ACTA AGROBOTANICA
Vol. 64 (3): 67–78
2011

COMPARISON OF GROWTH AND PRODUCTIVITY OF THE LOW MORPHINE POPPY *Papaver somniferum* L. cv. Mieszko DEPENDING ON THE SOWING DATE

Tadeusz Zając, Andrzej Oleksy, Agnieszka Klimek-Kopyra

The Hugo Kołłątaj University of Agriculture in Kraków, Institute of Crop Production,
al. A. Mickiewicza 21, 31-120 Kraków, Poland, e-mail: roleksy@cyf-kr.edu.pl

Received: 09.12.2010

Abstract

A single-factor field experiment was conducted in 2008 and 2009. The aim of this study was to evaluate the low-morphine poppy cv. Mieszko which was sown at three different dates: I-early, II-optimal, III-delayed. The results of the experiment demonstrate that there is no difference between morphological traits at characteristic growth stages. Plants in the population varied in the number of poppy heads (from 1 to 6). Plant productivity in the crop depended on the sowing date and growing year. Sowing poppy at the early and optimal date allowed more productive individuals that produced poppy heads with a higher unit weight to be obtained in the crop population. The most productive plants in the crop formed 3 or more poppy heads per plant. The results of experiment proved that the date of poppy sowing had a significant effect on plant growth and, as a consequence, on yield, in spite of the fact that it is a no-cost agrotechnical factor. For utilitarian reasons, efforts should be made to do sowing at the optimal time.

Key words: low-morphine poppy, date of sowing, growth, plant traits, yield

INTRODUCTION

The opium poppy (*Papaver somniferum* L.) belongs to the Papaveraceae family and is also called medicinal poppy (Hagel et al. 2008; Németh, 2006; Pushpangadan and Singh, 2001). This species is a very old cultivated plant and its species epithet – *somniferum* – can be translated as "sleep-bringing", which was and still is of great importance for people suffering from pain (Havel et al. 2008; Suchorska, 1990). Alkaloid compounds are distributed unevenly in high-morphine poppy plants, hence poppy heads – green or ripe – have been a source of alkaloids or opiates (Németh, 2006; Pushpangadan and Singh, 2001; Suchorska, 1990). On the other hand, poppy seeds have been used already from ancient times as a valuable, since energetically concentrated, food due to a high content of fat, ranging from 40 to 50%, and of protein – approx. 20-27% (Honermeier, 2006). Vašák and Vlk (2010) stress that among European countries the highest annual consumption of poppy seeds, amounting to 400 g per person, is in Poland, in the Czech Republic and Slovakia poppy seed consumption is 300 g, whereas it is much lower in Germany and in the former USSR countries, about 100 g. Blue-coloured varieties are currently recommended for growing, since such poppy seeds are preferred in the confectionary industry (Honermeier, 2006).

Analysis of poppy productivity in agricultural technology research has included seed yield of primarily poppy varieties belonging to the high-morphine form. Morphine content and yield have also been evaluated, depending on cultivated cultivars (Ogrodowczyk and Wawrzyniak, 2007), mineral fertilization and agro-climatic conditions (Lošák and Richter, 2004; Wójtowicz, 2007). So far, no broad-based field studies have been undertaken on the growth of plants at characteristic growth stages of poppy, in particular its low-morphine form, which gives a small pool of knowledge on its biology. As regards the high-morphine form, studies under controlled conditions have shown that the number of days with active photosynthesis between full emergence and flowering is the main determinant of plant biomass yield (Acock et al. 1996). The need to accelerate the date of sowing of the spring form of poppy under the temperate climatic conditions results from its quite long growing period, which is from 125 to

140 days; however, young plants withstand ground frost up to -8°C without major damage, which allows early sowing in the 3rd decade of March (Novák et al. 2010; Fulara, 1971). Kosek and Pšenička (2010) emphasise that low-weight poppy seeds need to be placed shallow in the soil, and the emergence rate is at a level of barely 25-33% of sown seeds. In the years with less favourable weather conditions in the spring, poppy sowing is much delayed and, as a consequence, crop yield is reduced (Wójtowicz, 2007). In some years, adverse weather conditions after seeding delay plant emergence and this growth stage of poppy can extend to 30 days (Budzyński, 1985).

The aim of the present study was to evaluate the effect of three sowing dates on yield and growth of low-morphine poppy plants, cv. Mieszko, with special reference to their morphological traits at characteristic growth stages, and to estimate the contribution of particular organs to biomass yield of a single plant.

MATERIALS AND METHODS

A single-factor field experiment, set up as a randomized block design, was conducted in the period 2008-2009 in a farm located in the village of Stradlice, Kazimierza County, Swiętokrzyskie Voivodeship. The test crop was the low-morphine poppy cv. Mieszko, sown at three dates: I – early date (as soon as possible); II – optimal date; III – delayed date (by one week). In the years 2008 and 2009, the calendar dates of poppy sowing were respectively on 27 March and 24 March (early date), 2 April and 30 March (optimal date), 9 April and 6 April (delayed date). The experiment was carried out on chernozem soil characterized by high availability of phosphorus, potassium and magnesium as well as by a neutral pH; the soil was classified as a very good wheat soil complex. Every year, dressed seeds of the low-morphine poppy cv. Mieszko were sown at a rate of 1 kg×ha^{-1}, which gave a plant density of 270 germinating seeds per 1 m^2. The poppy seed material was sown using a seed drill at a depth of 0.5-1 cm and with a row spacing of 40 cm, in a field following winter wheat. 60 kg N ha^{-1} in the form of ammonium nitrate, applied wholly pre--sowing, was used in poppy growing. Nitrogen and potassium fertilization was also applied in the form of boron superphosphate, which supplied 22 kg P, and in the form of potassium salt at a rate of 75 kg K×ha^{-1}. The experiment was carried out in quadruplicate, and each plot had 4 rows. Excess poppy plants were removed mechanically by thinning at the cotyledon stage, and then manually at the seedling stage after 3-4 true leaves developed, leaving 40 plants per 1 m^2, that is, there was a plant every 6 cm in a row. In 2009, due to spring drought (April), the assumed plant density was not achieved, in particular in the case of the delayed date of poppy sowing. Weed control in the plantation involved the application of mesotrion at a rate of 96 g×ha^{-1}, which took place at the 6-leaf stage of poppy (dicotyledonous weeds), and of quizalofop-P-tefuryl at a rate of 16 g×ha^{-1} at the 4-6-leaf stage of poppy (monocotyledonous weeds). During the growth of poppy, antifungal treatment was performed once using azoxystrobin at 250 g×ha^{-1} at the budding stage of the poppy plants.

