Journal of Central European Agriculture, 2016, 17(4), p.1096-1103 DOI: 10.5513/JCEA01/17.4.1816

The Impact of Multifunctional Crop Rotation on the Yield of Milk Thistle Fruits in the Years 2012 – 2015

Vplyv polyfunkčného osevného postupu na úrodu plodov pestreca mariánskeho v rokoch 2012 – 2015

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Abstract

Milk thistle can be an annual, rarely a biennial medicinal plant. Polyfactorial field experiment was established during the vegetation period of the years 2012–2015. Three evaluated factors were as follows: crop residues – intercrop – fertilization. Milk thistle was integrated to four crop rotation design with following order of crops: 1. common pea 2. winter wheat 3. milk thistle 4. 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, 2015). The recalculated yield of *Silybi mariani fructus* ranged in the amount from 297 kg*ha^{-1} (RMO treatment – with crop residues, with intercrop and without the use of fertilizers, year 2015) to 745 kg*ha^{-1} (KMF treatment – without crop residues, with intercrop and the use of fertilizers, year 2013). Statistical testing of individual factors found highly significant effect of year and highly significant effect of fertilization, and statistically inconclusive effect of sowing intercrop and ploughing crop residues. In the experiment was found a statistically significant difference between yield on the treatments without fertilization and the use of mineral fertilizers.

Keywords: milk thistle fruits, multifunctional crop rotation, *Silybum marianum*, yield

Abstrakt

Pestrec mariánsky je jednoročná, zriedkavo dvojročná liečivá rastlina. Polyfaktorový poľný pokus bol založený počas rokov 2012 – 2015. V pokuse boli sledované tri faktory: pozberové zvyšky – medziplodina – hnojenie. Pestrec mariánsky bol zaradený do štvorhonového osevného postupu s nasledovným sledom plodín: hrach

obyčajný – ozimná pšenica – pestrec mariánsky – kukurica. Varianty pokusov boli nasledovné: 1. K – bez pozberových zvyškov, R – s pozberovými zvyškami, 2. M – biela horčica ako vymŕzajúca medziplodina, B – bez medziplodiny, 3. O – bez hnojenia, F – s hnojením, 4. rok experimentu (2012, 2013, 2014, 2015). Prepočítaná úroda *Silybi mariani fructus* kolísala v množstve od 297 kg*ha^{-1} (RMO variant – s pozberovými zvyškami, s medziplodinou, bez použitia hnojív, rok 2015) do 745 kg*ha^{-1} (KMF variant – bez pozberových zvyškov, s medziplodinou, s hnojením, rok 2013). Štatistické testovanie jednotlivých faktorov potvrdilo vysoko preukazný vplyv ročníka a hnojenia, a štatisticky nepreukazný vplyv sejby medziplodiny a zaorania pozberových zvyškov. V pokuse bol zistený štatisticky preukazný rozdiel medzi úrodou dosiahnutou na variantoch bez hnojenia, a s použitím hnojenia.

Kľúčové slová: plody pestreca mariánskeho, polyfunkčný osevný postup, *Silybum marianum*, úroda

Introduction

Milk thistle can be annual, rarely biennial medicinal (Young, et al., 1978) plant from *Asteraceae* family (Sidhu and Saini, 2012). The seeds are shiny, black (Dostál, Červenka, 1992) achenes, 5 – 7 mm long (Andrzejewska, et al., 2011) and 1.5 mm wide (Zelený, 2004). Colour of seeds varied from black to brown (Qavami et al., 2013), seeds are terminated white, fine pappus (Sidhu and Saini, 2012). Achenes after grinding have freshly cocoa flavour and oily, bitter taste (Habán et al., 2009). Milk thistle is very adaptable to many growing conditions. Thanks to a strong root system can be grown on light soils with regular water deficit (Kapahi et al., 1995). Growing of milk thistle in Slovakia is suitable for beet, corn and warmer areas of potato production area from 200 to 600 above sea level (Habán, 2004). According to Kubínek (1987) during the critical period (second-third decade of May) the greatest influence on the yield of seeds has rainfall. As thermophilic plant, milk thistle is sensitive to large fluctuations in temperature between day and night, so it is best to grow it in areas with average annual temperature of 6-8 °C (Habán et al., 2008). Milk thistle is not demanding for the previous crop, it is followed after root crops with organic fertilizers or after cereals. A good forecrop for milk thistle is spring barley *Hordeum vulgare* (Habán and Šustr, 2009). During 2013 and 2014, milk thistle growing dominated among the medicinal plants in Slovakia (Habán et al., 2015).

