OIL CONTENT OF SUNFLOWER HYBRID "DEVEDA" DEPENDING ON THE MAIN SOIL TILLAGE SYSTEM

Nina Nenova, Margarita Nankova

Dobrudzha Agricultural Institute, General Toshevo, BULGARIA
Agricultural Academy, Sofia

Corresponding author e-mail:nina_n13@abv.bg

ABSTRACT

The research was conducted in a stationary field experiment of the Dobrudzha Agricultural Institute - General Toshevo in the period 2016 to 2022. The impact of seven main soil tillage systems (MSTS) with and without turning the cultivated layer, No-till, as well as the alternative alternation between them in a 4-field crop rotation (beans-wheat-sunflower-corn) on the content and yield of oil. The MSTS are: 1. CP - conventional plowing (24-26 cm); 2. D – disking (10-12 cm) 3. C – cutting (chisel-plough); 4. NT - No-till (direct sowing); 5. Coventional plowing (for spring crops) – No-till (for wheat); 6. Cutting (for spring crops) - Disking (for wheat) and 7. Coventional plowing (for spring crops) - Disking (for wheat). The main objectives of the study were: (i) to investigate the seasonal variability in sunflower: (i) in the kernal/husk ratio; (ii) the oil content of the whole seed and its components; (iii) the obtained yields of oil per 1 area. Meteorological conditions during the years of study have an extremely strong influence on the proportion of the kernel and that of the husk in the whole seed. The share of the kernel varies from 74.91% (2016) to 80.20% (2018). This inevitably affects the share of the husk, whose share is higher in 2016, 2019 and 2020. The oil content in the kernel is also characterized by a well-defined dynamic - from 61.81% (2021) to 64.46% and 64.47% (2017 and 2022). The highest percentage of oil in the husk was found in 2018. In the whole seed, this high level of differentiation in oil content values depending on weather conditions over the years was preserved. The seed produced in 2019 is the highes oil (50.85%), and the least - in 2016 (46.68%). Yields of kernels, husks and their oil content, as well as whole seed, were more strongly affected by weather conditions during the study period. The tillage systems with or no deep turning treatment of the plow layer applied in crop rotation constantly or in combination with shallow tillage or No-till lead to obtaining seed highest oil content and, accordingly, oil yield compared to the others. The strict adherence to crop rotation, regardless of the diversity in the main tillage systems tested and the high level of selection work lead to a lack of observation of the parasite broomrape. An additional contribution to this fact is that the areas around General Toshevo are lightly infected with aggressive races of this parasite.

Key words: Main soil tillage systems (MSTS), Sunflower, Kernel/Husk components, Oil content.

INTRODUCTION

Sunflower (*Helianthus annuus* L.)r is a major oilseed crop in almost the entire world. In recent years, the consumption of sunflower oil has increased significantly. In recent years, the consumption of sunflower oil has significantly increased. Application and combination of proper agrotechnics and the fact that the sunflower has a very good root system it can actively draw water and nutrients from the 2-meter soil layer (Mc Michael and Quisenberry, 1993; Angadi and Entz, 2002; Balalić et all, 2012). This fact is a prerequisite for expanding the area of distribution in drier conditions. According to Miladinović et all (2019), due to its ability to grow under different agro-ecological conditions and its moderate drought tolerance, sunflower may become a preferred oilseed crop in the future, especially in light of global environmental changes. Significantly earlier, Part of the research in Bulgaria on the problems of sunflower in relation to productivity and quality shows that these characteristics are dynamic and dependent not only on the genetic predisposition of the varieties/hybrids, but also on a number of important agrotechnical factors that fit into the different systems of agricultural production - the weather conditions, tillage, nutritional regime, care during the vegetation and others (Tonev and Nikolova, 1997; Tonev, 2006; Nankov, 2012; Koteva, 2014). Undoubtedly, the methods of soil cultivation under the relevant agro-climatic conditions play an essential role in obtaining maximally satisfactory yields and quality characteristics with the necessary respect for the environment (Botta et all, 2006; Celik et all, 2013). Dang et all (2015) and Peixoto et all (2020) no-till (no-till) practice is one of the three main principles of conservation agriculture. This practice has better protection against soil erosion and offers greater efficiency in plant nutrient uptake. Obtaining higher productive and quality characteristics is undoubtedly the ultimate goal of many researchers dealing with the agronomy and selection of this crop (Habib et all, 2007). In this connection our main objectives of the study were: (i) to investigate the seasonal variability in sunflower: (i) in the kernal/husk ratio; (ii) the oil content of the whole seed and its components; (iii) the obtained yields of oil per 1 area.

