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Original Paper

Weed infestation in the stand of milk thistle and infestation in sustainable crop rotation

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Milk thistle – *Silybum marianum* (L.) Gaertn. can be a winter annual or a biennial medicinal plant. This study was focused on milk thistle as a weed in the sustainable farming system with the crop rotation of maize for grain, common pea for grain, durum wheat and milk thistle. The assessment of the occurrence of Milk thistle in sustainable crop rotation was conducted at the Experimental Base of Faculty of Agrobiology and Food Resources, Slovak University of Agriculture in Nitra in the years 2013–2015. An actual weed infestation of maize, common pea and durum wheat stands with milk thistle was evaluated before preemergence application of herbicides, in the spring time. Second screening of actual weed infestation of all stands in sustainable crop rotation with milk thistle was done before crops harvest. Screening of each field was made on 1 m^2 area with three replications. The three randomly established sample quadrants were situated minimally 10 m from field margin and apart from each other, respectively. The level of infestation was evaluated according to average density of weeds per square meter. Obtained data were statistically analyzed by software Statistica 7.0 by Analysis of variance (ANOVA), LSD test (P = 0.05). According to statistical analyses, in the year 2014 maize stands was infested with the highest and highly significant amount of *Silybum marianum* (7.8 plants per m^2). Stands of pea for grain in the second year after milk thistle cropping were infested only with 1.23 plants per m^2. Durum wheat stands were infested with 0.96 milk thistle plants per m^2. The originality of this paper is in testing the introduction of a new perspective crops in sustainable crop rotation. Milk thistle not infestation fields within the reporting unit. Dominant weed species in canopy of *Silybum marianum* are: *Echinochloa crus galli*, *Chenopodium album*, *Amaranthus* spp. (*retroflexus*, *powelli*), *Atriplex* spp. (*patula*, *acuminate*, *prostrata*), *Avena fatua*, etc. All dominant weed species belongs to the group of annual early and late spring weeds. Next very dangerous group are perennial weeds *Cirsium arvense*, *Convolvulus arvensis* and *Sonchus arvensis*.

Keywords: *Sylibum marianum* L. Geartn., milk thistle, weed infestation, sustainable crop rotation

1. Introduction

Weeds are everywhere. Weeds exist only in relation to us. A weed solution can lead to unforeseen new problems. A plant we may find unsightly might be the very one on which other rely in order to thrive. Its removal can create opportunities for other more noxious plants to prosper (Edwards, 2015).

Silybum marianum (L.) Gaertn. – milk thistle – grown as a medicinal plant in several countries, is considered as a weed in pastures and cereal crops but also as an interesting plant for biomass production. As an additional contribution to the full exploitation of such promising species, two Sardinian populations of *Silybum marianum* were investigated for chemical composition, bioactive compounds and antioxidant properties at vegetative and reproductive stages (Sulas et al., 2015).

According to Carpino et al. (2003), milk thistle, as spontaneous weed, is scarcely consumed by large and small ruminants grazing on Mediterranean pastures but an increased animal preference has been observed in Sardinia by local farmers when milk thistle is harvested as silage or hay (*Sanna* S, pers. *comm*.). In order to reduce milk thistle biomass, grazing by goat has been suggested for non-crop areas (Khan et al., 2009).

However, milk thistle is considered a weed in sowed annual legume pastures (Sulas et al., 2008), waste areas, cereal crops, decreasing wheat yields (Khan et al., 2009), and along roadsides (Karkanis et al., 2011).

Milk thistle is a medicinal plant cultivated in agriculture. It is the most researched plant for the treatment of liver disease. The achenes, i.e. fruits of the plant, are commonly used as a medicinal drug; they are the raw material for isolation of different substances with liver-protection activity. Its therapeutic properties are due to the presence of silymarin. The seeds contain the highest amount of silymarin, but the whole plant

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is used medicinally. Milk thistle is grown successfully on a range of soil types, from sandy soils to much heavier clay soils. Milk thistle is directly seeded in soils. Sowing occurs in autumn and spring, and row spacing is usually 0.40–0.75 m, with 0.20–0.30 m between plants in the row. Nutrient requirements of this crop are low to moderate since it is adapted to poor quality soils and many different growing conditions. Milk thistle is good forecrop for maize in sustainable agricultural system. A limiting factor in milk thistle production is weed interference. Pendimethalin and metribuzin herbicides are safe for weed control in milk thistle, both alone and in combination. Milk thistle is considered drought resistant and normal rainfall will often suffice. In a Mediterranean environment, under severe drought conditions, the crops should be irrigated during seed growth and filling. Moreover, a few varieties of milk thistle have been developed (Carrubba et al., 1987; Macák et al., 2007, Habán et al., 2009; Karkanis et al., 2011).

