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THE IMPACT OF CROP YEAR AND A FEW AGROTECHNICAL ELEMENTS ON THE FATTY ACID COMPOSITION OF LO AND HO SUNFLOWER (*HELIANTHUS ANNUUS* L.) OIL

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ABSTRACT

The fatty acid composition of seven sunflower (*Helianthus annuus* L.) hybrids of different genotypes (LO = normal, linoleic acid, HO = high oleic acid) was examined in two different crop years (2012 and 2013) in Eastern Hungary (North latitude: 47º5' East longitude: 21º4') on calcareous chernozem soil. Genotypes, sowing dates and fungicide using were studied in small-plot experiment. The linoleic acid content of LO hybrids was between 44.5-61.0%, that of HO hybrids ranged between 2.2-14.0%, while their respective oleic acid content varied between 24.2-45.2% and 82.2-90.9%, depending on genotype and crop year. The impact of sowing date and fungicide treatment was moderate and insignificant in the majority treatments. The oleic acid content of HO hybrids showed significant differences in both years depending on genotype (88.6-90.3% in 2012 and 82.2-90.9% in 2013). There was a close negative correlation between the linoleic acid and oleic acid content of LO and HO hybrids (LO hybrids: -0.994^{**} – -0.918^{**}, HO hybrids -0.996^{**} – -0.995^{**}) in both crop years.In the experiment without isolation, the oleic acid content of HO hybrids was constantly above 80% in both years.

Key words: genotype, saturated and non saturated fatty acids, sowing date, fungicide.

INTRODUCTION

In the recent decades, the vegetable oil production of the world increased dynamically primarily due to the change of human consumption habits, the constantly increasing needs of various industrial sectors and the increasing production of biofuels (Szabó and Pepó, 2005). Although oil-palm, soybean, rape and sunflower are among the most important oil crops produced worldwide, the main oil crops produced in Hungary are sunflower (600–650 thousand ha) and winter oilseed rape (230–260 thousand ha). The hybrid portfolio of sunflower production significantly increased during the last decades. Not only hybrids of higher yield potential and better yield stability (more favourable biotic and abiotic stress tolerance) appeared, but the oil content and oil composition of sunflower hybrids also changed. These new hybrids can be characterised by different agrotechnical reactions (Pepó and Vad, 2011).

The quality of sunflower oil is determined by its fatty acid composition (Piva *et al.*, 2000, Izquierdo *et al.*, 2006). Nearly 90% of sunflower oil consists of unsaturated fatty acids, mostly oleic acid (18:1) and linoleic acid (18:2). The rest of oil content consists of saturated fatty acids, i.e., palmitic acid (16:0) and stearic acid (18:0) (Cucci *et al.*, 2007). About 10–14% of conventional sunflower hybrid (LO) oil are saturated fatty acids, about 20% are oleic acid and 80% are polysaturated fatty acids (mostly linoleic acid) (Lacombe and Berville, 2000). More than 80% of the oil of recently bred HO hybrids are oleic acid, but this quantity may change in accordance with environmental conditions (Demurin *et al.*, 1996). Several experimental results showed that the oil content and oil fatty acid composition of sunflower are equally determined by genotype, weather conditions of year and agrotechnical factors (Baydar and Erbas, 2005; Joksinovic *et al.*, 2006; Zheljazkov *et al.*, 2009; Turhan *et al.*, 2010). Several research results showed that the oil content of sunflower is higher in dry crop years (Sukkasem *et al.*, 2013) and that higher temperature during the achene filling period also affects oil composition (Harris *et al.*, 1978; Unger, 1980; Anastasi *et al.*, 2000).

The sowing date of sunflower has an impact on the oil content and the fatty acid composition of sunflower, in addition to yield. In the case of later sowing date, the oleic acid content of the oil decreased, while the linoleic acid content increased in the experiments of Unger and Thompson (1982); Gupta *et al.* (1994) and Petcu *et al.*, (2010).

The aim of our research was to examine the change of the oil composition of seven sunflower hybrids (2 LO and 5 HO type hybrids) in two crop years of different weather. Of the different agrotechnical factors, the impact of sowing date and the fungicide treatment of the population was examined on the oil composition of LO and HO hybrids.

