Effect of the date and harvest method on the yield and quality of milk thistle (*Silybum marianum* L. Gaertn.) cultivated on light soil

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Summary

Over 2004–2006 at the Agricultural Experiment Station at Mochełek (University of Technology and Life Sciences in Bydgoszcz), there was evaluated the effect of harvest methods and dates on the yield and quality of fruit (achene) of milk thistle cultivated on light soil. A two-stage harvest was applied when 30% of inflorescences had pappus and one-stage harvest when 30 or 50% of inflorescences developed the pappus. The highest fruit yield (1.43 $t \cdot ha^{-1}$) was recorded from the one-stage harvest when 30% of the flower heads were ripe. A delay in the one-stage harvest resulted in an increase in the content of silymarin (from 2.5 to 2.7%) but in a decrease in the fruit yield to 1.17 $t \cdot ha^{-1}$ that was comparable with the two-stage harvest (1.09 $t \cdot ha^{-1}$). At an earlier ripeness stage (30% of inflorescences with pappus) the content of silymarin was negatively correlated with the share of the pericarp in the achene weight as well as with the achene yield. The harvest dates and methods resulted in differences in the silymarin yield from 27.3 (two-stage harvest) to 35.6 $kg \cdot ha^{-1}$ (earlier one-stage harvest).

Key words: *milk thistle, Silybum marianum, silymarin, harvest date, two-stage harvest, one-stage harvest*

INTRODUCTION

Milk thistle (*Silybum marianum* L. Gaertn.) is an annual plant of *Asteraceae* family. This species is among the top medicinal plants cultivated in Poland. The complex of flavonolignans (silymarin), used for pharmaceutical purposes, is located in the achene pericarp. The extract of silymarin has antihepatotoxic and liver-protective properties.

Most authors recommend cultivation of milk thistle on fertile, humic soils of good moisture conditions [1-3]. In practice these soils are mostly allocated to high-yielding typical agricultural crops. A high demand for milk thistle achenes calls for looking for the cultivation potential also on light soils. Under such conditions milk thistle plants should develop a lower vegetative weigh and fewer inflorescences (flower heads) on lateral shoots, which should facilitate the one-stage harvest.

In general, since the vegetative weight has to dry, it is recommended to harvest milk thistle at two stages [1, 3]. Although, in that case, while threshing there are high raw-material losses. In the experiment reported by Załęcki and Górna [4], set up on good soil, very good effects were recorded by applying a one-stage harvest with the combine-harvester. Cutting at 30% of ripe flower heads, there were noted the highest fruit yields and the highest content of silymarin. Milk thistle demonstrates uneven inflorescence ripening. The inflorescences at the top of the stems develop and ripen earlier, and then, successively, on lateral branches. A delay in the milk thistle harvest causes shedding of the most precious achenes from the main flower heads [1, 4]. However, the more ripe the flower heads, the higher the content of silymarin in achenes. The highest content of flavonolignans is found in dark ripe achenes [5-7].

The aim of the present research was to determine the most beneficial date and method of cultivation and harvest date of milk thistle cultivated on light soil, considering the fruit yield-size, content of silymarin in the fruit.

MATERIALS AND METHODS

The single-factor field experiment, in four replications, was carried out over 2004–2006 at the Experiment Station of the Faculty of Agriculture at Mochełek, the University of Technology and Life Sciences in Bydgoszcz. The plot area was 30 m^2. The experiment was set up on luvisol, formed with the heavy loamy sand, of the agronomic category: light soil. The soil represented the IVb soil valuation class, of the good rye complex.

Milk thistle was cultivated after cereals in the third or fourth year after manure. Pre-sowing all across the area of the experiment mineral fertilisation was applied: N – 50, P – 30.5 and K - 58 $kg \cdot ha^{-1}$. 'Silma' - the Polish milk thistle cultivar was sown. Right after sowing which coincided between 1st and 10th of April Stomp 330 EC herbicide was applied.

The following harvest methods and dates were applied:

- two-stage harvest at the phase of 30% flower heads with pappus,
- one-stage harvest at the phase of 30% of flower heads with pappus,

- delayed one-stage harvest when 50% of flower heads had pappus, which was 3–5 days after the earlier one-stage harvest; at that stage in which most lateral flower heads of the first raw also produced pappus.