MATERIAL AND METHOD

The research was conducted in a stationary field experiment of the Dobrudzha Agricultural Institute - General Toshevo in the period 2016 to 2022. The impact of seven main soil tillage systems (MSTS) with and without turning the cultivated layer, No-till, as well as the alternative alternation between them in a 4-field crop rotation (beans-wheat-sunflower-corn) on the content and yield of oil. The MSTS are: 1. CP - conventional plowing (24-26 cm); 2. D – disking (10-12 cm) 3. C – cutting (chisel-plough); 4. NT - No-till (direct sowing); 5. Conventional plowing (for spring crops) – No-till (for wheat); 6. Cutting (for spring crops) - Disking (for wheat) and 7. Conventional plowing (for spring crops) - Disking (for wheat). The mineral fertilization in the crop rotation was as follows: Common bean – $N_{60}P_{60}K_{60}$; Wheat – $N_{120}P_{120}K_{60}$; Sunflower - $N_{60}P_{120}K_{120}$ and Maize – $N_{120}P_{60}K_{60}$.

For the indicated research period, an agrotechnical test of the Deveda hybrid was carried out. According to the main breeder of the team that created the hybrid, it is moderately injured. It is a single interline hybrid (Nenova, 2019). The seed oil content is 51.7% and the protein content- 27.1%. The hybrid is resistant to downy mildew /race 731and 730/ and broomrape and middle resistantce to phoma, phomopsis, althernaria and sclerotinia.

The oil content of the kernel and husk and the whole seeds was determined by the method of Rujkowski (1957).

RESULTS AND DISCUSSION

Many factors influence the value of a number of sunflower indicators distinguishing crop productivity and oil quality. The abiotic factors of the environment, as well as the applied agricultural techniques, are the basis for the full development of the genetic potential when using the agricultural techniques under the specific weather conditions.

The response of the hybrid “Deveda” seed components in terms of their share in the seed formed, oil concentration and oil yield in kernels and hulls varied widely over the study period average (Table 1). The values of the coefficients of variation are the lowest for the index of the share of the kernel in the seed, the concentration of oil in the kernel and the seed - between 3 and 5%. Values below 30% were found for yields of kernels, oil from kernels and whole seeds, while for the index of oil content from husk it was 43.92%, which is an indication of a high degree of dispersion of the data.

Table 1. Degree of variation in the performance of the sunflower oil content and yields in seeds components according to MSTS by for the period 2016-2022.

Stat. Parameters	N	Minimum	Maximum	Mean	Std. Deviation	CV%
Kernal % in seed	98	73.50	86.40	77.25	2.45	3.17
Kernel Oil %	98	55.50	68.85	63.53	2.60	4.10
Yield Kernels	196	1239.6	5567.4	3456.5	996.5	28.83
Kernal Oil Yield	196	732.6	3507.5	2200.1	656.4	29.83
Husk %	98	13.60	26.35	22.76	2.45	10.76
Husk Oil %	98	3.10	12.10	7.16	2.08	29.06
Yield Husks	196	505.7	2059.9	1256.4	353.1	28.11
Husk Oil Yield	196	18.0	214.0	75.1	33.0	43.92
Seeds Oil %	98	42.90	56.20	49.20	2.46	5.01
Total Oil Yield	196	763.6	3721.4	2275.2	678.3	29.81

On the basis of the statistical analysis, it was also found that the tested factors in the experiment influence to the maximum extent both the oil content of the individual components of the seed and the obtained oil content from them (Table 2).

Weather conditions during the years of study have a strong influence on the proportion of kernel and husk in the whole seed. The strength of their influence on the values for the share of the components with the seed is over 50%. For their oil content, it decreases with values for oil concentration in the kernel and the whole seed. The interaction between the two factors has a stronger influence than the independent influence of MSTS, which is determined between 7-10%.

Table 2. Analysis of variances of sunflower oil content and productivity by seeds component according to main soil tillage systems (MSTS) averaged for the period 2016 – 2022.

Source	df	Content, %			Yields		
		Dependent Variable	F	Sig.	Dependent Variable	F	Sig.
Years (1)	6	Kernal, % in seed	5381.640	0.000	Kernal Oil Yield	257.341	0.000
	6	Husk, % in seed	15346.791	0.000	Husk Oil Yield	498.755	0.000
	6	Kernel Oil, %	6067.919	0.000	Total Oil Yield	254.409	0.000
	6	Husk Oil, %	11279.234	0.000	Yield Kernels	236.901	0.000
	6	Seeds Oil ,%	4870.429	0.000	Yield Husks	211.444	0.000
MSTS (2)	6	Kernal, % in seed	1039.319	0.000	Kernal Oil Yield	129.396	0.000
	6	Husk ,% in seed	2928.442	0.000	Husk Oil Yield	206.727	0.000
	6	Kernel Oil, %	1397.607	0.000	Total Oil Yield	130.504	0.000
	6	Husk Oil, %	1979.329	0.000	Yield Kernels	128.102	0.000
	6	Seeds Oil, %	1212.097	0.000	Yield Husks	124.837	0.000
1 x 2	36	Kernal, % in seed	607.218	0.000	Kernal Oil Yield	18.848	0.000
	36	Husk, % in seed	1702.090	0.000	Husk Oil Yield	79.220	0.000
	36	Kernel Oil, %	1712.275	0.000	Total Oil Yield	19.378	0.000
	36	Husk Oil, %	964.402	0.000	Yield Kernels	15.862	0.000
	36	Seeds Oil, %	1342.879	0.000	Yield Husks	13.305	0.000

