



BIOLOGY OF FRUCTIFICATION – QUANTITATIVE CHANGES OF ACHENES  
IN COMMON SUNFLOWER (*HELIANTHUS ANNUUS* L.)  
DURING THEIR RIPENING

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**ABSTRACT.** Research was conducted in the years 1998–2001 at the Experimental Station of the Poznań University of Life Sciences in Przybroda. One open pollinated variety – ‘Wielkopolski’ and two hybrid varieties, ‘Frankasol’ and ‘Coril’ were tested. The experiment was carried out each year, at a constant density of plants of 50 thousand·ha<sup>-1</sup> and a constant amount of nitrogen fertilizer applied at 60 kg·ha<sup>-1</sup>. Only environmental factors were variable. Fruit was collected every seven days from the outer portion of the head. It was collected for the first time a week after flowering. The following parameters were analysed: the size of fruit, thousand achene weight and hull content.

**KEY WORDS:** sunflower, achenes, ripening, quantity, hull content

INTRODUCTION

In terms of the manner of utilisation in common sunflower (*Helianthus annuus* L.) we distinguish ornamental, silage, confection and oil-bearing forms, and among the above also older open pollinated varieties and interline hybrids, created in the last 50 years and produced by crossing selected inbred lines. Among these forms oil-bearing sunflower is of the highest economic value. After soy, palms and rape it is the most commonly cultivated oil-bearing crop worldwide (MUŚNICKI 1999). Achenes of oil-bearing forms contain large amounts of fat, thus they are used in the production of edible oils and margarines. This fat is characterised by a high content of linolic acid, an unsaturated fatty acid essential in the healthy human diet (ANDRUKHOV et AL. 1975, ZIEMLAŃSKI and BUDZYŃSKA-TOPOLEWSKA 1991).

Numerous studies have been conducted worldwide on the size of fruits (GUPTA and DAS 1997), their weight and yield (ROBINSON 1974, MUŚNICKI 1975, TERBEA and STOENESCU 1984), as well as their contents of chemical compounds (DORRELL and WHELAN 1978, BURLOV and SERBAJ 1988, KAFFKA et AL. 1982). However, this pertained only to the traits of achenes at the stage of processing maturity. In contrast, there are very few studies on quantitative and qualitative changes in fruits during their ripening. Thus the author decided to undertake such investigations growing sunflower under the Polish climate conditions.

MATERIAL AND METHODS

Analyses were conducted at the Experimental Station of the Poznań University of Life Sciences in Przybroda. Objects of the study included a Polish open pollinated variety (‘Wielkopolski’) and two hybrid varieties, i.e. one French (‘Frankasol’) and one American (‘Coril’). The experiment was conducted in successive years at a constant plant density of 50 thousand·ha<sup>-1</sup> and a constant rate of nitrogen fertilizer application of 60 kg·ha<sup>-1</sup>. The only variables were environmental factors (soil, forecrop and the set of weather conditions – Table 1). In the first year of observations plants were sown on brown soils, while in the next years plots were established on black earths. Most frequently the arable layer had the grain size distribution of light clay, which was characterised by slightly alkaline or neutral reaction. Only in 1998 it was light acid. In contrast, the humus layer was 40–50 cm in depth. These soils were classified to quality classes III b and III a, of the cereal-fodder strong complex or good wheat complex.

