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COMPLEX ANALYSIS OF THE SUNFLOWER HYBRID-SPECIFIC SOWING TIME ON LOESS IN HAJDÚSÁG

theses of doctoral dissertation

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1. INTRODUCTION

The sunflower (*Helianthus annuus* L.) is form the western part of North America and entered Europe in the decade of 1510 after the discovery of America. The sunflower appeared in that same period in plant production as an oil plant in Hungary, before that it was used as border plant and ornamental plant. In the beginning of the 20th century it was a basic commodity in the soap and paint production and only after the 1940s' got the sunflower oil more and more importance in human nourishment. Its use for culinary purposes is enabled because the produced sunflower varieties and hybrid's oil content is between 35-60 %, an energy source in our provisions with high energy content (29,3-39,8 kJ g^{-1}) and besides the transmitter of the oil-soluble vitamins.

After World War II its production area varied, the land area was defined by the production area of the forage crops needed for the livestock. The end of the 1970s' meant a big change in this tendency when sunflower oil produced in Hungary became significant exports, at this time its production area grew over 300 thousands hectares. This was made possible by appearance of varieties with high oil content and with them the average yield in Hungary did not, but the oil yield per hectares did increased considerably. The conscious development of the of the biological basis (the first sunflower hybrids went into the Hungarian civic production in 1975) and the positive changes in agro-technology resulted in the growth of the average yields, which only came to the surface under sound level of technology and discipline. The average yield came to stay around 2.0 t ha^{-1} in the years between 1980 and 1990 opposite to the average of the 1970s' 1.2 t ha^{-1}. To facilitate the integration of the sunflower production the first production systems appeared (for example Bácsalmás). It was verified that sunflower production has a right to exist in Hungary and its profitability indicators supported its production on bigger land area. This area was around 350 thousand hectares in the 1980s, its significant growth started from the end of the 1980s' (*Figure 1.*) Such considerable growth was not hindered by the available machinery because the sector's special equipment need is low, great deal of the technological procedures can be solved with the winter wheat production's machines.

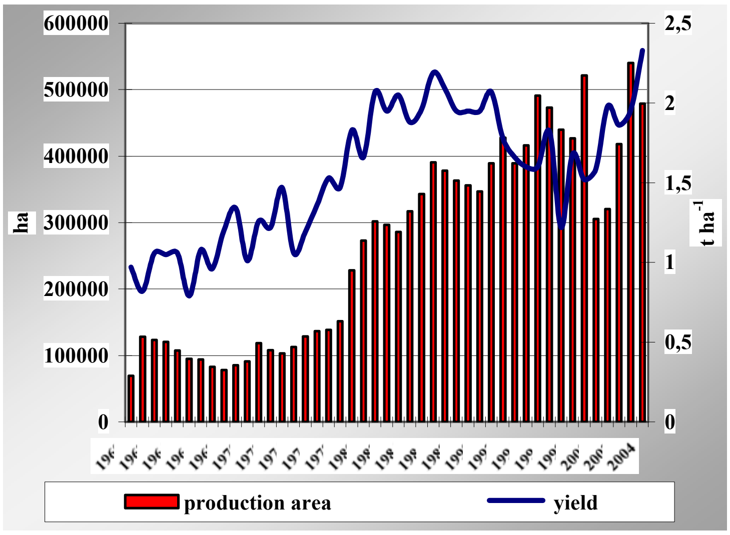

Figure 1.: **The development of the production area and average yield of sunflower between 1960 and 2004 in Hungary**
(based on data from CSO)

Hungary, based on its production indicators, had a place in the sun both in Europe and in the world. Based on the indicators of the year of 2004 from the major sunflower producing countries we had the second place just after France from the viewpoint of average yields. This result is more important because in Hungary the production of sunflower – as a result of the excellent adaptability of the plant – is mainly done on areas with less favorable characteristics. The produced sunflower's amount position of Hungary is on the 6th to 8th place in the world in the company of the United States of America and India, which means that Hungary appears as a potential exporting country on the world market. From the viewpoint of the role of sunflower in the farming rotation Hungary is in the lead besides Rumania and Ukraine with more than 10 %, which indicates the plant's essential role in the mentioned countries. The mentioned favorable indicators can only prevail if the marketability of the produced significant amount of sunflower on the world market is good, but in the recent years it caused problems. The main reason can be found in that the world market transformed, Russia and Ukraine took over the role of Argentina which previously ruled and these countries – because of their geographical situation – are the competitors of Hungary on the European markets until effective market protection measures are taken. Besides the mentioned countries Romania also produces significant amount of sunflower, but because of the possibility of marine transportation it has an advantage on the export markets. (*Table 1.*)

Table 1.: **The production indicators of the major sunflower producing countries**

Country	**Production area (ha)**	**Production are in the percentage of the arable land**	**Average yield ($t\ ha^{-1}$)**	**Yield (tons)**
Russia	4.500.000	3,64	0,95	4.300.000
Ukraine	3.320.000	10,20	1,02	3.400.000
India	2.070.000	1,28	0,60	1.250.000
Argentina	1.822.000	5,40	1,70	3.100.000
China	1.170.000	0,82	1,61	1.880.000
Romania	996.798	10,60	1,72	1.719.816
Spain	749.500	5,45	1,08	811.400
USA	720.350	0,40	1,50	1.086.440
France	616.000	3,33	2,36	1.456.000
South-Africa	630.000	4,27	1,12	710.000
Turkey	520.000	2,00	1,25	650.000
Hungary	***479.000***	***10,38***	***2,33***	***1.119.000***
World	**21.394.044**	**1,52**	**1,22**	**26.208.114**

