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Original Paper

Aspects of the production of sunflower (*Helianthus annuus* L.) depending on the year and different hybrid varieties of sunflower

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The aim of the experiment was to evaluate the impact of the year and different hybrid varieties of sunflower on the yield and oil content. The experiment was carried out in the years 2019–2020 in the fields of the Research Centre for Plant Biology and Ecology in Nitra – Dolná Malanta. Statistical analysis of experimental results confirmed the high significant influence of the year on selected quantitative and qualitative parameters of the sunflower. The year 2019 was statistically high significantly more effective for seed yield, were was monitored increase by 0.37 tons per hectare (t ha^{-1}) in relation to average yield. In 2020 was confirmed a statistically high significant higher oil content by 0.87%. The evaluation of the genetic potential of selected hybrids confirmed a statistically high significant effect on the yield and oil content of sunflower. Within the monitored years, the average seed yield was 3.47 t ha^{-1} and the average oil content was 46.22%. In the range of monitored hybrid varieties of sunflower, the highest average seed yield and oil content were recorded for the hybrids of Clearfield Plus. The best values were achieved by the SY Bacardi hybrid with a seed yield of 4.10 t ha^{-1} (+0.63 t ha^{-1}; rel. 18.29%) and with an oil content of 48.50% (+2.28%). The highest seed yield in conventional hybrid varieties of sunflower achieved SY Chronos 3.63 t ha^{-1} (+0.16 t ha^{-1}; rel. 4.69%) and the highest oil content achieved SY Duomo 47.34% (+1.13%). The highest yield in Express Sun hybrid varieties recorded NX 92251 3.56 t ha^{-1} (+0.10 t ha^{-1}; rel. 2.76%). And the highest oil content was monitored by Suffix hybrid 45.91% (-0.31%).

Keywords: sunflower, production, hybrid, yield, oil content

1 Introduction

Oil crops are important part of agriculture worldwide (Sharma et al., 2012). Sunflower oil is used in the food industry, because it contains a high proportion of unsaturated fatty acids. The composition of the oil contributes to maintaining normal blood cholesterol levels (Binkoski et al., 2005). Secondary products are proteins, that are used for gluten free food products (Wills and Kabirullah, 1981; Zorzi et al., 2020). Sunflower oil is also used in the energy industry as an alternative for diesel engines (Radu and Mircea, 1997).

The sunflower production process is significantly influenced by genotype, environment and their interaction (Mrdja et al., 2012). The extent of the interaction between genotype and environment is the result of variation of uncontrollable factors that change every year (Tabrizi et al., 2012). The influence of weather conditions during the growing season is an important and decisive factor in the process of yield formation and sunflower oil production (García-lópez et al., 2014).

Expected climate change will cause thermal and water stress in the plant production process (Pendergrass et al., 2017). The interaction of these factors can accelerate the phenological phases, thus disrupting the process of yield formation (Awais et al., 2018) and the quality of sunflower production (Petcu et al., 2001). Water stress affects the physiological activity of plants, which is related to the formation of quantitative and qualitative production parameters (Unger, 1982; Baldini et al., 2000).

Modern genetic tools are used to produce new sunflower hybrids. It can be used to eliminate negative climate effects (Liović et al., 2017). Choosing the right genotype can eliminate the negative impact of environmental conditions.

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Quantitative and qualitative parameters are genetically fixed and more or less correlate with the agroecological conditions of the year. The real yield formation depends on environmental conditions (Černý et al., 2011).

In sunflower cultivation systems are differentiated four types of hybrid varieties. Conventional hybrids do not have initial tolerance to specific herbicides. In this varieties is problematic the weeds control during the growing season (Delchev, 2019). The specific growing clip and the slow initial growth of sunflower allow to emergence of weeds, which due to competition, reduce the final yield (Pfenning et al., 2008). The yield reduction due to weeds in sunflower crops was estimated to be as high as 81%, which required the implementation of new hybrid varieties of sunflower (Simić et al., 2011).

