The profitability of millet cultivation on heavy soils

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Abstract: Between years 2013 and 2015, field treatments with millet variety Biserka was carried out in locality Milhostov, where experimental place of Agroecology Research Institute is situated. Two soil tillage technologies (conventional and reduce tillage) and two fertilization variants (control and soil conditioner PRP SOL) were examined. The economic effectiveness of individual variant of millet growing was evaluated. In experimental years 2013 – 2015 the highest costs (more than 560 € ha^{-1}) were determined for conventional tillage at variant with soil conditioner PRP SOL. The lowest costs, on level 330 € ha^{-1}, was on control variant under reduce tillage. In year 2015 the weather was very severe, which was the cause of the lowest millet yields and so the lowest gains were achieved, too. The highest profitability was determined for control variants under reduce tillage. Lower gains from variants with application of PRP SOL soil conditioner will be compensate in next years, when impact of this conditioner on soil environment will be more significant and will be effected of consecutive crops.

Introduction

The millet (*Panicum miliaceum* L.) is one of the oldest cultivated cereals in the world. At present, it is a basic food for over 400 million people. Millet contains polyphenols with antioxidant impact (Léder 2010). This cereal does not gluten and hence it is suitable for food production for people with celiac disease (Janovská 2014). Millet is also used for malt production, which is further utilized to brew celiac disease (Zarnkow et al. 2010; De Meo et al. 2011). Under climate change, with frequent and longer periods of drought, the millet cultivation is very interesting by reason of its high dryness (Agdag et al. 2001; Seghatoleslami 2008). PRP SOL soil conditioner is usually applied for amelioration of unfavourable properties of heavy clay soils and for formation of soil environment with positive impact on soil fertility, soil structure, soil water management and improvement of nutrients transport, too.

The objective of this manuscript was comparison the effect of soil conditioner in relation to millet yield and profitability of its cultivation under different tillage.

Material and methods

In year 2013, the field stationary treatment with millet, variety Biserka, was carried out. Studied crop was included in right crop rotation as follows: sweet sorghum *(Sorhum bicolor* L. *Moench.)* – buckwheat (*Fagopyrum esculentum Moench*.) – millet (*Panicum miliaceum* L.) – amaranth (*Amaranthus sp.* L.).

Gleyic Fluvisol in Milhostov is characterized as heavy, clay-loamy soil with average content of clay particles 53.08 % in topsoil. Gleyic Fluvisol was formed on heavy alluvial sediments during the long-time contact with groundwater and surface water. The topsoil has lump aggregate structure with high binding ability and it has a weak perviousness in its whole profile. In the depth 0.7–0.8 m of soil profile, a layer of dark grey clay is found. The level of underground water is high. Agronomical properties of Gleyic Fluvisol are significantly influenced by the high content of clay particles. The basic properties of topsoil of this soil type are as followed: average particle density was 2 607 kg m^{-3}, average bulk density 1 451 kg m^{-3}, average total porosity 44.35 % (Kotorová, Kováč 2017). The average values of chemical properties of the topsoil (depth from 0.0 to 0.3 m) are as follows: available phosphorus content 50 mg kg^{-1} (Mehlich III), available potassium content 240 mg kg^{-1} (Mehlich III), available magnesium content 460 mg kg^{-1} (Mehlich III), exchangeable calcium content 5 200 mg kg^{-1} (Mehlich III), soil reaction (1 M KCl) 6.3, humus content 3.2 %, the type of humus is from humate-fulvic to fulvic-humate with humic acids and fulvic acids ratio from 0.8 to 1.2 (Šoltysová 2013).

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Two tillage technologies, namely conventional tillage (CT) and reduce tillage (RT), were examined. At conventional tillage, after harvest of forecrop, were made agrotechnics arrangements as follows: stubble ploughing, later mean ploughing, pre-sowing soil prepare by skive-cultivator and sowing by sowing machine Great Plains. At reduce tillage, after harvest of forecrop, was made stubble ploughing by skive plough-harrow and before sowing the soil was prepared by skive-cultivator.

Soil conditioner PRP SOL was examined in millet stand. Two variants were monitored and it: 1. control variant – without mineral fertilizers nor conditioners, 2. PRP SOL variant – dose 200 kg ha^{-1} of PRP SOL conditioner was applied in pre-sowing soil prepare.