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 2012–2015. 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: 1. common pea – 2. winter wheat – 3. milk thistle – 4. maize for corn. Milk thistle was subjected to the experimental treatments as follows: 1. K – straw of a forecrop

removed from the field, R – straw incorporated into the soil, 2. M – white mustard as a freezing-out intercrop, B – no intercrop, 3. O – no fertilization, F – with mineral fertilization, 4. experimental year (2012, 2013, 2014, 2015). Data of sowing: 22 March 2012, 18 April 2013, 10 March 2014, 19 March 2015. Plant material was harvested in the stage of the achenes ripening at 23 July 2012, 6 August 2013, 17 July 2014, 21 July 2015. 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 registred in 1988 (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.

Results and discussion

The year 2012 was characterized by a lack of rainfall in March and May with a combination of very warm March, warm April, warm May and warm June (Table 1, 2) Growing period of milk thistle in year 2013 started in second decade of April, because of extraordinary wet March. In this years was noted dry April and normal weather conditions in May and June. Due to very warm March, the sowing date was at 10 March in 2014. The last experimental year 2015 was characterized by cold April and very cold May. These conditions have resulted the lowest yield of milk thistle achenes during the established period.

The yield of milk thistle seeds (Table 3) was remeasured in kg*ha^{-1}. In the period 2012 – 2015, the yield of *Silybi mariani fructus* ranged in the amount from 297 kg*ha^{-1} (RMO treatment – with crop residues, with intercrop and without the use of fertilizers, year 2015) to 745 kg*ha^{-1} (KMF treatment – without crop residues, with intercrop and with the use of fertilizers, year 2013).

Treatments, with removing crop residues, without intercrop (KB) were characterized by higher yields by using the application of mineral fertilizers (KBF). Their yields varied from 454 kg*ha^{-1} in 2015 to 627 kg*ha^{-1} in 2014. In comparison to the unfertilized variant (KBO) fertility was higher by more than 52 to 125 kg ha^{-1}. The most productive year in the monitored period of 2012-2015 was the vegetative year 2013, which reached the absolute highest yield of milk thistle per hectare, 745 kg*ha^{-1} (KMF treatment - without crop residues, with intercrop, with mineral fertilizers) and average yield across the years and treatments on the level 602.5 kg*ha^{-1}. Yield in this year on all treatments exceed the value of 400 kg*ha^{-1}. Yield in crop residues this treatment (R) varied from 556 to 715 kg*ha^{-1}.

As the second highest yield of *Silybi mariani fructus* was achieved in the third growing year 2014, when the average across all the examined treatments was 488.18 kg*ha $^{-1}$. The slightly higher yields were recorded in treatments with crop residues (441- 658 kg*ha^{-1}). The use of a fertilizer had a positive impact on the yield in 2014 because all the fertilized variants were higher (627, 493, 658 and 584 kg*ha^{-1}) than non-fertilized variants (502, 379, 536 and 441 kg*ha^{-1}). The third most productive growing year was 2012, when yields fluctuated in the range from 312 kg*ha^{-1} on non-fertilized treatments without crop residues, with intercrop (KMO) to 623 kg ha^{-1} on treatments with use of fertilizers, without crop residues, without intercrop (KBF). The average of all experimental treatments in this vegetation year was 424.62 kg*ha^{-1}. Treatments with fertilization achieve a higher yield compared to

unfertilized treatments in year 2012. The last experimental year 2015 was characterized by the least yield throughout the experimental period 2012-2015. This year was normal in terms of climatic conditions as well as rainfall (Table 2). Influence of cultivation year on drug *Silybi mariani fructus* confirmed the high variability of yields (Table 4).

Table 1. Average temperature of the experimental site in the years 2012 – 2015

Tabuľka 1. Priemerná teplota experimentálneho územia v rokoch 2012 – 2015

Month	+ Normal [°C]	2012		2013		2014		2015	
		°C	Δ t	°C	Δ t	°C	Δ t	°C	Δ t
III	5	8.12	2.6 warm	2.8	-2.3 cold	9.3	4.3 very warm	4.2	-0.8 normal
IV	10.4	12.07	0.9 normal	11.7	1.3 warm	12.4	2.0 warm	8.5	-1.9 cold
V	15.1	17.64	1.5 warm	15.2	0 normal	15.1	0.1 normal	12.8	-2.3 very cold
VI	18	20.39	1.6 warm	18.5	0.5 normal	19.3	1.3 warm	17.3	-0.7 normal
VII	19.8	22.95	2.4 very warm	22.2	2.4 very warm	21.8	2.0 warm	21.0	1.2 warm
VIII	19.3	22.1	2.4 very warm	22.85	1.6 warm	19.3	-0.4 normal	21.2	1.9 warm

