hybrid - with 1,41 fewer rare seeds in the head.

V.3. Productive indicators

V.3.1. Yield of seeds

In all tested sunflower hybrids, the higher soil fertility had a positive effect on their productivity for the entire study period (Table 6). Average for the three studied years, the thesis is confirmed that better soil nutrients has a positive effect on the yield of seed in all studied sunflower hybrids.

Table 6. The yield of seed, kg/da

Year	Soil nutrient	Hybrids				
		P64LE25	**LG 59.580**	**Subaro**	**Arcadia**	**Magma**
2018	Sn_1	337,5	351,4	337,6	280,3	296,9
	Sn_2	452,4	445,7	412,1	417,5	411,4
	±D	114,8	94,3	74,5	137,2	114,5
2019	Sn_1	194,9	271,3	203,8	186,5	174,0
	Sn_2	303,0	316,2	247,8	207,5	247,1
	±D	108,1	44,9	44,0	21,1	73,1
2020	Sn_1	262,7	329,5	239,3	245,0	240,3
	Sn_2	394,3	388,5	347,5	304,0	338,1
	±D	131,6	58,9	108,2	59,0	97,9
Avarage	Sn_1	265,03	332,36	260,23	237,27	228,07
	Sn_2	383,23	383,47	335,8	309,67	332,2
	±D	118,17	66,03	75,57	177,97	95,17

This is clear both from the direct average results and from the two-factor analysis of variance, where the influence of the soil nutrients factor and the influence of the hybrid factor is proved (Table 7).

During the three years of the study, the interaction between the two factors was not proven, which shows that the presence of nutrients in the soil is not associated with a dependent change in the yield of seed in all studied sunflower hybrids.

The reason for this is the lack of difference between the average yields of the two soil nutrients (84,3 kg), approximately as much as the difference between the most productive (LG 59.580) and the lowest yielding (Arcadia) hybrids - 84.4 kg.

Table 7. Two-factor dispersion analysis of yield of seed

Year	*Source of Variation*	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
2018	Soil nutrients	114639,8	1	114639,8	70,868	0,00*	4,17
	Hybrids	16502,2	4	4125,6	2,550	0,06^{ns}	2,69
	Variance	4494,5	4	1123,6	0,695	0,60^{ns}	2,69
2019	Soil nutrients	33868,9	1	33868,9	38,94	0,00*	4,17
	Hybrids	46178,8	4	11544,7	13,27	0,00*	2,69
	Variance	8937,9	4	2234,5	2,57	0,06^{ns}	2,69
2020	Soil nutrients	83018,5	1	83018,5	43,50	0,00*	4,17
	Hybrids	37618,1	4	9404,5	4,93	0,00*	2,69
	Variance	8097,6	4	2024,4	1,06	0,39^{ns}	2,69
Avarage	Soil nutrients	77175,7	1	77175,7	51,1	0,00*	4,17
	Hybrids	33433,0	4	8358,3	6,9	0,02*	2,69
	Variance	7176,8	4	1794,2	1,4	0,35^{ns}	2,69

* Proven action at $P<0.05$, **ns** - unproven action of the factor

Regarding their average productivity (for three years and both soil nutrients) the studied sunflower hybrids can be arranged in the following descending order: LG 59.580> P64LE25> Subaro> Magma> Arcadia.

V.3.2. Biological yield

Average for the three years of the study, the thesis is confirmed that better soil nutritional regime has a positive effect on the biological yield of plants by organs. This is clear from direct research (Table 8), where it is seen that better soil fertility leads to higher values of the amount of biomass accumulated by plants (by organs or whole plant).

Table 8. The biological yield of plants by organs, on average for three years, g

Hybrids	**Soil nutrients**	**Organs**				**Plant**
		Stem	**Leaf**	**Head**	**Seeds**	
P64LE25	Sn_1	81,93	39,80	94,19	83,83	299,76
	Sn_2	140,00	114,63	148,16	128,70	531,48
LG 59.580	Sn_1	119,81	69,70	128,62	104,50	422,63
	Sn_2	158,02	101,34	149,73	127,08	536,17
Subaro	Sn_1	100,22	61,90	111,85	92,47	366,45
	Sn_2	171,10	104,19	142,42	107,04	524,75
Arcadia	Sn_1	144,73	66,97	103,24	79,34	394,28
	Sn_2	212,79	100,09	135,42	103,85	552,15
Magma	Sn_1	90,00	72,89	93,39	79,36	335,64
	Sn_2	150,19	120,23	161,68	110,03	542,14

The difference in the nutritional regime affects the ratio of plant organs to the total biological yield of individual sunflower hybrids (Figure 6).

In the P64LE25 standard, in the conditions of lower soil nutrients with macroelements, 33,7% of seeds are formed, and at the higher level – 29,0% of seeds concerning the total biological yield. In the hybrid LG 59.580 SX – 30,5% seeds at lower soil nutrients and 28,3% at higher soil nutrients.

At Subaro - the difference in the ratio of seeds is the largest – 5,2% in favour of soil nutrients 1; in Magma – 3,3% and in Arcadia SU the difference between the two soil nutrients is the smallest – 2,3%.

The participation of stems in the formation of biological yield, the average for the three years of the study, follows opposite trends.

From the average results, it is established that the better soil nutritional regime has a positive effect on the proportion of stems, increasing it by between 0,4 and 3,3%.

Average over three years, higher soil fertility had a positive effect on leaf percentage in four of the sunflower hybrids tested, increasing it by between 0,7 and 7,9%.

Analyzing the total average values for all sunflower hybrids we can conclude that in the climatic conditions of Plovdiv the sunflower plant consists of 35% stems, 21% leaves, 17% pseudanthium and 27% seeds.