2. INTRODUCTION OF THE SUBJECT

The production of numerous and with different adaptability hybrids and the improvement of effectiveness of sunflower production make it reasonable to develop hybrid-specific production technologies. In the last decade the hybrid assortment increased in an enormous rate and as a result the hybrid assortment has significant heterogeneity from the viewpoint of production characteristics. This explains the examination of hybrids from the viewpoint of critical elements and genotype x environment interactions. The results from the variety comparing and production technology experiments that are going on for a decade at Látókép, the Experiment Site of the University of Debrecen, Centre of Agriculture, Faculty of Agricultural Sciences, Institute of Practice Farm and Ecology Research of Debrecen are exceptionally important, which provides inevitable information for the smaller production range – the Hajdúság.

In the biological optimum the time of sowing has a considerable effect on the development of crop. It directly affects the development of the plant and this way the quantity of yield and its oil content and indirectly the rate of disease infection by changing the length of the vegetation period.

In a very short time the *Diaporthe helianthi* (*anamorphic: Phomopsis helianthi* MUNT.-CVET. et al.) became one of the most important pathogen organism of sunflower besides the classical pathogens (*Sclerotinia sclerotorium* (LIB.) DE BARY, *Botrytis cinerea* (PERS.) FRIES.) in Hungary. The stem canker caused by this pathogen appears significantly in the yields, because besides the lessening of the assimilation surface and the damaging of the transportation tissues the dying of mechanical tissues the stem brakes and the plate become non-harvestable. The importance of the pathogen is enlarged because the results of chemical control against it are ambiguous. The main reason for that is that the infection dynamics of the fungi is not entirely known and this restricts the possibilities of foreseeing.

The effectiveness of fungicide protection can be greatly improved if the time of it is the same when the primer inoculum (asco-spore) appears or if it is slightly precedes it. With that the pathogenesis in the field can be greatly prevented. To do this it is inevitable to define the starting day of the infection. It is clear from the feedback from different parts of Hungary that this forecast cannot be done on a country level, so on a regional, but mainly on farm level forecasts are needed to define more accurately the time of using chemicals. Using the possibilities in the genetic basis can help to lessen the extent of damage done by the pathogen which means the production of resistant hybrids. The deep pathological analyses of the wide hybrid assortment and based on its results the effectiveness of production can be improved, because the hybrids characteristics and the behavior of the genetic basis against pathogens can be known on a smaller, regional range.

In my Ph.D. dissertation I summarized the results of my research from the experiments conducted at Látókép, the Experiment Site of the University of Debrecen, Centre of Agriculture, Faculty of Agricultural Sciences, Institute of Practice Farm and Ecology Research of Debrecen between 1994 and 2000 with the lead and professional guide of Professor Dr. Péter Pepó, head of department.
The objectives of my research are summarized below:

- the complex working mechanism of the different sowing times of sunflower
- the examination of the effect of different sowing times on the vegetative growth
- the interaction between the climatic factors and different sowing times
- the effect of different sowing times on the quantity of crop and oil content
- with the comparison of the examined hybrids the analyses of the biological basis on yield, oil content and agronomical characteristics
- examination of the environmental factors and the different sowing times on the damage in the case of *Diaporthe helianthi* and *Sclerotinia sclerotorium* pathogens
- in the case of the firstly mentioned pathogen the pathogenesis has been examined with the help of infection dynamic experiments

Our experimental results bear great significance in the improvement of effectiveness of regional sunflower production, defining the right sowing time and specifying the production technological parameters of hybrids.

3. MATERIALS AND METHODS

3.1. The experiment's site, soil characteristics

Our experiments were conducted at Látókép, the Experiment Site of the University of Debrecen, Centre of Agriculture, Faculty of Agricultural Sciences, Institute of Practice Farm and Ecology Research of Debrecen. The experimental site is located on the Loess of Hajdúság, 15 km away from Debrecen, next to the 33 main roadway.

The soil of the experiment field was calciferous chernozem developed on loess with deep mould. The experiment's soil is in good condition, middle bound (Arany bound number: 42), according to the soil physics it is classified as middle bound loam soil. The evenly mould layer's average mould content is 2.8 %. The cultivated layer's acidity (KCl pH) is between 6,3 and 6.5, the N-content is 0,12-0,15 %. Based on the N-content its N-supply can be classified as medium. By analyzing the results of ammonium-lactate diagnosis P_2O_5 and K_2O content it can be seen that the experimental site's soil has good Potassium content (240 mg kg^{-1}). The Phosphorous content of the field was medium (133 mg kg^{-1})

3.2. Agro-technology used in the experiment

A widely used production technology was used in the experiment. In the given years the early sowing time meant end of March - early April, the average sowing time mid-April and the late sowing time early May. In the experiment's years the sowing time altered as in the following:

Year	Early sowing	Average sowing	Late sowing
1999	04. 06.	04. 21.	05. 05.
2000	03. 29.	04. 12.	05. 04.
2001	03. 30.	04. 12.	05. 04.
2002	03. 28.	04. 16.	05. 06.
2003	04. 01.	04. 15.	05. 08.
2004	04. 01.	04. 13.	05. 04.