Table 2. Average percipitation of the experimental site in the years 2012 – 2015

Tabuľka 2. Priemerný úhrn zrážok experimentálneho územia v rokoch 2012 - 2015

Month	+ Normal [mm]	2012		2013		2014		2015	
		mm	(%) n	mm	(%) n	mm	(%) n	mm	(%) n
III	30,0	5,2	17,33 extremely dry	93,2	310,67 extremely wet	15,4	51,3 dry	44,4	148,0 wet
IV	39,0	39,8	102,05 normal	23	58,97 dry	48,9	125,4 normal	25,6	65,64 dry
V	58,0	15	25,86 very dry	65,6	113,10 normal	57,6	99,3 normal	83,0	143,10 wet
VI	66,0	47,6	72,12 dry	54,8	83,03 normal	52,5	79,6 normal	23,6	35,75 very dry
VII	52,0	109	209,62 extremely wet	2,2	4,23 extremely dry	64,1	123,3 normal	26,4	50,76 dry
VIII	61,0	15,4	25,25 very dry	15,4	114,75 normal	55,9	91,6 normal	77,4	126,88 wet

Table 3. Yield of *Silybi mariani fructus* (kg*ha^{-1}) grown in warm agri-climatic macroregion during the years 2012-2015

Tabuľka 3. Úroda *Silybi mariani fructus* (kg*ha^{-1}) pestovanom v teplej agroklimatickej oblasti v priebehu rokov 2012 - 2015

Crop residues	Intercrop	Fertilization	2012	2013	2014	2015
without (K)	without (B)	without (O)	486	437	502	402
		with (F)	623	621	627	454
	with (M)	without (O)	312	513	379	420
		with (F)	462	745	493	383
with (R)	without (B)	without (O)	344	657	536	380
		with (F)	589	576	658	432
	with (M)	without (O)	514	556	441	297
		with (F)	507	715	584	560

Table 4. Statistical evaluation of *Silybi mariani fructus* (kg*ha^{-1}) yield by analysis of variance

Tabuľka 4. Štatistické hodnotenie úrody Silybi mariani fructus (kg*ha^{-1}) analýzou rozptylu

Examined factor	Level of factor	F-test	Level of significance	Average	Homogenous group
Year	2015	68.541	0,0000 ++	375.6250	A
	2012			424.6250	B
	2014			488.1875	C
	2013			602.5	D
Crop residues	without	2.395	0,1244 -	448.0625	A
	with			475.9375	A
Intercrop	without	2.183	0,1423 -	449.1250	A
	with			474.8750	A
Fertilizers	without	61.711	0,0000 ++	404.6250	A
	with			519.3750	B

Statistical testing of individual factors found highly significant effect of year and highly significant effect of fertilization, and statistically inconclusive effect of sowing intercrop and ploughing crop residues. Statistically significant difference between the variants without fertilization and the use of fertilizers was identified by the experiment.

Andrzejewska and Skinder (2006) assessed the yield potential of milk thistle, which was grown during the growing years 2003 to 2005 at the experimental station in Mochelek (Bydgoszcz). Yields of variants with different sowing dates varied from 693 to 1190 kg*ha^{-1} in 2003. Andrzejewska et al. (2011) in the years 2004-2006 at the experimental station in Mochelek (Bydgoszcz) measured the average yield of milk thistle in the amount 1.23 t*ha^{-1}, which is a higher yield compared with the yield achieved in agroclimatic condition on Dolna Malanta experimental base during the years 2012 - 2015 (297 – 745 kg*ha^{-1}). In spite of this good yield potential, the yield of Milk thistle achenes growing at a field trial conducted on potato production area at the locality Vlková (710 m above sea level) reached the range from 256 kg ha^{-1} (treatment without the use of organic fertilizer) to 428 kg*ha^{-1} (treatment with organic fertilizers) during 2007 – 2008 (Habán and Šustr, 2009).

Conclusions

Impact of agro climatic condition during evaluated years confirmed the high yield variability of drug *Silybi mariani fructus* with high phenotypic plasticity.

In the most favourable growing conditions of the year 2013, the yield potential of Milk thistle reached average amount across the treatments 602.5 kg*ha^{-1} with significantly higher yield on treatment - without crop residues, with intercrop and with mineral fertilizers (KMF) by 745 kg*ha $^{-1}$.

Significant effect of fertilization, and statistically inconclusive effect of sowing intercrop and ploughing crop residues were also identified. In experiment were found found a statistically significant difference between yield on the treatments without fertilization and the use of mineral fertilizers. Based on the four-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.

Acknowledgements

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 agroenviromental indicators of sustainability and production capability of agroecosystem by diversification of crop rotation pattern in changing climate.

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