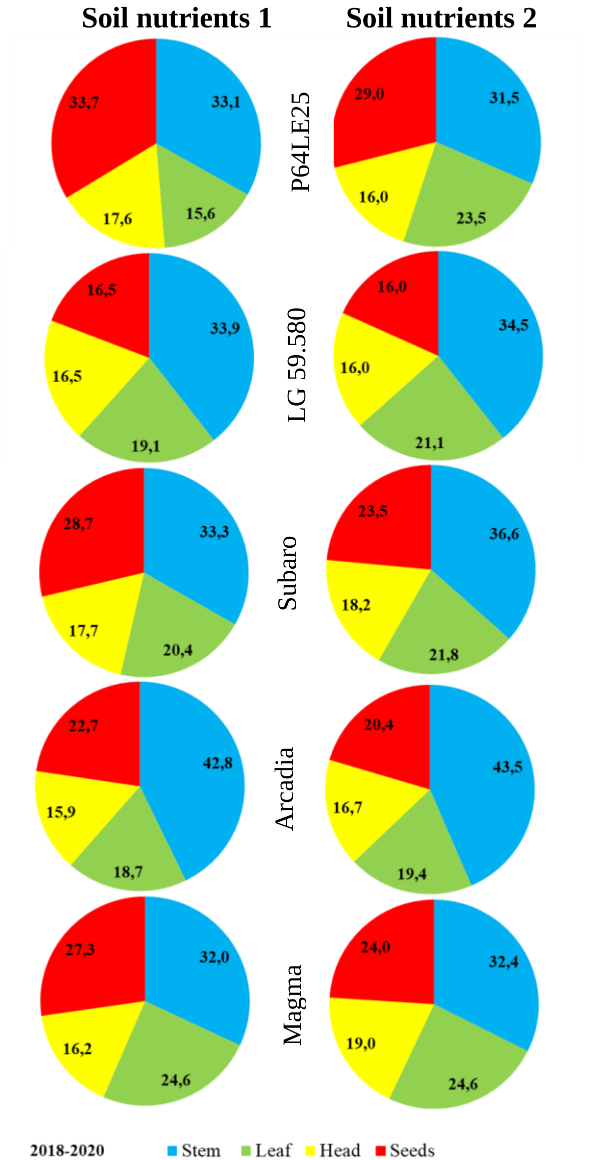

Figure 6. Correlation of the organs of the plants, an average of three years, %

The participation of seeds as an organ in the plant has a major contribution to the formation of yield, as it is in the most highly productive hybrids LG 59.580 SX (29,4%) and P64LE25 (31,3%) the share of seeds is the largest and most -lowest share of seeds in the plant is in the least productive hybrid Arcadia (21,5%).

V.3.3.1 Head harvest index

Average for the three years of the study, the thesis is confirmed that the increase in soil fertility has a negative effect on the head harvest index.

In the five studied hybrids, the better supply of soil with nutrients leads to a decrease in the head harvest index. In the Magma hybrid, the difference between the two nutritional regimes is the largest (0,066), and in the P64LE25 hybrid - the smallest (0,005) (Table 9).

Table 9.Head harvest index

Year	Soil nutrients	Hybrids				
		P64LE25	LG 59.580	Subaro	Arcadia	Magma
2018	Sn_1	0,651	0,692	0,615	0,579	0,622
	Sn_2	0,603	0,689	0,611	0,580	0,512
2019	Sn_1	0,633	0,575	0,568	0,563	0,598
	Sn_2	0,625	0,583	0,488	0,523	0,528
2020	Sn_1	0,683	0,661	0,658	0,616	0,647
	Sn_2	0,726	0,611	0,576	0,530	0,629
Avarage	Sn_1	0,656	0,643	0,614	0,586	0,622
	Sn_2	0,651	0,628	0,558	0,544	0,556

V.3.3.2. Seeds harvest index

Average for the three harvest years, the thesis is confirmed that the increase in soil fertility affects the seeds harvest index to varying degrees (Table 10).

Similar to the 2019 study year, in four of the hybrids (P64LE25, LG 59.580, Arcadia and Magma), the increase in soil fertility leads to a decrease in the seed harvest index by 0,02% in P64LE25 and Magma, and by 0,01%. in the hybrids LG 59.580 and Arcadia.

Only in the Subaro hybrid, better soil fertility leads to higher values of the indicator.

Table 10. Seed harvest index

Year	Soil nutrients	Hybrids				
		P64LE25	**LG 59.580**	**Subaro**	**Arcadia**	**Magma**
2018	Sn_1	0,74	0,77	0,76	0,72	0,73
	Sn_2	0,73	0,75	0,75	0,71	0,71
2019	Sn_1	0,74	0,72	0,66	0,63	0,68
	Sn_2	0,73	0,71	0,68	0,68	0,66
2020	Sn_1	0,71	0,70	0,72	0,71	0,73
	Sn_2	0,68	0,69	0,73	0,65	0,69
Avarage	Sn_1	0,73	0,73	0,71	0,69	0,71
	Sn_2	0,71	0,72	0,72	0,68	0,69

V.3.4. Seeds fat content

On average for the three harvest years, the fat content in the seeds maintains the tendency to decrease in better soil nutritional regime and the five studied hybrids (Table 11).

Table 11. Seeds fat content, %

Year	Soil nutrients	Hybrids				
		P64LE25	**LG 59.580**	**Subaro**	**Arcadi a**	**Magma**
2018	Sn_1	45,2	45,3	42,6	39,4	39,4
	Sn_2	40,1	40,1	40,3	38,2	38,7
2019	Sn_1	45,8	38,6	37,9	37,8	43,8
	Sn_2	42,9	34,6	31,1	32,2	31,8
2020	Sn_1	47,9	45,5	48,0	44,4	42,5
	Sn_2	39,4	38,0	46,8	35,0	34,7
Avarage	Sn_1	46,3	43,1	42,8	40,5	41,9
	Sn_2	40,8	37,6	39,4	35,1	35,1

The obtained results regarding the influence of the “soil nutrients” factor on the fat content in sunflower seeds are statistically proven (Table 12).

The largest difference between the two soil nutritional regime, the average for the three years of the study, is observed in the Magma hybrid, in which the increase in soil nutritional regime leads to a decrease in fat content by 6,8%, followed by hybrids.

Table 12. Two-factor dispersion analysis of seed fat content

Year	***Source of Variation***	***SS***	***df***	***MS***	***F***	***P-value***	***F crit***
2018	Soil nutrients	21,02	1	21,03	9,23	0,04*	7,71
	Hybrids	28,86	4	7,22	3,17	$0,15^{ns}$	6,39
2019	Soil nutrients	97,96	1	97,97	15,65	0,02*	7,71
	Hybrids	125,9	4	31,48	5,03	$0,07^{ns}$	6,39
2020	Soil nutrients	118,33	1	118,34	22,29	0,01*	7,71
	Hybrids	97,10	4	24,28	4,57	$0,09^{ns}$	6,39
Avarage	Soil nutrients	79,11	1	79,11	15,72	0,02*	7,71
	Hybrids	83,96	4	20,99	4,26	$0,10^{ns}$	6,39

* Proven action at P<0.05, **ns** - unproven action of the factor

P64LE25 and LG 59.580, at which difference is 5,5% in favour of soil nutrients 1; Arcadia hybrid with a minimal difference – 5,4% lower fat content in soil nutrients 2 and last place, with the lowest difference, remains the Subaro hybrid with 3,4% less fat in soil nutrients 2.