Clear Field and Clearfield Plus hybrids are characterized by resistance to imidazolinone herbicides designed for postemergence weed control. The herbicide tolerance trait occurs naturally in the wild population of *Helianthus annuus*, so varieties are not considered as tool of genetic modification (Pfenning et al., 2008). Express Sun hybrids are resistant to tribenuron methyl or sulfonylurea herbicides (Velasco et al., 2015), which are effective against problematic dicotyledonous weeds as well as the parasitic weed *Orobanche cumana*, which is a problem of low precipitation areas (Petcu and Ciontu, 2014).

Breeding of high performance hybrids in combination with the use of correct agronomic practices eliminates the influence of limiting factors of production and contributes to the increase of sunflower yield (Mrdja et al., 2012).

The aim of the paper was to evaluate the impact of the year and different hybrid varieties of sunflower on the yield and oil content of selected hybrids in the conditions of a dry, warm, lowland climate region.

2 Material and methods

The small plot experiment with sunflower (*Helianthus annuus* L.) was based in the years 2019–2020 on the experimental basis of the Center for Plant Biology and Ecology FAFR SUA in Nitra, Dolná Malanta. The experiment was based on the method of randomized complete block design with three replicates (Ehrenbergerová, 1995).

The plots are located in a corn production area, at an altitude of 175–180 meters above sea level. The soil is medium heavy, brown soil, loamy to clay – loam graining (Tobiašová and Šimanský, 2009). During the vegetation period in the years 2019–2020, the average total precipitation was 343.2 mm. From april to september, the average air temperature was 13.3 °C.

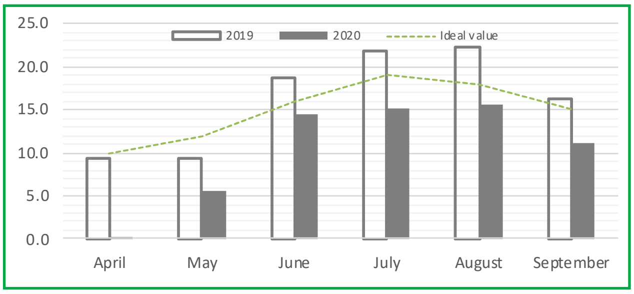

Figure 1 Temperature conditions (°C) during the experimental period

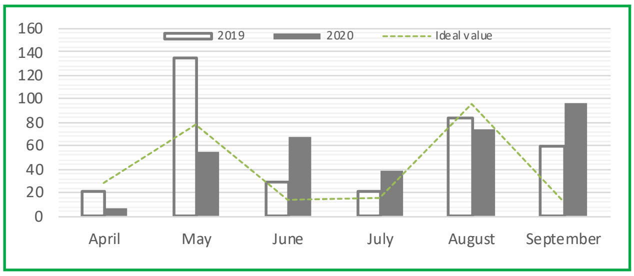

Figure 2 Total precipitation (mm) during the experimental period

In the range of agroclimatic zoning, is the interest area characterized as a warm macro area, with a temperature sum t >10 °C in the range of 3100–2400 °C. The area is mostly warm, with a temperature sum t >10 °C in the range of 3000–2800 °C. Subarea very dry, with the value of the climatic indicator of irrigation (VI.–VIII. month) K VI.–VIII. = 150 mm. District of mostly mild winter with an average of absolute minimums $T_{min.}$ = -18 -21 °C (Špánik et al., 2002).

The course of weather conditions during the growing season 2019–2020 is shown in Figure 1 and Figure 2. Data were provided from agrometeorological station of Institute of Landscape Engineering SPU in Nitra.

In the crop rotation system, the sunflower was included after the winter wheat (*Triticum aestivum* L.). The sowing was carried out with an 8 row seeder with sowing at the level of the growing clip 0.70 × 0.22 m.

