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PLANT HEIGHT AT DIFFERENT DEVELOPMENTAL STAGES IN OBSERVED TYPES OF SUNFLOWER (*HELIANTHUS ANNUUS* L.) CULTIVARS

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ABSTRACT. Changes in shoot length during development of two hybrid cultivars and one population cultivar of oilseed sunflower were compared in 3-year trials. Effects of cultivar, climatic factors, sowing density, and fertilization on plant height were analysed. In the conducted experiments, hybrid cultivars had higher shoots than cultivar 'Wielkopolski' since the first studied developmental stage (star stage). However, the large plant height does not have a positive effect on their agronomic value. Results of this study show that sunflowers were the highest in 1999 at all developmental stages, which resulted from more favourable weather conditions and soil type. The lowest final plant height was recorded when sunflowers were grown on brown-earth soil. This study confirms that increased sowing density caused a stronger elongation of shoots since the earliest developmental stages.

Key words: sunflower, shoots, changes in plant height

Introduction

Considering their application, cultivated forms of sunflower (*Helianthus annuus* L.) can be divided into ornamental, fodder, gnawing, and oilseed cultivars. They can be further subdivided into population cultivars (older) and hybrid cultivars (bred in the last four decades by crossing selected inbred lines). Among them, oilseed sunflower is most important in terms of economy. It is one of the most widely cultivated oil crops in the world, ranking fourth after soybean, palm and rape (**Muśnicki** 1999). Even in Poland, where the climate is colder than its thermal requirements, sunflower yields more than any other summer oil crops (**Muśnicki** et **al.** 1997).

The species comes from the south-western USA and northern Mexico (Podsolnechnik... 1975). The first records on its introduction to Europe date back from 1510, when it appeared in Spain. However, till the late 18th century, it was mainly an ornamental

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plant, although its seeds were also eaten (**Nowiński** 1970). As an oil crop it started to be cultivated on a large scale in the early 19th century (**Gonet** 1976).

The objective of this study was to analyse the growth dynamics of population and hybrid cultivars at various stages of development. Hybrids are commonly believed to have less variable habit than population cultivars (**Fick** and **Swallers** 1972, **Pirani** 1980, **Vranceanu** et **al.** 1987, **Łuczkiewicz** 1993 b, **Muśnicki** and **Toboła** 1996, **Maruthi** et **al.** 1998), but only few strictly controlled experiments have involved new hybrids. In this study, the above hypothesis was verified at early stages of development of sunflower, by analysing effects of environment and agrotechnical factors on plant height and its heritability.

Material and methods

The experiments were carried out in 1997-1999 in the Experimental Station at Przybroda near Szamotuły (Wielkopolska). Precipitation and temperature were recorded there (Table 1). Sum of precipitation in the growing season of sunflower (April-September) was the lowest in 1999, while in 1997 and 1998 it was close to the mean of 1953-1997. By contrast, sums of daily temperatures in that season in the three study years were higher than the mean of 1953-1997.

Table 1

Weather conditions in the growing season of sunflower (April to September)
Warunki pogody w sezonie wegetacyjnym słonecznika (kwiecień-wrzesień)

Weather parameters Parametry pogody	Year – Rok			Mean of 1953-1997 Wielolecie
	1997	1998	1999	
Sum of precipitation (mm) Suma opadów (mm)	329.1	337.6	262.5	327.2
Sum of average daily temperatures (°C) Suma średnich temperatur (°C)	2 878	2 954.6	3 119.2	2615.3

The study involved one Polish population of the 'Wielkopolski' cultivar and two hybrid (F1) cultivars: 'Frankasol' (French) and 'Coril' (American). Two levels of fertilization were applied (60 and 120 kg N/ha), and three levels of sowing density (50, 75, and 100 thousand/ha). Consequently, the sunflower cultivars were sown in a randomized block design with 18 combinations and two replicates.

In 1997 and 1999, the experiments were established on very fertile black-earth soils, whereas in 1998 on fertile brown-earth soils. The ploughing layer of black-earth soils was slightly alkaline and had a mechanical composition typical of light clay. By contrast, the brown-earth soils were slightly acidic and had a mechanical composition typical of strong clayey sand. In 1997, sunflower was sown after phacelia, in 1998 after summer wheat, and in 1999 after winter barley. The soil was cultivated every year according to the standard agrotechnical methods (**Muśnicki** 1999). Sunflower was sown

always in late April, i.e. within the recommended period for this species (**Horodyski** and **Muśnicki** 1985).

Plant height at successive developmental stages was measured from the soil surface to the top of the plant (flower head), at 2-week intervals, with a scaled meter, which was 2.5 m long. At each stage, 25 individuals in the two middle rows were measured in each of the 18 plots in two replicates, which gave in total 100 individuals for each combination, and 1800 for the whole experiment. The measurements were taken from the star stage (phot. 1), i.e. beginning of flower head formation, usually about 1.5 month after sowing, till the end of flowering of all individuals in the plot. The last measurement, of this type, determined as final height, was taken at the stage of technical seed ripeness. Other parameters presented in tables were measured during budding (phot. 2), at the beginning and end of flowering (phot. 3), and at the beginning of seed ripening (phot. 4).

The analysis of plant height variability at successive developmental stages was characterized, as recommended by **Kala** (1996), by standard deviation (absolute variability), and variation coefficient (relative variability). The variability of cultivars formed the basis for assessing heritability (h^2) in the general sense, according to the method suggested by **Płochiński** (1968) and **Bos** and **Caligari** (1995), expressed as the ratio of sum of squares of genetic variation (sums of squares of cultivars) to the sum of squares of total variation.