Although the effect of the hybrid factor on seed fat content was not significant in the analysis of variance, the studied sunflower hybrids can be ranked in the following descending order of average seed fat content: P64LE25> Subaro> LG 59.580> Magma> Arcadia.

V.3.5. Oil extraction

Average for the three harvest years, in all tested hybrids, the higher soil nutritional regime has a positive effect on the yield of oil (Table 13).

Oil yield increased the most at the P64LE25 - standard (33,0 kg/da), followed by the Subaro hybrid (23,3 kg/da); Magma (18,3 kg/da); Arcadia (14,3 kg/da) and the weakest influence on oil yield is in the hybrid LG 59.580 SX – 7,3 kg/da.

Table 13. Oil extraction, kg/da.

Year	Soil nutrients	Хибрид				
		P64LE25	**LG 59.580**	**Subaro**	**Arcadia**	**Magma**
2018	Sn_1	152,6	159,2	143,8	110,5	117,0
	Sn_2 ±D	181,4 28,8	178,7 19,6	166,1 22,3	159,5 49,0	159,2 42,2
2019	Sn_1	89,3	104,7	77,2	70,5	76,2
	Sn_2 ±D	130,0 40,7	109,4 4,7	77,1 -0,1	66,8 -3,7	78,6 -2,4
2020	Sn_1	125,8	149,9	114,9	108,8	102,1
	Sn_2 ±D	155,4 29,5	147,6 -2,3	162,6 47,8	106,4 -2,4	117,3 15,2
Avarge	Sn_1	122,6	137,9	112,0	96,6	98,4
	Sn_2 ±D	155,6 33,0	145,2 7,3	135,3 23,3	110,9 14,3	118,4 18,3

V.4. Seed quality indicators:

V.4.1. Mass of 1000 seeds

Average for the three years of the study, the thesis is confirmed that better soil nutritional regime has a positive effect on the indicator mass of 1000 seeds.

Table 14. Two-factor dispersion analysis of the mass of 1000 seeds

Year	*Source of Variation*	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
2018	Soil nutrients	911,07	1	911,07	25,95	0,00*	4,17
	Hybrids	2298,53	4	574,63	16,37	0,00*	2,69
	Variance	446,31	4	111,58	3,18	0,03*	2,69
2019	Soil nutrients	1862,95	1	1862,9	48,55	0,00*	4,17
	Hybrids	503,79	4	125,95	3,28	0,02*	2,69
	Variance	769,42	4	192,35	5,01	0,00*	2,69
2020	Soil nutrients	2475,90	1	2475,9	63,54	0,00*	4,17
	Hybrids	1511,49	4	377,87	9,70	0,00*	2,69
	Variance	488,93	4	122,23	3,14	0,03*	2,69
Avarage	Soil nutrients	1750	1	1750	46,01	0,00*	4,17
	Hybrids	1437,9	4	359,48	9,8	0,01*	2,69
	Variance	568,2	4	142,05	3,8	0,02*	2,69

* Proven action at $P<0.05$, **ns** - unproven action of the factor

This is confirmed by the average results, where increased soil fertility leads to an increase in the mass of 1000 seeds.

The largest difference between the two nutritional regimes is observed in the Magma hybrid – 20,50 g more seeds compared to the lower nutritional regime, and the smallest - in the LG 59.580 SX hybrid – 3,27 g.

These results are also confirmed by the two-factor analysis of variance during the three harvest years (Table 14), as the influence of soil nutrients, the influence of the "hybrid" factor and the interaction of these two factors is proved.

V.4.2. Hectolitre mass

Average for the three years of the study, the influence of soil fertility on the amount of accumulated hectolitre mass is ambiguous, similar to the first and third harvest years (Table 15).

Table 15. Two-factor analysis of variance of the hectoliter mass

Year	***Source of Variation***	***SS***	***df***	***MS***	***F***	***P-value***	***F crit***
2018	Soil nutrients	0,14	1	0,14	0,05	0,82^{ns}	4,17
	Hybrids	204,53	4	51,13	19,18	0,00*	2,69
	Variance	16,64	4	4,16	1,56	0,21^{ns}	2,69
2019	Soil nutrients	31,92	1	31,92	8,49	0,21^{ns}	4,17
	Hybrids	507,22	4	126,80	33,72	0,00*	2,69
	Variance	11,90	4	2,98	0,79	0,54^{ns}	2,69
2020	Soil nutrients	1,19	1	1,19	0,79	0,38^{ns}	4,17
	Hybrids	351,53	4	87,88	58,62	0,00*	2,69
	Variance	10,13	4	2,53	1,69	0,18^{ns}	2,69
Avarage	Soil nutrients	11,08	1	11,08	3,11	0,47^{ns}	4,17
	Hybrids	354,43	4	88,60	37,17	0,00*	2,69
	Variance	12,89	4	3,22	1,35	0,31^{ns}	2,69

* Proven action at P<0.05, **ns** - unproven action of the factor

In the hybrids, P64LE25, LG 59.580 SX and Arcadia, the better nutritional regime has a positive effect on the hectoliter mass, in the other two hybrids (Subaro and Magma) the values of this indicator decreased with higher soil nutrients. From the two-factor analysis of variance for the three harvest years and on average for them, it can be seen that the influence of the factor "soil nutrients" on the hectoliter mass is unreliable, and the interaction between the two factors is not proved. For the three years of the study, described differences between hybrids are reliable, due to the low level of F-crit., to F, which does not exceed the level of P, showing proven factor "hybrid".

V.4.3. Fatty acid composition of the oil

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

Average for the three years of the present study, the ratio of essential fatty acids changes differently, depending on the soil nutritional regime (Figure 7).

The content of saturated fatty acids decreases at the higher soil nutritional regime compared to the lower in three of the studied hybrids (P64LE25, LG 59.580 SX and Subaro). The difference between the two soil nutritional regimes in these three hybrids varies between 1,2 and 2,8% in favour of soil nutrients 1. In the Arcadia and Magma hybrids, the increase in soil fertility leads to an increase in the amount of saturated fatty acids, respectively by 0,7% in the Arcadia hybrid and by 1% in the Magma hybrid.