MATERIALS AND METHODS

The experiments were carried out on the Látókép Experimental Station of the Institute of Crop Sciences of the Faculty of Agricultural and Food Sciences and Environmental Management of the University of Debrecen on calcareous chernozem soil. The experiment site is located 15 km from Debrecen (North latitude: 47°5' East longitude: 21°4').

The experimental soil was calcareous chernozem loam (humus 2.6–2.8%, pH_{KCl} = 6.5, AL-soluble P_2O_5 and K_2O = 130 mg kg^{-1} and 240 mg kg^{-1}, respectively; heaviness index according to Arany: A_K = 42–44). The soil has favourable water management characteristics (the water holding capacity of the 0–200 soil layer is 680 mm out of which 50% is available water). The soil traits were measured in the Central Lab of Debrecen University according to international standards.

The experiments were established in 2012 and 2013 with a split–plot–plot design and four repetitions. The total (gross) plot size was 19.76 m^2 and the harvested area (net plot size) was 12.5 m^2. The inter row distance was 0.76 m. Three factors (genotype, sowing date, fungicide treatment) were examined in the experiment. The following sunflower hybrids were examined in the experiment: LO hybrids: NK Neoma, P63LE13; HO hybrids: NK Ferti, Tutti, SY Revelio, P64HE39, PR64H42. The following three sowing dates were examined in the two years of the experiment: early (late March), normal (mid-April), late (early May). We studied two fungicide models:a) control: without any fungicide treatments, b) two fungicide treatments: 1st treatment at the 8–10 leaf pair stage of sunflower (dimoxistrobin + boscalid) 2nd treatment at the beginning of sunflower flowering (dimoxistrobin + boscalid).

No isolation distance was left between LO and HO hybrids in either year.

The crop density of sunflower hybrids in the experiment was 55 thousand plants ha^{-1}. The agrotechnical elements were uniformed in the studied years and these elements fitted to the intensive crop technology used in our region. The previous crop was winter wheat and we used conventional tillage (in summer and autumn: disking + ploughing, in spring: seedbed preparation by combinator). The fertilizer doses were uniform in the two years: N = 68 kg ha^{-1}(in spring, before planting), P_2O_5 = 40 kg ha^{-1} and K_2O = kg ha^{-1}(in autumn before ploughing). We used preemergent herbicide application (S-metolachlor + oxyfluorfen). Sampo plot harvestor was used for the harvest in early, middle and late September depending on sowing dates.

The oil composition of the achene yield obtained during harvesting was determined with gas chromatography in accordance with the prescriptions of the Hungarian Standard (MSz ISO 5508:1992). During the determination of oil composition, oleic, linoleic and stearic acid contents were measured.

Analyses were performed in 2012 and 2013. The meteorological data of the two vegetation periods are shown in Table 1. In 2012, the amount of precipitation in June and July was average, while the weather was extremely dry and hot in August (in the period of oil accumulation). In March 2013, the significant amount of rainfall filled up the water stock of the soil and this could – partially – compensate for the unfavourable impact of the rainfall-deficient weather of the summer months (June-July-August).

The mathematical-statistical evaluation of the experiment results was performed with Microsoft Excel 2013 and SPSS for Windows 13.0. The obtained results were evaluated with ANOVA and Pearson's correlation analysis. In correlation analysis the *r* values mean weak (*r* = 0.3–0.5), average (*r* = 0.5–0.7) and strong (*r* =0.7–1.0) interactions.

RESULTS

In the recent decades, breeding techniques were used to change the conventional fatty acid composition of sunflower in order to meet the special needs of certain areas of use (food, various industrial sectors, biodiesel, etc.). As a consequence, high oil acid (HO) sunflower genotypes appeared in production in addition to conventional (LO) hybrids. These areas of use call for sunflower oil of stable and permanent fatty acid composition.