The two-stage harvest was made with the use of the hay mower, 20–30 cm above the soil surface. Once the plants got dry, threshing was performed with the plot combine harvester, Wintersteiger elite type. Harvesting the cuts for threshing was performed with maximum special care to limit shedding of plants and to minimise losses caused by achene shedding. Right after harvest achenes were cleaned and dried further to the moisture of 8%.

The following measurements and determinations were made: the number of achenes per main flower head for 10 randomly selected main flower heads (right prior to plant cutting), the achene yield, thousand fruit weight, share of dry pericarp in the achene weight. To separate the pericarp from the cotyledons of achenes, the method of determining the share of 'the rind' in barley grain was applied [8]. A hundred of fruits was weighted, placed into a gauze bags in the steam bath for half an hour. Then achenes were rinsed with cold water, crushed and the pericarp was separated from the seed. Having dried, the air-dry pericarp was weighted. The total content of silymarin in milk thistle fruit was determined with the spectrophotometric method following standard PN-91/R-87019 [9]. The results of chemical tests and measurements were verified with the analysis of variance. To evaluate the significance of treatment mean differences, the Tukey test was applied at $p=0.05$. The coefficients of simple correlation between the characters researched were calculated.

The latest milk thistle harvest date was on August 9, 2004 and the earliest on July 21, 2006. The weather conditions at the final vegetation period were, in general, favourable to milk thistle ripening and harvest (tab. 1).

Table 1.

Mean daily temperature and total precipitation recorded at the Experiment Station at Mochełek over ripening and harvest time of milk thistle.

month	decade	2004		2005		2006	
		temp. [°C]	precipitation [mm]	temp. [°C]	precipitation [mm]	temp. [°C]	precipitation [mm]
July	II	15.9	7.7	20.2	4.2	21.8	9.7
	III	17.9	16.0	18.5	29.4	22.7	10.0
August	I	19.8	53.8	15.3	25.7	17.6	80.1

RESULTS

The mean number of achenes per main head was 107.6 (tab. 2). A significantly higher number of achenes were noted in the flower heads allocated for two-stage harvest and for the earlier one-stage harvest (30% of flower heads with pappus).

A delay in the one-stage harvest (50% of flower heads with pappus) resulted in a decrease in the number of achenes, which was due to their partial shedding from the heads on the main stems. In all the years a lower weight was recorded for the fruit from the two-stage harvest treatments, which was also due to shedding of the biggest, earliest-ripening fruit. On average for the research period, the harvest date and method did not result in significant differences in the share of the dry pericarp in the achene weight. However, with a delay in the harvest date, a tendency to decrease of share of the pericarp in the fruit weight was observed. The achene yield was, on average, 1.23 $t \cdot ha^{-1}$. It was shown that the one-stage harvest when 30% of the heads were ripe allowed to produce significantly higher fruit yields than two-stage harvest. A delayed one-stage harvest did not result in a significant decrease in achene yield, but the yield difference was 260 $kg \cdot ha^{-1}$, as compared with the earlier harvest. No significant difference was recorded between the yield level from the delayed one-stage harvest when 50% of the flower heads were ripe and the two-stage harvest. The mean content of silymarin in milk thistle fruit was 2.55% d.m. of fruit. Milk thistle harvest at a one-stage at later head ripeness stage (50% of flower heads with pappus) contained significantly more silymarin in achenes than that harvested when 30% of the flower heads produced pappus. The yield of silymarin depended significantly neither on the harvest date nor method but there was recorded a clear tendency to its increase when the one-stage harvest was applied, especially at an earlier plant development stage than the two-stage harvest.

Table 2.