The norms in reference to Kavka et al. (2006) and Abrham et al. (2007) were used to cost evaluation of set of machines and working procedures. It was recalculated in conditions of heavy soils of the East Slovak Lowland. The total production was calculated on base of real production for regional processer according to approved contract price. Economy effectiveness of production technologies was evaluated in accordance with methodology Poláčková et al. (2010).

The calculation of economy effectiveness:

- production [€ ha^{-1}] = yield [t ha^{-1}] × realization price [€ t^{-1}]
- profit/loss [€ ha^{-1}] = production [€ ha^{-1}] - costs [€ ha^{-1}]
- profit/loss [€ t^{-1}] = realization price [€ t^{-1}] - costs [€ t^{-1}]
- profitability of costs per 1 hectare [%] = [profit/loss : costs] × 100
- income threshold for null profitability [t ha^{-1}] = costs [€ ha^{-1}] : realization price [€ t^{-1}]

Results and discussion

The millet is not of such commercial importance as wheat and barley, but interest in its cultivation is increasing, mainly for its using in alimentary production. It is also in connection with healthy eating and gluten-free diets. The quality of millet proteins is higher than winter wheat proteins (Kalinová and Moudrý 2006). The millet is unpretentious crop, but its cultivation requires attention at stand foundation (Agdag et al. 2006; Káš and Janovská 2011) as well as at its fertilization (Turgut et al. 2006).

The weather course has significantly effect on growth and development of cultivated plants. Experimental area is characterized as warm and very dry lowland continental climate region T 03 (Linkeš et al. 1996). The sum of the precipitation and average air temperature were compared to long-time normal (LTN) from years 1961–1990 (Mikulová et al., 2008). The long-term mean yearly precipitation shows 550 mm, during vegetation season 348 mm, the mean annual temperature is 8.9 °C, during vegetation season 16.0 °C. Course of meteorological factors were evaluated according to Kožnarová and Klabzuba (2002). Weather conditions at the site in experimental years are shown in Table 1.

Table 1. Evaluation of weather conditions

Year	Average air temperature			Sum of precipitation		
	°C	variation [°C]	eva.	mm	% LTN	eva.
LTN	8.9	0.0	N	550	100.0	N
2013	10.3	+1.4	VW	530	96.4	N
2014	11.1	+2.2	EW	613	111.5	H
2015	11.0	+2.1	EW	447	81.3	D

Where: eva. – evaulation, LTN – long-term normal, N – normal, VW – very warm, EW – extremely warm, H – humid, D – dry

The year 2013 from the point of view of the average air temperature indicated that this year was very warm. Average air temperature in years 2014 and 2015 was higher than long-term normal by 2.2 and 2.1 °C and both experimental years were extremely warm. From point of view of the sum precipitation, year 2013 was normal (96.4 % of LTN), year 2014 was humid (111.5 % of LTN) and year 2015 was dry with sum of precipitation only 81.3 % of LTN. Economic effectiveness of trial variants for 2013 year is shown in Table 2.

Material costs were higher for variant with PRP SOL application, what is related to the costs

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Table 2. Inputs and economics of millet cultivation in year 2013

Parameter	Unit	Control		PRP	
		CT	RT	CT	RT
Material cots	[€ ha^{-1}]	81.10	102.85	225.10	246.85
Costs of mechanized works	[€ ha^{-1}]	208.23	133.74	214.56	140.07
Variable costs common	*[€ ha^{-1}]*	*289.33*	*236.59*	*439.66*	*386.92*
Fixed costs	[€ ha^{-1}]	120.52	93.79	124.72	97.99
Total costs	[€ ha^{-1}]	**409.85**	**330.38**	**564.38**	**484.91**
Yield	[t ha^{-1}]	1.93	2.18	2.10	2.48
Exercise price	[€ t^{-1}]	400.00	400.00	400.00	400.00
Total production	[€ ha^{-1}]	772.00	872.00	840.00	992.00
Result of farming per hectare	**[€ ha^{-1}]**	**362.15**	**541.62**	**275.62**	**507.09**
Profitability per hectare	[%]	88.36	163.94	48.83	104.57
Income threshold for zero profitability	[t ha^{-1}]	1.02	0.83	1.41	1.21

Where: CT – conventional tillage, RT – reduce tillage

of the purchase soil conditioner. For variant with PRP SOL higher costs for mechanized works, in connection of its application, were determined, too. At conventional soil tillage, for variant with PRP Sol conditioner the total costs reached almost 565 € ha^{-1}. For variant with PRP SOL under reduce tillage, the total costs were lower by nearly 80 € ha^{-1}. The lowest total costs were at reduce tillage and it 330.38 € ha^{-1} on control variant. The millet yields, after PRP SOL application, under conventional soil tillage increased only about 0.25 t ha^{-1} and under reduce tillage it was about 0.38 t ha^{-1}.