Results

Plant height at each of the studied stages of development, was significantly affected by cultivar type, sowing density, climatic factors, and soil type. By contrast, fertilization affected this trait only at the flowering stage and at the final measurement. Among the three cultivars, 'Wielkopolski' always had the shortest shoots, whereas 'Frankasol' exceeded 'Coril' in this respect during the flowering stage. At the first two of the studied developmental stages, plant height was the smallest in 1997. In 1998, from the flowering stage till the end of the experiment, plant height was markedly lower than in 1997 and 1999. This was probably due to a lower precipitation in July and a different soil type. In 1999, throughout the experiment, plant height was higher than in other years. A higher sowing density always resulted in a stronger elongation of shoots. When the rate of fertilization was increased, plant height was slightly lower (Table 2).

During the first five measurements, standard deviation was usually greater in 'Wielkopolski' than in other cultivars. As the plants were growing, values of standard deviation were increasing. As a rule, 'Wielkopolski' had also the highest variation coefficients. Every year the least variable cultivar was 'Coril' during the first two measurements, and 'Frankasol' during the last three measurements. Final height was characterized by relatively high values of standard deviation, especially in 'Coril'. However, the variation coefficient, expressed in percentage, was markedly lower in both hybrid cultivars, probably because their shoots were generally much higher than in 'Wielkopolski'. The studied cultivars, in all years of observations, significantly differed from one another. The greatest height increments were always recorded between the star stage and budding (40-50 cm) and between budding and the beginning of flowering (50-70 cm). During the last two measurements, plants were slightly lower than just after flowering, because

Table 2

Sunflower plant height at successive developmental stages, depending on the level of analysed factors (1997-1999)
Wysokość słonecznika w różnych terminach pomiarów w zależności od poziomu analizowanych czynników (1997-1999)

Experimental factors Czynniki doświadczenia	Plant height (cm) – Wysokość roślin (cm)					
	7-11.06	21-25.06	5-9.07	19-22.07	2-6.08	final końcowa
Cultivars – Odmiany						
Wielkopolski	22.1	65.8	118.0	127.6	124.8	124.2
Frankasol	26.7	76.9	148.5	183.1	183.2	182.4
Coril	30.0	82.1	148.1	173.1	170.6	169.3
$NIR_{0.0\,5} - LSD_{0.05}$	*0.38*	*0.71*	*0.77*	*0.92*	*0.96*	*0.85*
Plant density – Zagęszczenie						
50 000/ha	25.2	68.8	128.8	149.0	146.5	146.3
75 000/ha	26.1	75.1	139.9	163.5	162.0	160.9
100 000/ha	27.6	81.0	145.8	171.2	170.1	168.8
$NIR_{0.05} - LSD_{0.05}$	*0.38*	*0.71*	*0.77*	*0.92*	*0.96*	*0.85*
Fertilization – Nawożenie						
60 kgN/ha	26.4	75.2	138.4	162.1	159.4	159.5
120 kgN/ha	26.1	74.7	138.0	160.4	159.7	157.8
$NIR_{0.05} - LSD_{0.05}$	–	–	–	*0.75*	–	*0.70*
Environment – Środowisko						
In year – w roku 1997	19.8	62.4	132.9	162.9	162.0	163.1
In year – w roku 1998	26.8	75.3	125.5	138.2	137.0	135.1
In year – w roku 1999	32.1	87.1	156.1	182.8	179.7	177.8
$NIR_{0.05} - LSD_{0.05}$	*0.38*	*0.71*	*0.77*	*0.92*	*0.96*	*0.85*

flower heads bent downwards during seed ripening. Generally the lowest variation during those two measurements was recorded in 1998, because plant height in all combinations was the lowest in that year. Interaction between year and cultivar was always significant. Final plant height ranged from 105 cm to 204 cm (Table 3).

In the structure of plant height variability at the star stage and budding stage, contributions of environment factors and individual (random) factors were the largest. At the later stages of development, genetic effects dominated, which means that heritability of this trait was gradually increasing, while the impact of environment and random factors was decreasing (Table 4).

Table 3

Characteristics of plant height variability of three cultivars at successive developmental stages
Charakterystyka zmienności wysokości trzech odmian mierzonej w różnych terminach

