Acta fytotechn. zootechn., 18, 2015(4): 79–82

Original Paper

Yield potential of milk thistle production in South-western Slovakia

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Milk thistle is annual to biennial medicinal plant from the *Asteraceae* family. Polyfactorial field experiment was established and investigated during the vegetation period of the years 2012–2014. The trial was arranged in one independent block. Plant material variety Silyb was harvested in the ontogenetic stage the achenes ripening. Three evaluated factors were as follows: crop residues – intercrop – fertilization. Milk thistle was integrated to four crop rotation design with following order of crops: common pea – winter wheat – milk thistle – maize. Average yield of milk thistle achenes significantly differ in the range from 479.6 kg ha^{-1} in 2012 up to 602.5 kg ha^{-1} in 2013. The highest yield of milk thistle was measured 745.0 kg ha^{-1} (2013 treatment: no crop residues, with intercrop, with fertilization). The impact of growing year on yield milk thistle achenes confirmed the high variability of yields. On output of yield milk thistle achenes we were confirmed highly significant effect of year and fertilization, and inconclusive impact of sowing intercrop and ploughing crop residues. In all evaluated years, significantly 20% higher average yield for treatments with mineral fertilization was confirmed. Based on the three-year results, it is recommended to continue the research of the production parameters of milk thistle yields in following growing seasons with focus to better used of yield potential of milk thistle in Slovak conditions.

Keywords: *Silybum marianum* L., yield, intercrop, fertilization, crop residues

1. Introduction

Milk thistle is annual (Habán, et al., 2009) to biennial medicinal plant from the *Asteraceae* family (Cwalina-Ambroziak et al., 2012), which could be planted as a cultural plant on arable land (Týr and Vereš, 2011). It is native to the Mediterranean, but is now widespread in many parts of the world (Malekzadeh, et al., 2011). Andrzejewska et al. (2011) reported that milk thistle is considered a plant drought resistant, and often it is sufficient normal rainfall. According Kubinek (1987) the greatest influence on the yield of seeds during the critical period (second-third decade of May) has rainfall. It is grown successfully on a wide range of soil types, from sandy soils to heavier clay soils (Karkanis et al., 2011). Many authors classified milk thistle as the most important medicinal plants (Wierzbowska et al., 2012). The achenes this medicinal plant, which is black, shiny, 5–7 mm long (Andrzejewska et al., 2011) content about 25% oil, which consists of 63% linoleic acid and about 20% oleic acid. Representation of the protein was 25–30% and flavonoids about 2% (Szczucińska et al., 2006).

Flavonoids are present in the drug active ingredient of milk thistle, which are collectively referred as a silymarin (Karkanis et al., 2011). The milk thistle achenes contents about 0.2–0.6% of silymarin, depending on the variety (Habán et al., 2010). Bhattacharya (2011) states, that milk thistle was once cultivated as a vegetable in Europe. After fending thorns, the leaves used in salads like spinach. The seeds are traditionally used in Europe as a means of supporting milk production in nursing mothers. In recent years the use of herbal preparations on the basis of milk thistle consumer has risen considerably in view of the return of native therapy (Tournas et al., 2013). It is also justified its use in human nutrition, as well as with specialists, dermatologists, beauticians and in oncology (Andrzejewska et al., 2011). In addition to medicinal value, the milk thistle can also be used within the phytoremediation of soil (clean soil by plants). Quality and production of drugs *Silybi mariani fructus* is largely influenced by culture (Habán et al., 2007). Czech origin have varieties Mirel (Habán and Habánová, 2009) a new varieties Aida and Verde released in 2014 (Habán, et al., 2015). Silma was bred and registered in 1990 in Poland (Karkanis et al., 2011). During 2013 and 2014, milk thistle growing dominated among the medicinal plants in Slovakia (Habán et al., 2015). There is a lack of information concerning agricultural systems of majority of medicinal plants. Incorporation of medicinal plant into crop rotation pattern helps to produce medicinal plant (Smatana and Macák, 2011)

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DOI: 10.15414/afz.2015.18.04.79–82

The aim of our research was to evaluate the influence of management of organic matter input and nitrogen fertilization on milk thistle yield of achenes.

2. Materials and methods

Field experiment was set up on an experimental basis Dolná Malanta, in the western part Žitava upland as a separate unit of the Danube Lowland. The locality has flat character with little declination to south (Habán et al., 2007). The average long-term (1961–1991) annual precipitation is 532.5 mm, for the vegetation period is 309.4 mm. The average long-term (1961–1991) annual temperature is 9.8 °C (Špánik et al., 1996).