The territory of the experimental parcels was 15 square meter. A single 55 thousand plant per ha^{-1} plant density was used in the experiments and the sowing was done with hand sowing-gun. A protection method that is spread in practice was used in the crop. The harvest was done with a self-propelling reaping-machine.

3.3. Methodology of the results and discussion

Ten sunflowers with different genotypes were deeply examined in every year in the experiments (*Table 2.*). In the 6 year long experiment series altogether 25 hybrids were tested.

Table 2.: **Hybrids in the experiment**
(Debrecen-Látókép, 1999-2004)

1999	2000	2001	2002	2003	2004
Alexandra[2]	Alexandra[2]	Alexandra[2]	Alexandra[2]	Alexandra PR[2]	Alexandra PR[2]
Arena[3]	Arena[3]	Arena PR[3]	Arena PR[3]	Altesse[2]	Altesse RM[2]
Flores[1]	Fleuret[2]	Diabolo (fj)[3]	Diabolo[3]	Arena PR[3]	Arena PR[3]
Florix[2]	Florix[2]	Fleuret[2]	Floyd[1]	Astor[2]	Astor[2]
Hysun 321[2]	Hysun 321[2]	Hysun 321[2]	Larisol[2]	Diabolo[3]	Diabolo[3]
Lympil[3]	Larisol (fj)[2]	Larisol[2]	LG 5385[1]	Larisol[2]	Louidor[1]
Natil[2]	Lucil[2]	LG 5385[1]	Louidor[1]	LG 5385[1]	NK Brio[2]
Rigasol[2]	Lympil[3]	Lympil[3]	Magnum[2]	Louidor[1]	PR63A82[2]
Trentil[2]	Rigasol[2]	PR63A90[2]	PR63A82[3]	PR64A63 (fj)[3]	PR64A63[3]
Util[3]	Util[3]	Rigasol PR[2]	Rigasol PR[2]	Rigasol PR[2]	Rumbasol[2]

[1]very early ripening
[2] early ripening
[3]mid-ripening

The features, phenometrical, shooting and flowering dynamical, agronomical and pathological features of the hybrids in the experiments were recorded in four repetition. When determining the disease's infection details of *Diaporthe helianthi* the occurrence of the symptoms on the stem was taken as a basis. In the casual block, four repetition experiment the recordings were done seven times, in every tenth day in the period between June 20 and August 20. Besides counting the diseased plants a special scale indicating the spread of the disease was used. The unusually wide scale values from 0 to 10 were considered necessary because the appearance and seriousness of the symptoms showed great variability. A contamination index was calculated as an indicator of the disease's importance. The contamination index is defined as follows:

$F_i = (\Sigma a_i \times f_i)/n$, where
a_i = the given contamination scale value (intensity of the disease)
f_i = the frequency of the scale value (the frequency of the disease)
n = the number of examined plants

The contamination values in the dissertation are the last contamination values at August 20, the contamination-dynamical results because of the low level of contamination did not make it possible to define the exact contamination differences of hybrids and different sowing times except for the year of 1999. In the case of the *Sclerotinia sclerotonium* pathogen the mycelia contamination (wilting) and from the ascosporic contamination symptoms the stem patchiness are presented together. During harvesting the raw yield and the moisture content of the parcels was defined. By using these data the yield results were standardized and in the table values recalculated for 8 % moisture content. The experimental results were statistically analyzed with SPSS for Windows™. The graphical presentation was done with Microsoft Excel.

3.3. The effect of the weather of the examined years on the development of sunflower crops

The main characteristics of the examined years are presented in *Table 3.*

Table 3.: The **main characteristics of the examined years**

(Debrecen-Látókép, 1999-2004)

Year	The climatic characteristics of the shooting period	The climatic characteristics of the vegetation period	Year effect
1999	Favorable, even	More there average precipitation, More than average temperature	average
2000	In the case of early sowing unfavorable, later even	Less then average precipitation, High temperature	favorable
2001	Low soil temperature in all three sowing period	Average precipitation, Average temperature	unfavorable
2002	Great variability of soil temperature	Average precipitation, Average temperature	average
2003	Great variability of soil temperature	Less then average precipitation, More than average temperature	favorable
2004	Low soil temperature in all three sowing period	More there average precipitation, Average temperature	average

4. EXPERIMENTAL RESULTS AND DISCUSSION

4.1. The effect of sowing time on the sunflower hybrids' time of shooting and shooting-dynamics

The length of the period from sowing to shooting has a significant effect on the early development of the plant. During a lengthy shooting the seed and the seedling are many time vulnerable to the pathogens (pests from the soil, fungi contamination from the soil, mould fungi etc.) that is why a fast and single shooting is important. The time of shooting is defined by the state of the soil (moisture content, temperature, quality of the seedbed, soil characteristics) and the given hybrid genetically coded shooting features.

Based on multiple year experiments altogether it can be stated that on chernozem soil in the Hajdúság comparing the sunflower shooting times this indicator is the longest in the early, end of March sowing period, where in the average of years it is 17 days with extreme values of 11 to 25 days depending on the hybrid. In the average, mid-April sowing the shooting time can be characterized with shorter, 12 days value in the average of the years, from 6 to 18 days extreme values. The shooting becomes shorter in the late, early May sowing (average 8 days), in the interval from 4 to 13 days. From the examined hybrids, the *Rigasol*/*PR* and *PR64A63* hybrids are characterized with really favorable shooting which showed short shooting period in different years and sowing times, too. When statistically analyzing the experimental results it can be seen that the existing differences in every year, in every sowing time and every hybrid and their combinations are strongly significant.