Cultivar Odmiana	Arithmetic mean Średnia arytmetyczna			Standard deviation Odchylenie standardowe			Variation coefficient Współczynnik zmienności		
	1997	1998	1999	1997	1998	1999	1997	1998	1999
07-11. 06 (Star stage – Gwiazdka)									
Wielkopolski	16.1	22.9	27.1	4.14	4.89	4.72	25.7	21.4	17.4
Frankasol	20.4	27.6	32.0	4.40	5.02	5.33	21.6	18.2	16.7
Coril	22.5	30.0	37.1	4.45	4.44	5.40	19.8	14.8	14.6
$LSD_{0.05}$	*0.47*	*0.69*	*0.61*	*x*	*x*	*x*	*x*	*x*	*x*
21-25.06 (Budding – Pąkowanie)									
Wielkopolski	54.3	67.1	75.6	10.9	10.6	12.1	20.1	15.8	16.0
Frankasol	64.4	78.3	88.1	10.6	7.68	12.0	16.5	9.80	13.6
Coril	66.8	80.4	98.2	10.0	6.37	11.7	14.9	7.93	11.9
$LSD_{0.05}$	*1.01*	*1.10*	*1.14*	*x*	*x*	*x*	*x*	*x*	*x*
05-09.07 (Beginning of flowering – Początek kwitnienia)									
Wielkopolski	115.8	105.2	132.6	14.4	11.1	15.1	12.4	10.5	11.4
Frankasol	142.3	137.0	166.1	11.8	8.20	13.5	8.30	5.99	8.14
Coril	139.6	134.2	170.0	12.0	7.85	14.7	8.57	5.85	8.65
$LSD_{0.05}$	*1.17*	*1.07*	*1.26*	*x*	*x*	*x*	*x*	*x*	*x*
19-22.07 (End of flowering – Koniec kwitnienia)									
Wielkopolski	131.6	110.2	140.6	17.2	12.4	18.0	13.1	11.2	12.8
Frankasol	184.6	155.3	209.4	14.8	11.6	14.8	8.04	7.46	7.07
Coril	170.9	149.1	199.4	16.3	11.2	19.1	9.55	7.54	9.57
$LSD_{0.05}$	*1.34*	*1.46*	*1.43*	*x*	*x*	*x*	*x*	*x*	*x*
02-06.08 (Beginning of ripening – Początek dojrzewania)									
Wielkopolski	128.1	107.9	137.6	17.5	12.4	17.5	14.0	11.5	12.7
Frankasol	186.6	155.4	207.4	17.2	11.5	14.8	9.36	7.37	7.15
Coril	169.4	147.8	195.0	17.5	11.3	18.3	10.5	7.68	9.40
$LSD_{0.05}$	*2.02*	*1.44*	*1.41*	*x*	*x*	*x*	*x*	*x*	*x*
Final plant height – Wysokość końcowa									
Wielkopolski	129.3	105.0	137.4	16.9	13.4	17.8	13.1	12.8	13.0
Frankasol	188.8	153.9	204.4	17.0	12.0	15.2	9.03	7.83	7.42
Coril	169.7	146.3	191.5	17.3	13.3	18.9	10.2	9.09	9.87
$LSD_{0.05}$	*1.38*	*1.46*	*1.47*	*x*	*x*	*x*	*x*	*x*	*x*

LSD = Least Significant Difference.

Table 4
Contributions (%) of environment, agrotechnical and genetic factors to the shaping of plant height variability at successive developmental stages (1997-1999)
Udział czynników środowiska, agrotechniki i odmian (%) w kształtowaniu zmienności wysokości roślin w różnych terminach pomiarów (1997-1999)

Data of measurement Data pomiaru	Source of variability – Źródło zmienności				
	environment środowisko	agrotechnical agrotechnika	genetic genotyp	interactions interakcje	random factors zmienność losowa
7-11.06	42.8	1.7	18.2	2.7	34.6
21-25.06	39.9	9.8	18.1	4.8	27.3
5-9.07	32.5	9.4	38.9	3.4	15.8
19-22.07	28.6	7.3	50.3	3.6	10.2
2-6.08	25.6	8.0	52.4	3.4	10.6
Final – Końcowa	26.2	7.4	52.0	3.2	11.2

Discussion

There are few reports on plant height at successive developmental stages of sunflower. **Łuczkiewicz** (1973) reported that heritability of this trait does not change during plant growth. This contrasts with results of the present study. **Fraszewska** (1962), in research on population cultivars, observed at the budding stage the largest daily increment, reaching up to 7 cm. **Faiguenbaum** and **Baginsky** (1992) in their experiment sowed sunflower achenes of various size and measured plant height after 11 and 22 days. Shoots developed from larger achenes were heavier but had a similar length as those from smaller achenes.

Plant size is one of the most variable traits in cultivated sunflower. In this respect, the species is divided into dwarf (> 60 cm), very low, low, moderately high, and very high forms (> 250 cm). For practical reasons, low and uniform cultivars are preferred, as their mechanical harvesting is easier (Suncokret 1988). Fabry (Olejniny... 1992) determined the range of final height of oilseed forms as 40-200 cm Vranceanu (Floarea... 1974) as 80-260 cm, Pustovojt (Podsolnechnik... 1975) as 60-200 cm, and **Vasilev** (1990) as 60-250 cm. Only fodder sunflower can reach up to 500 cm in height (**Gonet** 1976).

Experiments conducted by the Centre for Research on Crop Cultivars (Wyniki doświadczeń...) showed that the mean plant height of cultivar 'Wielkopolski' in 1979--1981, 1991-1994 and 1992-1995 was 112, 114 and 119 cm, respectively, while that of cv. Frankasol, which was analysed in the last two experiments, reached 140 and 161 cm. In the present study, the mean value for 'Wielkopolski' was insignificantly higher than reported by COBORU, while the hybrid Frankasol was characterized by shoots up to 40 cm higher. **Muśnicki** (1975) presented data on plant height of 'Wielkopolski' grown on three different sites, where it reached on average 114 cm, so it was 10 cm lower than in

the present study. Another population cultivar – 'Czernianka 66' – reached only 98 cm. Older population cultivars studied by **Fraszewska** (1962), reached over 160 cm, while those studied by **Fedorowska** (1971), were on average 115 and 150 cm high. **Dembiński** et **al.** (1971) estimated that the mean plant height in various sunflower cultivars ranged from 78.7 cm to 142.3 cm. However, untended plants were smaller. Various foreign cultivars compared by **Kłoczowski** (1967 a) were 73.9-168 cm high, while new hybrids bred by him reached a mean height of 120 cm (**Kłoczowski** 1967 b). In the work carried out by **Kłoczowski** and **Kołodziejczak** (1967), sunflower shoots reached 111.7-153.7 cm, whereas in experiments conducted by **Marjanac** (1988), plant height varied from 132 cm to 238 cm. **Khan** et **al.** (1999), who evaluated hybrids, found that the highest cultivar, which was the most suitable for cultivation, reached 131 cm in height. In trials carried out by **Suzer** (1998), sunflowers reached on average 157.6 cm, while in a work by **Zhang Yund** (1988), the plants reached 178-217 cm.