In the experiment were used the following hybrid varieties of sunflower:

a) Conventional hybrids:
- SY Chronos (the variety of twice – cross early hybrid, high tolerance to drought, and stem breaking, hybrid combines performance of early sunflower segment with very good disease resistance);
- SY Duomo (the variety of twice – cross early hybrid with a high oil content. The hybrid has a deep root system and higher resistance to disease);

- Edison (the variety of twice – cross mild late hybrid, resistant to 9 races of mold with excellent tolerance to *Orobanche*, hybrid is characterized by very high seed yield) (Syngenta, 2021a).

b) Clearfield Plus:

- SY Bacardi (the variety of twice – cross mild early hybrid with high seed yield potential under stressful conditions. The hybrid is resistant to lodging and disease and tolerant to the active substance imazamox);
- SY Gracia (the variety of twice – cross mild early hybrid with high tolerance to imazamox, resistant to lodging, very good resistance to stem diseases and flower diseases);
- SY Onestar (the variety of twice – cross early to medium early hybrid with high yield and oil content, very high resistance to the active substance imazamox) (Syngenta, 2021b).

c) Express Sun:

- Subaro (the variety of twice – cross mild early hybrid resistant to drought and high temperatures with deep root system, excellent solution against the most resistant weeds because the hybrid is tolerant to tribenuron methyl herbicide);
- NX 92251 (the variety of twice – cross mild early hybrid with a high yield potential and resistant to tribenuron methyl herbicides);
- Suffix (the variety of twice – cross early hybrid, with lower growth and very good health. Tolerant to tribenuron methyl herbicide, good combination of crop potential and adaptability in different cultivation conditions) (Syngenta, 2021a).

The crop was harvested at full maturity, in the growth phase BBCH 99, with a modified CLAAS small plot harvester (CLAAS GmbH & Co. KGaA, Haewinkel, Germany). Samples for the determination of the crop yield were analyzed and subsequently recalculated to unit tons per hectare (t ha^{-1}) in the laboratory of the Institute of Agronomic Sciences FAFR SPU in Nitra.

The oil content was determined by the extraction method using a SOXSHLET extraction apparatus in accordance with the Shahidi (2003) methodology. For the analysis was used the required number of samples (according to the number of variants and replicates) with a weight of seeds 200 g. Prior to extraction, the seeds were mechanically crushed using a laboratory homogenizer to an average particle size of 1 mm. The direct oil extraction was performed using petroleum ether reagent at 60 °C. Total extraction time during the analysis was 60 minutes (15 min direct extraction samples immersed in the extraction reagent and 45 min exposure to reagent vapours). After extraction, the crude oil was directly weighed, and oil content was recalculated in the sample. The analysis was performed in the laboratories of the Institute of Nutrition and Genomics FAFR SPU in Nitra.

The results of experimental measurements were evaluated by analysis of variance (ANOVA) in the program STATISTICA 10 (StatSoft, Inc., Tulsa, Oklahoma, USA), graphs were created in the Microsoft Excel program (version 16.51).

3 Results and discussion

In the sunflower production process, the weather conditions of the year can be considered as a decisive factor in crop production (Veverková and Černý, 2012). The average yield of seeds for the monitored period was 3.47 t ha^{-1}. The agroecological conditions of the monitored years had a statistically high significant effect on the sunflower seed yield (Table 2). In 2019 was recorded a higher average seed yield (3.65 t ha^{-1}), while in 2020 it was at the level of 3.28 t ha^{-1} (Table 3).

The used graphical analysis of seed yield during the monitored years 2019–2020 presents the influence of weather conditions and selected hybrids on different values of sunflower seed yield (Figure 3).

The diversity of genetic material can be considered as an important factor influencing the production process and the final yield of sunflower seeds (Černý et al., 2013; Angeloni et al., 2017). In the range of selected hybrids, the highest average yields, compared to the average value, were recorded by Clearfield Plus hybrid varieties. The highest yield was achieved by the hybrid SY Bacardi

Table 1 Overview of applied substances for selected hybrid varieties of sunflower

Hybrid	Preparation	Active substance	Date of application	Applied dose
Conventional	Wing P	Pendimethalin (250 g l^{-1}) Dimethenamid-P (212.5 g l^{-1})	Pre-emergence application	4.0 l ha^{-1}
Clearfield Plus	Listego Plus	Imazamox (25 g l^{-1})	BBCH 12–18 (2–8 leaves)	2.0 l ha^{-1}
Express Sun	EXPRESS® 50 SX	Tribenuron (500 g kg^{-1}) in the form of Tribenuron methyl ester	BBCH 18 (8 leaves)	42 g ha^{-1} +0.1%