Fruits were collected from the outer portions of the heads at 7-day intervals from 10 specimens from two replications for each variety. The first sample was collected a week after blooming of this inflorescence section and the last at full maturity. In the 3-year experimental cycle size was measured each time on 30 fruits using a caliper, i.e. determining their length, width and thickness. In the 4-year cycle the weight of 1000 achenes was determined, while in the last two years of the study also the percentage content of hulls in fruits was analysed. For this purpose samples of 100 whole achenes were first weighed and next epicarps were

TABLE 1. Multiyear (1953-1992) month temperatures (°C) and precipitation (mm) in Przybroda and deviation in years 1998-2001

Month	Multiyear (1953-1992)		Temperatures				Precipitation			
	temperatures	precipitation	1998	1999	2000	2001	1998	1999	2000	2001
IV	7.4	34	3.8	3.2	6.1	0.8	8	38	-22	-2
V	12.9	49	2.9	1.8	4.2	2.8	-12	-22	1	-42
VI	16.5	59	2.0	0.8	2.2	-0.7	20	26	-17	19
VII	18.0	78	0.9	3.6	-0.9	2.8	-28	-48	-7	-36
VIII	17.4	58	0.3	2.1	2.1	3.0	-1	-25	28	7
IX	13.5	45	1.1	4.9	-0.1	-1.4	29	-29	-11	49

removed and the weight of epicarps and seeds were determined separately.

Variation in the traits of fruit size at different stages of maturity was characterised following the recommendations by KALA (1996), using standard deviation and the coefficient of variation. Regression equations were calculated for data concerning weight of 1000 achenes and their hull contents.

## RESULTS

Fruit length in all varieties practically did not change during their setting and ripening. This trait significantly differed between cultivars, except for the second date of fruit collection in the years 1999-2000. At each measurement the longest achenes were found most frequently in the hybrid cv. 'Frankasol', while the shortest in cv. 'Coril'. Sunflowers formed the smallest fruit in the dry year of 1999. When analysing values of the coefficient of variation it was found that cv. 'Wielkopolski' always exhibited the lowest uniformity. Also in that cultivar the value of standard deviation was most frequently the highest (Table 2, Figs 1-2).

Fruit width increased between the first and second week of their ripening. It was most evident in the year 2000. At the next measurements this trait increased

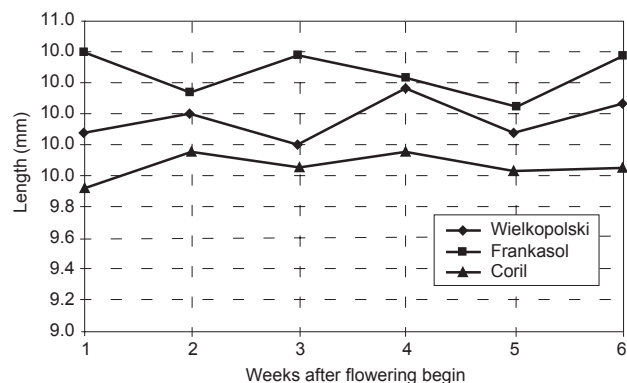


FIG. 1. Changes of achenes length during formation and ripening of fruits of three sunflower cultivars (averages of 1998-2001 years)

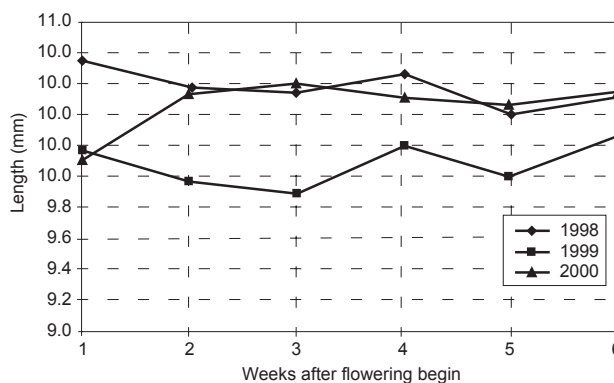


FIG. 2. Changes of achenes length during formation and ripening of fruits of three sunflower cultivars (averages for three cultivars)

only sporadically. The width of achenes did not differ significantly between varieties only in the second date in the years 1999-2000 and in the sixth in 1999. This trait in all the analysed sunflowers generally reached the highest value in 2000, while the lowest in 1999. In individual years of observations most frequently with widest fruits were observed in cv. 'Wielkopolski', with this cultivar also being characterised by their biggest variability (Table 2, Figs 3-4).