The exercise price of millet in year 2013 was on level 400 € t^{-1}. from point of view of the highest total production was achieved for PRP Sol variant under reduce soil tillage and it was 992 € ha^{-1}. On this variant the profit amounted to 507.09 € ha^{-1}. Despite lower millet yield from the hectare, more profit was obtained from control variant under reduce soil tillage (541.62 € ha^{-1}). Profitability per hectare for this variant was 163.94 % and control variant under reduce tillage would be profitable at yield higher than 0.83 t ha^{-1}.

In year 2014 the costs in comparison to year 2013 significantly altered, but exercise price decreased to 350 € ha^{-1}. At conventional tillage the millet yields were significantly higher than 3 t ha^{-1} and from this reason for conventional tillage variants not only the total production, but also higher profit in comparison to reduce tillage variants were achieved (Table 3.). The control variants without fertilization were more profitable than PRP SOL variants. The highest profit was obtained from control variant under conventional tillage and it was 377.32 € ha^{-1}, the profitability per hectare was more than 166 %.

In year 2015 the costs of millet cultivation were not radically changed. The millet yields in this year were significantly lower in comparison

Table 3. Inputs and economics of millet cultivation in year 2014

Parameter	Unit	Control		PRP	
		CT	RT	CT	RT
Material cots	[€ ha^{-1}]	80.93	103.43	240.93	263.43
Costs of mechanized works	[€ ha^{-1}]	206.23	132.44	212.51	138.72
Variable costs common	*[€ ha^{-1}]*	*287.16*	*235.87*	*453.44*	*402.15*
Fixed costs	[€ ha^{-1}]	120.52	93.79	124.72	97.99
Total costs	[€ ha^{-1}]	**407.68**	**329.66**	**578.16**	**500.14**
Yield	[t ha^{-1}]	3.1	2.2	3.2	2.19
Exercise price	[€ t^{-1}]	350.00	350.00	350.00	350.00
Total production	[€ ha^{-1}]	1085.00	770.00	1120.00	766.50
Result of farming per hectare	**[€ ha^{-1}]**	**677.32**	**440.34**	**541.84**	**266.36**
Profitability per hectare	[%]	166.14	133.57	93.72	53.26
Income threshold for zero profitability	[t ha^{-1}]	1.16	0.94	1.65	1.43

Where: CT – conventional tillage, RT – reduce tillage

Table 4. Inputs and economics of millet cultivation in year 2015

Parameter	Unit	Control		PRP	
		CT	RT	CT	RT
Material cots	[€ ha^{-1}]	85.55	109.85	249.55	273.85
Costs of mechanized works	[€ ha^{-1}]	195.71	125.61	201.72	131.63
Variable costs common	*[€ ha^{-1}]*	*281.25*	*235.46*	*451.27*	*405.48*
Fixed costs	[€ ha^{-1}]	120.52	93.79	124.72	97.99
Total costs	[€ ha^{-1}]	**401.77**	**329.25**	**575.99**	**503.47**
Yield	[t ha^{-1}]	1.65	1.58	1.93	1.88
Exercise price	[€ t^{-1}]	380.00	380.00	380.00	380.00
Total production	[€ ha^{-1}]	627.00	600.40	733.40	714.40
Result of farming per hectare	**[€ ha^{-1}]**	**225.23**	**271.15**	**157.41**	**210.93**
Profitability per hectare	[%]	56.06	82.36	27.33	41.90
Income threshold for zero profitability	[t ha^{-1}]	1.06	0.87	1.52	1.32

Where: CT – conventional tillage, RT – reduce tillage

with yields in 2014, mainly for control variant. In year 2015, the exercise price increased on 380 € ha^{-1}, but total production from 1 hectare was lower than in year 2014 (table 4.). For experimental variants, viz. control and PRP SOL variants, the profit was obtained, but more profit was determined for control variant. These results confirm statistically significant effect of meteorological factors on millet yield and also effect of exercise price on profitability of millet cultivation. The lowest profit, namely only 157.41 € ha^{-1}, and the profitability per hectare only 27.33 % were reached from variant with PRP Sol application under conventional tillage.