The proportion of kernel in seed by year of study varied from 74.91% (2016) to 80.20% (2018) (Figure 2). These results have an impact on the values of the share of the husk in the seed accordingly. The same is the lowest in 2018 - 19.96%, when the kernel occupies the largest share in the seed. Both have the largest share in the seed in 2016 - 25.11%.

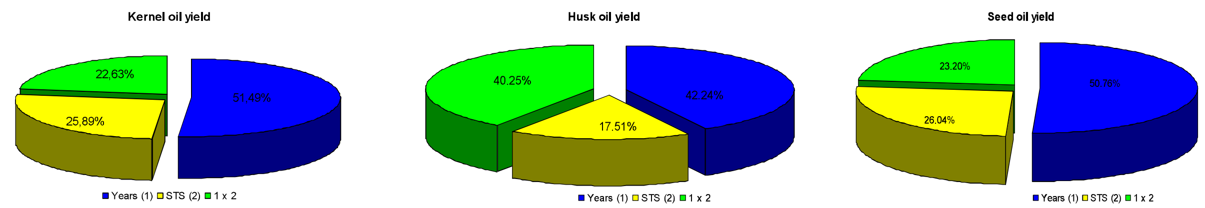


Figure 1. Strength of effect of the factors and their combinations average for the period 2016-2022 on the oil yields of sunflower seed according main STS, %

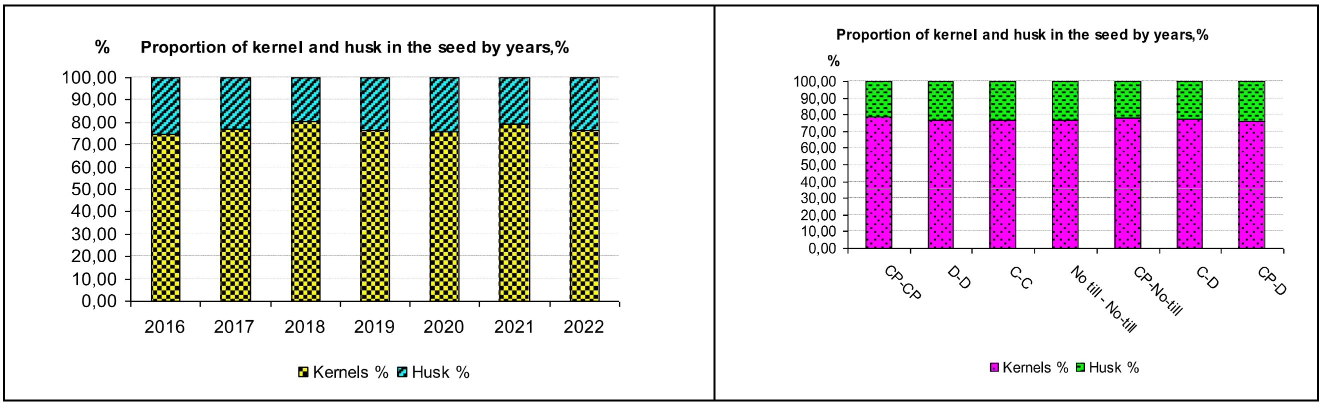


Figure 2. Proportion of seed components in seed according to years and MSTS, %

On average for the period 2016-2022, the share of the kernel in the seed in the tested MSTS was 77.25%. Only with the constant application of conventional plowing in the conventional plowing (CP-CP) and the alternative rotation CP-No-till, the share of kernels reaches 78.73% and 78.06%, respectively. The oil content of seed components and whole seed varied significantly between years (Figure 3). Kernels have the highest oil content in 2019 (66.38%). Against the background of the long-term experiment (2016-2022), the hybrid “Deveda” stands out with the highest oil content in 2017 (64.46%) - above the average for the experiment (63.53%). The kernels of the obtained product has the lowest oil content in 2021 - 61.81%. By years of study, oil content ranges from 4.50% (2022) to 9.66% (2018). Thus, the differentiation in the oil content of the whole seed is maximally expressed.