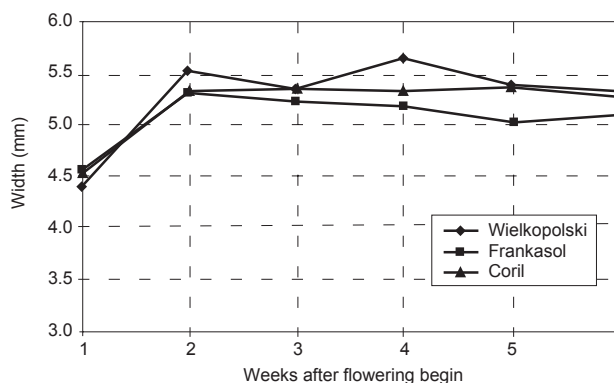


FIG. 3. Changes of achenes width during formation and ripening of fruits of three sunflower cultivars (averages of 1998-2001 years)

TABLE 2. Variation in character of achene length, width and thickness (mm) during formation and ripening of fruits in three sunflower cultivars

Varieties	Length of achenes				Width of achenes				Thickness of achenes																		
	arithmetic mean		standard deviation		arithmetic mean		standard deviation		arithmetic mean		standard deviation		coefficient of variation														
	1998	2000	1998	2000	1998	2000	1998	2000	1998	2000	1998	2000	1998	2000													
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
1st week after onset of flowering																											
Wielkopolski	10.6	10.4	9.83	0.54	0.77	0.77	5.12	7.37	7.83	5.10	4.65	3.43	0.53	0.30	0.67	10.4	6.50	19.4	2.87	2.59	1.16	0.67	0.38	0.28	23.5	14.5	23.9
Frankasol	11.3	10.3	10.8	0.41	0.43	0.46	3.60	4.19	4.24	4.76	4.86	4.08	0.42	0.30	0.53	8.85	6.19	12.9	2.52	2.77	1.84	0.58	0.44	0.66	22.9	15.8	35.7
Coril	10.3	9.76	9.73	0.43	0.68	0.45	4.15	6.97	4.61	5.07	5.14	3.42	0.41	0.37	0.41	8.13	7.13	12.1	3.01	3.33	1.07	0.45	0.46	0.23	15.0	13.8	21.2
LSD <sub>0.05</sub>	0.24	0.330	0.297	x	x	x	x	x	x	0.234	0.167	0.279	x	x	x	x	x	x	0.295	0.218	0.221	x	x	x	x	x	x
2nd week after onset of flowering																											
Wielkopolski	10.6	10.0	10.6	0.53	0.60	0.68	4.99	5.96	6.42	5.58	5.43	5.53	0.48	0.63	0.60	8.58	11.5	10.8	3.78	3.80	3.46	0.37	0.45	0.74	9.91	11.9	21.3
Frankasol	11.0	10.1	10.5	0.49	0.34	0.51	4.45	3.36	4.85	5.33	5.23	5.42	0.31	0.23	0.31	5.85	4.44	5.68	3.67	3.55	3.89	0.27	0.22	0.39	7.41	6.23	9.89
Coril	10.1	9.85	10.5	0.38	0.48	0.34	3.79	4.84	3.28	5.33	5.36	5.27	0.31	0.35	0.68	5.75	6.63	12.9	3.42	3.61	3.18	0.31	0.40	0.85	9.20	11.1	26.7
LSD <sub>0.05</sub>	0.24	-	-	x	x	x	x	x	x	0.192	-	-	x	x	x	x	x	x	0.166	0.191	0.353	x	x	x	x	x	x
3rd week after onset of flowering																											
Wielkopolski	10.3	9.48	10.8	0.64	0.47	0.75	6.18	4.97	6.88	5.55	4.81	5.66	0.52	0.52	0.74	9.41	10.8	13.1	3.80	3.49	3.87	0.33	0.51	0.80	8.68	14.5	20.7
Frankasol	11.2	10.4	10.7	0.44	0.29	0.51	3.94	2.78	4.75	5.15	5.22	5.30	0.23	0.24	0.28	4.47	4.59	5.28	3.73	3.81	3.81	0.33	0.34	0.47	8.88	9.05	12.5
Coril	10.1	9.77	10.3	0.44	0.33	0.21	4.35	3.36	2.08	5.13	5.30	5.67	0.22	0.36	0.45	4.32	6.72	7.91	3.34	3.50	3.81	0.32	0.31	0.44	9.45	8.75	11.7
LSD <sub>0.05</sub>	0.26	0.191	0.28	x	x	x	x	x	x	0.181	0.200	0.269	x	x	x	x	x	x	0.167	0.202	-	x	x	x	x	x	x