4.2. The relationship between sowing time and flowering in the examined hybrids

The length of the period between the sowing and the flowering consists the vegetative growth of the plant that is why its length is determining from the viewpoint of the plant's development. The realized stress effects later appear strongly in the yield results, that is why it is important to know the length and the environmental factors (temperature, precipitation) of this period.

It can be stated that by postponing the sowing time the length of the period until the blooming is significantly decreased. In the early sowing time the length of this period is 81 days in the average of the hybrids, from the extreme values of 76 to 89 days, depending on the hybrid and the year. In the mid-April, average sowing time the average period is 72 days with the extreme values of 65 to 83 days, while in the late, early May sowing the average length of the period till the blooming is 65 days (interval of 56 to 73). In the case of the time of flowering similar statements can be declared, but from the different sowing time, considerable smaller differences emerged. In the early sowing the blooming period was 19 days in the average of the hybrids (15-24 days), this value in the average sowing time was 17 days (12-23 days), while in the late, early May sowing it was 15 days (10-22 days) under Hungarian circumstances.

4.3. The effect of sowing time on the level of stem weakening

Based on the experimental results it can be stated that in the average of the years and the hybrids, the level of weakening stems decreased when postponing the sowing time, but it is a small scale decrease, so this indicator is only been affected on a small scale by the sowing time and influenced mainly by the hybrid's characteristics. In the early, end of March sowing period an average 7,7 % weakened stem characterized the hybrids with the extreme values of 1.6 -17.8 %, in the average, mid-April sowing with 1.7-14.6 % extreme values the stem weakening was 5.9 % average. In the late, early May sowing the average value of weakening was 4.6 % (0.7 to 12.0 %). A favorable level was shown by the *PR63A82* and *PR64A63* hybrids independently from the sowing time.

4.4. The effect of sowing time on the stem breaking under the plate

The breaking of the stem under the plate can be one of the main sources of loss during harvesting, mainly during late harvest. As a result of the breaking on the neck of the stem, the plate is more vulnerable to mechanical damage and at the same time the seed loss of such plates during harvest is increased profoundly, in extreme conditions the stem may break. The measure of breaking under the plate is greatly affected by the firmness of the upper part of the stem and the size of the plate, but it is increased as a result of the hindered development because of different stem diseases. Based on these we can assume that this indicator affects the sowing time less significantly, but based on our results we found that it has a considerably modifying effect.

It can be declared that in the development of the break under the plate, this indicator is significantly affected by the stem firmness of the hybrids, but the sowing time too defines its measure. As a tendency it can be seen that the amount of breaking in the early sowing time this value was the highest (average 5.7 %, with extreme values of 1.9 to 24.9 %), which decreased in the average sowing time (average 4.5 %, extreme values of 1.3 to 14.7 %), while it was the lowest in the late, early May sowing time (average 2.9 %, extreme values of 0.6-12.9 %). Favorable values characterized the *Rigasol* and *Alexandra* hybrids from the examined hybrids in the different years, while the *Diabolo*'s breaking under the plate showed extremely high values in the hybrids and the years.

4.5. The effect of sowing time on the height of hybrid plants

The height of the plant is basically the genetic feature of the given plant, but greatly affected by the environmental factors. A single hybrid can produce different heights in different years and can even change as a result of the change of the environmental factors – e.g. change in fertilizing, crop density - in one year. In this system the sowing time – as a significant impact factor – can be a determining factor in the different years from the viewpoint of the plant's height.

It can be stated during the analysis of the plant height values based on 6 years' experimental results that the sowing time has less influence on the genetically coded growth of the hybrids in most of the years, but in some year the applied sowing time had a considerable modifying effect. By comparing the examined years it can be seen that in all three sowing times the highest results originated from the year of 1999. It can be declared by analyzing the differences between the hybrids that the most unified plant height was measured in the early sowing period (values between 139.1 and 222.4 cm), this interval somewhat widened in the mid-April sowing time, which was considered to be the optimal (142.6-233.8 cm), and the widest was in the late sowing period (129.0-242.6 cm). From the examined hybrids the *Lympil*, *PR64A63* and *PR63A82* hybrids were tall, while the *Fleuret* and *Louidor* hybrids were characterized by low plant height.

4.6. The influence of sowing time on the sunflower hybrids' extent of infection of stem canker (*Diaporthe helianthi*)

In Hungary the stem canker has become the most significant disease from the stem diseases. The highly infected stem will break at the slightest mechanical effect and appears as direct yield loss. The extent of infection is determined by environmental factors (precipitation, temperature), but at the same time the genetically coded resistance of the hybrids considerably affects the seriousness of the disease. Most of the production technological factors directly or indirectly affects the extent of damage done and from the sowing technology emerges with the applied sowing time.

Infection-dynamical examinations conducted by using the data from the year of 1999 it can be stated that the sowing time influences the development of infection during the vegetation period. In the average of the hybrids the development of infection is very similar in the early and late sowing times, while in the late sowing time the infection's progress is slower, the curve is less sharp (*Figure 2*.)