As in the present study, **Vranceanu** et **al.** (1987) and **Tobola** and **Muśnicki** (1997) noted that hybrid cultivars greatly exceeded population cultivars in respect of plant height. By contrast, in a comparative experiment with hybrids and population cultivars grown on dry and sloping sites, hybrids were lower than population cultivars (**Pirani** 1981). Also **Todorov** et **al.** (1987) found that population cultivars were 20-40 cm higher than hybrids. Similar conclusions were drawn by **Kotovska** (1987). Plant height in both groups of cultivars was about 160 cm, and the highest was a Soviet population cultivar Peredovik, considered as a model cultivar. High temperatures and lack of rainfall limited their growth. Similar investigations were conducted by **Georgev** et **al.** (1990 b). Always the highest was Peredovik (~180 cm), while hybrids were on average 150 cm high, so they were more suitable for mechanical harvesting. In another work, **Georgev** et **al.** (1990 a), hybrids were characterized by about 10-30 cm shorter shoots.

Derco and **Vrtalik** (1975) found that shoot length in the studied cultivars varied from 157.5 cm to 224.5 cm, depending on year and locality. Also **Liang Guo-Zhen** (1988) noted large differences between localities and between cultivars in respect of plant height, which ranged from 138 cm to 245 cm. This was confirmed by **Todorov** et **al.** (1987), who found that the mean plant height of the analysed cultivars was 150 cm. **Tanimu** et **al.** (1988) reported that shoot length was not affected by site conditions. **Rizzo** and **Di Bari** (1988) noted that intensive and frequent irrigation, started at the budding stage, caused an increase in plant height. This was confirmed by **Salera** and **Baldini** (1998), who observed significant environmental effects on this trait. The maximum plant height in an experiment conducted by **Chaudhry** et **al.** (1998) was 173.3 cm, but non-irrigated sunflowers were always lower. The same was noted by **Miller** et **al**. (1984), **Guiducci** (1988) and **Sadras** et **al.** (1993). **Deibert** and **Utter** (1989) in their study found that sunflowers were higher when tillage and precipitation were limited than in the following year, when conventional tillage and irrigation were applied. Other authors revealed that plant height may be also affected by light level (**Villalobos** et **al.** 1992, **Goyne** and **Schneiter** 1987), day length and temperature (**Goyne** and **Hammer** 1982), defoliation level (**Ahmad** et **al.** 1998), sowing date (**Yadava** and **Singh** 1978, **Unger** 1980, **Lanza** et **al.** 1988, **Maiorana** et **al.** 1988, **Ahmad** and **Quresh** 2000), application of herbicides (**Stoimenova** 1982), thinning (**Miller** and **Roath** 1982), methods of cultivation (**Gonzalez-Fdez** et **al.** 1988), and heating of pollen grain during pollination (**Ljach** et **al.** 1998).

As in the present study, **Tobola** et **al.** (1991) found that plant height of 'Wielkopolski' was the lowest when sowing density was 50 thousand/ha. An increase in plant height

with increasing sowing density was observed also by **Goksoy** et **al.** (1998). This was confirmed by **Chalermpone-Sampet** et **al.** (1988), who evaluated several hybrids and did not detect any significant differences between them. **Ahmad** and **Quresh** (2000) noted that the differences resulting from uneven sowing density became visible as late as in the middle of the flowering period and during seed ripening. Also **Robinson** et **al.** (1980) reported that a rise in sowing density was accompanied by a rise in plant height and resistance to lodging, which was confirmed by **Miller** et **al.** (1984). **Karami** (1977) found that plant height declined with growing intervals between irrigation and with decreasing density. **Radenovic** (1983) observed that if sowing density increased from 31 to 67 thousand/ha, then the mean plant height increased from 140 to 161 cm. **Wantana-Waratanakun** (1984) noted that mean shoot length (167.3 cm) did not differ significantly when different sowing densities were compared, while **Ionescu** and **Draghicioiu** (1989) recorded only slight differences. In contrast, **Tenebe** et **al.** (1996) found that plant height decreased with growing sowing density.

Tobola et **al.** (1993) noted that nitrogen fertilization (60 kg/ha) resulted in a reduced plant height. By contrast, **Muśnicki** et **al.** (1980) observed that a higher level of fertilization, depending on soil type, caused an increase in shoot length or did not affect it. **Akhtar** et **al.** (1992) found that shoots were longer when fertilization was enhanced. **Singh** et **al.** (1987) revealed that growth dynamics showed an increasing trend up to the fertilization level of 80 kg N/ha. According to **Ayub** et **al.** (1998) sunflowers were the highest at 150 kg N/ha. **Lozanovic** and **Stanojevic** (1988), who studied effects of nitrogen fertilization (0-150 kg N/ha) did not detect any interaction with plant height. **Hussain** et **al.** (1998) observed that changes in the level of nitrogen fertilization affect plant height. In experiments carried out by **Kadar** and **Vass** (1988), fertilization and liming resulted in longer shoots. **Hussein** et **al.** (1988) noted that the height of shoots of the tested population cultivar, reached about 3 m on average and did not change significantly when sowing density or fertilization was altered. An increased rate of nitrogen fertilization enhanced plant height in one year but limited it in the following year. **Karami** (1980) noted that an increase in nitrogen fertilization from 0 to 50 kg/ha resulted in a rise in plant height, while an increase in density or number of achenes per nest had the opposite effect.