Yield of milk thistle achenes and silymarin as well as its structure components

harvest method and date	number of achenes [no.$\cdot$ flower head^{-1}]	thousand fruit weight [g]	share of pericarp in the fruit weight [%]	achene yield [$t \cdot ha^{-1}$]	silymarin content [%]	silymarin yield [$kg \cdot ha^{-1}$]
two-stage (30%)*	113.0	27.3	49.2	1.09	2.50	27.3
one-stage (30%)*	110.0	28.4	48.9	1.43	2.49	35.6
one-stage (50%)*	99.8	28.3	48.0	1.17	2.66	31.1
LSD	9.73	n.s.	n.s.	0.316	0.114	n.s.
mean	107.6	28.0	48.7	1.23	2.55	31.3

n.s. – no significant difference at p=95%
* two-stage (30%) – two-stage harvest at the stage of 30% flower heads with pappus
one-stage 30% – one-stage harvest for 30% of flower heads with pappus
one-stage 50% – one-stage harvest for 50% of flower heads with pappus.

In general, relationships of correlation between the characters researched were similar for variants – two- and earlier one-stage harvest (30% of flower heads with pappus) and different when the one-stage harvest date was delayed (tab. 3). While harvesting when 30% of the flower heads was ripe, irrespective of the harvest method, there was noted a significant negative correlation between the achene yield and the content of silymarin as well as the share of the pericarp and the content of silymarin. The greater was the increase in the thousand fruit weight, the higher the increase the achene yield. While applying the one-stage harvest, irrespective of the harvest date, there was recorded a highly negative correlation between the thousand fruit weight and the content of silymarin.

Table 3.

Coefficients of correlation between selected characters of milk thistle

harvest method and date	character	thousand fruit weight	share of pericarp in fruit weight	silymarin content
two-stage harvest (30%)	achene yield	0.7411**	0.4873	–0.5653*
	thousand fruit weight	–	–0.0606	–0.0175
	share of pericarp in the fruit weight	–	–	–0.8946**
one-stage harvest (30%)	achene yield	0.6055*	0.1998	–0.7095**
	thousand fruit weight	–	0.5297	–0.8045**
	share of pericarp in fruit weight	–	–	–0.6517*
one-stage harvest (50%)	achene yield	0.4445	0.0562	–0.3086
	thousand fruit weight	–	0.1339	–0.6952**
	share of the pericarp in the fruit weight	–	–	–0.1368

*critical value of the coefficient of correlation 0.5324 (for v = 12 at the significance level $\alpha=0.05$)
**critical value of the coefficient of correlation 0.6614 (for v = 12 at the significance level $\alpha = 0.01$)

DISCUSSION

In the present experiment the milk thistle achene yield cultivated on light soil was, on average, 1.23 $t \cdot ha^{-1}$, with the content of silymarin of 2.55%. Under climatic conditions of Poland, especially on good soils the average yields are 1.0–1.7 $t \cdot ha^{-1}$, while the content of silymarin ranges from 2 to 3% [1-3, 10-12]. The present research results also point to light soils as applicable to grow milk thistle.

The results reported by Załęcki & Górna [4] demonstrated that the highest achene yields are reached for 30% of ripe flower heads. The results of Argentinean experiments [13] present a greater tolerance towards the milk thistle harvest date. According to these authors, the harvest can be performed after 14–18 days, when 20–50% inflorescences are dry. The present research showed that traditional two-stage harvest resulted in significantly lower fruit yields than one-stage harvest performed when 30% of flower heads had pappus. However, one shall remember that the one-stage harvest, as compared with the two-stage harvest, requires higher inputs for further raw-material drying since even ripe achenes over threshing get moist again. A delay in the one-stage harvest until 50% of flower heads had pappus did not have a significant effect on the decrease in achene yield as compared with the earlier one-stage harvest. However, it was the difference in the yield of 260 kg·ha^{-1}, which at the price of about PLN 3 per 1 kg of raw material could determine the cost-effectiveness of cultivation.

One of the biggest problems of milk thistle growing is achene shedding; the highest fruit losses concern fruit of the main flower heads which ripen earlier [1, 4, 6]. It is also confirmed by present results. In the flower heads allocated for earlier harvest there were more achenes than in the flower heads of the plants collected when 50% of flower heads had pappus. The number of achenes obtained in the main flower head (107.6) and in lateral flower heads (95.0) was, however, lower than reported by Kaźmierczak and Seidler-Łożykowska [14], which must have been due to cultivation under poorer soil conditions.