According to the obtained research results (*Table 2-3*), the linoleic acid content of LO hybrids was 44.5-56.4% in 2012 and 47.5-61.0% in 2013, depending on genotype, sowing date and fungicide treatment. The linoleic acid content of HO hybrids was significantly lower (2.2-14.0% in 2012 and 2.2-7.8% in 2013). Of the examined LO hybrids, the linoleic acid content of NK Neoma exceeded that of P63LE13 in both years of examination. Of HO hybrids, the relatively highest linoleic acid content was measured in the case of NK Ferti in both years of examination. The linoleic acid content of LO hybrids increased in later sowing dates in comparison with average and early sowing dates, while the lowest linoleic acid content of HO hybrids was measured in average (mid-April) sowing dates in the majority of cases. The differences in both hybrid types were not significant in either hybrid types.

Our examination results showed (*Table 4-5*) that the HO hybrids have the minimum 80% oleic acid content, only in some treatments (NK Ferti, early sowing date in 2012: 76.5-78.0%, SY Revelio, early sowing date in 2013: 78.7%) did not reach the 80% content in 2012 and 2013 years. At the same time, the oil acid content of HO genotypes did not significantly differ from each other. Hybrids P64HE39 and PR64H42 showed

exceptionally high oil acid content in both years (88.0-90.6% in 2012 and 82.2-90.9% in 2013). The oleic acid content of LO hybrids was between 31.6-45.2% in 2012, while its interval was significantly lower (24.2-40.4%) in 2013. Of LO hybrids, NK Neoma, which has a higher linoleic acid content, showed a lower oleic acid content than that of P63LE13 in both years of examination.

Based on the obtained examination results, the most stable fatty acid component of sunflower oil was shown to be stearic acid (*Tables 6-7*). The stearic acid content of LO and HO hybrids had a nearly identical interval in both years. The stearic acid content of LO hybrids was between 3.4-3.9% in 2012 and 2.6-4.1% in 2013, while that of HO hybrids was between 2.2-3.4% in 2012 and 2.5-3.7% in 2013. Despite this fact, the significant effect of several factors on stearic acid could be shown. In 2012, the stearic acid content of LO hybrids was significantly reduced by late sowing date, similarly to HO hybrids. In 2013, sowing date did not have any significant impact on the stearic acid content of LO and HO hybrids. No significant effect of fungicide treatments was observed on the stearic acid content of sunflower hybrids.

In the experiment, LO and HO hybrids were sown without any isolation strip in both years. The obtained examination results showed that the fatty acid composition of LO and HO hybrids is genetically determined. Averaged over the different sowing dates and fungicide treatments, the linoleic acid content of conventional LO hybrids was between 46.9-55.3%, while that of HO hybrids ranged between 2.2-9.4% (*Figure 1*). The linoleic acid content of both LO and HO hybrids showed significant differences which could still be observed in different crop years. The oil acid content of LO and HO hybrids (*Figure 2*) was also shown to be genetically determined. The oleic acid content of LO hybrids ranged between 28.5-42.2% and that of HO hybrids was between 81.4-90.0%, averaged over the different sowing dates and fungicide treatments. There was a negative correlation between linoleic acid and oil acid content. Also, differences were found in the oil acid content of HO hybrids. Due to their high oleic acid content, hybrids P64HE39 and PR64H42 have to be emphasised in the group of examined genotypes.

Of the examined fatty acids, stearic acid was found in the lowest quantity in sunflower oil (*Figure 3*). Based on the obtained examination results, there was no significant difference in the stearic acid content of LO and HO hybrids, averaged over different sowing dates and fungicide treatments. The stearic acid content of LO hybrids ranged between 3.4-3.7%, while that of HO hybrids was between 2.3-3.4%, depending on the genotype.

The results of the Pearson's correlation analysis (*Table 8*) showed no correlation between sowing dates, fungicide treatments and the unsaturated fatty acid content (linoleic acid, oleic acid) of sunflower. A medium negative correlation (-0.494^{**} – -0.744^{**}) was found between stearic acid content and sowing date, but the fungicide treatment did not modify the stearic acid content. The performed analyses showed a very close negative correlation between linoleic acid and oleic acid content both in the case of LO (-0.994^{**} – -0.918^{**}) and HO hybrids (-0.996^{**} – -0.995^{**}).