TABLE 2 – cont.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
4th week after onset of flowering																											
Wielkopolski	10.7	10.5	10.5	0.46	0.47	0.67	4.30	4.45	6.40	5.67	5.29	5.98	0.50	0.38	0.57	8.73	7.12	9.57	3.77	3.97	4.26	0.31	0.32	0.55	8.19	8.09	12.9
Frankasol	11.0	10.2	10.7	0.47	0.41	0.54	4.28	3.99	5.02	5.18	5.07	5.36	0.35	0.31	0.44	6.76	6.20	8.23	3.64	3.53	3.97	0.30	0.27	0.49	8.21	7.59	12.4
Coril	10.3	9.87	10.3	0.38	0.41	0.34	3.72	4.15	3.31	5.22	5.08	5.65	0.27	0.43	0.42	5.09	8.56	7.46	3.50	3.25	3.78	0.33	0.46	0.48	9.36	14.3	12.7
LSD <sub>0.05</sub>	0.23	0.220	0.27	x	x	x	x	x	x	0.196	0.194	0.248	x	x	x	x	x	x	0.160	0.185	0.261	x	x	x	x	x	x
5th week after onset of flowering																											
Wielkopolski	10.4	9.93	10.5	0.63	0.48	0.55	6.07	4.79	5.22	5.46	4.81	5.88	0.53	0.47	0.87	9.71	9.68	14.8	3.79	3.47	4.14	0.28	0.52	0.80	7.49	14.9	19.3
Frankasol	11.2	10.2	10.7	0.45	0.37	0.31	4.04	3.58	2.89	5.04	5.09	4.96	0.32	0.41	0.35	6.44	7.99	7.15	3.51	3.40	3.55	0.36	0.47	0.32	10.4	13.8	9.06
Coril	10.0	9.86	10.2	0.51	0.58	0.25	5.07	5.85	2.44	5.26	5.09	5.65	0.32	0.24	0.28	6.12	4.70	5.00	3.38	3.35	3.75	0.45	0.45	0.36	13.5	13.3	9.72
LSD <sub>0.05</sub>	x	0.247	0.20	x	x	x	x	x	x	0.207	0.196	0.291	x	x	x	x	x	x	0.192	-	0.278	x	x	x	x	x	x
6th week after onset of flowering																											
Wielkopolski	10.3	10.5	10.6	0.60	0.80	0.60	5.85	4.60	5.67	5.57	4.85	5.53	0.41	0.41	0.47	7.31	8.37	8.45	3.83	3.35	3.79	0.35	0.39	0.52	9.10	11.6	13.7
Frankasol	*	10.4	10.7	*	0.38	0.44	*	3.66	4.10	*	4.98	5.32	*	0.32	0.37	*	6.37	7.01	*	3.24	3.97	*	0.33	0.37	*	10.2	9.37
Coril	*	9.88	10.3	*	0.44	0.45	*	4.41	4.37	*	5.03	5.57	*	0.41	0.32	*	8.24	5.73	*	3.36	4.02	*	0.42	0.33	*	12.6	8.25
LSD <sub>0.05</sub>	0.27	0.292	0.26	x	x	x	x	x	x	-	-	0.201	x	x	x	x	x	x	-	-	-	x	x	x	x	x	x

\*No data.

