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Breeding of high oleic sunflower hybrids and high linolenic linseed varieties in the Cereal Research Non-Profit Ltd. Co.

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Abstract

Sunflower and linseed are traditionally bred in Szeged, Hungary. Originally, breeder's main aim was to increase the productivity of these species but the quality of the vegetable oils came into the limelight during the last two decades. Analytical examinations prove that the quality of sunflower oil is represented by the oleic acid content while in case of linseed the linolenic acid plays the key role. Improving the linolenic acid level did not cause yield depression in linseed but higher oleic acid contents resulted in significantly lower yields in sunflower. Improving resistance to diseases and selecting for earlier maturity we managed to decrease the yield loss from 10% to 3-5%.

Keywords

Cold pressing, *Helianthus annuus*, linolenic acid, *Linum usitatissimum*, oleic acid, tocopherol

Breeding and release of varieties

The Cereal Research Non-Profit Ltd. Co. was founded in 1924 and is one of the Hungarian public institutes engaged in oil crop breeding. The institute has its centre in Szeged, South Hungary, where sunflower (*Helianthus annuus* L.) and linseed (*Linum usitatissimum* L.) nurseries are located. Breeding of sunflower started in Szeged in the 1960s with maintaining Russian varieties and developing own varieties. In 1974 the first hybrid breeding program began with the development of own maintainer, male sterile and restorer lines. Thanks to international relations a very valuable genebank was established at that time. During the 1980s and 1990s, 61 Szeged sunflower hybrids were successfully registered in Hungary and abroad and they were successfully grown in 17 countries (*Table 1*). This success was acknowledged with the International Export Trophy and the Hungarian Innovation Grand Prize. However, the growing area of Szeged varieties decreased significantly by the expansion of multinational seed companies by the early 2000s. In 2010, Hungarian farmers grew our hybrids on less than 15000 ha.

Linseed breeding in Szeged is almost as old as the institute itself. First programs began in 1929 when the Hungarian aircraft production was the main costumer of linseed oil. Since then, more than dozen of Szeged linseed varieties were successfully registered in Hungary, Austria, Denmark, France and the United Kingdom (*Table 2*). Until today the Cereal Research Non-Profit Ltd. Co. is the only base of linseed breeding in Hungary. Although linseed is a well known crop in Hungary its growing area is only about 2500 ha. On the other hand, Szeged linseed varieties are popular with British and New Zealand farmers because of their excellent yield potential and high oil content.

Table 1: **Szeged sunflower hybrids on the market (FR, France; HU, Hungary; RO, Romania)**

	Registration	
Hybrid	Year	Country
Viki	1988	FR, HU
Bambó	1990	HU
Marica 2	1994	HU
Sonrisa	1996	HU
Magóg	1999	HU
Masaï	1999	HU
Manitou	2003	HU
Superflor	2007	RO
Supersol	2007	RO
Larissa	2008	RO
Mandala	2010	RO

Table 2: **Szeged linseed varieties on the market (AT, Austria; DK, Denmark; HU, Hungary; UK, United Kingdom)**

	Registration	
Variety	Year	Country
Sandra	1987	HU
	1991	AT
Crystal	1990	UK
Barbara	1989	UK
	1992	HU, DK
	1993	FR
	1994	AT
Hungarian Gold	1995	AT
Zoltán	1993	UK
	1996	HU
Juliet	1999	UK
	2001	HU
Nikol	2006	HU
GK Emma	2009	UK

Sunflower and linseed oil quality

The best way to increase growing area and popularity of sunflower and linseed is breeding for oil quality. Previous-

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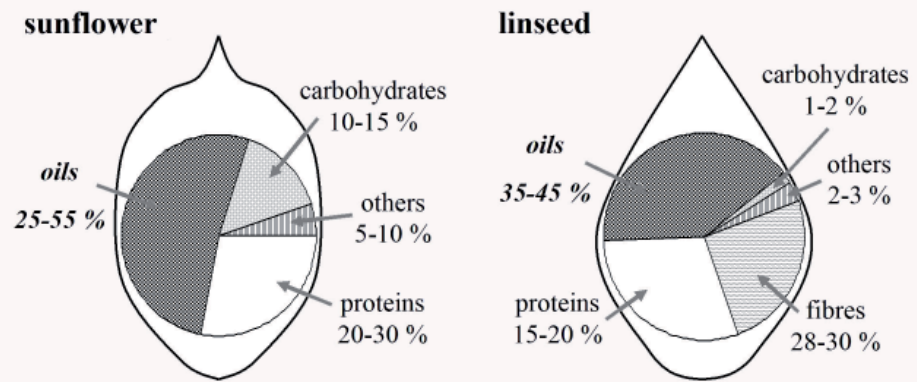