Table 1. Some agrometeorological parameters in the vegetation period of sunflower (Debrecen, 2012–2013)

Month	Rainfall (mm)			Temperature (îC)		
	2012	2013	30-year average	2012	2013	30-year average
March	1.4	136.3	33.5	6.3	2.9	5.0
April	20.7	48.0	42.4	11.7	12.0	10.7
May	71.9	68.7	58.8	16.4	16.6	15.8
June	91.7	30.8	79.5	20.9	19.6	18.7
July	65.3	15.6	65.7	23.3	21.2	20.3
August	4.1	32.2	60.7	22.5	21.5	19.6
Total Average	*255.1*	*331.6*	*340.6*	*16.85*	*15.63*	*15.02*

Table 2. Effect of sowing date and fungicide treatment on the linoleic acid content (%) of LO and HO sunflower hybrids (Debrecen. 2012).

Sowing date	Fungicide treatment	LO hybrids (linoleic acid %)		HO hybrids (linoleic acid %)				
		NK Neoma	P63LE13	NK Ferti	Tutti	SY Revelio	P64HE39	PR64H42
Early	control	52.0	45.6	12.7	6.0	5.5	1.6	2.2
	2x fungicide	53.1	45.7	14.0	4.8	5.2	1.6	1.9
Normal	control	54.1	51.0	7.4	4.2	3.8	3.9	2.2
	2x fungicide	51.6	49.2	8.2	5.0	5.0	1.8	2.8
Late	control	55.7	44.5	8.0	4.7	6.9	1.7	2.6
	2x fungicide	56.4	45.7	6.2	5.2	5.9	2.8	2.2

$LSD_{5\%}$ sowing date	*3.1*	*1.4*
$LSD_{5\%}$ hybrid	*1.6*	*1.0*
$LSD_{5\%}$ fungicide	*2.6*	*1.1*

Table 3. Effect of sowing date and fungicide treatment on the linoleic acid content (%) of LO and HO sunflower hybrids (Debrecen. 2013).

Sowing date	Fungicide treatment	LO hybrids (linoleic acid %)		HO hybrids (linoleic acid %)				
		NK Neoma	P63LE13	NK Ferti	Tutti	SY Revelio	P64HE39	PR64H42
Early	control	55.9	47.9	7.8	3.4	7.3	3.8	3.2
	2x fungicide	54.8	47.5	6.0	3.0	6.7	2.5	2.2
Normal	control	57.2	49.9	5.9	3.5	5.4	1.7	2.6
	2x fungicide	56.4	48.2	7.3	4.1	7.1	2.1	2.4
Late	control	49.6	54.1	7.0	3.6	8.0	1.6	2.5
	2x fungicide	61.0	54.7	6.7	3.7	8.1	3.2	2.7
$LSD_{5\%}$ sowing date		*3.8*				*1.1*		
$LSD_{5\%}$ hybrid		*2.7*				*0.7*		
$LSD_{5\%}$ fungicide		*3.1*				*0.9*		

Table 4. Effect of sowing date and fungicide treatment on the oleic acid content (%) of LO and HO sunflower hybrids (Debrecen. 2012).

Sowing date	Fungicide treatment	LO hybrids (oleic acid %)		HO hybrids (oleic acid %)				
		NK Neoma	P63LE13	NK Ferti	Tutti	SY Revelio	P64HE39	PR64H42
Early	control	35.3	43.4	78.0	85.2	85.2	90.6	90.1
	2x fungicide	34.2	43.3	76.5	86.3	85.5	90.4	90.3
Normal	control	33.3	37.5	83.3	90.7	87.9	88.0	90.1
	2x fungicide	36.6	39.7	82.5	86.3	86.5	90.4	89.4
Late	control	31.8	45.2	82.8	86.6	84.7	90.5	89.6
	2x fungicide	31.6	44.1	85.0	85.5	85.7	88.6	90.3
$LSD_{5\%}$ sowing date		*3.7*				*1.7*		
$LSD_{5\%}$ hybrid		*1.8*				*1.3*		
$LSD_{5\%}$ fungicide		*3.1*				*1.4*		

Table 5. Effect of sowing date and fungicide treatment on the oleic acid content (%) of LO and HO sunflower hybrids (Debrecen. 2013).