The plot area was 24 m^2. Poppy plants being at fully characteristic growth stages were sampled from two middle rows of each plot from an area of 0.75 m^2. Five growth stages of poppy were included in the investigations: leaf rosette (BBCH 19) – 9 or more true leaves unfolded; budding (BBCH 51) – flower buds visible; flowering (BBCH 67); green maturity (BBCH 77) – capsules have reached 70% of their final size; full maturity (BBCH 89) (BBCH Monograph 2001). After sampling, the plants were labelled individually and subsequently their height, number of leaves, stem and leaf weight were measured. The plant material was dried in an air circulation drying oven at a temperature of 72°C for 72 hours.

At the end of the ripening stage of poppy, biometric measurements of the plants were made in three 1 m^2 areas in each plot as well as their density was determined. After the plants reached maturity, the plants were pulled out from the 1 m^2 areas and air dried; number of poppy heads per plant, length of the main shoot and of lateral shoots and poppy head length were determined. The area of a single harvest plot was 12 m^2. The air-dry weight was determined for the individual components of the poppy plants; it was established following the above described procedure. In order to conduct an in-depth evaluation of poppy yield, the harvest index was calculated per plant, not per area. The obtained results were subjected to two-factorial analysis of variance, whereas the significance of differences between means was evaluated by Tukey's test at the 5% level of probability. Regression equations, together with multiple regression coefficients, were calculated for selected pairs of traits using Statistica® 9 software.

RESULTS

The weather patterns during the experimental years varied (Table 1). More favourable conditions for the growth and development of poppy were in 2008, in spite of relatively low rainfall levels in May and June. In 2009 April was dry and warm. Mean daily air temperature was higher by 3.3°C than the long-term average and there was practically no rainfall, which had a very negative effect on poppy emergence and significantly reduced the growth and development of the plants at the initial stages. Higher rainfall occurred as late as the second half of May. Intense rainfall events, with rainfall levels much exceeding the long-term rainfall average, were recorded in July 2008 and in June 2009.

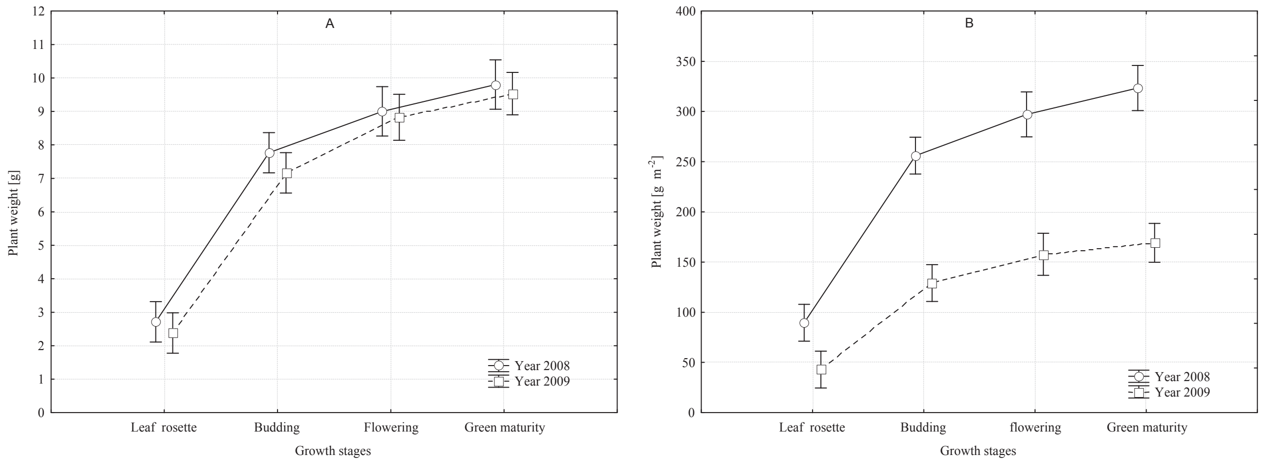

Fig. 1. Poppy plant weight depending on the growth stage and growing year (A) and the weight of plants per unit area (1 m^2) depending on the growth stage and growing year (B).