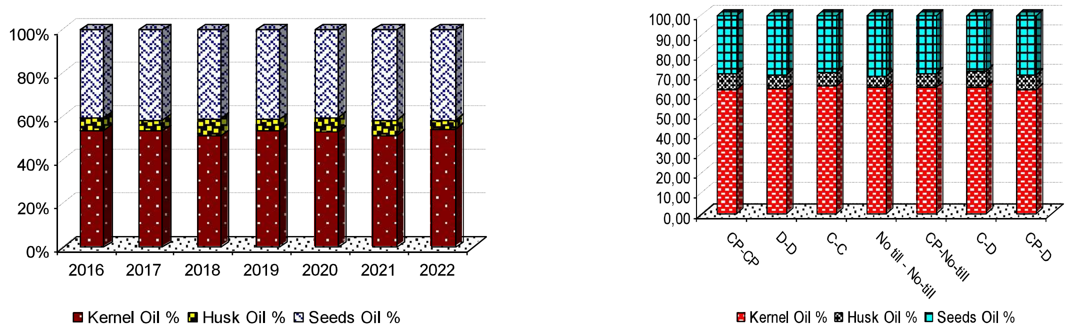


Figure 3. Oil content (%) in sunflower seed and it components, according to years and MSTS

The production of seeds in 2019 and 2018 is distinguished by the highest % oil, 50.85% and 50.45% respectively. The most unfavorable conditions for the processes related to the formation of oil in the seed were in 2016 (46.68%) and 2020 (47.48%). In the remaining years of the study, the oil content in the seeds was between 49% and 50%.

The tested tillage systems are also characterized by a well-expressed differentiation in the values of the investigated indeces, and to a maximum extent. The percentage of oil in the kernel varied from 62.63% in (CP-D) to 64.83% in the deep non-rotating treatment (C-C).

On average for the period 2016-2022, the C-C systems (49.89%) are distinguished by the largest oil content in the seeds; constant No-till (49.70%); CP-No-till (49.66%); C-D (49.51%) and CP-CP (49.37%).

Discussing the obtained results for oil content from kernels by year we obtain values that distinguish each of the MSTS within the same year (Figure 4). This means that their place is not fixed in a strictly defined order. Almost every year there is a trend towards a lower oil content from kernel with permanent direct seeding. In two of the years (2017 and 2020), the three intermittent deep tillage systems (turned and no-turned tillage) in terms of kernel oil yield approached the constant application of conventional plowing in the crop rotation. In the variant with its 1-year break with (No till-No till) in 2016, 2020 and 2022 an excess over CP-CP was found by 15.48%, 24.96% and 16.56%, respectively.

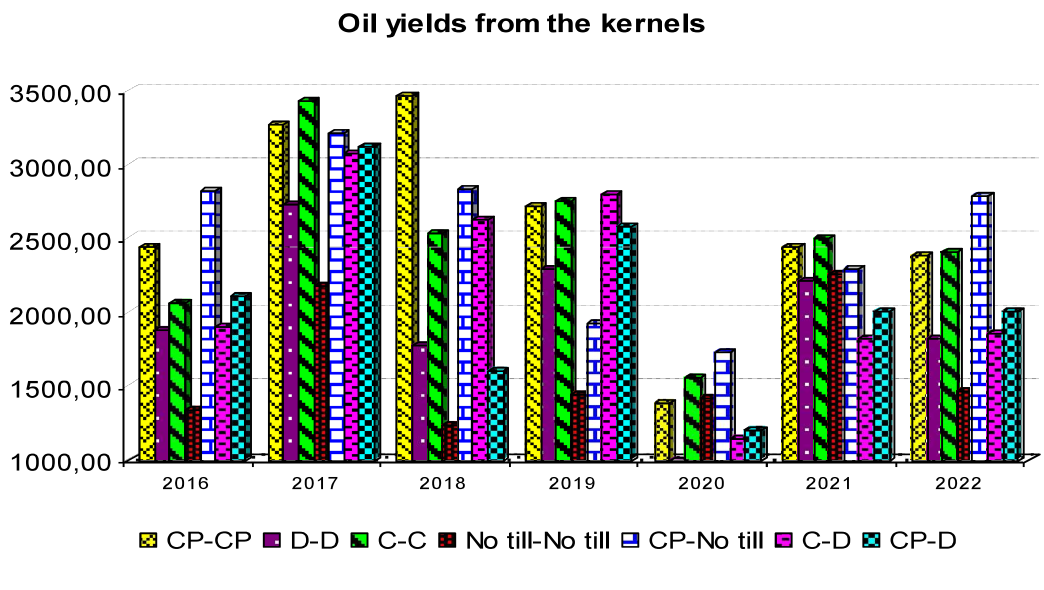
The influence of MSTS on the values of the obtained oil yields from the husks is expressed in a wide scale variation - from 19.49 kg/ha (2022) with the constant application of direct sowing in the crop rotation (No till-No-till) to 156.53 kg/ha (2016) the constant application of conventional plowing in the crop rotation (CP-CP).