S. marianum as medicinal plant is used in pharmacy for silymarin isolation from its fruits. But the cropping of milk thistle has several disadvantages: the first is its morphological characteristics (it can heart skin through its thistles), the second is that milk thistle has potential to become serious weed in arable land (Vereš and Týr, 2012).

Afshar et al. (2014; 2015) noted that, potential of Milk thistle for biomass production in semiarid regions is very perceptive from point of view of interactive effects of different irrigation and soil organic amendments and production of Milk thistle.

We focused our study on milk thistle as a weed in the sustainable farming system within the crop rotation of maize for grain, pea for grain, durum wheat and milk thistle.

2. Material and methods

Assessment of the *Silybum marianum* (L.) Geartn., milk thistle, occurrence in sustainable crop rotation (Table 1) was conducted at the Experimental Base of Faculty of Agrobiology and Food Resources, Slovak University of Agriculture in Nitra, in the years 2013–2015. Experimental base is situated in cadastre of Dolná Malanta (village near Nitra), Slovak Republic (18° 07' E, 48° 19' N). Geographically, this locality is situated in the western part of the river Žitava upland. The experimental locality has flat character with little declination to south. The altitude is 177 m to 180 m above sea level (Hanes et al., 1993 In Tobiašová and Šimanský, 2009).

The weed mapping was realized in the framework of agro-climatic areas in the territory with the following features:

- macro area: warm with the sum of temperature during days when t >10 °C in a range of 3100 to 2400 °C;
- area: predominantly warm with temperature t > 15 °C in a range of 3000 to 2800 °C;
- sub area: very dry with climatic humidity factor for the months June–August $K_{VI–VIII}$ = 150 mm; Ward: predominantly mild winter with the average of absolute temperature minimum Tmin is from -18 °C to -21 °C.

The average annual temperature values were in 2012 – 11.2 °C, in 2013 – 10.3 °C, and in 2014 – 11.6 °C. The sum of annual precipitations: in 2012 – 473.3 mm, in 2013 – 613.8 mm, and in 2014 – 590.2 mm.

The average long-term (1961 to 1990) annual precipitation is 532.5 mm, for the vegetation period it is 309.4 mm. The average long-term (1961 to 1990) annual temperature is 9.8 °C and for the vegetation period it is 16.4 °C (Špánik et al., 1996).

Type of the soil is brown soil; selected soil properties were: proportional soil weight 2.60–2.63 t m^{-3} content of humus in arable soil/topsoil 1.95–2.28%; soil reaction 5.03–5.69 (acidic, almost mild acidic). The experimental soil was created at the proluvial sediments. The soil profile of brown soil contains three genetic horizons (Ap, Bt, C). Their stratography is following: humus horizon (Ap) with the depth of 0–0.32 m; underneath is the main diagnostic luvisolic horizon (Bt), which was created as a result of alluvial accumulation of translocated colloids, and whose depth is from 0.33 to 0.65 m; then, there is a transitional horizon (Bt/C) with the depth from 0.66 to 0.85 m followed continually with the soil forming substrate up to the depth of 1.5 m. The studied brown soil is clayey in its sub-layer and in its topsoil is mildly firm. Humus is of a humo-phulvate type (Hanes et al., 1993).

An actual weed infestation of maize, peas and durum wheat stands with milk thistle was evaluated before preemergence application of herbicides, in the spring time. Second screening of actual weed infestation of all stands was done before crops harvest. Screening of

Table 1 Sustainable crop rotation on the Experimental Base Dolná Malanta

2012	2013	2014	2015
Maize for grain	Pea for grain	Durum Wheat	**Milk Thistle**
Milk Thistle	Maize for grain	Pea for grain	Durum Wheat
Durum Wheat	**Milk Thistle**	Maize for grain	Pea for grain
Pea for grain	Durum Wheat	**Milk Thistle**	Maize for grain

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Table 2 Evaluation scale of actual weed infestation