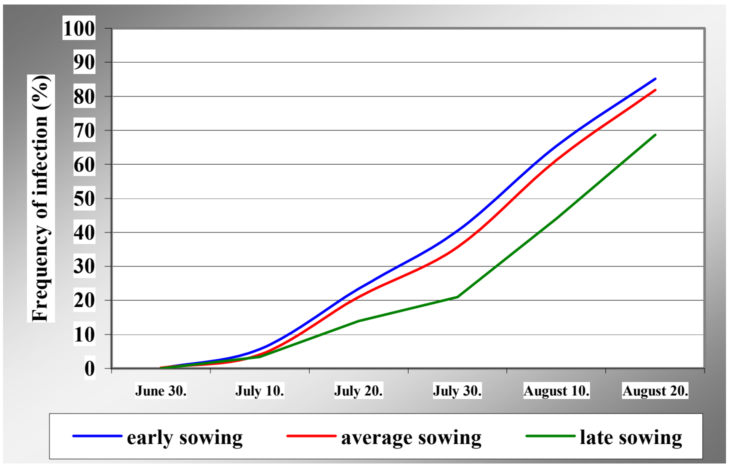

Figure 2.: **The development of *Diaporthe* stem patchiness and rotting during the vegetation period in the different sowing periods**
(average of hybrids)
(*Debrecen-Látókép, 1999*)

There are more significant differences in the infection index between the sowing periods. Despite that there were no significant difference in the percentage of the frequency of infection between the early and optimal sowing times, there is a significant difference in the infection index. This leads to that the seriousness of the infection and frequency of the more serious symptoms that belongs to higher scale values has a higher frequency in the early sowing despite that the number of diseased plants is nearly the same (*Figure 3.*).

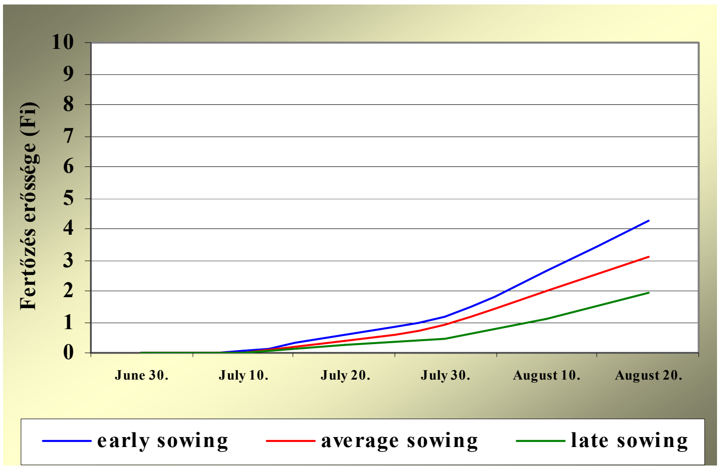

Figure 3.: **The development of infection index of *Diaporthe* and rotting during the vegetation period in different sowing periods**
(average of hybrids)
(*Debrecen-Látókép, 1999*)

The development of infection index depends on the susceptibility characteristics of the given hybrid. In our researches the hybrids sensitive to the *Diaporthe helianthi* the development of the infection was very sharp, there were more significant differences between the sowing times. In the more resistant hybrids against the pathogen the infection curve was less sharp and there were only little differences between the sowing times (*Figure 4.*).

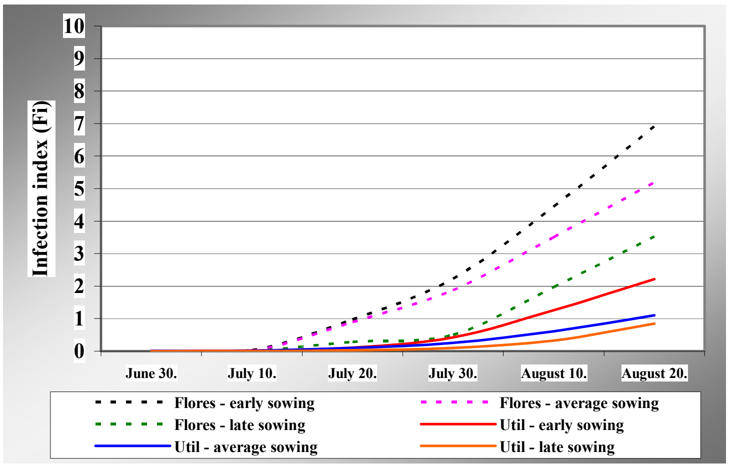

Figure 4.: **The development of infection during the vegetation period in the hybrids with more and less resistance against the *Diaporthe helianthi***
(*Debrecen-Látókép, 1999*)

4.7. The effect of sowing time on the sunflower hybrids' *Sclerotinia sclerotorium* infection

The *Sclerotinia sclerotorium has* many symptoms on the sunflower. First, during the period of blooming the shock-like wilting of the plant indicates the disease and later stem patchiness and plate rotting develops. There are considerable differences in regard of the hybrids' susceptibility, but production technological factors (mainly the nutrient supply and the crop density) also influence the extent of infection.

In the examination of sowing time in the sunflower hybrids' *Sclerotinia sclerotorium* infection we found that in the late sowing period the infection of sunflower hybrids decreased (0.7 % in the average of the hybrids and years), in the average sowing this value was 1.6%, while in the early sowing it was the highest (2.1 %). The extreme values of infection were also the widest at that sowing period (0.0 to 18.0 %), these were smaller in the average sowing (0.0 to 7.3 %) and these were small in the late, early May sowing (0.0-3.7

%). Based on the experimental results the *PR63A82* and *Lympil* hybrids had favorable parameters.