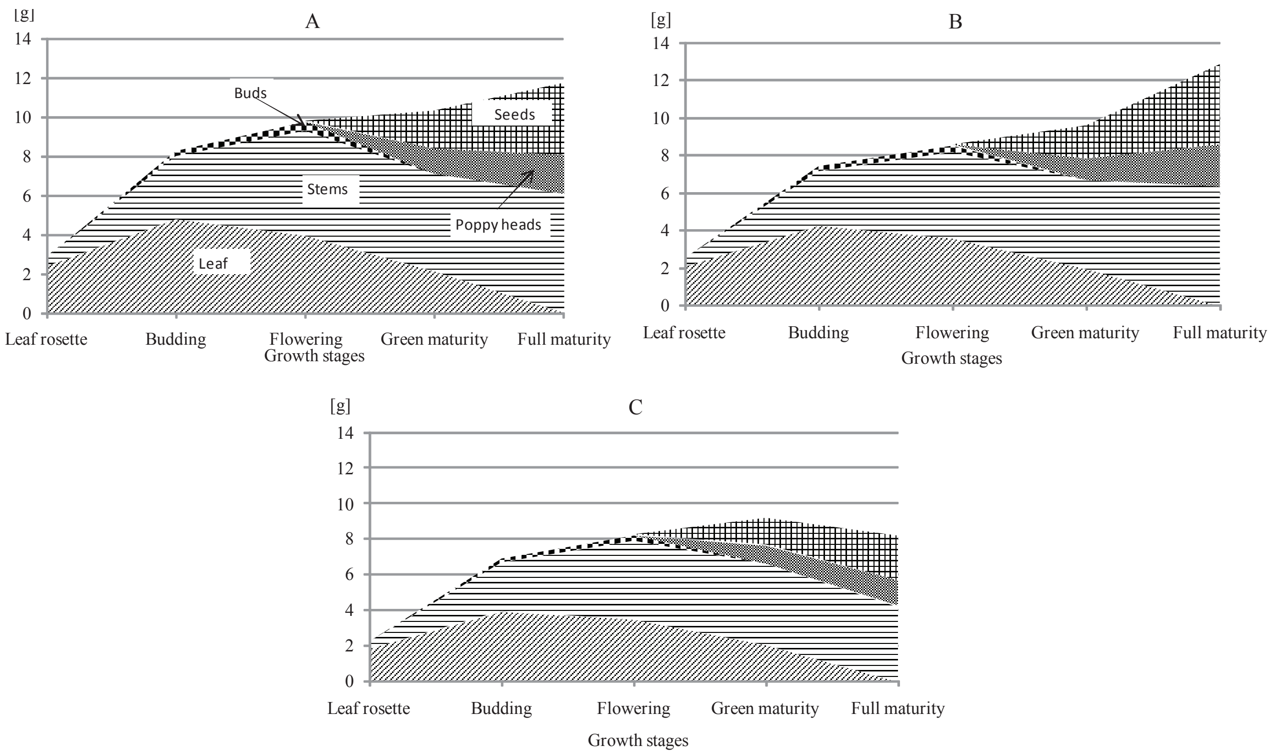

Fig. 2. Comparison of the proportions of individual plant components in dry weight of poppy plants at characteristic growth stages originating from the following sowing dates (means for growing years), A – early date, B – optimal date, C – delayed date.

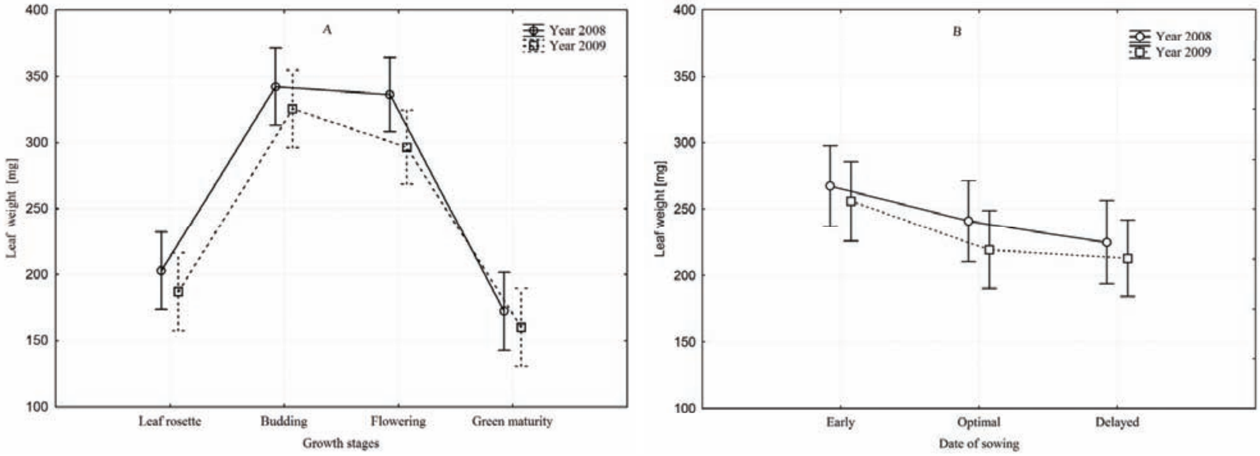

Fig. 3. Single leaf weight of the poppy plant depending on the growth stage and growing year (A) and on the sowing date and growing year (B).

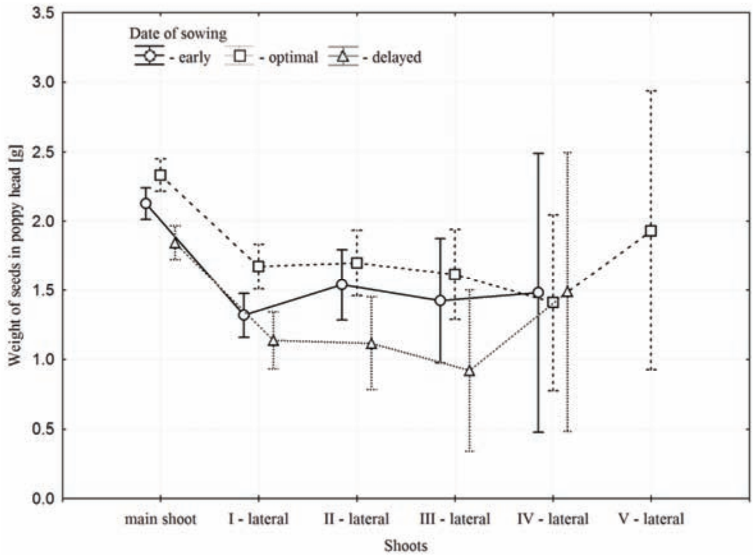

Fig. 4. The effect of the poppy sowing date on seed weight per poppy head depending on the type of shoot – main or lateral shoots.