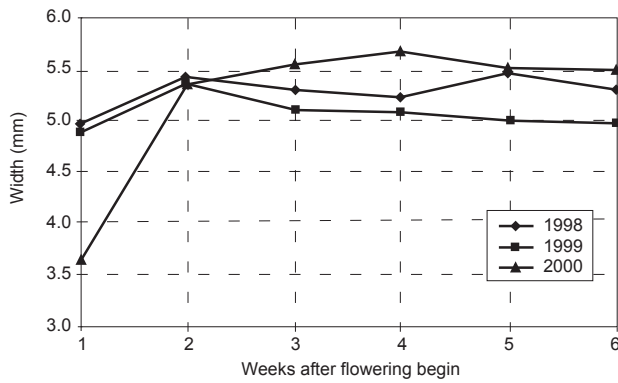


FIG. 4. Changes of achenes width during formation and ripening of fruits of three sunflower cultivars (averages for three cultivars)

Fruit thickness increased also markedly between the first and second week of measurements. These differences were most evident in the last year of the study. At the successive collections of achenes the thickness increased very rarely. Each year none of the sunflowers exhibited any marked tendency towards the formation of the thickest fruits. Starting from the third year

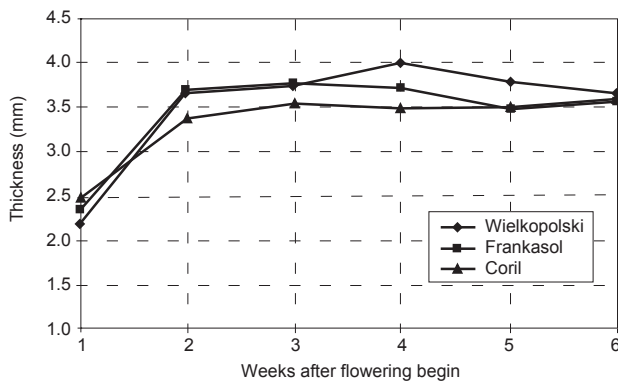


FIG. 5. Changes of achenes thickness during formation and ripening of fruits of three sunflower cultivars (averages of 1998-2001 years)

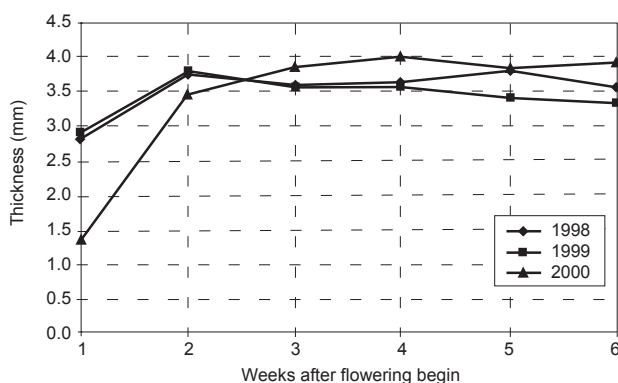


FIG. 6. Changes of achenes thickness during formation and ripening of fruits of three sunflower cultivars (averages for three cultivars)

of achene collection, also the smallest were formed in 1999. Cultivars only in the fifth and sixth dates of dates in 1999 and in the third and last in the next season were not significantly varied. Values of standard deviation and the coefficient of variation were not uniform for individual cultivars (Table 2, Figs 5-6).