Table 2 Analysis of variance (ANOVA) for the monitored years 2019–2020

Variability source	Monitored parameter	
	yield of seeds (t ha^{-1})	oil content (%)
	P-values	
Year	0.000000**	0.000073**
Hybrid	0.000000**	0.000000**

** statistically high significant influence, * statistically significant influence

Table 3 The average of the values within the monitored factors and significance of their differences at the level of 99% (Tukey test)

Factor	Statistical element	Sunflower seed yield (t ha^{-1})			Sunflower oil content (%)		
		average	SD	HG – Tukey	average	SD	HG – Tukey
Year	2019	3.65	0.0659	b	45.78	0.3362	a
	2020	3.28	0.0931	a	46.65	0.3614	b
Conventional hybrids	SY Chronos	3.63	0.0931	a	46.25	0.3670	acd
	SY Duomo	3.03	0.1537	b	47.34	0.6300	ae
	SY Edison	3.60	0.0693	a	45.60	0.2551	bc
Clearfield plus	SY Bacardi	4.10	0.0946	d	48.50	0.3918	e
	SY Gracia	3.70	0.1268	ad	47.08	0.4062	ad
	SY Onestar	2.98	0.1778	b	47.48	0.3787	ae
Express sun	Subaro	3.12	0.1564	bc	44.72	0.6061	b
	NX 92251	3.56	0.1004	a	43.08	0.3809	f
	Suffix	3.46	0.1688	ac	45.91	0.4284	bcd

different indices (a, b, c, d) in values indicate a statistically significant difference; HG – homogeneous groups

4.10 t ha^{-1} (+0.63 t ha^{-1}; rel. 18.29%), followed by SY Gracia 3.70 t ha^{-1} (+0.24 t ha^{-1}; rel. 6.85%). Within the mentioned hybrid varieties, the lowest yield was recorded by hybrid SY Onestar 2.98 t ha^{-1} (-0.48 t ha^{-1}; rel. 13.92%). SY Onestar achieved the lowest yield in the whole spectrum of monitored hybrids (Figure 3).

The highest seed yield in conventional hybrids was recorded by hybrid SY Chronos 3.63 t ha^{-1} (+0.16 t ha^{-1}; rel. 4.69%). The SY Edison hybrid achieved a yield at the level of 3.60 t ha^{-1} (+0.13 t ha^{-1}; rel. 3.87%). In the range of monitored hybrids, SY Duomo achieved the lowest seed yield at the level of 3.03 t ha^{-1} (a decrease of 0.44 t ha^{-1}; rel. 12.58%) (Figure 3).

In Express Sun hybrids achieved the highest seed yield NX 92251 hybrid 3.56 t ha^{-1} (+0.10 t ha^{-1}; rel. 2.76%), followed by the Suffix with a yield of 3.46 t ha^{-1} (-0.003 t ha^{-1}; rel. 0.07%). The lowest yield was achieved by the Subaro hybrid 3.12 t ha^{-1} (-0.34 t ha^{-1}; rel. 9.88%) (Figure 3).

The weather conditions of the growing season 2019–2020 had a statistically high significant effect on the oil content in sunflower seeds. The genetic variability of individual hybrids can significantly affect the qualitative parameters of sunflower seeds (Černý et al., 2018), which is in accordance with the obtained results, where the high significant effect of hybrids on the oil content in seeds was confirmed (Table 2). The average oil content of selected hybrids and the variability caused by the agroecological conditions within the monitored growing years 2019–2020 are shown in the graphic analysis (Figure 4).

The average oil content of hybrids for the observed period 2019–2020 was 46.22%. In the formation process of qualitative parameters, in the range of individual years, was agroecologically more effective year 2020, where oil content was at the level of 46.65%. In year 2019 was recorded a decrease of oil content by 0.87% to the level of 45.78% (Table 3).

In sunflower hybrids are observed differences in oil content due to the different genetic background, which affects the final oil content in the seeds (Černý et al., 2018). In the range of monitored hybrids, the highest values were recorded by Clearfield Plus hybrids. SY Bacardi achieved the highest oil content of 48.50% (+2.28%), followed by SY Onestar, which achieved an oil content of 47.48% (+1.26%). The SY Gracia hybrid recorded oiliness at the level of 47.08% (+0.86%) (Figure 4).