Group of weeds*	Actual weed infestation				
	none	weak	low	medium	heavy
	Infestation level				
	0	1	2	3	4
	Number of weeds per m²				
Excessively dangerous	–	≤2	3–5	6–15	≥16
Less dangerous	–	≤4	5–8	9–20	≥21
Less important	–	≤8	9–15	16–30	≥31

– not significant, + significantly,++ weary significantly)
* weed species checklist modified by Smatana and Týr, 2011

each field was made on 1 m² area with three replications. The three randomly established sample quadrants were situated minimally 10 m from field margin and apart from each other, respectively. The level of infestation was evaluated according to average density of weeds per square meter (Table 2). Obtained data was statistically analyzed by Statistica 7.0 analysis of variance (ANOVA) and LSD test ($P = 0.05$).

3. Results and discussion

Weeds infestation in canopy of milk thistle is very different in species. Dominant weed species are: *Echinochloa crus galli*, *Chenopodium album*, *Amaranthus* spp. (*retroflexus*, *powelli*), *Atriplex* spp. (*patula*, *acuminate*, *prostrata*), *Avena fatua*, etc. All dominant weed species belongs to the group of annual early and late spring weeds. Next group of weed species are perennial weeds *Cirsium arvense*, *Convolvulus arvensis* and, *Sonchus arvensis*. The raising problem for canopy of milk thistle is Portulaca oleracea- late spring weed from last two year. Application of preemergent's herbicide is very disputably. Due to the dense stand, the late weed infestation of Milk thistle can be solved only by mechanical way. Result of mechanical control is that Portulaca oleracea does not endanger the collection and quality.

Table 3 Weed infestation of milk thistle (*Sylibum marianum* L. Gaertn.) canopies in the years 2013–2015

Weed species	Weeds number per m²			
	2013	2014	2015	average
Chenopodium album	12.00	10.00	2.00	8.00
***Amaranthus* spp.**	6.00	11.00	2.00	6.33
***Atriplex* spp.**	5.00	8.00	2.00	5.00
Echinochloa crus galli	16.00	13.00	9.00	12.67
Avena fatua	2.00	6.00	8.00	5.33
Cirsium arvense	2.00	6.00	2.00	3.33
Convolvulus arvensis	1.00	3.00	2.00	2.00
Solanum nigrum	1.00	1.00	0.00	0.67
Portulaca oleracea	0.00	2.00	4.00	2.00
Persicaria lapathifolia	1.00	1.00	1.00	1.00
Persicaria maculosa	1.00	2.00	3.00	2.00
Polygonum aviculare	1.00	1.00	1.00	1.00
Tripleurospermum perforatum	0.00	2.00	2.00	1.33
Sonchus oleracea	2.00	2.00	2.00	2.00
Sonchus arvensis	2.00	2.00	4.00	2.67
Sum	52.00	70.00	44.00	54.67

Weed species, which occurred in the milk thistle canopies, we could divide into two groups. First group are weeds which infested *S. marianum* stands during the growth period. The most powerful competitor in our survey from this group was *Chenopodium album*. Its infestation was 8.0 plants per m² in an average of the years 2013–2015. The most dominant monocotyledon weed was *Echinochloa crus galli* with infestation level of 12.67 plants per m² in three year average. Dicotyledonous weed infested *S. marianum* canopies were *Amaranthus* spp., *Atriplex* spp. and *Avena fatua* (Table 3). Second group of weeds infested *S. marianum* fields occurred on the stubbles after milk thistle harvest. Weed species spectrum of the Milk thistle field were detected. The most troublesome were *Cirsium arvense*, *Convolvulus arvensis* and *Sonchus arvensis*.

Milk thistle (*Sylibum marianum* L. Gaertn.) was incorporated in sustainable crop rotation r as a forecrop for maize for grain. Due to this fact, the highest infestation with *S. marianum* as a weed was determined in canopy of maize. The amount of *Sylibum marianum* seeds in the soil seed bank fall statistically significantly down during the planting of cultural crops in the second and third year after milk thistle (Table 4). Similar results have also published by Broster et al., 2012.

The highest amount of *Sylibum marianum* weeds before harvest was statistically very significant in the year 2015 and in stand of maize for grain (Table 5 and Table 6).