Sowing time	Fungicide treatment	LO hybrids (oleic acid %)		HO hybrids (oleic acid %)				
		NK Neoma	P63LE13	NK Ferti	Tutti	SY Revelio	P64HE39	PR64H42
Early	control	30.3	40.4	83.8	87.5	78.7	84.0	82.2
	2x fungicide	27.1	40.4	84.4	87.5	84.2	89.5	90.3
Normal	control	29.5	38.4	84.0	87.2	84.7	89.5	88.3
	2x fungicide	28.8	36.9	82.4	86.2	83.0	90.2	89.9
Late	control	31.2	32.0	83.0	87.5	83.2	90.9	89.9
	2x fungicide	24.2	32.6	82.1	87.8	83.2	89.0	89.5
$LSD_{5\%}$ sowing date		*4.6*				*1.6*		
$LSD_{5\%}$ hybrid		*3.1*				*1.5*		
$LSD_{5\%}$ fungicide		*3.7*				*1.3*		

Table 6. Effect of sowing date and fungicide treatment on the stearic acid content (%) of LO and HO sunflower hybrids (Debrecen. 2012).

Sowing date	Fungicide treatment	LO hybrids (stearic acid %)		HO hybrids (stearic acid %)				
		NK Neoma	P63LE13	NK Ferti	Tutti	SY Revelio	P64HE39	PR64H42
Early	control	3.7	3.6	3.3	3.0	3.3	2.6	2.2
	2x fungicide	3.9	3.6	3.4	3.0	3.2	2.7	2.3
Normal	control	3.5	3.8	3.4	3.0	3.1	3.0	2.5
	2x fungicide	3.8	3.9	3.4	3.1	3.2	2.7	2.4
Late	control	3.5	3.4	3.4	3.0	3.0	2.7	2.4
	2x fungicide	3.4	3.4	2.9	2.9	3.0	2.7	2.3
$LSD_{5\%}$ sowing date		*0.1*				*0.2*		
$LSD_{5\%}$ hybrid		*0.1*				*0.1*		
$LSD_{5\%}$ fungicide		*0.1*				*0.1*		

Table 7. Effect of sowing date and fungicide treatment on the stearic acid content (%) of LO and HO sunflower hybrids (Debrecen. 2013).

Sowing date	Fungicide treatment	LO hybrids (stearic acid %)		HO hybrids (stearic acid %)				
		NK Neoma	P63LE13	NK Ferti	Tutti	SY Revelio	P64HE39	PR64H42
Early	control	3.8	4.1	3.6	3.4	3.7	3.5	2.8
	2x fungicide	3.8	4.1	3.6	3.4	3.6	3.2	2.6
Normal	control	3.5	3.6	3.5	3.3	3.4	3.0	2.7
	2x fungicide	3.5	3.7	3.2	3.0	3.4	2.8	2.5
Late	control	2.6	3.5	3.2	3.3	3.1	2.9	2.6
	2x fungicide	3.1	3.4	2.6	3.0	3.0	2.7	2.6
$LSD_{5\%}$ sowing date		*0.2*				*0.2*		
$LSD_{5\%}$ hybrid		*0.2*				*0.2*		
$LSD_{5\%}$ fungicide		*0.2*				*0.3*		

Table 8. Correlation analysis by Pearson among the agrotechnical elements and fatty acid composition of sunflower hybrids (Debrecen. 2012–2013).