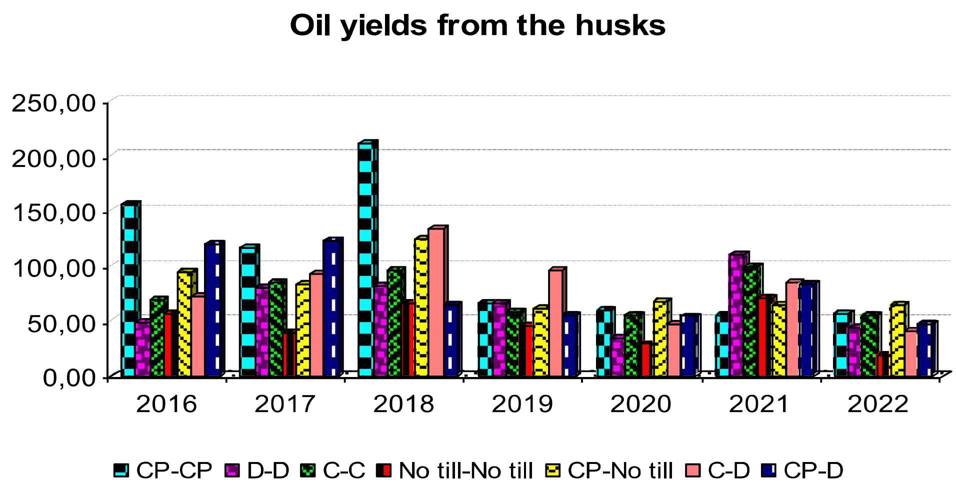
As a result of their share in the seed, the values of oil yields obtained from the husks are significantly lower than those obtained from the kernels. However, they are a valuable raw material in the preparation of animal feed. The indicated trends for the impact of MSTS on kernel oil yield are almost preserved for husk oil yield. Our results collaborates the view of Leon et all (2003) that the oil content and oil yield are complex quantitative traits, determined by genetic and environmental factors, along with interaction between them.

Final, whole seed oil yields as a composite measure also vary significantly by MSTS. The differentiation between the tillage options tested was enhanced in years with unfavorable weather conditions. An example of this is 2020, when seed oil yield varies from 874.13 kg/ha (D-D) to 1804.45 kg/ha (CP-No till). In the year with the most favorable conditions for developing the productive potential of the hybrid “Deveda” (2017), the variation was from 2222.48 kg/ha (No till - No till) to 3526.72 kg/ha (C-C) and 3388.61 kg/ha (CP- CP).

The factor with the greatest influence on the values of the tested indicators is meteorological dynamics in the amount of precipitation and temperature during the growing season. In our experiment, the interaction between these two main meteorological elements is the key factor determining the magnitude of oil yields (Table 3). The final oil yields formed are practically a complex of yields from the components of the seed and their oil content. On average for the long-term study period, the obtained oil yields from the seed ranged from 3095.85 kg/ha (2017) to 1376.62 kg/ha (2020) with an average yield in the experiment for the period 2016-2022 of 2275.15 kg/ha. This means an increase in oil yield by 36.07% on average for the tested MSTS under favorable conditions for culture development and, accordingly, with a combination of different types of stress, a drop to 60.51% of the average for this period of time.

A number of studies have been carried out in DAI-General Toshevo in relation to sunflower culture and the behavior and application of various agrotechnical practices on its productivity and quality, as well as the economic efficiency of its production in the country (Klochkov and Nankov, 1987; Nankov and Tonev, 1994; Nankov, 1996; Nankova et al, 1999; Nankov et al, 2002; Nenov et al, 2004). In this respect, Nankov's studies (1982a,b, Nankov and Dimitrov, 1985) related to the influence of autumn-winter moisture reserves in sunflower varieties and hybrids deserve special attention.





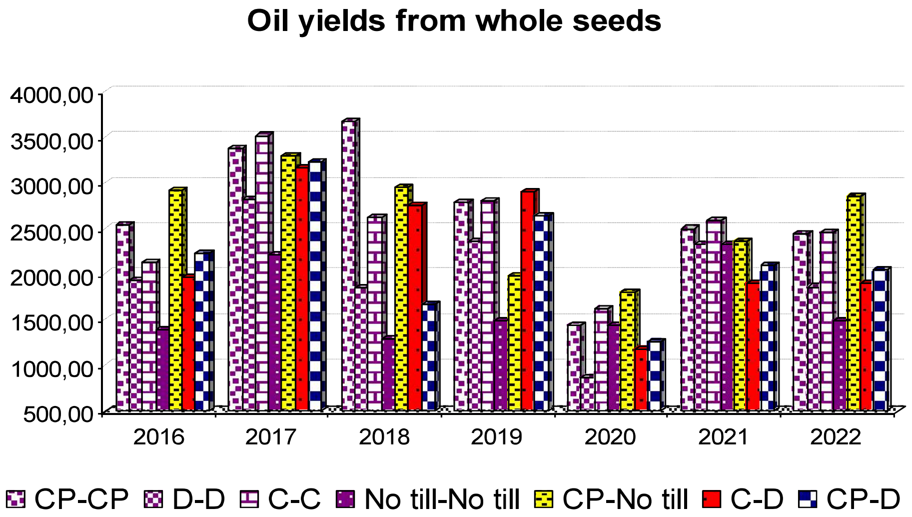


Figure 4. Final yields of sunflower seed oil and their components, kg/ha

Table 3. Yields of kernels and husks and yields of oil in them and whole seed depending on weather conditions in the years studied, kg/ha