Łuczkiewicz (1973) recorded a higher variability of plant height than in the present study. In a later study (**Łuczkiewicz** 1992), he found that different groups of cultivars varied most strongly in plant height. High values of variation coefficient were recorded for final plant height. In experiments conducted by **Kłoczowski** (1983), shoots reached 125-256 cm. Variation coefficient of this trait exceeded 10%. In another work (**Kłoczowski** 1975), he noted an even lower level of variation between cultivars, but a higher level of variation between years. When comparing F1 and F2 generations of sunflowers, **Kłoczowski** (1971) found that shoot length decreased in F2. **Sen** et **al.** (1985) observed that shoot length was characterized by a low variability. **Miller** and **Hammond** (1991) assessed heritability of reduced plant height. They tested 3 population cultivars, which reached 65-90 cm and whose variation coefficients ranged from 6.3% to 24.6%. Such sunflowers were crossed with a higher breeding line. In F1 both plant height and variation coefficients were higher, and in F2 even higher than in F1. **Nikolova** et **al.** (1998), who crossed *H. annuus* with *H. praecox* ssp. *hirtus*, observed that the height of hybrids was often higher than that of parental lines and increased in successive generations. Single individuals had markedly higher or lower shoots, so standard variation in some cases exceeded 70 cm.

Łuczkiewicz (1993 a) found that final plant height depends to a large extent on genotype, which is also confirmed in the present study. According to earlier works by that author (**Łuczkiewicz** 1973, 1992) and **Fraszewska** (1962), the most heritable traits of oilseed sunflower include plant height. **Chaudhary** and **Anand** (1987) noted that individuals sown earlier were characterized by a greater heritability of plant height in the flowering period and during harvest. **Tariq** et **al.** (1992) found that shoot length was highly heritable, as a dominant trait, but was characterized by a high phenotypic and genotypic variability. The same was observed by **Holtom** et **al.** (1995), who compared hybrids in generations F1-F3. Studying the general heritability of combination ability of shoot length, **Secerov-Fiser** (1994) reported that this trait is determined by genes with non-additive effects. This was confirmed in generations F1 and F2 by **Hladni** (1999).

Kłoczowski (1983) found that plant height affected yields only in 50%. **Velkov** (1984) noted that when breeding new cultivars, not only yields should be taken into account, but also relatively low plant height, as it facilitates sunflower harvesting to a large extent and affects positively other yield components.

Conclusions

1. In the conducted experiments, hybrid cultivars had higher shoots than cultivar 'Wielkopolski' since the first studied developmental stage (star stage). However, the large plants height does not have a positive effect on their agronomic value.

2. Results of this study show that sunflowers were the highest in 1999 at all developmental stages, which resulted from more favourable weather conditions and soil type. The lowest final plant height was recorded when sunflowers were grown on brown-earth soil.

3. This study confirms that increased sowing density caused a stronger elongation of shoots since the earliest developmental stages.

References

Ahmad G., Quresh Z. (2000): Plant population of sunflower under different planting dates. Pak. J. Biol. Sci. 3, 11: 1820-1821.

Ahmad G., Quresh Z., Ahmad R., Begum F., Taj F.H. (1998): Effect of defoliation on the yield and yield components of sunflower. Sarhad J. Agric. 14, 5: 433-436.

Akhtar M., Nadeem M.A., Ahmad S., Tanveer A. (1992): Effect of nitrogen on the seed yield and quality of sunflower (*Helianthus annuus* L.). J. Agric. Res. 30, 4: 479-484.

Ayub M., Tanveer A., Iqbal Z., Sharar M.S., Azam M. (1998): Response of two sunflower (*Helianthus annuus* L.) cultivars to different levels of nitrogen. Pak. J. Biol. Sci. 1, 4: 348-350.

Bos I., Caligari P. (1995): Selection methods in plant breeding. Chapman & Hall, London.

Chalermpone-Sampet, Songchao-Insomphun, Anand-Isarasenee (1988): Crop physiological studies on growth and yields of hybrid sunflower. J. Agric. 4, 1: 19-29.

Chaudhary S.K., Anand I.J. (1987): Genetic and morphological variability for quantitative characters in sunflower. J. Oilseeds Res. 4, 1: 97-102.

Chaudhry S.R., Khan M.A., Shah S.M., Malik M.A. (1998): Studies on irrigation scheduling in spring sown sunflower (*Helianthus annuus* L.). Sarhad J. Agric. 14, 3: 193-197.

Deibert E.J., Utter R.A. (1989): Sunflower growth and nutrient uptake: response to tillage system, hybrid maturity and weed control method. Soil Sci. Soc. Am. J. 53, 1: 133-138.

Dembiński F., Horodyski A., Jabłoński M. (1971): O uprawie słonecznika oleistego w polskich warunkach klimatycznych. Pam. Puł. 49: 5-43.

Derco M., Vrtalik A. (1975): Studium vhodnosti odrod a hybridov slnecnice olejnatej. Rostl. Vyroba 21, 9: 1013-1020.

Faiguenbaum M.H., Baginsky G.C. (1992): Efecto del tamano de aquenio sobre la germinacion, vigor y crecimiento inicial de las plantas en un hibrido de maravilla. Simiente 62, 4: 285-289.

Federowska B. (1971): Wpływ stopnia dojrzałości słonecznika oleistego na właściwości techniczne i technologiczne niełupek. Część I. Hod. Rośl. Aklim. Nasienn. 15, 6: 559-576.

Fick G.N., Swallers C.M. (1972): Higher yields and greater uniformity with hybrid sunflowers. North Dakota Agric. Exper. Stn 29, 6: 7-9.

Floarea-soarelui. (1974). Ed. A.V. Vranceanu. Academiei Republicii Socialiste Romania, Bucuresti.

Fraszewska T. (1962): Przyczynek do poznania dynamiki wzrostu i cech morfologicznych ośmiu jarych roślin oleistych. Pam. Puł. 5: 131-156.