Crop year		2012			2013		
Hybrid	Factors	Stearic acid	Oleic acid	Linoleic acid	Stearic acid	Oleic acid	Linoleic acid
LO	Sowing date	-0.494(**)	-0.068(^{NS})	0.14(^{NS})	-0.744(**)	-0.195(^{NS})	0.256(^{NS})
	Fungicide	0.196(^{NS})	0.05(^{NS})	-0.025(^{NS})	0.069(^{NS})	-0.233(^{NS})	0.126(^{NS})
	Stearic acid	1	-0.173(^{NS})	0.123(^{NS})	1	0.276(^{NS})	-0.291(*)
	Oleic acid		1	-0.994(**)		1	-0.918(**)
HO	Sowing date	-0.096(^{NS})	-0.218(**)	0.214(**)	-0.447(**)	0.002(^{NS})	0.019(^{NS})
	Fungicide	-0.119(^{NS})	-0.012(^{NS})	0.003(^{NS})	-0.13(^{NS})	-0.003(^{NS})	0.009(^{NS})
	Stearic acid	1	-0.481(**)	0.465(**)	1	-0.443(**)	0.444(**)
	Oleic acid		1	-0.996(**)		1	-0.995(**)

(*) Correlation on $LSD_{5\%}$ level
(**) Correlation on $LSD_{1\%}$ level
(^{NS}) Non significant

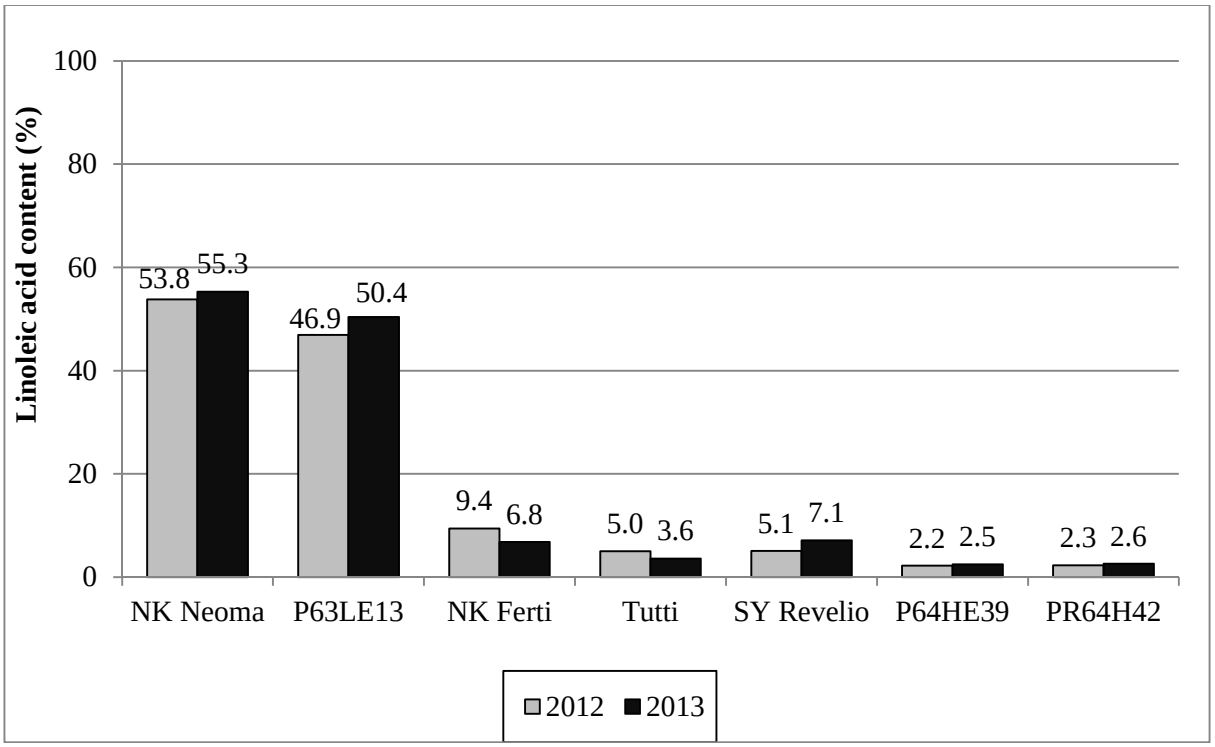

Fig. 1. Effect of crop year on the linoleic acid content (%) of LO and HO sunflower hybrids (average of sowing dates and fungicide treatments) (Debrecen. 2012-2013)