Years	Kernel Oil Yield	Husk Oil Yield	Total Oil Yield	Yield Kernels	Yield Husks
2016	2079.5 b	80.7 d	2160.2 b	3329.4 b	1249.9 c
2017	**3006.4 e**	89.5 e	**3095.9 e**	**4675.4 d**	**1669.0 e**
2018	2297.4 cd	**111.6 f**	2409.1 d	3639.5 c	1342.0 d
2019	2361.9 d	64.7 c	2426.6 d	3556.8 c	1194.9 b
2020	1326.5 a	50.1 b	1376.6 a	2122.4 a	795.9 a
2021	2222.2 c	81.7 d	2303.9 c	3600.5 c	1378.3 d
2022	2106.7 b	47.1 a	2153.8 b	3271.6 b	1164.9 b

The MSTS have a strong influence on the amount of yields obtained from the components of the seed and their oil yields (Table 4). The highest yields for the 7-year study period were obtained with the constant application of traditional plowing in the crop rotation. The total oil yield of 2685.68 kg/ha exceeds the average of all tested variants with MSTS by 18.04%. For the individual components of the seed, this increase is respectively for the husks by 25.92% and for the kernels - by 17.78%.

Table 4. Yields of kernels and husks and yields of oil in them and whole seed depending on the MSTS, kg/ha

MSTS	Kernel Oil Yield	Husk Oil Yield	Total Oil Yield	Yield Kernels	Yield Husks
CP-CP	2591.2 e	94.5 e	2685.7 e	4116.1 f	1525.1 f
D-D	1938.3 b	67.9 b	2006.2 b	3057.2 b	1118.7 b
C-C	2466.3 d	74.8 c	2541.0 d	3817.7 d	1351.4 d
No till - No-till	1621.0 a	47.1 a	1668.1 a	2547.1 a	925.9 a
CP-No-till	2517.0 de	80.7 d	2597.7 de	3956.6 e	1439.6 e
C-D	2175.5 c	81.5 d	2257.1 c	3390.6 c	1215.4 c
CP-D	2091.4 c	78.8 d	2170.3 c	3310.3 c	1218.9 c

Three of the tested MSTS in seed oil yield exceeded the experimental average yield (2275.15 kg/ha). These are the two deep (24-26 cm) and constantly applied soil treatments - conventional plowing (CP-CP) with turning the cultivated layer and deep loosening without turning it. The oil yield increase was 18.04% and 11.69%, respectively. Of the alternatively alternating treatments, only CP-No till stands out with an excess of 14.08%. The amount of seed oil yields obtained shows that over this long-term period of time, characterized by diversity in the combination of meteorological factors, none of the MSTS tested outperformed the continuous application of traditional/conventional plowing in the crop rotation. Significant correlations were found between the individual components of the seed, their productivity, oil content and the obtained oil yields from the whole seed. There were a number of negative correlations between the proportion of kernel in the seed with that of the husks and with the percentage of oil in the kernel (Table 5). The interrelationship between the proportion of the husk with the concentration of oil in it and the whole seed is also negative. The most strongly expressed positive correlation between the oil in the nut and that in the whole seed - 0.699**. Kaya et all, (2007) through regression analysis results found a different relationship between seed yield of hybrids and oil content. The authors indicate that up to an oil content of 40%-45% the correlation with yield is negative.

Table 5. Pearson Correlation between sunflower seed components content and their oil concentration, 2016-2022

Indeces	Kernal, %	Husk ,%	Kernel Oil, %	Husk Oil, %	Seeds Oil, %
Kerna,l %	1				
Husk, %	-0.995(**)	1			
Kernel Oil,%	-0.203(*)	0.221(*)	1		
Husk Oil, %	0.445(**)	-0.439(**)	-0.314(**)	1	
Seeds Oil, %	0.485(**)	-0.468(**)	0.699(**)	0.034	1

High levels of correlations were found between the oil yields of the seed components and their relative share in the seed (Table 6). The R-values between oil extraction of the kernel with the indicated indices is in the order of over 0.900, while in oil extraction in the husk the level of R is above 0.600. The correlation between the yield of oil in the kernel and the yield of oil in the whole seed stands out with the highest correlation value - 0.999.