The weight of 1000 achenes in each of the observed varieties increased markedly in the course of their ripening. The biggest changes were observed between the first and fourth week from flowering. In turn, growth dynamics in the weight of 1000 fruit decreased between the fourth and sixth measurement dates, when it already stabilized in the cv. 'Wielkopolski' and 'Frankasol', but it continued to increase in hybrid 'Coril'. At the first date the heaviest achenes were recorded in cv. 'Wielkopolski', while in the next ones, except for the last, fruits of sunflower cv. 'Frankasol' dominated in terms of weight (Fig. 7). In the years 1998-2000 achene weight increased from the first to the sixth week, while in 2001 it was increasing up to the seventh sampling date (Fig. 8).

The percentage hull content dropped markedly in all compared cultivars between the first and third week from flowering. Between the third and fifth date of fruit collection the dynamics of changes in this trait was smaller and from that time it remained at a similar

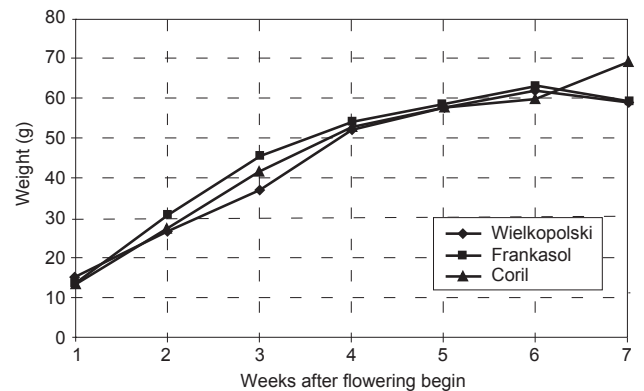


FIG. 7. Changes of 1000 achenes weight during formation and ripening of fruits of three sunflower cultivars (averages of 1998-2001 years)

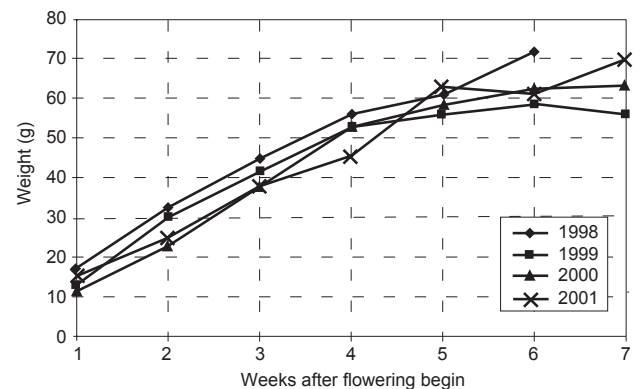


FIG. 8. Changes of 1000 achenes weight during formation and ripening of fruits of three sunflower cultivars (averages for three cultivars)

level. The hybrid cv. 'Coril' was always characterised by the smallest percentage hull content, while in the last weeks before harvest sunflower cv. 'Frankasol' had the biggest amount of hulls (Fig. 9). Changes in their content were similar in both years. In the year 2000, at the beginning and at the end of sample collection, achenes had the lowest percentage of hulls than in the next season (Fig. 10). In the first week after flowering the coat

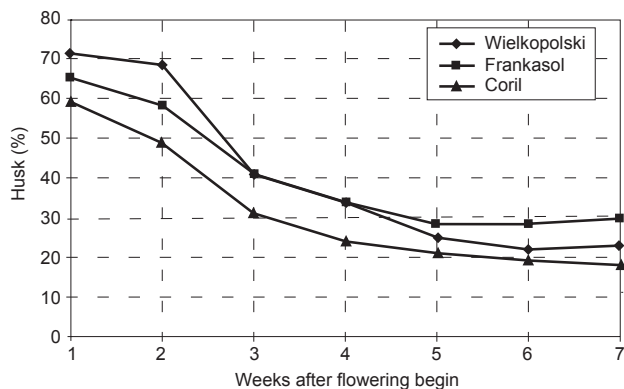


FIG. 9. Changes of husk content during formation and ripening of fruits of three sunflower cultivars (averages of 2000-2001 years)