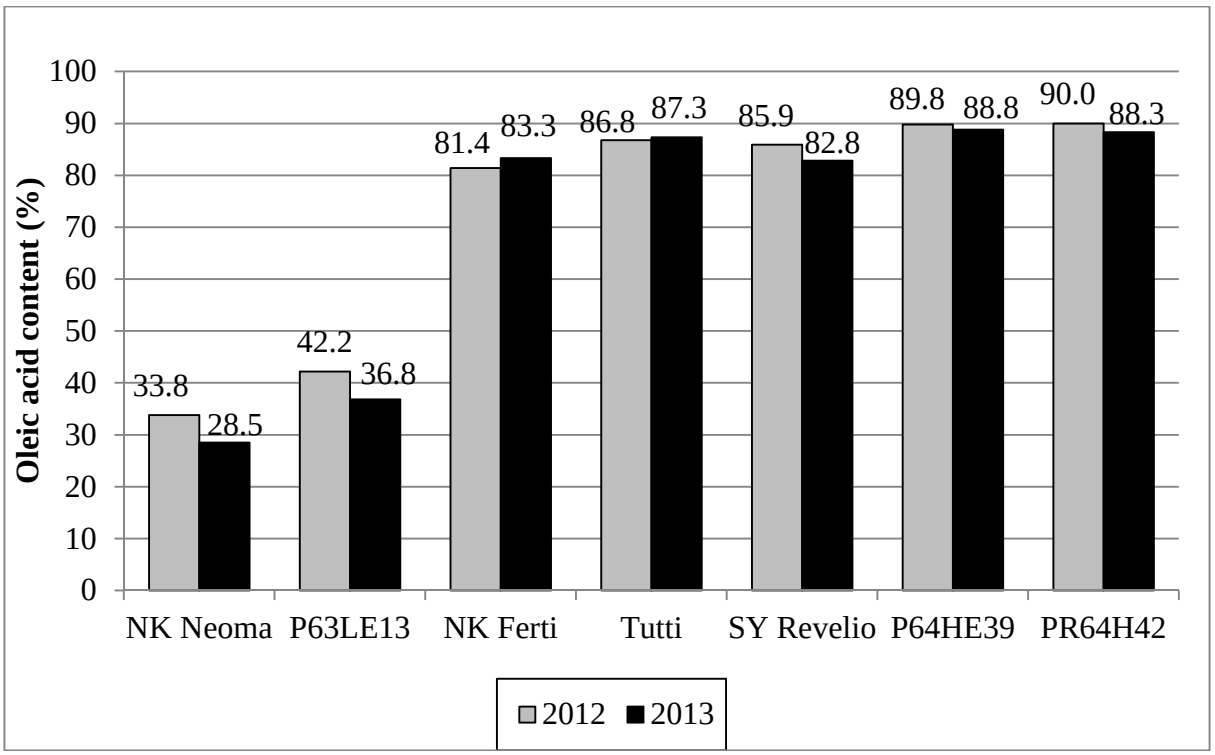

Fig. 2. Effect of crop year on the oleic acid content (%) of LO and HO sunflower hybrids (average of sowing dates and fungicide treatments) (Debrecen. 2012-2013).