Table 6. Pearson Correlation between sunflower seed components yields and their oil yields, 2016-2022

Indeces	Kernal Oil Yield	Husk Oil Yield	Total Oil Yield	Yield Kernels	Yield Husks
Kernal Oil Yield	1				
Husk Oil Yield	0.649(**)	1			
Total Oil Yield	0.999(**)	0.677(**)	1		
Yield Kernels	0.993(**)	0.669(**)	0.994(**)	1	
Yield Husks	0.944(**)	0.680(**)	0.946(**)	0.976(**)	1

* Correlation is significant at the 0.05 level (2-tailed).

** Correlation is significant at the 0.01 level (2-tailed).

CONCLUSIONS

Meteorological conditions during the years of study have an extremely strong influence on the proportion of the kernel and that of the husk in the whole seed. The share of the kernel varies from 74.91% (2016) to 80.20% (2018). This inevitably affects the share of the husk, whose share is higher in 2016, 2019 and 2020. The oil content in the kernel is also characterized by a well-defined dynamic - from 61.81% (2021) to 64.46% and 64.47% (2017 and 2022).

The highest percentage of oil in the husk was found in 2018. In the whole seed, this high level of differentiation in oil content values depending on weather conditions over the years was preserved. The seed produced in 2019 is the richest in oil (50.85%), and the least - in 2016 (46.68%).

Yields of kernels, husks and their oil yields, as well as whole seed, were more strongly affected by weather conditions during the study period compared to the effect of the MSTS. With the highest yields of the components of the seed, oil from the kernels and the whole seed, 2017 is noted, and unfavorable - in 2020.

The tillage systems with or no deep turning treatment of the plow layer applied in crop rotation constantly or in combination with shallow tillage or No-till lead to obtaining seed richer in oil content and, accordingly, oil yield compared to the others. Close to this systems are the results obtained when traditional plowing is interrupted with No-till when sowing wheat in the crop rotation.

The independent permanent application of deep cutting (chisel-plough) oil yield is less with 144.7 kg/ha compared to traditional plowing, while in the application of CP-No-till system this difference is only 88 kg/ha.

Shallow tillage alone and in combination, as well as long-term self-application of No-till lead to an increase in the share of husks and a lower yield of oil compared to the deep main tillage. The lowest yields of oil in the seed were obtained with the constant application of No-till - 1668.1 kg/ha, i.e. with 1017.6 kg/ha less compared to the constant application of traditional plowing.

The reliability of the obtained results is of the maximum degree of expression. The influence of meteorology as a factor is more pronounced than that of main STS. It has approximately the same values for kernel, %/husk, % in the seed, as well as for the percentage of oil in the kernel and the whole seed. However, it was found to have a much stronger influence on oil content in the husk compared to the kernel and whole seed.

The strict adherence to crop rotation, regardless of the diversity in the main tillage systems tested and the high level of selection work lead to a lack of observation of the broomrape parasite (Orobanche ssp.). An additional contribution to this fact is that the areas around DZI- General Toshevo are lightly infected with aggressive races of this parasite.

The proportion of kernel in the seed is strongly negatively correlated (-0.995**) with that of the husk. The proportion of kernel in the seed was also in a well-pronounced positive correlation with the percentage of oil in the seed (+0.485**) and the oil content in the husk (+0.445**). There is also a well-expressed correlation between the oil content of the kernel and that of the seed (+0.699**). The correlation dependences between oil yields from the individual components of the seed are positive and with a very high level of statistical reliability. The highest correlation value was found between oil yields in kernel and seeds - 0.999.

REFERENCES

Angadi S.V. and M.H. Entz, 2002. Root system and water patterns of different heigth sunflower cultivars. Agronomy Journal, Vol. 94, Issue 1, 136-145

Balalić I., Zorić M., Branković G.,Terzić S., Crnobarac J.2012. Interpretation of hybrid×sowing date interaction for oil content and oil yield in sunflower Field Crops Research, Vol. 137, 70-77

Botta G.E., Jorajuria D., Balbuena M., Ressia C., Ferrera H., Rosatto and Tourn M. 2006. Deep tillage and traffic effect on supsoil compaction and sunflower (*Helianthus annuus* L.) yields. Soil and Tillage Research, Vol. 91, Issues 1-2, 164-172

Celik A., Atikat S., Way T.R. 2013. Strip tillage width effect on sunflower seed emergence and yield. Soil and Tillage Research, Vol. 131, 20-27

Dang, Y.P., Moody, P.W., Bell, M.J., Seymour, N.P., Dalal, R.C., Freebairn, D.M., Walker, S.R. 2015. Strategic tillage in no-till farming systems in Australia's northern grainsgrowing regions: II. Implications for agronomy, soil and environment. Soil Tillage Res. 2015,152, 115–123.