Georgev S., Berczev G., Todorov S.T. (1990 a): Sravnitelno prouchvane na yugoslavski hibridi slynchogled. Rastenev'd. Nauki 27, 8: 37-41.

Georgev S., Zdravkova I., Tanev T., Vasileva K. (1990 b): Izpitvane na nyakoi sortove i hibridi slynchogled. Rastenev'd. Nauki 27, 10: 29-33.

Goksoy A.T., Turan Z.M., Acikgoz E. (1998): Effect of planting date and plant population on seed and oil yields and plant characteristics in sunflower (*Helianthus annuus* L.). Helia 21, 28: 107-116.

Gonet Z. (1976): Słonecznik pastewny. PWRiL, Warszawa.

Gonzalez-Fdez P., Giraldez J.V., Fereres E., Martin I., Valera A. (1988): Is sunflower suited for zero tillage dry farming. Proc. 12th Int. Sunf. Conf. Novi Sad, Yugoslavia: 372-378.

Goyne P.J., Hammer G.L. (1982): Phenology of sunflower cultivars. II. Controlled-environment studies of temperature and photoperiod effects. Aust. J. Agric. Res. 33, 2: 251-261.

Goyne P.J., Schneiter A.A. (1987): Photoperiod influence on development in sunflower genotypes. Agron. J. 79, 4: 704-709.

Guiducci M. (1988): Effect of water deficit on leaf area development and par absorption of a sunflower summer crop. Proc. 12 Int. Sunf. Conf. Novi Sad, Yugoslavia: 89-94.

Hladni N. (1999): Nasledjivanje arhitekture biljke suncokreta (*Helianthus annuus* L.) u F_1 i F_2 generaciji. Poljopriv. Fak., Novi Sad, Yugoslavia, Abs. Diss. M. Sci.

Holtom M.J., Pooni H.S., Rawlinson C.J., Barnes B.W., Hussain T., Marshall D.F. (1995): The genetic control of maturity and seed characters in sunflower crosses. J. Agric. Sci. 125, 1: 69-78.

Horodyski A., Muśnicki Cz. (1985): Problemy związane z wprowadzeniem słonecznika oleistego do uprawy w Polsce w świetle wyników doświadczeń. Nowe Roln. 11-12: 4-6.

Hussain Z., Khan B., Badshah S. (1998b): The effect of NPK levels on the oil production of a sunflower hybrid. Sarhad J. Agric. 14, 4: 269-276.

Hussein M.A., El-Hattab A.H., Ahmed A.K. (1980): Effect of plant spacing and nitrogen levels on morphological characters, seed yield and quality in sunflower (*Helianthus annuus* L.). Z. Acker Pflanzenb. 149, 2: 148-156.

Ionescu N., Draghicioiu V. (1989): Influenta densitatii asupra unor hibrizi de floarea soarelui in conditiile S. C. A. Albota, Arges. Probl. Agrofit. Teor. Aplic. 11, 1: 33-45.

Kadar I., Vass E. (1988): Fertilizing and liming sunflower on acid sandy soil. Proc. 12 Int. Sunf. Conf. Novi Sad, Yugoslavia: 242-246.

Kala R. (1996): Elementy wnioskowania parametrycznego dla przyrodników. Wyd. AR, Poznań.

Karami E. (1977): Effect of irrigation and plant population on yield and yield components of sunflower. Indian J. Agric. Sci. 47, 1: 15-17.

Karami E. (1980): Effect of nitrogen rate and the density of plant population on yield and yield components of sunflower. Indian J. Agric. Sci. 50, 9: 666-670.

Khan M.A., Usman Z., Ahmad K., Baloch M.S., Sadiq M. (1999): Behavior of some genotypes of sunflower. Pak. J. Biol. Sci. 2, 3: 735-736.

Kłoczowski Z. (1967 a): Charakterystyka ważniejszych cech i właściwości niektórych zagranicznych odmian słonecznika oleistego w warunkach ekologicznych Polski. Biul. Inst. Hod. Aklim. Rośl. 6: 81-88.

Kłoczowski Z. (1967 b): Z badań nad nowymi formami słonecznika oleistego wyhodowanymi w SHB-Borowo. Biul. Inst. Hod. Aklim. Rośl. 6: 89-93.

Kłoczowski Z. (1971): Porównanie F_1 i F_2 mieszańców liniowych słonecznika oleistego. Hod. Rośl. Aklim. Nasienn. 15, 1: 71-86.

Kłoczowski Z. (1975): Studia nad niektórymi cechami słonecznika oleistego i ich znaczeniem w hodowli tej rośliny w Polsce. Hod. Rośl. Aklim. Nasienn. 19, 2: 89-131.

Kłoczowski Z. (1983): Zależność plonu niełupek słonecznika oleistego od cech i właściwości roślin. Mater. Symp. „Genetyka ilościowa roślin uprawnych". Zesz. Probl. Post. Nauk Roln. 290: 375-384.

Kłoczowski Z., Kołodziejczak A. (1967): Zmienność ważniejszych cech pierwszego pokolenia różnego typu mieszańców słonecznika oleistego. Biul. Inst. Hod. Aklim. Rośl. 6: 95-99.

Kotovska N. (1987): Prouchvane na nyakoi sortove i hibridi slynchogled w centralna severna Bylgariya. Rastenev'd. Nauki 24, 8: 65-68.

Lanza F., Cilardi A.M., Ferri D., Losavio N., Santamaria P. (1988): Le tournesor en culture derobee en Italie du Sud: perspectives et limites par rapport aux dates de semis et aux differents hybrides. Premiers resultats de rendements quanti-qualitatifs. Proc. 12 Int. Sunf. Conf. Novi Sad, Yugoslavia: 223-228.