4.8. The effect of sowing time on the yield of sunflower hybrids

In the case of sunflower the success of production is indicated by the amount of produced oil per land area, which depends on the oil content of the panicle and the amount of produced panicles. The amount of yield is influenced by many factors, but the production technology has a fundamental role in this system.

When analyzing the effect of sowing time on the crop it can be declared that the highest yield resulted from the early sowing period (3964 kg ha^{-1}), the yield result was somewhat smaller than that in the average sowing time (3866 kg ha^{-1}), while the consequently smaller average yield in every year resulted from the late, early May sowing time (3423 kg ha^{-1}). From the examined years the most favorable was the year of 2003 from the viewpoint of the quantity of crop (3951 to 5142 kg ha^{-1}), while the lowest yields were harvested in 2001 (2376-3790 kg ha^{-1}) (*Table 3.*).

Table 3.: **The development of the yield of sunflower in different sowing periods**
(average of hybrids)
(*Debrecen-Látókép*)

Year	Early sowing time			Average sowing time			Late sowing time		
	min (kg/ha)	max (kg/ha)	average (kg/ha)	min (kg/ha)	max (kg/ha)	average (kg/ha)	min (kg/ha)	max (kg/ha)	average (kg/ha)
1999	2329	4707	**3516**	2612	4482	**3624**	2703	4340	**3597**
2000	2805	4564	**3791**	4033	5114	**4434**	2583	3960	**3168**
2001	3114	3790	**3440**	2798	3462	**3101**	2376	3193	**2770**
2002	3427	4643	**4108**	3103	4360	**3640**	2764	3602	**3177**
2003	4338	5142	**4676**	3951	5049	**4629**	4083	4885	**4462**
2004	3428	4996	**4250**	3207	4380	**3767**	2511	3918	**3362**
Average	***3240***	***4630***	***3964***	***3284***	***4474***	***3866***	***2441***	***3983***	***3423***

$SzD_{5\%}$ in the average of hybrids between the different sowing periods: 188 kg ha^{-1}

From the hybrids that were used in more years the *Util* and *Louidor* had a sensitive response for the changes in sowing time, while the modification of sowing time had little effect on the yield of *Alexandra/PR, LG 5385* and *PR63A82* hybrids. In the early sowing time the highest yields characterized the *Lympil*, *Arena/PR*, *Alexandra/PR* and *Floyd* hybrids in different years, while the lowest yields resulted from the *Flores*, *Larisol*, *Rigasol*/*PR* and *LG 5385* hybrids in that sowing period. In the average sowing period the highest yields were harvested from the *Lympil*, *Diabolo*, *Magnum*, *Alexandra*/*PR* and *Floyd* hybrids, wile in the case of *Flores*, *Larisol*, *Rigasol*/*PR* and *LG 5385* hybrids the yields were the lowest in the given years. In the case of late sowing the hybrids of *Lympil*, *Diabolo*, *Magnum* and *Altesse* can be distinguished by their relatively favorable yields.

4.9. The effect of sowing time on the oil content of sunflower hybrids

We found during the analysis of the effect of sowing time on the oil content that the effect of sowing time are greatly influenced by the given year. In the early and late sowing periods nearly similar oil content was measured in the examined experimental period (48.5 and 48.2 % in the average of the years and hybrids), significant decrease happened only in the late, early May sowing (47.3 %) which supports that early sowing is not going together with decrease of oil content. The difference between hybrids was the smallest in early sowing (extreme values of 41.6 and 54.1 %), this increased in the average sowing (40.1-54.2 %), and the highest change was measured in the late, early May sowing (38.6-55.4 %).In the examined years the highest oil content resulted from the years of 2002 and 2003 in the average of hybrids and sowing periods. The sensitivity of the examined hybrids was proved to be strong for the sowing time in the *Fleuret*, *Magnum*, *Larisol*, *Trentil*, *Alexandra*/*PR* hybrids (hybrid-specific sensitivity), while the *Hysun 321*, *Diabolo*, *Flores*, *Lucil*, *Lympil*, *Louidor* and *Altesse* hybrids were less characterized by this change (hybrid-specific stability). In the early sowing period from the examined hybrids higher than average (52-54%) oil content was measured in *Trentil*, *Util*, *Lympil*, *Fleuret*, *Hysun 321*, *Diabolo*, and *PR63A82* hybrids. In the average sowing time the oil content of *Trentil*, *Util*, *Lympil*, *Fleure*, *Hysun 321* and *PR63A82* hybrids were higher than the average and in the case of late sowing the *Util*, *Arena*/*PR*, *Lympil*, *Lucil*, *Hysun 321*, *LG 5385*, *Diabolo* and *Louidoe* hybrids produced better than average values (*Table 4.*).

Table 4.: **The development of oil content of sunflower in different sowing periods**

(average of hybrids)

(*Debrecen-Látókép*)

Year	Early sowing period			Average sowing period			Late sowing period		
	min (%)	max (%)	average (%)	min (%)	max (%)	average (%)	min (%)	max (%)	average (%)
1999	41,6	45,7	**44,1**	40,1	48,7	**44,9**	42,4	48,6	**45,8**
2000	41,9	48,7	**46,1**	44,9	53,9	**48,7**	38,6	50,4	**44,8**
2001	46,1	54,1	**49,1**	41,4	51,0	**46,9**	40,1	51,1	**46,4**
2002	45,0	52,6	**50,5**	45,5	54,2	**49,8**	43,8	55,4	**49,6**
2003	48,1	53,8	**50,8**	47,5	52,5	**49,9**	46,1	53,2	**48,8**
2004	45,7	53,0	**50,1**	46,6	51,5	**49,2**	43,6	49,7	**48,2**
Average	***44,7***	***51,3***	***48,5***	***44,3***	***52,0***	***48,2***	***42,4***	***51,4***	***47,3***