The content of unsaturated fatty acids, on average for three years, represents between 79,8 - 90% of the total oil composition in all the tested hybrids. In the hybrid P64LE2 (standard), the content of unsaturated fatty acids at lower soil nutritional regime is 82,7% (51,6% monounsaturated + 31,1% polyunsaturated). Better nutrient supply of the soil leads to an increase in the content of unsaturated fatty acids to 85,4% (56,2% monounsaturated + 29,2% polyunsaturated).

In the hybrid LG 59.580 SX, the content of unsaturated fatty acids at the first nutritional regime is 81,4% (45,6% monounsaturated + 35,8% polyunsaturated). The higher supply of soil with nutrients leads to an increase in the content of unsaturated fatty acids to 84,3% (50,8% monounsaturated + 33,5% polyunsaturated).

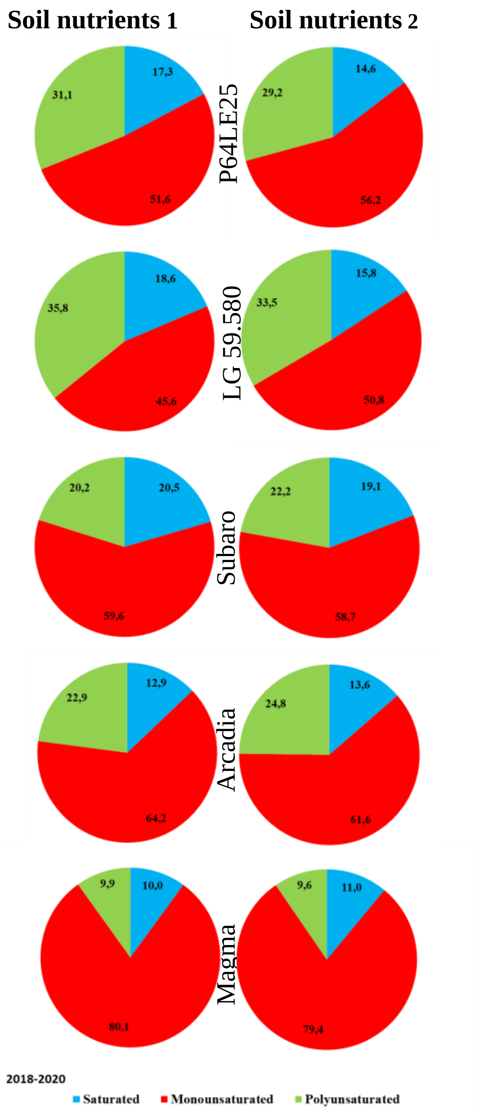

Figure 7. The ratio between saturated and unsaturated (polyunsaturated + monounsaturated) fatty acids, average over three years.

In the Subaro hybrid, the content of unsaturated fatty acids at the first stock is 79,8% (59,6% monounsaturated + 20,2% polyunsaturated). The higher supply of soil with nutrients leads to an increase in the content of unsaturated fatty acids to 80,9% (58,7% monounsaturated + 22,2% polyunsaturated).

In the Magma hybrid, the content of unsaturated fatty acids at the first stock is 90% (80,1% monounsaturated + 9,9% polyunsaturated). The higher supply of soil with nutrients leads to a decrease in the content of unsaturated fatty acids to 89% (79,4% monounsaturated + 9,6% polyunsaturated).

Apart from 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 appropriate batch of oil as linoleic or oleic type. According to the standards adopted for oil, the standard sunflower oil is linoleic type. High oleic is considered to be one in which the oleic acid content is over 75% (Codex Stan., 2015) and according to the latest standards (National Sunflower Association, 2018) the oil containing more than 82% oleic acid is defined as high oleic.

Average for the three studied years, the thesis is confirmed that the content of the four main fatty acids that form the oil of the five studied sunflower hybrids changes under the influence of soil nutrient supply (Figure 8). The other 10 fatty acids are in very small amounts, and in some variants are not present in the oil at all, so they are combined as "others".

In the P64LE25 hybrid, the linoleic acid content in the lower soil nutrient supply average for three years is 31,0%. Better soil nutritional regime has a negative impact, reducing the content to 29,1%. A reverse trend in the influence of soil nutritional regime was observed in the oleic acid content. At the first soil regime, the oleic acid content is lower (51,3%), and at the higher soil nutrients, it increases to 55,9%. At lower soil nutritional regime, the content of palmitic acid is 13,5%, and at better - decreases by 3%. A reverse trend was recorded in the content of stearic acid - at the lower nutritional regime content of the stearic acid was 3,3%, while at the higher soil that the availability and content are increased to – 3,7%.

In the second studied hybrid (LG 59.580 SX) the thesis is confirmed that the linoleic acid content is the highest compared to the other four hybrids. Similar to the standard, the linoleic acid content at the first soil nutrients is 35,7%, and the increase in soil fertility has a negative impact, as the linoleic acid content decreases by 2,3%. The tendency of the influence of the soil nutritional regime on the oleic acid content is reversed - in the first soil nutrients, the oleic acid content is lower (45,4%), and in the second – 50,5%. At lower soil nutritional regime, the content of palmitic acid is 14,8%, and at higher, it decreases by 2,9%. A reverse trend was recorded in the content of stearic acid - in the first soil nutritional regime it is 3,2%, and in the second it increases to 3,4%.

In the next studied hybrid (Subaro) the content of linoleic acid, on average for three years, at the lower soil nutrients is 20,0%. A better soil regime has a positive effect, as the linoleic acid content increases by 2%.

Reverse tendency to the influence of better soil nutrient supply is recorded in the content of oleic acid. In the first soil nutrients , its content is higher (59,1%) and in the second – 57,9%. In the lower preservation of the soil with nutrient content of palmitic acid was 15,4%, and at better soil contents, it is reduced by 1%. The same trend was observed in the content of stearic acid - in the first soil nutrients it is 4,5%, and in the second it decreases to 4,1%.

Average for three years, the content of linoleic acid in the hybrid Arcadia, in the first nutritional regime is 22,7%. The higher soil nutritional regime has a positive impact and the content increases to 24,7%. The opposite trend is the influence of the soil nutrients on the oleic acid content - in the first soil nutrients, the oleic acid content is higher – 64,0%, and in the second - decreases by 2,8%. In the first nutritional regime, the content of palmitic acid is 9,3%, and in the second it increases to 9,6%. The same tendency was observed in the content of stearic acid - in the first soil nutrients it is 3,3%, and in the second it increases again, as in the case of palmitic acid by 0,3%.