Liang Guo-Zhen (1988): Confectionery sunflower in China and agronomic characters of main cultivar. Proc. 12 Int. Sunf. Conf. Novi Sad, Yugoslavia: 337-341.

Ljach V.A., Gasenko N.A., Soroka A.I. (1998): Influence of pollen heating on the quality of resulting sporophyte germination in sunflower. Helia 21, 29: 103-108.

Lozanovic M., Stanojevic D. (1988): Effect of increasing nitrogen doses on important quantitative, biological, and morphological traits of sunflower. Proc. 12 Int. Sunf. Conf. Novi Sad, Yugoslavia: 274-275.

Łuczkiewicz T. (1973): Zmienność i odziedziczalność szeregu cech i właściwości naturalnych i indukowanych promieniami X u słonecznika (*Helianthus annuus* L.). PhD thesis. Typescript. Katedra Genetyki AR, Poznań.

Łuczkiewicz T. (1992): Dziedziczenie cech ilościowych i analiza wartości hodowlanej słonecznika oleistego (*Helianthus annuus* L.). Rocz. AR Pozn. Rozpr. Nauk. 230.

Łuczkiewicz T. (1993 a): Odziedziczalność wybranych cech słonecznika oleistego (*Helianthus annuus* L.). Zesz. Nauk. AR Wroc. 223, Roln. 58: 83-89.

Łuczkiewicz T. (1993 b): Zależność pomiędzy cechami linii wsobnych słonecznika oleistego a plonem ich mieszańców poly-crossowych. Zesz. Nauk. AR Wroc. 223, Roln. 58: 77-81.

Maiorana M., De Giorgio D., Ferri D., Rizzo V. (1988): Comparison among sowing times in different hybrida of sunflower (*Helianthus annuus* L.) in southern Italy. Proc. 12 Int. Sunf. Conf. Novi Sad, Yugoslavia: 221-222.

Marjanac D. (1988): Uporedna vrednost nekih NS hibrida suncokreta na podrucju Srednjeg Banata u 1986. i 1987. Uljarstvo 25, 3-4: 193-197.

Maruthi V., Subba R.G., Vanaja M. (1998): Evaluation of sunflower genotypes under late sown rainfed conditions. Helia 21, 28: 97-106.

Miller B.C., Oplinger E.S., Rand R., Peters J., Weis G. (1984): Effect of planting date and plant population on sunflower performance. Agron. J. 76, 4: 511-515.

Miller J.F., Hammond J.J. (1991): Inheritance of reduced height in sunflower. Euphytica 53, 2: 131-136.

Miller J.F., Roath W.W. (1982): Compensatory response of sunflower to stand reduction applied at different plant growth stages. Agron. J. 74, 1: 119-121.

Muśnicki Cz. (1975): Perspektywy uprawy słonecznika oleistego w Polsce. Post. Nauk Roln. 6: 3-17.

Muśnicki Cz. (1999): Rośliny oleiste. In: Szczegółowa uprawa roślin. Red. Z. Jasińska, A. Kotecki. WAR, Wrocław: 363-493.

Muśnicki Cz., Dembińska H., Gruszczyński S. (1980): Reagowanie słonecznika oleistego na wzrastające dawki nawozów azotowych. Rocz. AR Pozn. 118: 63-73.

Muśnicki Cz., Toboła P. (1996): Słonecznik – mało znana w Polsce roślina oleista. Top Agrar. Pol. 4: 30-33.

Muśnicki Cz., Toboła P., Muśnicka B. (1997): Produkcyjność alternatywnych roślin oleistych w warunkach Wielkopolski oraz zmienność ich plonowania. Rośl. Oleiste 18, 2: 269-278.

Nikolova L., Khristov M., Nikolova V., Shindrova P., Encheva V. (1998): Interspecific hybridization between *H. annuus* L. and *H. praecox* ssp. *hirtus* Engleman & Gray. Helia 21, 28: 15-22.

Nowiński M. (1970): Dzieje upraw i roślin uprawnych. PWRiL, Warszawa.

Olejniny. (1992). Red. A. Farby. Ministerstvo Zemedelstvi CR, Praha.

Pirani V. (1980): Confronto fra varieta di girasole. Sementi Elette 26, 1: 15-21.

Pirani V. (1981): Valutazione agronomica di costituzioni ibride e analisi di caratteri per migliorare la produzione del girasole (*Helianthus annuus* L.). Sementi Elette 27, 5: 17-21.

Płochiński N. (1968): Odziedziczalność. PWRiL, Warszawa.

Podsolnechnik. (1975). Ed. V.S. Pustovojt. Kolos, Moskva.

Radenovic B. (1983): Uticaj sklopa biljaka na morfoloske i bioloske osobine suncokreta N-S-H-26 RM u agroekoloskim uslovima Kosova. Poljopriv. Znan. Smotra 61: 197-213.

Rizzo V., Di Bari V. (1988): Effects of fewer water applications on sunflower (*Helianthus annuus* L.) in the south of Italy. Proc. 12 Int. Sunf. Conf. Novi Sad, Yugoslavia: 453-458.

Robinson R.G., Ford J.H., Lueschen W.E., Rabas D.L., Smith L.J., Warnes D.D., Wiersma J.V. (1980): Response of sunflower to plant population. Agron. J. 72, 6: 869-871.

Sadras V.O., Connor D.J., Whitefield D.M. (1993): Yield, yield components and source-sink relationships in water-stressed sunflower. Field Crops Res. 31, 1-2: 27-39.

Salera E., Baldini M. (1998): Performance of high and low oleic acid hybrids of sunflower under different environmental conditions. Note I. Helia 21, 28: 41-54.