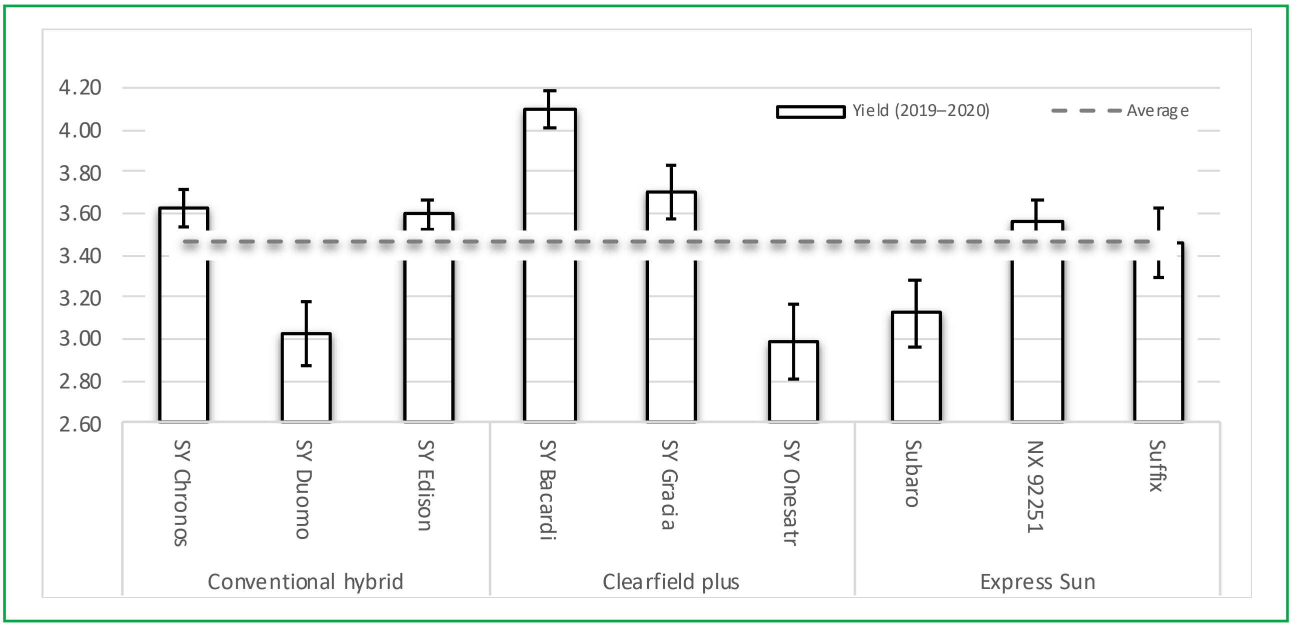

Figure 3 Sunflower seed yield (t ha^{-1})
the dashed line indicates the average value of genotypes for the whole statistical set. Error bars represent standard deviation (SD)

The highest average oil content in the conventional hybrid varieties reached the SY Duomo 47.34% (+1.13%). The decrease in oil content is followed by the hybrid SY Chronos 46.25% (increase by 0.03%) and SY Edison 45.60% (-0.62%) (Figure 4).

In Express Sun hybrids, the highest oil content reached Suffix hybrid 45.91% (-0.31%). The other monitored hybrids reached the following oil content: Subaro 44.72% (-1.50%) and by hybrid NX 92251 was recorded the lowest oil content at the level of 43.08% (-3.14%) (Figure 4).