Habibullan H., Sadaqat Mehdi S., Muhammad Ashfaq Anjum and Rashid Ahmad R. 2007. Genetic Association and Path Analysis for Oil Yield in Sunflower (Helianthus annuus L.) Int. J. Agri. Biol., Vol. 9, No. 2, 359–361,

Kaya Y., Göksel E., Sezgin D., Veli P. and Tahir G. 2007. Determining the Relationships between Yield and Yield Attributes in Sunflower, Turkish Journal of Agriculture and Forestry: Vol. 31: No. 4, 237-244 Article 3.

Klochkov B., Nankov N. 1987. The sunflower under adverse conditions. Agriculture, 1, 16-18

Koteva V., 2014. Effectiveness of Mineral Fertilization on Sunflower, Cultivated on Pellic Vertisol in Southeastern Bulgaria in Favorable and Risky Meteorological Conditions. Soil Science Agrochemistry and Ecology, Vol. XLVIII, № 2

Leon AA.J., Andrade F.H., and Lee M., 2003. Genetic analisis of seed-oil concentration across generations and environment in sunflower. Crop Breeding, Genetics & Cytology, Vol. 43, Issue 1, 135-140

Mc Michael B.L.and Quisenberry J.E. 1993. The impact of environment on the grown of root system. Environmental and Experimental Botany, Vol. 33, Issue 1, 53-61

Miladinović, D., Hladni, N., Radanović, A.,Jocić, S., & Cvejić, S. (2019). Sunflower and Climate Change: Possibilities of Adaptation Through Breeding and Genomic Selection. Genomic Designing of Climate-Smart Oilseed Crops, 173-238.

Nankov N. 1996. Status and expectation of sunflower commertial production the Republic of Bulgaria. Proceeding of 14 th International Sunflower Conference, II, Beijing / Shenyang, China, 12 - 20 June, pp 849 - 852

Nankov N. 1982[a]. Investigating the role of autumn-winter precipitation in predicting parameters of sunflower seeding density. PhD Theses, Sofia

Nankov N. 1982b. Influence of autumn-winter precipitation on the density parameters of sunflower hybrids. NAPU - 30 years of "Dobrudzha" Wheat and Sunflower Institute , pp. 40 - 46

Nankov N., Iv. Dimitrov. 1985. Influence of autumn-winter precipitation on the water consumption of sunflower in the conditions of North-Eastern Bulgaria. Plant Sciences, 5, 33 - 40

Nankov N., Nenov N., Nankova M. 2002. State of sunflower production and the use of mineral fertilizers in this culture in Bulgaria. Scientific works, vol. XLVII, book 1, 437 - 443, Jubilee Scientific Conference "Acad. Pavel Popov and the achievements of plant breeding science in Bulgaria", Agricultural University, Plovdiv.

Nankov N., Tonev T. 1994. Economic efficiency of the production of high oleic sunflower variety Viola, depending on some agrotechnical factors. Sci. Tr. NIIMESS, Mechanization of processes in crop production, item 5, ser.1, 29 – 36.

Nankov N.2012. Economic justification of the agronomy elements in wheat and sunflower production according to the system of agriculture in the region of Dobrudzha. Third International Scientific Congress "50 years of Technical University, Varna", 04-06 October, 2012, Varna, Bulgaria, volume 7,185-191.

Nankova M., Nankov N., Nenov N., Hristov M. 1999. Biological requirements of sunflower in relation to potassium nutrition and state of mineral fertilization of this crop in Bulgaria. National seminar on the topic "Potassium fertilization needs of the main agricultural crops in Bulgaria", 48 - 57, June 9, Sofia, Bulgaria.

Nenov N., Nankova M., Hristov M. 2004. Influence of some complex fertilizers on elements of sunflower productivity. Scientific communications of SUB, Dobrich branch, volume 6, number 1, 85-90.

Nenova, N. 2019. New perspective Bulgarian sunflower hybrid Deveda. Field Crops Studies, XII(1), 9-16.

Peixoto, D.S., Silva L.D., Melo L.B., Azevedo R.P., Araújo B.C.L., Carvalho T.S.D., Moreira, S.G., Curi, N., Silva, B.M. 2020. Occasional tillage in no-tillage systems: A global meta-analysis. Sci. Total Environ. 2020, 745, 14887.

Rujkowski, S.V.1957. Methods of research in the selection of oilseed plants for oil content and its quality. Pishempromizdat, 83-88. (Ru)

Tonev, T. 2006. Oil Yield in Sunflower as Effected by Predecessor, Previous-Year and Pre-sowing Nitrogen Rate. Plant science, 43, 310-315

Tonev, T., Nikolova V. 1997. Influence of agroecological conditions on the oil content of the seeds and the fatty acid composition of sunflower oil. Soil Science Agrochemistry and Ecology, No. 3, 165-167