Secerov-Fiser V. (1994): Mode of inheritance for plant height in ornamental sunflowers. Genetika 26, 3: 175-181.

Sen D.K., Miah F.U., Ahmed A. (1985): Variability, heritability and correlation studies in sunflower (*Helianthus annuus* L.). Bangladesh J. Agric. Res. 10, 2: 105-110.

Singh S.P., Singh P.P., Singh V. (1987): Studies on growth and yield of sunflower varieties in relation to nitrogen rates. J. Oilseeds Res. 4, 2: 169-174.

Stoimenova I. (1982): Herbisidni smesi za borba s plevelite slynchogledovi posevi. Rastenev'd. Nauki 19, 1: 73-78.

Suncokret. (1988). Ed. D. Skoric, T. Vrebalov. Nolit, Beograd.

Suzer S. (1998): Effects of different phosphorus rate and application time on sunflower seed yield and yield components. Helia 21, 28: 117-124.

Tanimu B., Ado S.G., Kaigama B.K. (1988): Agronomic performance and oil content of sunflower (*Helianthus annuus* L.) in the Nigerian savanna. Proc. 12 Int. Sunf. Conf. Novi Sad, Yugoslavia: 356-360.

Tariq M., Idrees G., Tahir A. (1992): Genetic variability and correlation studies in sunflower. Sarhad J. Agric. 8, 6: 659-663.

Tenebe V.A., Pal U.R., Okonkwo C.A.C., Auwalu B.M. (1996): Response of rainfed sunflower (*Helianthus annuus* L.) to nitrogen rates and plant population in the semi-arid savanna region of Nigeria. J. Agron. Crop Sci. 177, 3: 207-215.

Toboła P., Muśnicki Cz., Jodłowski M. (1991): Wpływ obsady roślin i ich rozmieszczenia na plonowanie słonecznika oleistego. Zesz. Probl. Inst. Hod. Aklim. Rośl. „Rośliny oleiste" 2: 41-50.

Toboła P., Muśnicki Cz., Jodłowski M. (1993): Wpływ różnych sposobów nawożenia na plonowanie słonecznika Wielkopolski. Post. Nauk Roln. 6: 127-133.

Tobola P., Muśnicki Cz. (1997): Kształtowanie się cech użytkowych odmian słonecznika oleistego (*Helianthus annuus* L.) w zmiennych warunkach pogody. Rośl. Oleiste 18, 2: 279-286.
Todorov T.C., Dakova D., Vylkanov V.C., Dimitrov S. (1987): Prouchvane na nyakoi sortove i hibridi slynchogled v usloviyata na severoiztochna Bylgariya. Rastenev'd. Nauki 24, 8: 69-72.
Unger P.W. (1980): Planting date effects on growth, yield, and oil of irrigated sunflower. Agron. J. 72, 6: 914-916.
Vasilev D.S. (1990): Podsolnechnik. Agropromizdat, Moskva.
Velkov V.N. (1984): Skhema na mnogokraten individyalno-familen otbor pri slynchogleda. Rastenev'd. Nauki 21, 6: 92-96.
Villalobos F.J., Soriano A., Fereres E. (1992): Effects of shading on dry matter partitioning and yield of field-grown sunflower. Eur. J. Agron. 1, 2: 109-115.
Vranceanu A., Stoenescu F., Pirvu N., Iuoras M. (1987): Ameliorarea florii-soarelui si a altor plante oleaginoase. An. Inst. Cercet. 55: 113-140.
Wantana-Waratanakun (1984): An investigation on plant spacing of sunflower. Kasetsart Univ., Bangkok, Thailand.
Wyniki doświadczeń odmianowych ze słonecznikiem oleistym przeprowadzonych w latach 1979--1995. Typescript. COBORU.
Yadava T.P., Singh H. (1978): Note on the comparative performance of Romanian hybrids and improved populations of sunflower in Haryana. Indian J. Agric. Sci. 48, 11: 686-688.
Zhang Yunda (1988): Soil salinity index of planting sunflower in saline-alkali soil. Proc. 12 Int. Sunf. Conf. Novi Sad, Yugoslavia: 325-327.

WYSOKOŚĆ ROŚLIN W RÓŻNYCH FAZACH ROZWOJU U BADANYCH TYPÓW ODMIAN SŁONECZNIKA ZWYCZAJNEGO (*HELIANTHUS ANNUUS* L.)

S t r e s z c z e n i e

W pracy przedstawiono zmiany długości pędów w różnych fazach ich rozwoju, jakie zaobserwowano podczas trzyletnich doświadczeń porównawczych nad dwoma mieszańcami liniowymi i odmianą populacyjną słonecznika oleistego. Badano wpływ na tę cechę czynników klimatycznych, zmian gęstości siewu i dawek nawozu azotowego. Uzyskane wyniki poddano analizom statystycznym, określono także odziedziczalność wysokości roślin w różnych fazach rozwoju. W przeprowadzonym doświadczeniu mieszańce liniowe zaczynały dominować wysokością nad odmianą 'Wielkopolski' już przy pierwszym pomiarze długości pędów w fazie gwiazdki. Stwierdzono jednak, że duża wysokość roślin nie wpływa korzystnie na wartość rolniczą tych odmian. Wyniki referowanych doświadczeń wykazały, że obserwowany w 1999 roku najwyższy wzrost roślin, w różnych etapach ich rozwoju, był spowodowany najkorzystniejszymi dla tego procesu warunkami pogodowymi i rodzajem podłoża. Najmniejszą wysokość osiągnęły łodygi słoneczników rosnących na glebach brunatnych. Rezultaty badań własnych dowodzą, że zwiększenie gęstości roślin, już od wczesnych faz rozwojowych, powodowało wydłużanie się łodyg.