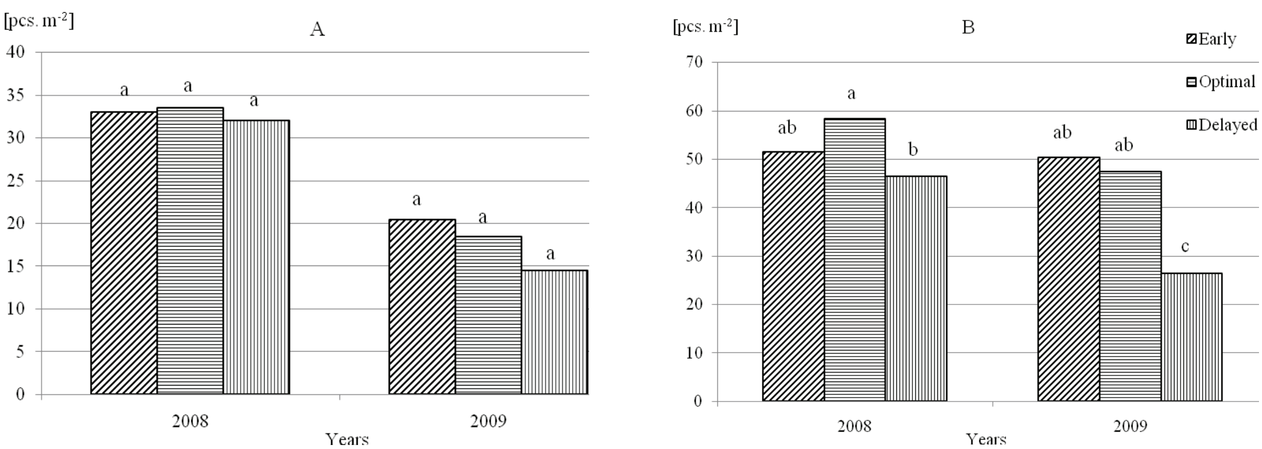

Fig. 5. The effect of the poppy sowing date and growing year on the number of poppy plants per 1 m^2 (A) and the number of poppy heads per 1 m^2 (B). Bars designated with different letters are significantly different at the level of p=0.05.

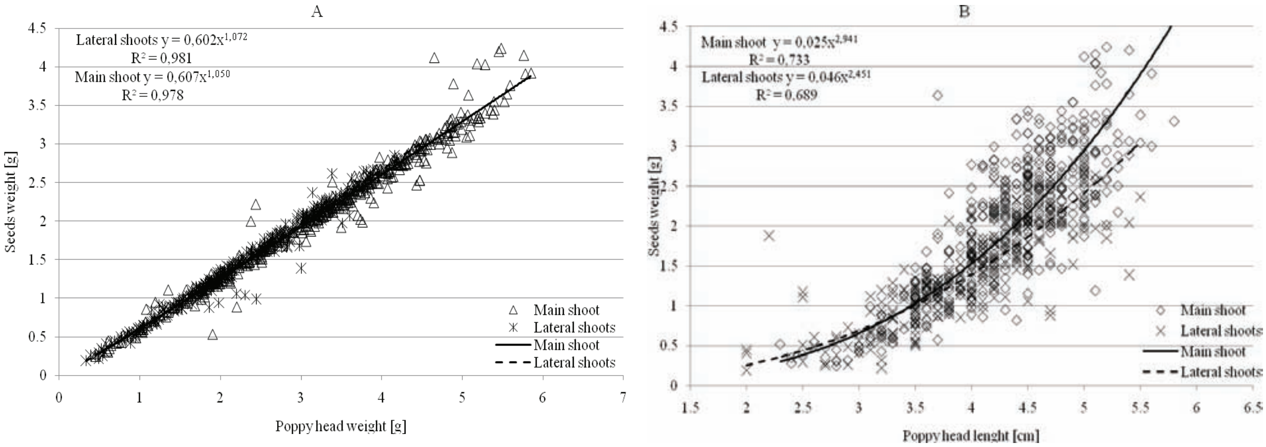

Fig. 6. Seed weight per poppy head of the main shoot or lateral shoots depending on the total weight of the fruit (A) and its length (B).

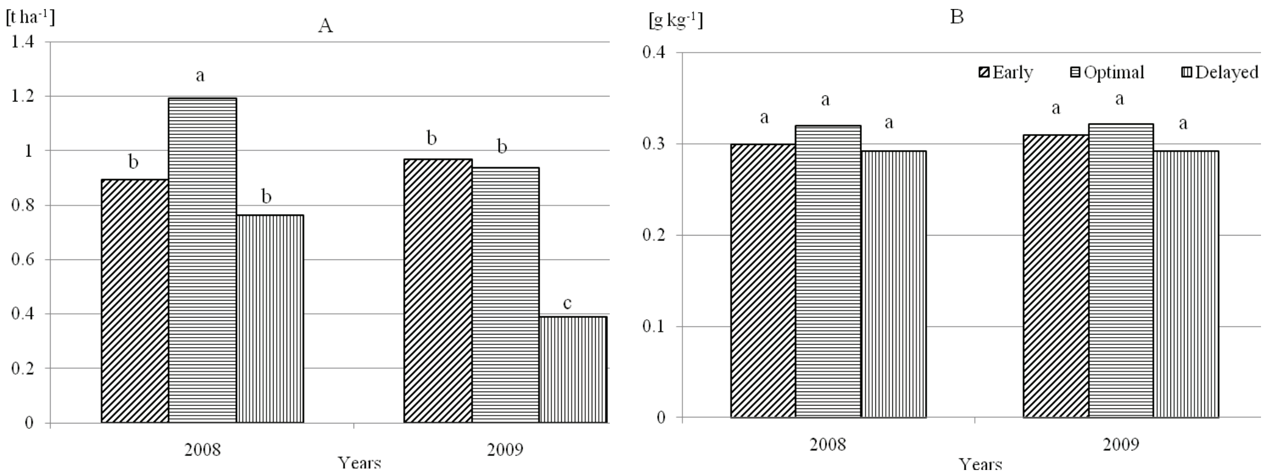

Fig. 7. Poppy seed yield (A) and the harvest index (B) depending on the sowing date and growing year. Bars designated with different letters are significantly different at the level of p=0.05.