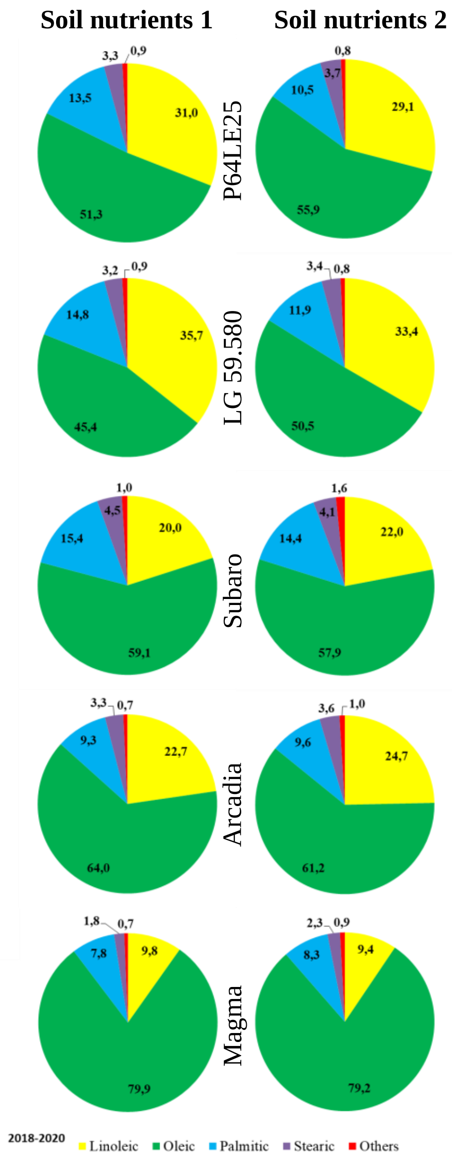

Figure 8. Fatty acid composition of oil, average for three years,%

In the Magma hybrid, an average of three years, the thesis is confirmed that the contents and the ratio of linoleic and oleic acid are the most different in comparison to all other hybrids in this study - contains the least linoleic acid and the most oleic acid in the oil. The content of linoleic acid in the first soil nutrients is 9,8%. Higher soil nutritional regime has a negative impact, as the linoleic acid content decreases to 9,4%.

The same tendency of the influence of the soil nutrients is observed in the content of oleic acid - in the first soil nutrients, the content of oleic acid is higher (79,9%), and in the second it decreases by 0,7%. In the first nutritional regime, the content of palmitic acid is 7,8%, and in the second it increases to 8,3%. The same trend was recorded in the content of stearic acid - in the first nutrients it is 1,8%, and in the second it increases by 0,5%.

VI.5. Correlation between quantitative and qualitative indicators in sunflower.

To establish the relationship between the variables (quantitative and qualitative characteristics) in sunflower, a correlation analysis was performed, in which the correlation coefficients between each of the variables were expressed, as well as visually by graphically representing the relationship between the main quantitative (yield of seeds) and quality (fat content in the seeds) indicators. Quantitative traits are those that are measured in absolute terms - a specific numerical expression represented in physical terms - fractions (kg/da), meter (m), number, etc. Qualitative characteristics are measured in relative quantities - they represent the ratio of two absolute or two average magnitudes - (%, index, etc.). Positive and negative correlations were reported, and according to the accepted methodological scheme (Zapryanov and Marinkov, 1978) the correlations were weak (<0,333) medium (0,333-0,666) and strong (> 0,666).

VI.5.1. Correlation between quantitative indicators in sunflower.

The yield of seeds is directly related to all other quantitative indicators, as the values of the correlation coefficients vary widely

(Table 16). Strong positive correlations (above 0,666) with a yield of seeds were reported with oil yield (0,925), and of the structural elements of the plant the strongest influence on the yield of seeds was exerted by leaf area (0,842), the number of seeds in the pseudanthium (0,841), the pseudanthium (head) diameter (0,832) and the stem thickness (0,758). Besides the high positive correlation coefficients, the absolute values of these signs have a very low correlation distraction, which further demonstrates the strong effect of the signs on the yield of seeds (Figure 10).

Visually, the connection of the yield with the other quantitative indicators is clearly expressed through the spatial arrangement of their vectors to them compared to the yield of seeds (Figure 9).

Table 16. Correlation analysis between quantitative indicators in sunflower.

Variables	Seed yield	Height	Stem diameter	Leaf area	Disk diameter	Number of seeds in disk	Disk density	Stem mass	Leaf mass	Disk mass	Seeds mass	Oil extraction
Seed yield	**1**	0,119	**0,758**	**0,842**	**0,832**	**0,841**	-0,134	0,269	0,067	-0,090	0,263	**0,925**
Height	0,119	**1**	0,314	**0,373**	0,271	0,020	**-0,371**	0,183	0,234	0,031	0,297	-0,063
Stem diameter	**0,758**	0,314	**1**	**0,846**	**0,896**	**0,491**	**-0,555**	**0,522**	**0,405**	0,226	0,307	**0,535**
Leaf area	**0,842**	**0,373**	**0,846**	**1**	**0,896**	**0,611**	**-0,464**	0,337	**0,512**	0,098	0,261	**0,643**
Disk diameter	**0,832**	0,271	**0,896**	**0,896**	**1**	**0,628**	**-0,555**	**0,439**	0,301	0,140	0,257	**0,629**
Number of seeds in disk	**0,841**	0,020	**0,491**	**0,611**	**0,628**	**1**	0,274	0,111	0,043	-0,280	**0,375**	**0,832**
Disk density	-0,134	**-0,371**	**-0,555**	**-0,464**	**-0,555**	0,274	**1**	**-0,375**	**-0,368**	**-0,486**	0,053	0,131
Stem mass	0,269	0,183	**0,522**	0,337	**0,439**	0,111	**-0,375**	**1**	**0,500**	0,308	0,105	0,126
Leaf mass	0,067	0,234	**0,405**	**0,512**	0,301	0,043	**-0,368**	**0,500**	**1**	**0,454**	**0,499**	-0,187
Disk mass	-0,090	0,031	0,226	0,098	0,140	-0,280	**-0,486**	0,308	**0,454**	**1**	-0,091	-0,242
Seeds mass	0,263	0,297	0,307	0,261	0,257	**0,375**	0,053	0,105	**0,499**	-0,091	**1**	0,188
Oil extraction	**0,925**	-0,063	**0,535**	**0,643**	**0,629**	**0,832**	0,131	0,126	-0,187	-0,242	0,188	**1**