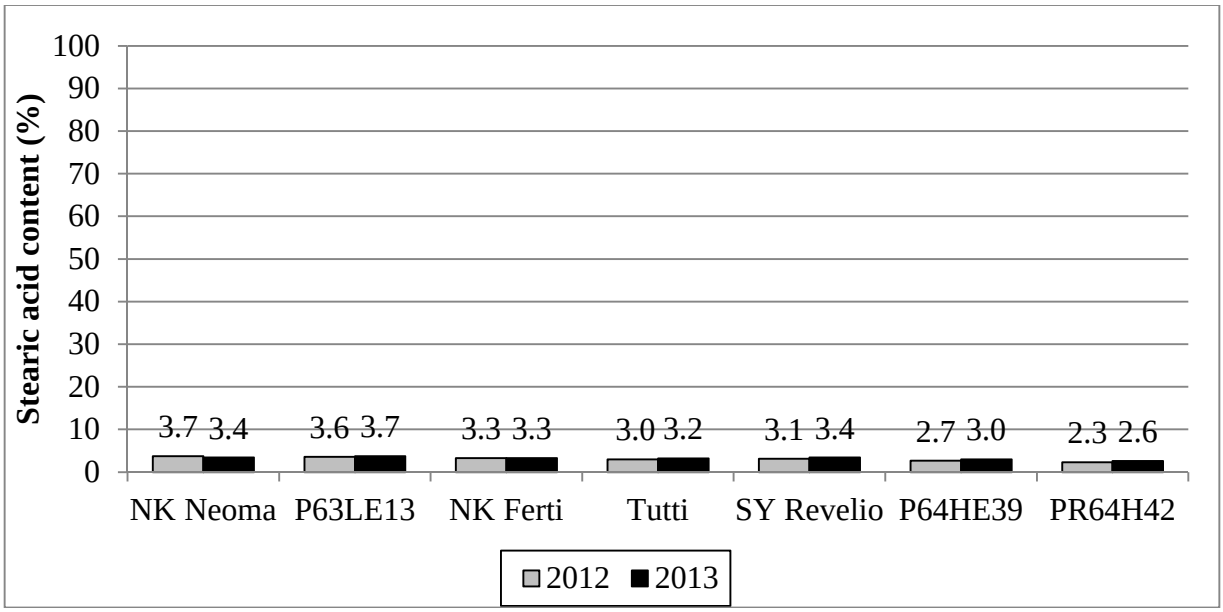

Fig. 3. Effect of crop year on the stearic acid content (%) of LO and HO sunflower hybrids (average of sowing dates and fungicide treatments) (Debrecen. 2012-2013).

DISCUSSION

The fatty acid composition of sunflower oil is genetically determined (Baydar and Erbas. 2005. Zheljazkov *et al*.. 2009). However. there may be smaller or bigger differences in the oil composition of LO and HO hybrids. but fatty acid composition is also affected by environmental (primarily weather) factors (Skoric, 1992. Baldini *et al*.. 2002. Izquierdo *et al*.. 2002) and certain agrotechnical elements (e.g. sowing date. etc.).

As a result of fungicide treatment. there were changes of different direction in terms of linoleic acid content. However. these differences were not significant. Our examination results were similar to the results of Garside (1984) who measured the highest linoleic acid content in the case of the April sowing date and concluded that the linoleic acid content decreased both in the case of the early and late sowing dates.

There is a negative correlation between the amounts of oleic acid and linoleic acid in sunflower oil. According to the examinations of Roche *et al.* (2006). the combination of the proper choice of genotype and sowing date. as well as water management is able to influence the synthesis of oil components. Our examination results showed that the oleic acid content of sunflower hybrids was basically determined by genotype. Based on the examinations of Demurin *et al.* (1996) . the oleic acid content of HO hybrids exceeds 80%. Of the examined factors. the oleic acid content of hybrids is primarily determined by genotype. However. neither the different sowing dates. nor fungicide treatments had any significant impact.

The fatty acid composition of the conventional. linoleic acid (LO) and high oleic acid content (HO) sunflower hybrids was observed in two different crop years (2012 and 2013). The weather (mainly the temperature and precipitation during the achene filling period) affected the linoleic acid content of hybrids. The obtained results confirmed the statements of Sukkasen *et al.* (2013) and Baldini *et al.* (2002). Based on the performed analyses. the oleic acid and stearic acid content of the examined hybrids were stable in different crop years. The oleic acid content of HO hybrids ranged between 80–90%. i.e.. there were significant differences between genotypes. Similarly to the examinations of Piva *et al.* (2000) a negative correlation was found between oleic acid and linoleic acid content both in the case of LO and HO hybrids. No significant difference was found between LO and HO hybrids in terms of stearic acid content. According to our scientific results. the fatty acid composition of sunflower oil was less influenced by different sowing dates and fungicide treatments. At the same time. the performed experiments also showed that the HO hybrids of special fatty acid composition maintained their high oleic acid content (min. 80%) even without an isolation strip.

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