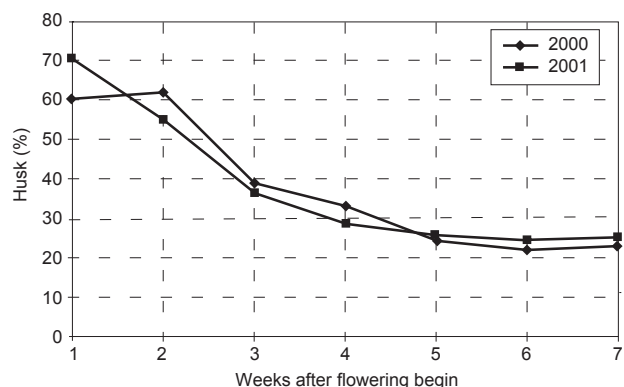


FIG. 10. Changes of husk content during formation and ripening of fruits of three sunflower cultivars (averages for three cultivars)

accounted for as much as 65% fruit weight, while at processing maturity it was approx. 23%.

## DISCUSSION

Among numerous studies concerning sunflower fruits only four publications were found in available literature on quantitative changes in achenes during their ripening. FEDOROWSKA (1971) conducted her studies on older open pollinated varieties. Her investigations showed that weight of 1000 achenes increased with the passing ripening period. At semi-technical maturity it was 71-90.5 g, while at the full ripening stage it was 87-96.3 g. This thesis was also confirmed in this study.

FEDOROWSKA (1971) analysed also pericarp content in fruits and stated that its highest share was recorded at the semi-technical stage, while the lowest was found at full maturity. The earlier achenes were collected for analyses, the higher the hull percentage was, which was confirmed in this study.

JOVANOVIĆ (1988) investigated changes in 1000 fruit weight in two hybrid varieties (NS-H-Helios and NS-H-43). He collected achenes at every 10 days, starting from the 20th day after the completion of flowering, until physiological maturity was reached. The weight of 1000 seeds was definitely higher in the outer part than in the central part, but only in one hybrid it stabilized already at the 30th day, while in the other it increased up to the last measurement. VASILIEV (1990) showed that with fruit ripening the weight of 1000 seeds stabilized around the 30th-35th day after overblowing. DORRELL (1978) collected achenes from open pollinated varieties every seven days, in the first year starting from the 21st day after flowering to day 49, while in the other starting from the seventh to 27th day and on the 49th day. He investigated the effect of harvest date on fruit weight. The biggest 1000 seed weight was found on the 35th day from flowering. The author recorded inconsistent results for hull percentage. In the first year of the study it stabilized on day 28, while in the second it decreased up to the 49th day. In this study the percentage hull content stabilized around the 35th day from overblowing, but the weight of 1000 fruit increased up to the last harvest date (49th day).

## CONCLUSIONS

1. The size of achenes (length, width and thickness) generally significantly differentiated the analysed varieties. Length was least varied during fruit formation. Width and thickness of achenes increased between the first and the second week of their maturing.

2. Most frequently the longest fruits were observed in a hybrid cv. 'Frankasol', while the shortest in cv. 'Coril'. The widest achenes were formed by sunflower cv. 'Wielkopolski'. It was also the most variable in terms of fruit length and width.

3. Weight of 1000 fruits in each of the observed cultivars increased markedly with their ripening. The biggest changes were observed between the first and the fourth week from flowering. In turn, the dynamics of increase in the weight of 1000 achenes decreased between the fourth and the sixth week of measurements. The heaviest fruits were most frequently observed in sunflower cv. 'Frankasol'.

4. The percentage hull content decreased considerably in all the compared varieties between the first and the third week from flowering. Between the third and the fifth date of achene collection the dynamics of changes was already lower. Cultivar 'Coril' was always characterised by the lowest percentage hull content.

5. Dynamics of quantitative changes in achenes was similar in all years of the study and only the limited amount of precipitation in 1999 had a negative effect on fruit size.



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