4 Conclusions

The results of the statistical analysis declare that the agroecological conditions during the growing season 2019–2020 had a high significant effect on the yield and oil content in the sunflower seeds. The year 2019 was better for the seed yield (3.65 t ha^{-1}) (+0.37 t ha^{-1}), on the other side, the year 2020 was more effective for the oil content (46.65%) (+0.87%). By hybrids of sunflower, which have been classified into several varieties, a statistically

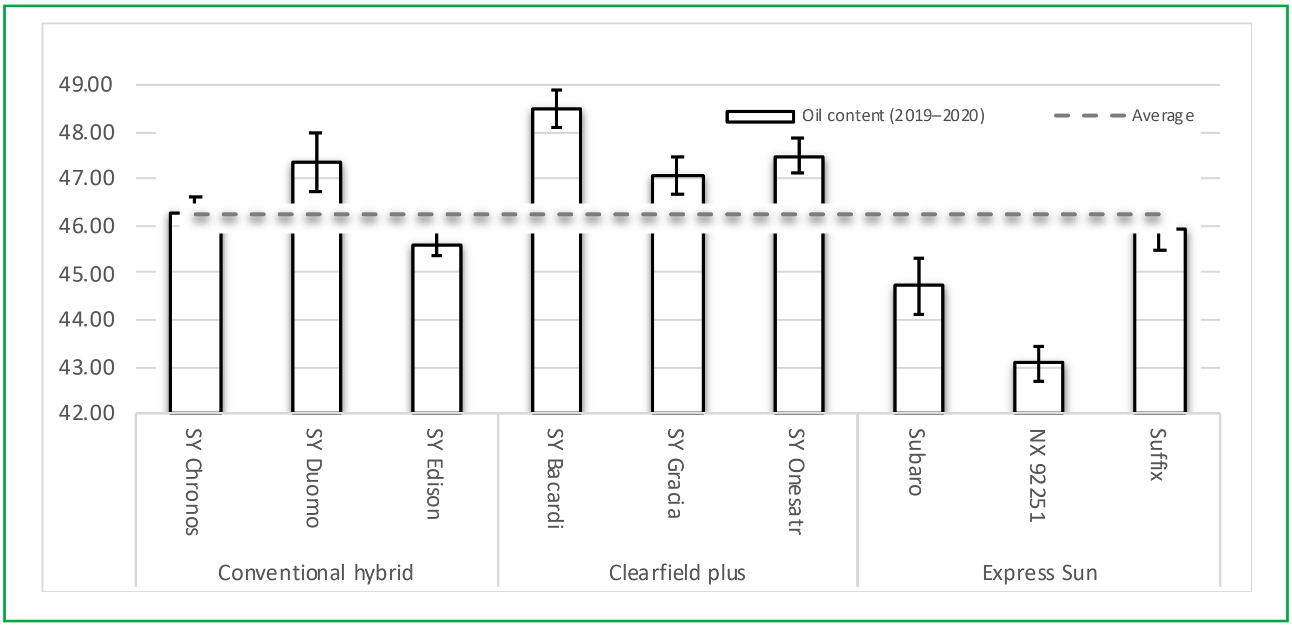

Figure 4 Sunflower oil content (%)
the dashed line indicates the average value of the varieties for the whole statistical set. Error bars represent standard deviation (SD)

high significant effect on the yield and oil content of sunflower seeds has been confirmed.

Experimental results of statistical analysis confirmed the highest seed yield and oil content by hybrid varieties of Clearfield Plus. The highest values were achieved by the SY Bacardi with seed yield 4.10 t ha^{-1} (+0.63 t ha^{-1}; rel. 18.29%) and with oil content at the level of 48.50% (+2.28%). The mentioned hybrid could be a prospect for use in intensive agriculture. In the range of monitored hybrids was recorded the lowest yield by SY Onestar hybrid 2.98 t ha^{-1} (-0.48 t ha^{-1}; rel. -13.92%) and the lowest oil content was recorded for the SY Gracia hybrid at a level of 47.08% (+0.86%).

Experimental results of the statistical analysis confirmed the lowest seed yield and oil content by hybrid varieties of Express Sun. The highest yield achieved hybrid NX 92251 3.56 t ha^{-1} (+0.10 t ha^{-1}; rel. 2.76%) and the highest oil content was recorded by Suffix (45.91%) (-0.31% below average). The lowest yield was achieved by the Subaro hybrid 3.12 t ha^{-1} (-0.34 t ha^{-1}; rel. 9.88%) and the lowest oil content was achieved by the hybrid NX 92251 43.08% (-3.14%).

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