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Table 4 Number of milk thistle (*Sylibum marianum* (L.) Gaertn.) plants per m² in sustainable crop rotation in the spring time at three different crops in the years 2013–2015

Crop	Number of SYLMA plants per m² in the spring time
Maize for grain	13.32++
Pea for grain	4.00+
Durum wheat	0.96-

The data with different letter are significantly different at the $P = 0.05$

Table 5 Number of milk thistle (*Sylibum marianum* (L.) Gaertn.) plants per m² in sustainable crop rotation before harvest, in the years 2013–2015

Year	Number of SYLMA plants per m² before harvest
2013	1.31-
2014	0.99-
2015	2.79+

The data with different letter are significantly different at the $P = 0.05$

Table 6 Number of milk thistle (*Sylibum marianum* (L.) Gaertn.) plants per m² in sustainable crop rotation before harvest in different crops

Crop	Number of SYLMA plants per m² before harvest
Maize for grain	6.65+
Pea for grain	0.76-
Durum wheat	0.09-

The data with different letter are significantly different at the $P = 0.05$

According to statistical analyses (Table 7) in the year 2013 the maize stands was infested with the highest statistically very significant amount of *S. marianum* (6.65 plants per m²). Stands of pea for grain growing in the second year after milk thistle cropping were infested only with 0.76 plants per m². Durum wheat stands were infested with 0.09 plants per m² of *Sylibum marianum*. The interaction of year and crop as affected the numbers of milk thistle is documented in the table 7.

Silybum marianum is not only cultivated crop which suffer from crop – weed competition but *Sylibum marianum* is also important weed of grains (winter wheat, wheat durum) (Marwat and Khan, 2007). It's a serious weed in many areas of North and South America, Africa, Australia, Asia and Middle East (Holm et al., 1997). It can be found as a garden ornamental and shows up in flower and vegetable seed packets. Once milk thistle has found a niche, it is a competitive thistle and tends to establish in tall dense patches that eliminate other plant species, either by shading or by competition for water and nutrients (Berner et al., 2002; Habán et al., 2009; Smatana and Macák, 2011; Vereš and Týr, 2012).

For several authors *S. marianum* is not medicinal plant but from the agronomical point of view, the forecrop value of Milk thistle is significant as well (Vereš and Týr, 2012). The milk thistle is recommended for incorporation into arable crop as forecrop of maize, mainly maize cultivated for silage (Macák et al., 2007). Limiting factors in *S. marianum* production is weed interference. Generally, weed infestation and control increased the content of silymarin and decreased the amount of seed oil.

4. Conclusions

Milk thistle (*Silybum marianum* (L.) Gaertn.) was incorporated into sustainable crop rotation, because of integrated soil management and economical profitability, but cropping of milk thistle has several disadvantages. The first is its morphological characteristics (it can heart skin through its thistles), the second is that milk thistle has potential to become serious weed in arable land. As a plant from the family *Asteraceae* has a great anticipation to have vital seeds in soil profile for long time as well as *Helianthus annuus* L. On the base of our three year research, we can conclude that the *Silybum marianum* seeds are vital in soil profile for three and more years. We can also conclude that in third year after milk thistle cropping infestation of durum wheat stands was noted, but *S. marianum* plants germinate after the harvest of durum wheat at the stubbles in August or September. On the base of statistical analyses we concluded that the very significant highest infestation with *Silybum marianum* was in maize for grain stand in the year 2014. In the spring time the infestation of maize for grain, pea for grain and durum wheat stands with milk thistle filled very significantly down from 17.78 plants per m² in maize stand to 2.56 plants per m² in durum wheat stand. Dominant weed species in canopy of *S. marianum* are: *Echinochloa crus galli*, *Chenopodium album*, *Amaranthus* spp. (*retroflexus*, *powelli*), *Atriplex* spp. (*patula*, *acuminate*, *prostrata*), *Avena fatua*, etc. All dominant weed species

Table 7 The field infestation of maize, pea, and durum wheat by milk thistle

Number of SYLMA plants per m² before harvest	2013	2014	2015
Maize for grain	2.93+	21.10++	15.93+
Pea for grain	0.33-	0.96-	0.99-
Durum wheat	0.00-	0.10-	0.19-

The data with different letter in a column are significantly different at the $P = 0.05$

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belongs to the group of annual early and late spring weeds. Next very dangerous group are perennial weeds *Cirsium arvense*, *Convolvulus arvensis* and *Sonchus arvensis*.

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