*The values in **bold** are proven at a level of α = 0.05*

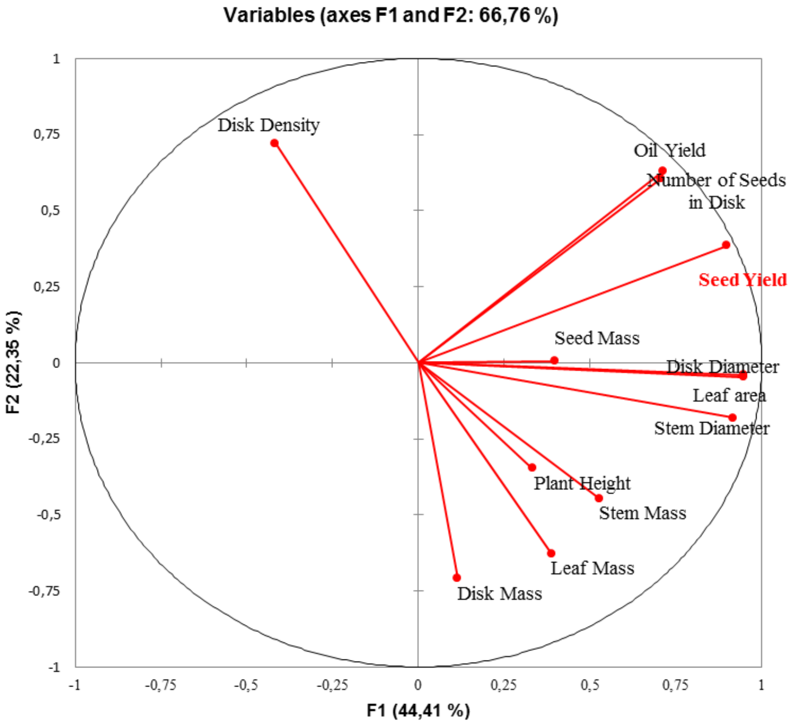

Figure 9. Principle component analysis (PCA) of quantitative indicators in sunflower.

The other quantitative indicators correlate weakly with the yield of seeds, the values of correlation coefficients were statistically unproven and have a very strong correlation distraction.

The height of the stem is the sign that correlates the least with the other quantitative signs in sunflower. With this indicator only two of the correlation coefficients are proved - the leaf area is positively related (0,373) and the density of the head - negatively (-0,371. Both dependencies are average. Stem diameter is a trait positively associated with a strong correlation with a head diameter (0,896), leaf area (0,846), oil extraction (0,535), stem thickness (0,522), number of seeds in the pseudanthium (0,491) and the mass of the leaves (0,405). There is an average negative correlation between the stem thickness and the density of the head (-0,555).

The leaf area is positively strongly related to the diameter of the head (0,896), on average related to the oil extraction (0,643), the number of seeds in the pseudanthium (0,611), the mass of the leaves (0,512), and the increase in leaf area lead to a decrease in density of the head (-0,464).

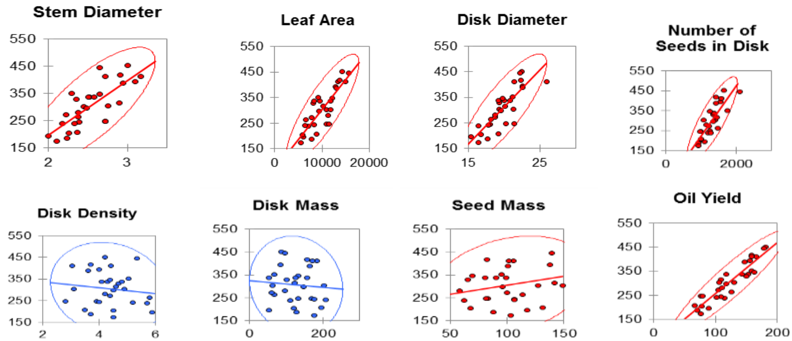

Figure 10. Correlation scattering between the yield of seeds and quantitative indicators in sunflower.

The pseudanthium diameter correlates on average positively with the oil extraction (0,629), the number of seeds in the head (0,628) and the stem thickness, and the increase in the values of the diameter of the head leads to an average decrease in the density of the head (-0,464). The number of seeds in the head is strongly related to the oil extraction (0,832) and on average - to the mass of seeds in the head (0,375). The density of the head is the indicator with the most negative correlations. Mean negative correlation (-0,486) was reported with the mass of pseudanthium, the mass of stem (-0,375) and the mass of leaf (-0,368). The mass of the stem is on average positively related to the mass of the leaves (0,500), and the mass of the leaves - to the mass of the pseudanthium (0,454) and the mass of the seeds (0,499).

VI.5.2. Correlation between quality indicators in sunflower.

The fat content is the main quality indicator for sunflower as an oil crop. This is the reason why this qualitative indicator is perceived as the main value in the comparison with the other variables in the present study. The fat content in sunflower seeds is mostly related to the two harvest indices - the head (0,660) and the seeds (0,556), which leads to the conclusion that the increase in the ratio of seeds in the head and the nut in the seed are the two main indicators increasing the fat content in the seeds (Table 17). This is also evidenced by the very low correlation scattering of these two traits (Figure 12). An average negative correlation was reported with the mass of 1000 seeds (-0,373). The links with the other indicators are not statistically proven and cannot be considered reliable. A sign of this is the strong correlation scattering of these signs (Figure 12).

The relationship between the fat content and other quality indicators is also established visually by the location of the trait vectors relative to that of the fat content in the seeds (Figure 11).

The head harvest index is on average positively related to the harvest index of seeds (0,492) and the hectoliter mass (0,438).

Table 17. Correlation analysis between quality indicators in sunflower.