Reports by Carrier et al. [6] show that the synthesis of flavonolignans starts from the beginning of inflorescence fading in milk thistle. Therefore, the length of the ripening period and weather conditions at that time should be decisive for the synthesis of silymarin. In the present research a delayed one-stage harvest until 50% o flower heads with pappus increased the content of silymarin in achenes. Załęcki and Górna [4], however, recorded the highest content of silymarin (3.9%) when applying the one-harvest harvest when 30% of flower heads were ripe.

As reported by Andrzejewska and Skinder [10], a positive correlation between the achene yield and the content of silymarin was demonstrated. In present research, the higher was the achene yield, the lower the content of silymarin, but also for the harvest performed for 30% of flower head ripeness. Besides, the fruit harvested when 30% of flower heads had pappus showed a negative correlation between the share of the pericarp and the content of silymarin. While harvesting plants at a later date when 50% of the flower heads were ripe, no such relationship was recorded any more. The research by other authors [15] demonstrate that silymarin is not accumulated in all the layers of the pericarp. Therefore, the share of dry pericarp is not necessarily connected with the accumulation of flavonolignans but it can be important for the technological process of obtaining silymarin. Therefore, it is difficult, based on the present results and those reported by other authors to determine finally whether there is dependence between the size of achenes and the content of silymarin. Najda and Dyduch [16] point that plump fruit accumulates more silymarin. The analyses of the material involved in the present research showed, however, an opposite correlation. It seems that here there is no simple dependence but overlapping of many factors, including weather.

CONCLUSIONS

1. Cultivation of milk thistle on light soil makes it possible to produce the fruit yield comparable to the cultivation under better soil conditions and achenes meet the requirements of the content of silymarin in the pharmaceutical raw material.

2. The highest milk thistle fruit yield was recorded from the one-stage harvest when 30% of the flower heads were ripe. A few-day delay in the one-stage harvest resulted in an increase in the content of silymarin but, at the same time, achene shedding and a clear tendency to decreasing achene yield to the level recorded for the two-stage harvest.
3. The harvest date and method did not have a considerable effect on the silymarin yield, although there was noted a tendency for the benefit of a one-stage harvest, especially performed when 30% of the flower heads developed pappus.

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WPŁYW TERMINU I SPOSOBU ZBIORU NA PLON I JAKOŚĆ OSTROPESTU PLAMISTEGO (*SILYBUM MARIANUM* L. GAERTN.) UPRAWIANEGO NA GLEBIE LEKKIEJ

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

W latach 2004–2006 w Rolniczej Stacji Badawczej Mochełek, należącej do Uniwersytetu Technologiczno-Przyrodniczego w Bydgoszczy, oceniano wpływ sposobów i terminów zbioru na plony i jakość owoców (niełupek) ostropestu plamistego uprawianego na glebie lekkiej. Stosowano zbiór dwuetapowy w fazie, gdy 30% kwiatostanów posiadało puch kwiatostanowy oraz zbiory jednoetapowe wtedy, gdy 30 lub 50% kwiatostanów wykształciło puch kwiatostanowy. Największy plon owoców (1,43 $t \cdot ha^{-1}$) uzyskano ze zbioru jednoetapowego w fazie, gdy 30% koszyczków było dojrzałych. Opóźnienie zbioru jednoetapowego skutkowało wzrostem zawartości sylimaryny (z 2,5 do 2,7%), ale spadkiem plonu owoców do poziomu 1,17 $t \cdot ha^{-1}$, czyli porównywalnego ze zbiorem dwuetapowym (1,09 $t \cdot ha^{-1}$). We wcześniejszej fazie dojrzałości (30% kwiatostanów z puchem) zawartość sylimaryny była ujemnie skorelowana z udziałem perykarpu w masie niełupek, a także z plonem niełupek. Terminy i sposoby zbioru zróżnicowały plon sylimaryny w zakresie od 27,3 (zbiór dwuetapowy) do 35,6 $kg \cdot ha^{-1}$ (zbiór jednoetapowy wcześniejszy).

Słowa kluczowe: *ostropest plamisty, Silybum marianum, sylimaryna, termin zbioru, zbiór dwuetapowy, zbiór jednoetapowy*