Polyfactorial field experiment was established during the vegetation period of the years 2012–2014. The experiment was arranged in one independent block. Three evaluated factors were as follows: crop residues – intercrop – fertilization. Milk thistle was integrated to four crop rotation design with following order of crops: common pea – winter wheat – milk thistle – maize. Milk thistle was subjected to the experimental treatments as follows:

1. K – straw of forecrop removed from the field, R – straw incorporated into soil,
2. M – white mustard as a freezing-out intercrop, B – no intercrop,
3. O – no fertilization, F – with fertilization,
4. experimental year (2012, 2013, 2014).

Data of sowing: 22 March 2012, 18 April 2013, 10 March 2014. Plant material was harvested in the stage of the achenes ripening at 23 July 2012, 6 August 2013, 17 July 2014. Harvesting was done with adapted combine harvester. The yield data of milk thistle fruits were taken from randomly selected areas (3 × 1 m^2, two replications in each treatments) and calculated to the yield in kg per ha. Variety Silyb was registered in 1988. This variety is a silybinin chemovariety, containing approximately 2.5%. Silychristin in an amount of 1.5%, while silydianin absent (Indrák and Chytilová, 1992). The obtained data were evaluated statistically using the STATISTICA software with the analysis of variance (ANOVA), significant differences were calculated by the Tukey test.

3. Results and discussion

Yield of milk thistle achenes was significantly influenced by the year conditions and level of mineral fertilization (Table 1). The incorporating of crop residues or intercrop have no significant effect on yield of achenes.

The combination of temperature and precipitation pattern of growing period of milk thistle was not most appropriate for expression of yield potential of milk thistle variety Silyb in the years 2012–2014.

Table 1 Effect of crop residues, intercrops and fertilization on yield of *Silybi mariani fructus* in kg ha^{-1} during 2012–2014 (ANOVA)

Factor	Level of factor	F-test	Level of significance
Year	2012, 2013, 2014	54.516	0.0000^{++}
Crop residues	K – straw of forecrop removed from the field R – straw of forecrop incorporated into soil	1.835	0.1790
Intercrop	M – white mustard as a freezing-out intercrop B – no intercrop	1.833	0.1792
Fertilization	O – no fertilization F – with fertilization	25.277	0.0000^{++}

Table 2 Average temperature and rainfall of the experimental site in the years 2012–2014

Month	2012		2013		2014		Normal 1961–1990	
	temperature in °C	rainfall in mm	temperature in °C	rainfall in mm	temperature in °C	rainfall in mm	temperature in °C	rainfall in mm
I	1.1	51.0	-1.2	58.0	2.7	37.2	-1.7	31
II	-2.7	17.4	1.2	82.4	4.4	37.5	0.7	32
III	8.12	5.2	2.8 cold	93.2	9.3	15.4	5	30
IV	12.07	39.8	11.7	23 dry	12.4	48.9	10.4	39
V	17.64	15	15.2	65.6	15.1	57.6	15.1	58
VI	20.39	47.6	18.5	54.8	19.3	52.5	18	66
VII	22.95	109	22.2	2.2	21.8	64.1	19.8	52
VIII	22.1	152.3	22.85	15.4	19.3	55.9	19.3	61

DOI: 10.15414/afz.2015.18.04.79–82

Growing period of milk thistle was characterized by very warm March and warm April, warm Mai and warm June in 2012, with combination of lack of rainfall and extraordinary dry March and very dry Mai (Table 2). The yield of milk thistle achenes vary in very low range of yield from 312 kg ha^{-1} to 623 kg ha^{-1}.

Could but extraordinary wet March delay the start of sowing date to second decade of April. Dry April and normal wheatear condition in Mai and June were noted in 2013. Unfortunately extraordinary dry and very warm June cause loss of achenes before harvest. Year 2014 with extraordinary warm March wet deficit of precipitation (51% of Normal) with warm April condition supported only 527.5 kg ha^{-1} of achenes.

The year 2013 was the most productive year of whole evaluated period of 2012–2014. Treatments without forecrop residues reached yield from 437.0 kg ha^{-1} to 745.0 kg ha^{-1} while the yield of seeds with crop residues incorporation was in the range from 556.0 kg ha^{-1} to 715.0 kg ha^{-1}.

The second most productive growing year was 2014, when the crop yield fluctuated in an amount of 379.0 kg ha^{-1} for unfertilized treatment without crop residues after intercrop (KMO) to 658 kg ha^{-1} in fertilized treatment with crop residues without intercrop (RBF).