Variables	Oil content	Disk harvest index	Seed harvest index	Mass of 1000 seeds	Hectolitre mass	Saturated	Mono-	Poly-	Linoleic	Oleic	Palmitic	Stearic
Oil content	**1**	**0,660**	**0,556**	**-0,373**	0,306	0,207	0,012	-0,091	-0,087	0,013	0,323	-0,318
Disk harvest index	**0,660**	**1**	**0,492**	-0,269	**0,438**	0,045	0,029	-0,046	-0,041	0,037	0,179	**-0,450**
Seed harvest index	**0,556**	**0,492**	**1**	-0,168	**0,782**	-0,278	-0,205	0,301	0,308	-0,202	-0,217	-0,294
Mass of 1000 seeds	**-0,373**	-0,269	-0,168	**1**	-0,096	-0,101	0,293	-0,248	-0,246	0,293	-0,061	-0,175
Hectolitre mass	0,306	**0,438**	**0,782**	-0,096	**1**	-0,099	-0,126	0,157	0,163	-0,124	-0,047	-0,211
Saturated	0,207	0,045	-0,278	-0,101	-0,099	**1**	-0,113	-0,268	-0,270	-0,119	**0,966**	**0,423**
Mono-	0,012	0,029	-0,205	0,293	-0,126	-0,113	**1**	**-0,927**	**-0,926**	**1,000**	0,058	**-0,643**
Poly-	-0,091	-0,046	0,301	-0,248	0,157	-0,268	**-0,927**	**1**	**1,000**	**-0,925**	**-0,421**	**0,466**
Linoleic	-0,087	-0,041	0,308	-0,246	0,163	-0,270	**-0,926**	**1,000**	**1**	**-0,924**	**-0,422**	**0,461**
Oleic	0,013	0,037	-0,202	0,293	-0,124	-0,119	**1,000**	**-0,925**	**-0,924**	**1**	0,053	**-0,650**
Palmitic	0,323	0,179	-0,217	-0,061	-0,047	**0,966**	0,058	**-0,421**	**-0,422**	0,053	**1**	0,178
Stearic	-0,318	**-0,450**	-0,294	-0,175	-0,211	**0,423**	**-0,643**	**0,466**	**0,461**	**-0,650**	0,178	**1**

*The values in **bold** are proven at a level of α = 0.05*

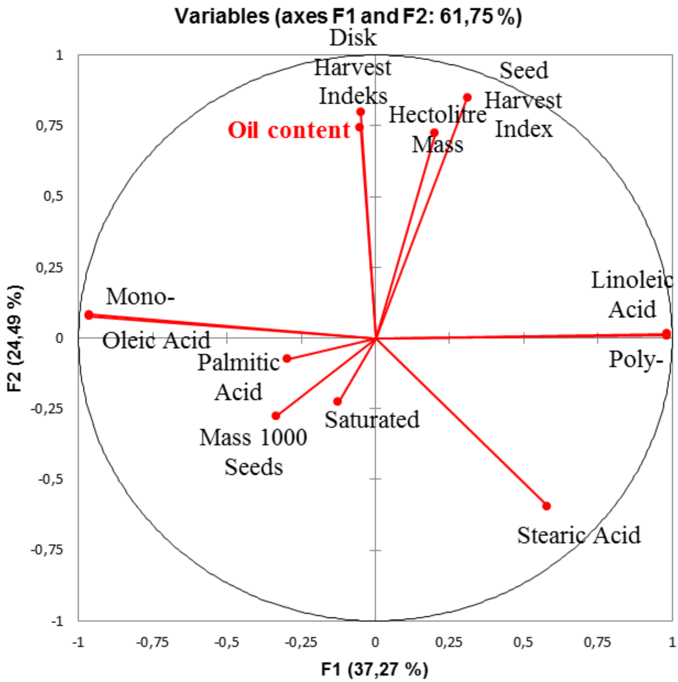

Figure 11. Principle component analysis (PCA) of quality indicators in sunflower.

The total content of saturated fatty acids is logically related to the two main saturated fatty acids in sunflower (palmitic and stearic), as namely palmitic acid to a much great extent, determine the content of saturated fatty acids (0,966), while the dependency of the saturated fatty acid stearic acid is less than (0.423).

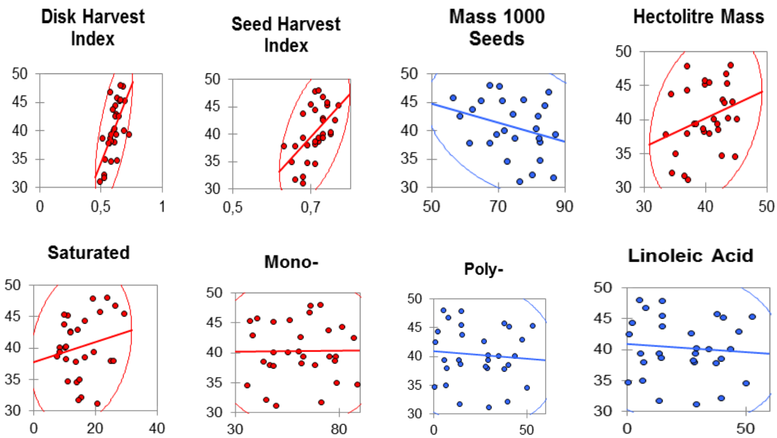

Figure 12. Correlation scattering between seed fat content and sunflower quality indicators.

The content of monounsaturated fatty acids is very strongly negatively related to the total content of polyunsaturated fatty acids (-0,927) and linoleic (-0,926) and stearic (-0,643) acids. The content of polyunsaturated fatty acids is negatively related to the content of oleic (-0,925) and palmitic (-0,421) acids. The content of polyunsaturated fatty acids has a positive effect on the content of stearic acid (0,466).

The linoleic acid content is very strongly negatively related to the other main unsaturated fatty acid - oleic (-0,924) and moderately negatively related to the palmitic acid content (-0,422).

A positive correlation was reported between linoleic and stearic acid content (0,461). There is a medium negative correlation between the content of oleic and stearic acids (-0,650).