Table 1.
Weather conditions of poppy vegetation period in two years

Month	Temperature [°C]			Precipitation [mm]		
	2008	2009	Long-term	2008	2009	Long-term
IV	8.6	11.4	8.1	35.1	0.0	50.2
V	14.1	13.6	13.7	27.5	99.6	65.3
VI	18.5	16.2	16.5	25.9	163.4	80.0
VII	19.1	20.2	18.2	142.1	71.7	74.9
VIII	18.2	18.8	17.9	45.2	66.7	78.5
Range of vegetation period	15.7	16.04	14.9	275.8	401.4	348.9

Table 2.
Stem and leaf dry matter (g) in poppy plants at characteristic growth stages depending on the sowing date and growing year

Stage	Year	Stem dry matter				Leaf dry matter			
		Date of sowing							
		early	optimal	delayed	mean for years	early	optimal	delayed	mean for years
Leaf rosette	2008	0.50±0.17	0.47±0.19	0.42±0.09	0.46±0.16	2.51±1.08	2.33±1.20	1.89±0.41	2.24±0.97
	2009	0.44±0.08	0.42±0.09	0.39±0.08	0.42±0.08	2.25±0.74	1.83±0.39	1.79±0.36	1.96±0.55
	$\overline{x}$	0.47±0.13	0.44±0.15	0.41±0.08		2.38±0.91	2.08±0.91	1.84±0.38	
	$NIR_{0,05}$ – $LSD_{0.05}$		r.n. – *n.s.*		r.n. – *n.s.*		r.n. – *n.s.*		r.n. – *n.s.*
Budding	2008	3.36±0.70	3.05±1.08	2.82±0.83	3.07±0.88	4.93±1.49	4.51±1.95	4.07±1.39	4.50±1.61
	2009	3.16±0.43	2.82±0.83	2.65±0.65	2.88±0.67	4.63±0.92	3.93±1.32	3.78±1.18	4.11±1.18
	$\overline{x}$	3.26±0.58	2.93±0.95	2.73±0.73		4.78±1.22	4.22±1.65	3.93±1.26	
	$NIR_{0,05}$ – $LSD_{0.05}$		r.n. – *n.s.*		r.n. – *n.s.*		r.n. – *n.s.*		r.n. – *n.s.*
Flowering	2008	5.38±1.30	4.80±1.17	4.42±0.65	4.89±1.11	3.93±0.58	3.57±0.77	3.39±0.66	3.64±0.68
	2009	5.38±1.30	4.53±0.65	4.53±0.65	4.78±0.94	3.93±0.58	3.49±0.63	3.49±0.63	3.62±0.62
	$\overline{x}$	5.38±1.25	4.65±0.91	4.48±0.63		3.93±0.55	3.53±0.67	4.45±0.62	
	$NIR_{0,05}$ – $LSD_{0.05}$		r.n. – *n.s.*		r.n. – *n.s.*		r.n. – *n.s.*		r.n. – *n.s.*
Green maturity	2008	5.08±0.50	4.77±0.78	4.59±0.68	4.83±0.66	2.11±0.39	2.06±0.43	1.95±0.35	2.04±0.38
	2009	5.01±0.50	4.68±0.71	4.52±0.67	4.72±0.65	2.09±0.36	2.00±0.40	1.97±0.36	2.01±0.37
	$\overline{x}$	5.04±0.48	4.72±0.71	4.54±0.65		2.10±0.36	2.02±0.40	1.96±0.34	
	$NIR_{0,05}$ – $LSD_{0.05}$		r.n. – *n.s.*		r.n. – *n.s.*		r.n. – *n.s.*		r.n. – *n.s.*
$NIR_{0,05}$ – $LSD_{0.05}$ between stages		0,626	0.665	0.524		0.803	0.960	0.708	

Table 3.
Comparison of plant height and number of leaves in poppy plants at characteristic growth stages depending on the sowing date and growing year

Stage	Year	Plant height (cm)				Number of leaves (pcs.)			
		Date of sowing							
		early	optimal	delayed	mean for years	early	optimal	delayed	mean for years
Leaf rosette	2008	9.6±3.1	9.8±3.0	10.7±3.3	10.0±3.1	10.9±1.4	11.2±1.5	10.6±1.0	10.9±1.3
	2009	9.2±3.3	10.7±3.3	9.2±3.4	9.7±3.3	10.6±1.3	10.5±1.0	10.4±1.0	10.5±1.0
	$\overline{x}$	9.4±3.2	10.2±3.1	9.9±3.3		10.8±1.3	10.9±1.3	10.5±0.9	
	$NIR_{0,05} – LSD_{0.05}$		r.n. – *n.s.*		r.n. – *n.s.*		r.n. – *n.s.*		r.n. – *n.s.*
Budding	2008	60.3±4.9	60.2±6.7	59.5±6.2	60.0±5.8	13.1±1.9	13.0±2.0	12.8±1.6	13.0±1.8
	2009	60.6±5.0	58.8±6.2	57.9±5.4	59.1±5.5	12.9±1.5	12.4±1.5	12.4±1.6	12.6±1.5
	$\overline{x}$	60.5±4.8	59.5±6.3	58.7±5.7		13.0±1.7	12.7±1.8	12.6±1.6	
	$NIR_{0,05} – LSD_{0.05}$		r.n. – *n.s.*		r.n. – *n.s.*		r.n. – *n.s.*		r.n. – *n.s.*
Flowering	2008	110.3±11.5	108.7±11.5	110.3±10.5	109.8±10.7	14.6±1.4	15.0±1.4	15.2±1.5	14.9±1.7
	2009	70.4±10.9	70.5±12.1	70.1±12.6	70.3±11.5	14.5±1.3	15.1±1.3	15.1±1.4	14.9±1.3
	$\overline{x}$	90.4±10.8	89.6±11.5	90.2±11.3		14.6±1.9	15.1±1.3	14.2±1.3	
	$NIR_{0,05} – LSD_{0.05}$		r.n. – *n.s.*		r.n. – *n.s.*		r.n. – *n.s.*		r.n. – *n.s.*
Green maturity	2008	127.7±3.5	126.8±4.1	127.8±4.0	127.4±3.8	12.3±2.6	13.6±2.6	13.2±2.6	13.0±2.5
	2009	87.2±3.1	88.2±4.4	87.4±3.6	87.6±3.7	12.7±2.5	13.3±2.4	13.7±2.3	13.2±2.4
	$\overline{x}$	107.5±3.2	107.5±4.1	107.6±3.9		12.5±2.5	13.5±2.3	13.5±2.4	
	$NIR_{0,05} – LSD_{0.05}$		r.n. – *n.s.*		r.n. – *n.s.*		r.n. – *n.s.*		r.n. – *n.s.*
$NIR_{0,05} – LSD_{0.05}$ between stages		5,19	5.81	5.64		1.64	1.51	1.44	