The lowest yield of *Silybi mariani fructus* were achieved in the vegetation year 2012, with average yield across the treatments 479.62 kg ha^{-1}. The higher yields was achieved on fertilization treatments from 507 kg ha^{-1} (RMF) to 623 kg ha^{-1} (KBF).

Seeds yield was statistically significant in descending order of 2013 – 2012 – 2014. During years 2012, 2013 and 2014 significantly higher yield was reached on fertilization treatments (600 kg ha^{-1} in an average) with comparison to treatments without mineral fertilization (479.5 kg ha^{-1} in an average).

Andrzejevska and Skinder (2006) evaluated yield potential of milk thistle, which was grown during the growing years 2003–2005 on an experimental station in Mochelek (Bydgoszcz). Yields achieved on the treatments with different sowing dates in the year 2003 range from 693 kg ha^{-1} to 1190 kg ha^{-1} and between growing years 2004 and 2005, from 1496 kg ha^{-1} to 1732 kg ha^{-1}.

In the most productive year of 2006, yield of milk thistle achenes reached a value of 1425.6 kg ha^{-1} at treatments with incorporation of forecrop residues without intercrop and fertilization up to 1832.0 kg ha^{-1} on treatments without crop residues and without intercrop, with the application of fertilizers at the locality Dolna Malanta (Habán et al., 2007).

The two-year field experiment (2007–2008) founded in potato production area in the area Vlková situated 710 m about see level, reached the yield of milk thistle seeds in the range from 256 kg ha^{-1} in 2007 without the use of organic fertilizer to 1132 kg ha^{-1} in 2008, in treatment with the use of organic fertilizers (Habán and Šustr, 2009). Milk thistle yields correspond with the conclusions of the authors regarding to the impact of crop residues, crop and fertilization. Wierzbowska et al. (2012) state that the milk thistle yield can be increased by nitrogen fertilization also

Table 3 Average yield in kg ha^{-1} of milk thistle achenes (*Silybum marianum* L. Gaertn.) at the standard humidity level (14%), and level of significance of fertilization treatments and years 2012–2014

Treatments	Intercrop	Fertilization	Yield/year		
Crop residues			**2012**	**2013**	**2014**
Crop residues removed from the field (K)	no intercrop (B)	no fertilization (O)	486	437.0	502.0
		with fertilization (F)	623	621.0	627.0
	with intercrop (M)	no fertilization (O)	312	513.0	379.0
		with fertilization (F)	462	745.0	493.0
Average			470.8	579	500.3
Crop residues incorporated into soil (R)	no intercrop (B)	no fertilization (O)	344	657.0	536.0
		with fertilization (F)	589	576.0	658.0
	with intercrop (M)	no fertilization (O)	514	556.0	441.0
		with fertilization (F)	507	715.0	584.0
Average			488.5	626	554.8
Total 2012, 2013, 2014			479.6[c]	602.5[a]	527.6[b]
With fertilization		600	545.3[a]	664.25[a]	590.5[a]
No fertilization		479.5	414.1[b]	560[b]	464.5[b]

Means follows with different letter are significantly different within year and fertilization at probability level *P* ≤0.01 according Tukey test.

DOI: 10.15414/afz.2015.18.04.79–82

Geneva et al. (2008) stated foliar application of nutrients as an effective way for improving yield of milk thistle.

4. Conclusions

The combination of temperature and precipitation pattern of growing period of milk thistle was not most appropriate for expression of yield potential of milk thistle variety Silyb, mainly during sowing and harvest period in the years 2012–2014. Average yield of milk thistle achenes significantly differ in the range from 479.6 kg ha^{-1} in 2012 up to 602.5 kg ha^{-1} in 2013. Yield of milk thistle achenes was significantly influenced by the year conditions and level of mineral fertilization. The incorporating of crop residues or intercrop have no significant effect on yield of achenes. Significantly higher yield was reached on fertilization treatments (600 kg ha^{-1} in an average) with comparison to treatments without mineral fertilization (479.5 kg ha^{-1} in an average).

5. Acknowledgement

This paper was supported by the Scientific Grant Agency VEGA of The Ministry of Education of the Slovak Republic and Slovak Academy of Sciences, Grant No. 1/0544/13: The research of agrienvironmental indicators of sustainability and production capability of agroecosystem by diversification of crop rotation pattern in changing climate and by VEGA 1/0127/14: Determination of total polyphenols and antioxidant capacity of plant sources of natural and agroecological conditions of the Slovak Republic and their utilisation in improving of population health.

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