VII. CONCLUSIONS

1. The average vegetation period of sunflower in the conditions of Plovdiv is 152 days, and the difference between the earliest and the latest hybrid is 10 days. The earliest hybrid is Arcadia, and the latest is the Magma hybrid. The longest is the interphase period end of flowering - ripening (57 days), and the shortest - 2nd - 4th pair of leaves (6,5 days). Soil nutritional regime does not affect the phenological development of sunflower.
2. Better soil nutritional regime has a positive effect on stem height and thickness in all tested hybrids. The lowest plants form a hybrid Magma, and the highest - a hybrid Arcadia. The influence of the "hybrid" factor on the thickness of the stem is not statistically significant.
3. Better soil fertility has a positive effect on the diameter of the head and the number of seeds in it, but negatively on the density of the head. The strongest negative impact on the density of the head was reported in the Magma hybrid due to the excessive effect of the higher soil nutritional regime on the diameter of the head and the size of the seeds, which cannot be compensated by the higher number of seeds in the pseudanthium.
4. Better soil nutritional regime has a positive effect on the yield of seeds in all studied sunflower hybrids. The interaction between the two factors (‘hybrid’ and ‘soil nutrients’) is not proven, due to the lack of difference between the average yields of the two soil stock with macronutrients (84,3 kg), approximately as much as the difference between the highest and the lowest yielding hybrids (84,4 kg).
5. The average yield of seeds of the investigated express tolerant sunflower hybrids allows them to be arranged in the following descending order: LG 59.580> P64LE25> Subaro> Magma> Arcadia.
6. Strong positive correlations with the yield of seeds were reported with oil extraction. From the structural elements of the plant, the strongest influence on the yield of seeds is exerted by the leaf area, the number of seeds, the diameter of the pseudanthium and the diameter of the stem.

7. The studied sunflower hybrids consisted of 35% stems, 21% leaves, 17% pseudanthium and 27% seeds. The participation of seeds as an organ in the plant has a major contribution to the formation of yield because it is in the most productive hybrids (LG 59.580 SX and P64LE25) the share of seeds is the largest, and the lowest share of seeds in the plant is the most -low-producing hybrid Arcadia.
8. The increased content of macronutrients in the soil leads to higher values of the mass of 1000 seeds, does not affect the hectoliter mass and causes a decrease in the fat content in the seeds.
9. The studied hybrids can be ranked in the following descending order of average seed fat content: P64LE25> Subaro> LG 59.580> Magma> Arcadia, and in oil yield, they retain the same ranking as in yield of seeds.
10. The increase in the proportion of seeds in the head and the nut in the seed are the two main indicators that have a positive effect on the fat content in the seeds due to the high correlations between these traits.
11. The studied hybrids contain on average 15% saturated and 85% unsaturated fatty acids. The lowest content of saturated and the highest of unsaturated fatty acids is in the hybrid Magma, and the highest content of saturated and the lowest of unsaturated - in the hybrid Subaro. The nutrient content of the soil has an ambiguous effect on the ratio of fatty acids in the seeds.
12. The highest content of linoleic acid is the hybrid LG 59.580, and the highest oleic - hybrid Magma. In drought conditions during seed formation, the content of oleic and palmitic acid increases, and the content of stearic and especially linoleic acids decreases.

VIII. CONTRIBUTIONS

Scientific and theoretical contributions:

1. The phenological development of express-tolerant sunflower hybrids in the conditions of Plovdiv depending on the agro-meteorological conditions of the years of research has been established. The dates of occurrence of the main phenological

phases are described, as well as the interphase periods for the three years of the study.

2. The influence of soil nutritional regime on stem height and thickness in all tested hybrids was studied. It was found that the lowest plants form a hybrid Magma, and the highest - a hybrid Arcadia.
3. It was found that the better supply of soil with macronutrients has a positive effect on the head diameter and the number of seeds in it, but negatively on the density of the pseudanthium.
4. Positive correlations were found between the yield of seeds, oil extraction, leaf area, number of seeds in the pseudanthium, the diameter of the head and diameter of the stem, as well as between the fat content and the harvest indices of the head and seeds.

Scientific and applied contributions:

1. The influence of soil nutritional regime on yield of seeds was monitored, and it was found that increased soil fertility has a positive effect on all studied sunflower hybrids. The study found that the most productive express tolerant sunflower hybrid in the conditions of Plovdiv is LG 59.580, followed by P64LE25, Subaro, Magma and Arcadia.
2. The average composition of sunflower hybrids by organs (35% stems, 21% leaves, 17% pseudanthium and 27% seeds) was established, as the main contribution to the formation of yield is the participation of seeds as an organ in the plant.
3. It was found that the higher soil nutritional regime increases the mass of 1000 seeds, does not affect the hectoliter mass and reduces the fat content in the seeds. The highest average seed fat content is in the P64LE25 hybrid, followed by Subaro, LG 59.580, Magma and Arcadia.
4. The express tolerant hybrids of sunflower contained on average 15% saturated and 85% unsaturated fatty acids. Hybrids with the lowest content of saturated and the highest of unsaturated fatty acids (Magma), as well as with the highest content of saturated and the lowest of unsaturated (Subaro) were found.

Scientific publications related to the dissertation:

Garapova, A. 2020. Yield of seeds and some structural elements of the pseudanthium in Tribenuron-Methyl resistant sunflower hybrids, grown under different soil nutrition regime *Scientific Papers*. Series A. Agronomy, Vol. LXIII, No. 1, ISSN 2285-5785 (293-298).

VIII. SUMMARY

The present study aims to determine the influence of soil nutrition regime on some biological and economic qualities by express tolerant sunflower hybrids.

To achieve the goal and objectives of the study, three annual field trials have been conducted in the period 2018-2020 on the experimental field of the Department of Crop Science at the Agricultural University - Plovdiv. The experiment has been carried out by the method of split-plots in four replications after the predecessor triticale. The effect of two soil nutrition regimes - lower and higher has been investigated (main plots). Five sunflower hybrids, all from the Tribenuron-methyl resistant hybrids group has been studied: P64LE25 (standard); LG 59.580 SX; Subaro HTS; ES Arcadia SU and Magma SU. The following indicators have been studied: phenological development, biometric and productivity indicators, seed quality parameters and chemical composition of the oil.

It has been established, that the yield of seeds by all studied sunflower hybrids is positively affected by the higher soil fertility. The structural elements of the yield (pseudanthium) of the studied sunflower hybrids are affected differently depending on the nutrient storage of the soil. The higher nutrition regime found out to have a positive effect on the indicator of the diameter of the head. The density of the pseudanthium is also positively affected, with the exception only of the Magma hybrid, where the higher soil fertility has a negative effect.

The increase in the share of seeds in the pseudnthium and the nut in the husk are the two main indicators that have a positive effect on the fat content in the seeds due to the high correlations between

these traits. The highest content of linoleic acid is the hybrid LG 59.580, and the highest oleic - hybrid Magma. In drought conditions during seed formation, the content of oleic and palmitic acid increases, and the content of stearic and especially linoleic acids decreases.