Figure 1: **Chemical composition of the seed of sunflower and linseed**

ly, breeders considered only so called quantity traits (high yield and marketable product at low costs) represented by profit oriented farmers. Nowadays, scientists are interested in quality traits too since modern costumers consciously buy healthy and tasty food products. They look for nice smelling and nice tasting cooking, frying and dressing oils. Oils which do not smoke during heating and rancidity is not typical to them. If the breeder is able to satisfy quantity and quality requirements new varieties and hybrids can be created which lead to premium oils and consequently to a healthier life.

The chemical composition of sunflower and linseed seeds are similar (*Figure 1*) but the fatty acid profile and the tocopherol components are different (*Table 3* and *Table 4*). In case of sunflower the oil quality is represented by the oleic acid content while in case of linseed the main value of the oil is the linolenic acid content. These fatty acids have diverse positive effects on the human body, e.g. reduction of the LDL-cholesterol level, strengthening of the immune system, protection against stroke, heart and circulatory diseases, improvement of fitness, stimulation of the brain and healing of arthritis and liver troubles. The minor compound tocopherols play also an essential role since they prevent fatty acid oxidation and development of cancer. The health beneficiary effects are the reason why breeding for oil quality became necessary. Soldatov, a Russian researcher was the first who managed to change the fatty acid profile of sunflower via mutagenesis (SOLDATOV 1976). He used the so called Pervenets population and selected individuals with increased oleic acid content. His population served as a genetic source for breeders during the last decades. It is generally admitted that his scientific activity was the key to the high oleic (HO) hybrids. Criteria for official registration of HO varieties depend on national VCU rules. In Hungary, only hybrids with >85% oleic acid can be registered as HO varieties.

Modification of the fatty acid profile of linseed was done at first time in Canada in 1990. Using the McGregor variety and the mutagenesis method, Rowland found plants with increased linolenic acid content (ROWLAND et al. 1995). However, high linolenic (HLNA) linseed varieties did not come into general use. There is no limit for the linolenic acid content in the Hungarian official variety registration system but 55% is an expected value.

Table 3: **Fatty acid profile of sunflower and linseed oils**

Fatty acids (%)	Stearic	Oleic	Linoleic (Omega-6)	Linolenic (Omega-3)
Saturation	$C_{18:0}$	$C_{18:1}$	$C_{18:2}$	$C_{18:3}$
Sunflower	1-5	25-65	25-65	<1
Linseed	3-7	15-25	10-15	30-50

Table 4: **Tocopherol content of sunflower and linseed oils**

Tocopherols ($mg.l^{-1}$)	α	β+γ	δ	Total
Sunflower	150-950	10-80	<1	200-1000
Linseed	<1	400-500	<1	400-500

High oleic sunflower and high linolenic linseed breeding

Breeding of HO sunflowers began in Szeged in the 1990s with changing lines, development of HO genebank and production of maintainer, male sterile and restorer lines. During the 2000s, the first test crossings were done and the combining ability of the new lines was studied. As a result, four female lines (H305, H309, MO1, MO3) and two restorer lines (PHC1707, R4) were successfully registered. The application of the first HO hybrids into official trials is planned for the 2010s. The development of HLNA linseed genebank started also in the 1990s and was followed by crossings and breeding of lines A, B, C and D. By the 2000s, a content of 50% linolenic acid was reached and two quality varieties, i.e. Nikol (52%) and GK Emma (54%), were successfully registered.

Field trials with HLNA linseeds and HO sunflowers provided interesting data. We sow three traditional and three HLNA varieties in four locations (two in Szeged, two in Cambridge, UK) in three seasons and measured their yield and linolenic acid content. *Figure 2* shows the average values of the results. It is clearly visible that HLNA varieties did not produce lower yield than traditional varieties. Hence, in case of linseed breeding for quality is not detrimental to grain quantity. This is not the case in sunflower. A field trial with 4 traditional and 4 HO hybrids was carried out in Szeged in four seasons and their yield and oleic acid content was determined. *Figure 3* shows the average values of the results. It is obvious that genotypes with 90% oleic acid content produce lower yields than traditional varieties. The yield difference was about 10%. Therefore, if we want to breed for oil quality we must consider the negative correlation between quality and quantity.