$SzD_{5\%}$ in the average of hybrids between the sowing periods: 1,09 %

There is an obvious tendency in the case of oil yield in the average of years and hybrids. The highest oil yield resulted from the early sowing period (1929 kg ha^{-1}), the amount in the average sowing period was somewhat smaller than that (1872 kg ha^{-1}) and at the same time the early May, late sowing significantly decreased the oil yield (1622 kg ha^{-1}). A small scale (200-300 kg ha^{-1}) oil yield difference characterized the *Hysun 321*, *Rigasol*/*PR*, *LG 5385*, *PR63A82*, *Altesse* an *Alexandra*/*PR* hybrids in the different sowing periods. The very same indicator differed greatly (500-700 kg ha^{-1}) in the *Fleuret*, *Util*, *Magnum* and *Diabolo* hybrids. From the hybrids in the give year compared to the average of the hybrids high oil yield (2100-2500 kg ha^{-1}) characterized in the early sowing the *Lympil*, *Diabolo* and *Magnum* hybrids, in the average sowing besides the mentioned hybrids the *Astor* and *Floyd*, while in the late sowing period (1900-2300 kg ha^{-1}) the *Lympil*, *Lucil*, *Diabolo* and *Floyd* hybrids (*Table 5*.).

Table 5.: **The development of the sunflower's oil yield in different sowing periods**

(average of hybrids)

(*Debrecen-Látókép*)

Year	Early sowing period			Average sowing period			Late sowing period		
	min (kg/ha)	max (kg/ha)	average (kg/ha)	min (kg/ha)	max (kg/ha)	average (kg/ha)	min (kg/ha)	max (kg/ha)	average (kg/ha)
1999	984	2126	**1555**	1138	2090	**1634**	1174	2092	**1650**
2000	1176	2148	**1750**	1867	2457	**2161**	997	1908	**1426**
2001	1437	1873	**1687**	1159	1766	**1457**	1044	1591	**1289**
2002	1690	2373	**2077**	1440	2362	**1818**	1340	1792	**1575**
2003	2144	2567	**2376**	1906	2530	**2308**	1931	2371	**2173**
2004	1781	2468	**2127**	1635	2137	**1853**	1213	1914	**1620**
Average	***1535***	***2259***	***1929***	***1524***	***2224***	***1872***	***1283***	***1945***	***1622***

$SzD_{5\%}$ in the average of hybrids between the sowing period: 31,66 kg ha^{-1}

4.10. Analysis of the interaction between the examined agro-technical parameters with Pearson correlation

The different agro-technical parameters affect each other directly or indirectly. As a result of these effects the success of sunflower production, the quantity of the crop and the oil content are manifested, that is why it is important to know the factors that have significant influence on the other factors. The direction of the influence can be positive (the increase of the affected factor improves the influence factor) or negative (the increase of the affected factor decrease the influence factor). During the Pearson correlation analysis of the connection the resulting correlation values were used to characterize the strength of the relationship between the examined parameters and the direction of the interactions. When the correlation values are between 0.5 and 0.7 then the connection is medium, while greater than 0.7 the connection is strong. Every examined agronomical parameter from the sowing time experiments served as the basis of our analysis. It has been proved in all three sowing period that the oil yield is mainly defined by the quantity of crop and not the oil content of the given hybrid. Medium and strong correlation was found in the *Diaporthe helianthi* and oil content and the break under the plate, in the first it was negative, while in the second it was positive, which leads to that the disease has a significant influence on the development of stem firmness parameter.

5. NEW AND INNOVATIVE SCIENTIFIC RESULTS

- Based on the results of experiments conducted on the Loess in Hajdúság in different years and sowing periods the time of shooting was determined. The shooting is the longest in the early, end of March sowing period, when it is 17 days in the average of the years with the extreme values of 11 to 25 days depending on the hybrid. In the average, mid-April sowing period shooting can be characterized by shorter, 12 days period in the average of the years with the extreme values of 6-28 days. In the case of the late, early May sowing the shooting period shortened (average 8 days) in the interval of 4 to 13 days.

- The period until blooming of sunflower hybrids in different years and sowing periods were defined. We found that with the postponing of the sowing the length of the period until blooming was significantly decreased. In the early sowing the length of this period was 81 days in the average of the hybrids with the extreme values of 76 to 89 days depending on the hybrids and the year. The mid-April, average sowing period the average interval was 72 days with the extreme values of 65 to 83 days, while in the late, early May sowing period the average length of the period until blooming was 65 days (values between 56 to 73 days).
- In the development of the stem breaking under the plate the stem firmness features of the hybrids greatly determine this indicator, but the sowing time also has an effect on the extent of breaking. We stated that the value is the highest in the early sowing period, it decreases in the average sowing period and the lowest in the late, early May sowing period.
- The results of infection-dynamics experiments showed that sowing time influences the development of *Diaporthe helianthi* in the vegetation period. The development of the disease in percentage in the average of the hybrids is very similar in the early and average sowing periods, while in the late sowing the development of the infection is slower and the curve is less sharp.
- By using the infection index the infection differences between the hybrids and sowing periods can be made more punctual. The higher index values in the early sowing period lead to that the seriousness of *Diaporthe helianthi* infection and the more serious symptoms belonging to higher scale values have greater frequency in the early sowing period.
- We found during examining the influence of sowing time on the *Sclerotinia sclerotorium* of sunflower hybrids that the infection of sunflower hybrids is significantly lessened in the late sowing period, this value increased in the average sowing period and was the highest in the early sowing period.
- We declared during the analysis of the effect of sowing time on the yield that the highest yield resulted from the early

sowing (3913 kg ha^{-1}), the yield was somewhat smaller in the average sowing period (3865 kg ha^{-1}), while the hybrids produced a significantly average yield in the late, early May sowing period (3422 kg ha^{-1}). From the examined years the quantity of crop was the most favorable in 2003, while the lowest yields resulted from 2001 which was in connection with the weather of the given year.