The result of farming per hectare between 2013 and 2015 years are shown on fig. 1. From fig. 1 it becomes clear, the lowest profits were achieved in year 2015, because from point of view of weather conditions it was dry and extremely warm year. Similarly, the lowest profits were determined for variant with PRP SOL conditioner application under conventional tillage of heavy soil.

For economy of plant production is very important evaluation of plant cultivation profitability. From development of this economics parameter of millet cultivation on fig. 2 resulted, that the highest profitability per 1 ton of millet grain was achieved from variant without PRP SOL application under reduce soil tillage technology.

Conclusions

The highest production of millet was achieved in year 2013 at reduce tillage with PRP SOL application and that was 992 € ha^{-1} with a profit of 507.09 € ha^{-1}. The control variant without fertilization under reduce tillage was more profitable (541.62 € ha^{-1}) and profitability per 1 hectare was 163.94 %. In year 2014 from conventional tillage variants was higher production and also higher profit in comparison

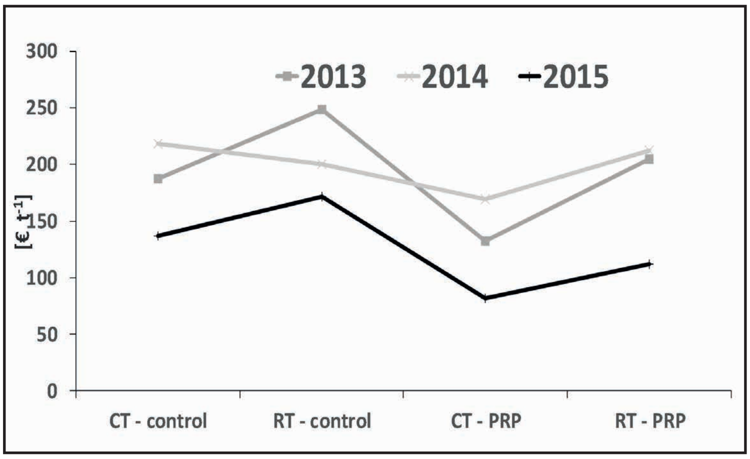

Figure 1. Profitability of millet cultivation per 1 ton

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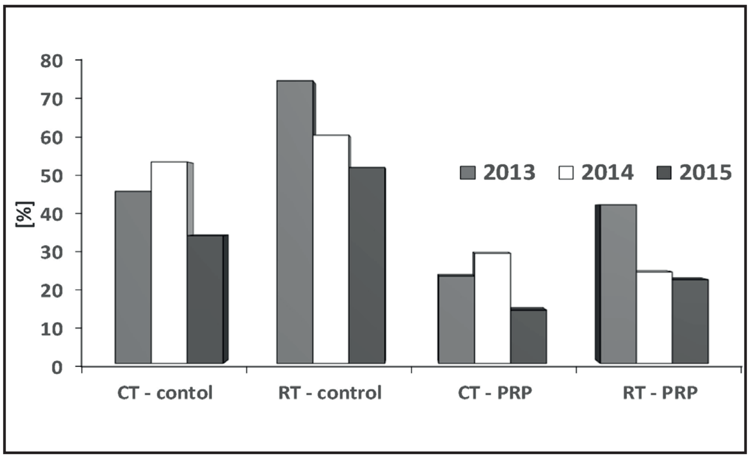

Figure 2. Result of farming per 1 ton of millet cultivation

to reduce variants. From comparison control and PRP SOL variants result more profitable were control variants without fertilization. The highest profit (677.32 € ha^{-1}) was determined for control variant under conventional tillage.

In year 2015 the total production from all variants was lower than in year 2014. All control variants given higher profit. The lowest profit (157.41 € ha^{-1}) was found for PRP sol variant under conventional tillage.

The highest profitability was reached under reduce tillage of soil at no-fertilized control variant. In all more profitable were no-fertilized control variants in compared with variants PRP SOL.

Soil conditioner PRP SOL, from point of view of farmers, increase total costs on millet cultivation in 1st year of growing, but PRP SOL activity in soil profile is distributed during two to the three follows years. Favourable effect of PRP SOL on soil properties was confirmed in our experiments. In our experiments the need to combine application of soil conditioner PRP SOL with mineral fertilizers, mainly nitrogen, were also validated.

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