For the breeder it is important to know the factors which are responsible for the yield loss of HO varieties. Basically, our HO population proved to be sensitive to different pathogens, e.g. *Erwinia carotovora*, *Plasmopara halstedii*, *Sclerotinia sclerotiorum*, *Diaporthe helianthi*, *Bothritis cinerea*, *Alternaria helianthi*, *Phoma macdonaldi*, *Macrophomina*

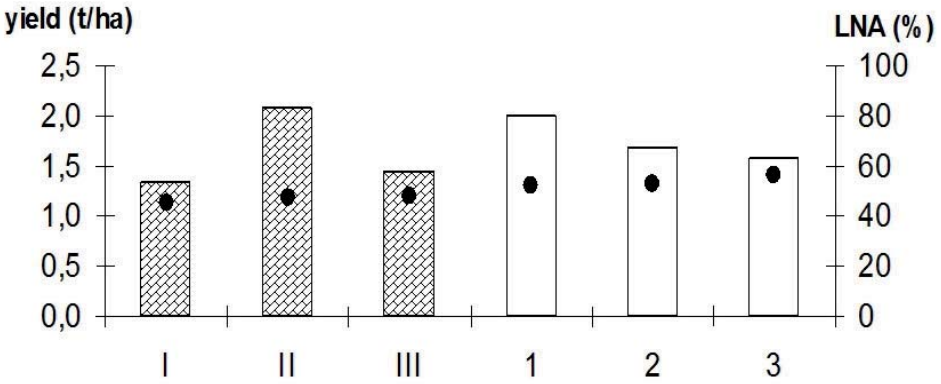

Figure 2: **Mean seed yield and oil quality in linseed. Dots indicate the linolenic acid (LNA) content, white bars represent HLNA varieties, hatched bars represent traditional varieties**

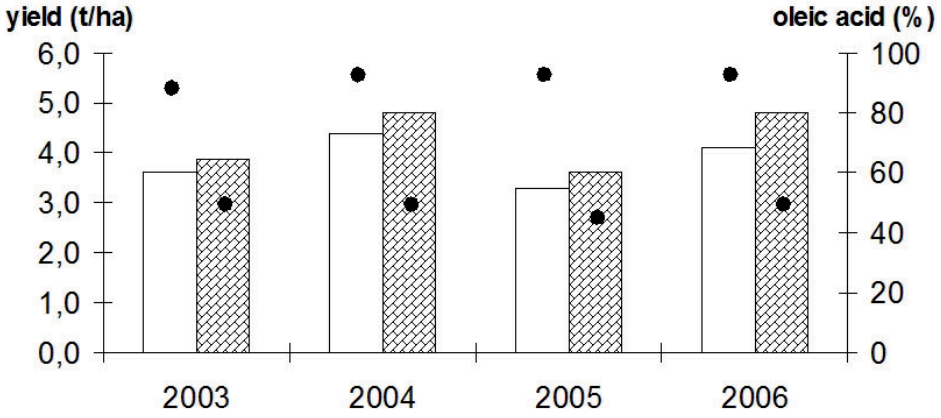

Figure 3: **Mean seed yield and oil quality in sunflower. Dots indicate the oleic acid content, white bars represent high oleic (HO) varieties, hatched bars represent traditional varieties**

phaseolina, *Rhisopus stolonifer* and *Orobanche cumana*. Additionally, HO hybrids exhibited late maturity. In order to improve resistance we screened our plant material in three steps. Using molecular markers *HaP3* and *ORS1036* we established a marker assisted selection for the *Pl6* and *OR5* resistance genes against *P. halstedii* and *O. cumana*, respectively. Moreover we used artificial infection methods, e.g. in vitro germination on water contaminated with *P. helianthii* spores and sowing in *O. cumana* infected soil in the greenhouse. A third step of selection was done in so called pathological nurseries where sunflower is grown in monoculture over years and, therefore, the soil is full with spores of pathogens to provoke a high pressure of diseases. As a result of this three step selection we managed to improve resistance and to shorten the vegetation period (from 140 to 120 days). Thereby, we decreased the yield deficit of our HO material compared to traditional hybrids. Of course this does not mean the end of our work. We continue with selection until any yield loss of HO hybrids is eliminated.

Realization of oil quality of HO sunflowers and HLNA linseeds is possible only with the cold pressing technology. Compared to chemical extraction, this is not a mass production method and does not use chemical solvents for extraction of vegetable oils. Natural tocopherols remain in cold pressed oils since the temperature during processing does not reach their decomposition point. In this way, oleic and linolenic acids susceptible to oxidation can be protected by tocopherols. By the expansion of the cold pressing technology a new trait, the so called cold extractable oil content, became important. Today this content is between 30 and 40% and depends on the skin/kernel ratio which can be influenced by breeders.

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