- During analyzing the effect of sowing time on the oil content we stated that the effect of sowing time is greatly influenced by the given year. In the early and average sowing periods the oil content was nearly identical, significant decrease only appeared in the late, early May sowing.
- From the viewpoint of oil yield the definite and consequent influence of the years and hybrids was proved. The highest oil yield resulted in the early sowing period, the value in the optimal sowing period was somewhat smaller and the value form early May, late sowing resulted a lot less oil yield.
- During the use of Pearson correlation analysis in the connection between the examined parameters the resulted correlation results were used to characterize the strength of connection between the examined features and the direction of the interactions. As a result of the correlation analysis we stated that the oil yield was mainly defined by the quantity of crops and only partially by the hybrids' oil content. Medium and strong correlations were found between the diaporthe infection and oil content and the extent of the stem breaking under the plate, which is positive in the first and negative in the second.

6. SCIENTIFIC RESULTS FOR THE PRACTICE

- *Lympil, Arena/PR, Hysun 321, Diabolo, Magnum, PR63A82, Alexandra/PR, NK Brio* and *PR64A63* hybrids had the best production ability (4500-5500 kg ha^{-1}) on chernozem soil in the Hajdúság from the examined sunflower hybrids.
- From the viewpoint of oil content under the circumstances of our experiments *the Fleuret, LG 5385, Floyd, Magnum,*

Astor, Diabolo and Louidor hybrids can be distinguished (above 52 %).

- In regard of the oil yield per hectare the *Lympil, Hysun 321, Fleuret, Magnum, Diabolo, NK Brio, PR64A63 and Astor* hybrids proved to be the best in the 6 years research period.
- Based on the complex assessment of the hybrids that were present in multiple years it can be stated that based on the crop quantity, oil content and oil yield per hectare the *Lympil, Diabolo, Magnum, PR64A63, Arena/PR* and the very early ripening *LG 5345* hybrids can be produced successfully.
- In regard of the *Diaporthe helianthi* infection the *Util, Alexandra/PR and Lympil* hybrids can be produced with favorable infection parameters.
- By analyzing the influence of sowing time on the *Diaporthe helianthi* infection index it can be declared that in the case of *Flores, Natil,* and *Rigasol/PR* hybrids the sowing time has a significant effect on the seriousness of the infection, while the *Lympil* and *Util* hybrids are less characterized by that. This leads to that in the case of hybrids more sensitive to the pathogens the late sowing time considerable decreases the damage done by the disease, while the values of hybrids with more resistance against the pathogen are less affected by the sowing period.
- Based on the experimental results the *PR63A82, Lympil* and *Diabolo* hybrids were characterized by low *Sclerotinia sclerotorium* infection independently of the applied sowing.
- In the early sowing period in different years the highest yields characterized the *Lympil, Arena/PR, Alexandra/PR* and *Floyd* hybrids, in the average sowing period the highest yield was produced by the *Lympil, Diabolo, Magnum, Alexandra/P*R and *Floyd* hybrids. In the case of the late sowing the *Lympil*, *Diabolo*, *Magnum* and *Altesse* hybrids can be distinguished from the hybrids.
- In the early sowing period higher than average oil content was measured in the *Trentil*, *Util*, *Lympil*, *Fleuret*, *Hysun 321*, *Diabolo* and *PR63A82* hybrids. In the optimal sowing period the *Trentil*, *Util*, *Lympil*, *Fleuret*, *Hysun 321*, *Diabolo* and *PR63A82* hybrids had he highest oil content,

and we can state the same in the late sowing about the *Util*, *Arena*/*PR*, *Lympil*, *Lucil*, *Hysun 321*, *LG 5385*, *Diabolo* and *Louidor* hybrids.

- The *Hysun 321*, *Rigasol*, *LG 5385*, *PR63A82*, *Altesse* and *Alexandra*/*PR* hybrids were characterized by a small scale oil content change in the different sowing periods. In a given year a relatively high oil content – compared to the average of the hybrids – characterized the *Lympil*, *Diabolo* and *Magnum* hybrids, in the optimal sowing period the *Astor* and the *Floyd* hybrids and in the late sowing the *Lympil*, *Lucil*, *Diabolo* and *Floyd* hybrids.
- Based on our results it can be stated that if a strong early spring (end of March) warming makes it possible to sow sunflower it is worth to do that on easily warming loam or loam structured soils. Late sowing should be avoided, but when the circumstances forces it than by using *Lympil*, *Diabolo*, *Magnum*, *Arena*/*PR*, *Hysun 321*, *LG 5385*, *Louidor* or *Floyd* hybrids can we expect the lowest yield loss.

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Scientific Journal

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