Table 4.
Comparison of classes of poppy plants with a different number of capsules originating from particular sowing dates, including their proportion in the population, height of individuals and plant dry matter, including seeds, as well as the harvest index. Analysis of the contribution of plant classes to seed yield per 1 m^2

Date of sowing	Number of capsules per plant	Proportion of plants in the crop population (%)	Plant height ± SD (cm)	Plant dry matter (stem with capsules) (g)	Weight of seeds per plant (g)	Contribution of plant classes to seed yield per 1 m^2 (%)	Harvest index (HI) (%)
Early	1	55.3	101.6±10.1	6.18±2.28	1.71±0.64	32.2	27.8
	2	29.1	106.2±11.1	11.16±2.32	3.47±0.80	34.4	31.0
	3	11.3	96.5±15.3	16.08±3.05	5.37±1.13	20.7	33.6
	4	3.6	91.6±16.4	23.86±2.55	8.43±0.96	10.3	35.5
	5	0.7	101.5±12.5	29.69±9.85	10.13±2.03	2.4	34.9
Optimal	1	51.2	94.3±9.3	6.09±2.97	1.81±0.93	25.5	29.2
	2	27.3	100.7±8.9	12.19±2.41	4.16±0.98	31.4	34.0
	3	12.5	99.8±10.6	17.31±3.26	6.00±1.33	20.7	34.5
	4	6.6	99.4±11.3	23.46±3.39	8.31±1.83	15.1	35.2
	5	1.7	98.8±13.9	25.69±3.34	9.34±2.00	4.7	36.2
	6	0.7	110.1±1.3	38.47±0.54	13.70±0.47	2.6	35.6
Delayed	1	65.4	93.8±13.4	5.39±2.35	1.54±0.80	41.8	27.7
	2	22.4	98.9±11.9	10.47±2.16	3.35±0.78	31.2	31.9
	3	8.4	98.4±16.3	14.69±2.44	4.74±0.89	16.6	32.3
	4	2.8	102.2±5.5	18.93±2.44	5.89±0.78	6.9	31.1
	5	0.9	90.7±8.9	29.08±2.02	10.12±0.86	3.5	34.9

Stem and leaf dry weight per poppy plant, at characteristic growth stages associated with plant greenness, did not differ significantly (Table 2). Both the delay in sowing date and worse plant growth conditions in 2009 had an effect on the reduction in the weight of stems and leaves – the main components of above-ground plant biomass, in particular at the leaf rosette and budding stages. The weight of leaves at the leaf rosette and budding stages was higher than that of stems. It was as late as the flowering stage that the stems gained an advantage in total plant matter. In turn, at the green maturity stage of the poppy plants, the weight of leaves declined but their number did not decrease significantly, probably due to some equivalent processes, i.e. the falling of large leaves after the end of the life cycle which had a large area and weight and were located in the lower and middle part of the stem (plant), as well as due to the formation of small leaves in the upper sections of the main and lateral shoots. At this stage, stem dry matter also decreased minimally, in this case probably on account of redistribution of assimilates from this organ to the developing seeds. Plant dry weight per poppy plant was lower in 2009, in particular at the flowering stage (Fig. 1). In turn, plant dry weight per 1 m^2 was significantly lower in 2009 due to soil drought during seed germination. In this year, two adverse events occurred simultaneously after sowing, that is, self-thinning of plants in the crop as a consequence of poor emergence. On the other hand, the plants strongly sought after generative development the duration of which was shortened; therefore, they were not able to increase their biomass to such a degree that there would be a significant compensation of the above-ground biomass of the poppy plants. An area chart (Fig. 2) shows the proportions of individual components of a single poppy plant in the participation in dry matter at all growth stages, depending on the sowing date.

Plant height at particular stages was determined to a small extent by the sowing date of poppy (Table 3). The delay in sowing date showed a slight tendency towards a reduction in plant height at the budding stage. Plant height was reduced more strongly by the growing conditions in particular years. In 2009 the poppy plants were lower from the budding stage. The poppy growth conditions in this year are described above. The lower poppy plants in 2009 had more lateral branches, which should be considered to be an adaptive element that shows signs of compensation in a less dense crop. Number of leaves is a very similar characteristic due to high leaf polymorphism of the poppy plant. As a result of this correlation, the rosette leaves and those growing out of the stem below have a larger area and, in particular, a larger weight. However, the upper and sessile small leaves, functioning at the green maturity stage of poppy, had a similar weight, even though their number did not decrease significantly compared to foliage at the flowering stage. Figure 3 presents additional and precise information on this aspect. The data on dry weight per leaf at successive growth stages inform that at the budding and flowering stages, irrespective of the study year, these organs of the poppy plants had the highest unit weight. The delay in sowing date caused a trend towards a reduction in dry weight per leaf in the poppy plants.

Table 4 and Figure 4 presents poppy plant classes distinguished on the basis of the number of seed capsules formed. Poppy seeds sown at the optimal date produced plants that had even six capsules. But the percentage of this group of plants in the crop population should be estimated as low, as it reached a bare 0.7%. In analysing the poppy plant populations originating from particular sowing dates, a similar growth trend can be noticed – a slightly higher height of the plants that produced more seed capsules. This direction in the growth of low-morphine poppy plants should be interpreted as their efforts to ensure the best exposure of poppy heads to the inflow of photosynthetically active radiation (PAR) to the fruits located in such a way. In the case of the delayed sowing date, the number of plants with a single capsule increased in the crop. A direct comparison of the group of single-capsule poppy plants, grown from seeds sown at different dates, shows slightly higher productivity of those sown at the optimal time (Fig. 5).

Seed yield from the single-capsule plants originating from optimal and delayed sowing was, respectively, 1.81 and 1.54 g. In spite of the highest proportion of single-capsule plants in the poppy population, in the case of the optimal and delayed sowing dates the plants that had produced two capsules had the largest contribution to seed yield per unit area. Seed weight per poppy head of the main or lateral shoots, depending on the total weight of the fruit (a) and its length (b), was significantly high and showed a linear pattern (Fig. 6). The number of fruits – poppy heads produced on a single poppy plant depended on the sowing date, as shown in the results presented in Figure 7. It was determined that poppy sowing at the early and optimal date allows a similar yield to be obtained, whereas the delay in sowing date significantly decreased yield, in particular in 2009 (Fig. 7).

DISCUSSION

The studied sowing dates of low-morphine poppy, cv. Mieszko, resulted in significant variation in plant growth during the growing period. Both the delay in sowing date in both years of the study and inappropriate seed germination conditions in 2009 reduced leaf and stem dry matter per plant, in particular at the beginning of ontogenesis, i.e. at the leaf rosette and budding stages. In the literature on poppy biology and productivity, dry matter per plant at characteristic growth stages has not been generally analysed for poppy plants grown under field conditions. This applies to both the high- and low-morphine form. Wang et al. (1997) determined that the growth of young poppy plants under controlled conditions (phytotron), from the young plant stage to the flowering stage, was not dependent on the temperature parameters under investigation.

The proportions of particular components of a single poppy plant at all growth stages were in accordance with expectations. The contribution of particular plant organs to above-ground plant biomass was dependent on the sowing dates studied and this agrotechnical factor had a significant corrective force. Two leading components of the poppy plant – that is, stems and leaves – had a dominant role in determining plant weight. Zając et al. (2010) found that the cv. Mieszko, representing low-morphine poppy, showed a high constancy of its specific characters and, as a result of that, plant density in the crop was significantly related to climatic patterns. In turn, plant density determines the number of head capsules per plant in the crop. In a more dense poppy population, plants with a larger number of poppy heads were higher and due to this they were more massive and, at the same time, more productive. A detailed biological inventory made at the full maturity stage showed that in the low-morphine poppy crop different categories of plants could be distinguished which produced a different number of poppy heads, and the direction of this biological process was almost the same for the sowing dates under comparison. The number of heads per poppy plant was dependent on plant density in the crop which was determined by climatic conditions of the growing year and sowing time, therefore it fluctuated within quite a wide range; this conclusion confirms both older findings made by Jabłoński (1967), Fulara (1971), and Budzyński (1985), and more recent ones made by Wójtowicz (2007). In their study of 404 genotypes from a world-wide collection of poppy, Brezinová et al. (2009) found that a single plant produced an average of 2.05 poppy heads, and the range of this trait was relatively small, since it was from 1.45 to 2.94, which are the minimum and maximum values. Variation in seed yield per poppy head is determined by flowering biology, since a single flower of the poppy plant blooms for one day in sunny and warm weather, while in the conditions of cloudy, cold and rainy weather flowering extends to 2-3 days. The flower on the main shoot of the plant blooms first, and then the flowers on the lateral shoots bloom, hence a single plant flowers for several days, while flowering of the crop extends over a period of 8-15 days (Muśnicki, 2003). It has been determined that high-morphine poppy plants grown with a row spacing of 30-40 cm and 10-20 cm distance between the plants in the row produce on average 3-4 poppy heads per plant (Németh, 2006). Plants of the low-morphine poppy cv. Sujata, grown in India at a similar row spacing, have a similar number of fruits (US Patent, 2004). In the present study, the low-morphine poppy plants sown at the optimal date formed on average 2.2 poppy heads. A record number of poppy heads, that is, more than six pieces per poppy plant of the cv. Shyama, were obtained after foliar application of the growth regulator Triacontanol®, whereas in the control treatments the plants produced only four fruits (Srivastava and Sharma, 1990). But other authors have not verified poppy productivity using this method. Under the conditions of pot experiments with nitrogen fertilization of poppy, some researchers observed a much lower number of poppy heads per plant - ca. 1.4 pieces (Lošák and Richter, 2004). The results of the present study showed that there were strict and linear correlations between the total weight of the poppy head and the weight of seeds from this fruit; however, the location of the fruit on the main or lateral shoots was irrelevant. The poppy heads situated on the main shoots of the low-morphine poppy plants gave higher seed yield compared to capsules located on the lateral shoots. In the Czech Republic, a world-leading producer of poppy seed, poppy growers now seek to have a density of 65-70 poppy plants per 1 m^2 which will jointly produce about 100 poppy heads; the assumption is that plants should have one or two poppy heads that will individually produce seed yield of 2.2-2.5 g (Novák et al. 2010).

CONCLUSIONS

The date of poppy sowing did not affect stem or leaf dry weight per poppy plant at characteristic growth stages. Number of leaves and plant height did not differ, either. Poppy leaves at the budding and flowering stages had the highest unit weight. However, different groups developed in the population of plants growing individually in the rows. Ultimately, this phenomenon resulted in increased variation in morphological traits of the plants.

Sowing poppy at the early and optimal date allowed individuals that produced poppy heads with a higher unit weight to be obtained in the crop population. The presence of massive plants was found in the plant populations originating from two sowing dates under comparison, that is, the early and optimal sowing time; they were higher and had a larger number of heads, hence they were more productive and gave above-average, 3-4-times higher yield per unit area. These plants optimized the harvest index for the whole crop.

The low-morphine poppy cv. Mieszko shows the capacity for certain compensation of the loss in plant density through a higher number of poppy heads per plant. But a delay in sowing by 1 week significantly reduces seed yield. The date of poppy sowing was shown to have a significant effect on yield in spite of the fact that it is a no-cost agrotechnical factor; therefore, efforts should be made to do sowing at the optimal time.

REFERENCES

Acock M.C., Wang Z., Acock B., 1996. Flowering and vegetative growth in opium poppy as affected by photoperiod and temperature treatments. Biotronics, 25: 11-21.

BBCH Monograph., 2001. Growth stages of mono-and dicotyledonous plants. 2 Edition (ed. U. Meier), Braunschweig.

Brezinová B., Macák M., Eftimová J., 2009. The morphological diversity of selected traits of world collection of poppy genotypes (*Genus Papaver*). J. Cent. Eur. Agric. 10 (2): 183-190.

Fulara A., 1971. Poppy cultivation. PWRiL W-wa, :89. (in Polish).

Hagel J.M., Weljie A.M., Vogel H.J., Facchini P.J., 2008. Quantitative 1H nuclear magnetic resonance profiling as a functional benomics platform to investigate alkaloid biosynthesis in opium poppy. Plant Physiol. 147(4): 1805-1821.

Havel J., Hájková M., Koprna R., Faberová I., Vrbovský V., 2008. Klasifikátor *Papaver somniferum* L. VÚO Opava, :16. (in Czech).

Honermeier B., 2006. Mohn: 262-270. W. Ölfrüchte, Faserpflanzen, Arzneipflanzen und Sonderkulturen. Heyland K.-U., Hanus H., Keller E.R. (eds.) Eugen Ulmer KG. (in German).

Jabłoński M., 1967. Impact of row spacing and crop thinning methods on poppy yield. Pam. Puł. 25: 205-221. (in Polish).

Kosek Z., Pšenička P., 2010. Osivo maku:103-116. [In:] Mak praca zbiorowa J. Vašák (ed.). Powerprint Praha. (in Czech).

Lošák T., Richter R., 2004. Split nitrogen doses and their efficiency in poppy (*Papaver somniferum* L.) nutrition. Plant Soil Environ. 50 (11): 484-488.

Muśnicki Cz., 2003. Oil poppy.: 463-472. [In:] Szczegółowa Uprawa Roślin Z. Jasińska, A. Kotecki (eds). Tom 2, AWA Wrocław. (in Polish).

Németh E., 2006. Cultivation of poppy in the temporate zone: 224-240. [In:] Poppy. The genus Papaver. J. Berneth (ed.). University of Horticulture and Food Industry. Budapest.

Novák J., Vašák J., Zukalová H., 2010. Biologie maku, pozadavky na prostredi, ideotyp, alkaloidy: 33-64. [In:] Mak praca zbiorowa J. Vašák (ed.). Powerprint Praha. (in Czech).

Ogrodowczyk M., Wawrzyniak M., 2007. Investigations of morphine content in capsules from main and lateral plant stems in different forms of opium poppy (*Papaver somniferum* L.). Rośliny oleiste – Oilseed Crops. XXVIII: 109-117.

Pushpangadan P., Singh S.P., 2001. Poppy: 261-268. [In:] Handbook of herbs and spices K.V. Peter (ed.). Woodhead Publishing Cambridge England.

Srivastava N.K., Sharma S., 1990. Effect of Triacontanol on photosynthesis, alkaloid content and growth in opium poppy (*Papaver somniferum* L.). Plant Growth Regulation, 9: 65-71.

Suchorska K., 1990. Mak lekarski – *Papaver somniferum* L.: 283 i 317. [In:] Leksykon Roślin Leczniczych. A. Rumińska i A. Ożarowski (eds.). Państwowe Wydawnictwo Rolnicze i Leśne Warszawa. (in Polish).

US Patent 6730838., 2004. Opiumless and alkaloid-free nonnarcotic opium poppy (*Papaver somniferum*) variety 'Sujata'.

Vašák J., Vlk R., 2010. Zakladni informacje: 11-22. [In:] Mak praca zbiorowa J. Vašák (ed.). Powerprint Praha. (in Czech).

Wang Z., Acock M.C., Acock B., 1997. Phases of development to flowering in opium poppy (*Papaver somniferum* L.) under various temperatures. Ann. Bot. 80(4): 547-552.

Wójtowicz M., 2007. Effect of environmental and agronomic conditions on yield of poppy cultivars. Rośliny oleiste – Oilseed Crops. XXVIII: 261-270. (in Polish).

Zając T., Oleksy A., Klimek-Kopyra A., 2010. The influence of sowing date on yield and features of low morphine poppy (*Papaver somniferum* L.) cv. Mieszko. Rośliny oleiste – Oilseed Crops. XXXI: 333-350. (in Polish).

Porównanie wzrostu i produkcyjności niskomorfinowego maku (*Papaver somniferum* L.) odm. Mieszko w zależności od terminu siewu

Streszczenie

Jednoczynnikowe doświadczenie polowe z terminami siewu maku, niskomorfinowej odm. Mieszko, (L-M P) przeprowadzono w latach 2008-2009. Porównano trzy terminy siewu maku: I – wczesny; II – optymalny; III – opóźniony. Stwierdzono, że termin siewu nie oddziaływał istotnie na cechy morfologiczne roślin maku w charakterystycznych fazach wzrostu. Wykazano występowanie w łanie maku populacji roślin różniących się liczbą wykształconych makówek od 1 do 6. Intensywność wydzielania się w łanie zróżnicowanych rozwojowo i produkcyjnie grup roślin L-M P, zależała od terminu siewu i lat wegetacji. Wysiew maku w terminach wczesnym lub optymalnym umożliwił uzyskanie w populacji łanu roślin wykształcających makówki o większej jednostkowej masie, które były bardziej produktywne. Rośliny maku o trzech i więcej makówkach, w znaczącym stopniu kreowały plonowanie z jednostki powierzchni. Udowodniono, że termin siewu maku, pomimo że jest beznakładowym czynnikiem agrotechnicznym, ma znaczący wpływ na rozwój roślin, co w konsekwencji przenosiło się na plonowanie. Z utylitarnych względów należy dążyć do przeprowadzenia siewu L-M P w terminie optymalnym.