

EFFECT OF TILLAGE SYSTEM AND SOIL CONDITIONER APPLICATION ON SOYBEAN (*GLYCINE MAX* (L.) MERRILL.) AND ITS CROP MANAGEMENT ECONOMIC INDICATORS

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Experiments with soybean on heavy soils of East Slovak Lowlands were established in the years 2010–2012. The effect of mineral fertilisers and soil conditioner application on soybean's yield using three tillage systems (minimum tillage (MT), conventional tillage (CT) and no tillage (NT)) was studied. Production costs and economic efficiency of crop management practices were evaluated. The influence of production year on soybean crop was significant in the order of 2011, 2010 and 2012. Statistical evaluation confirmed that the effects of CT and MT systems were more significant compared with NT system. No significant differences were found between the variants of the mineral fertiliser and conditioner application. Differences in the total cost of soybean cultivation, as measured between years, were not significant. Fertilisation variants with application of HUMAC agro and NPK generated the highest costs. On the other hand, the lowest

costs were achieved at fertilisation variants with application of NPK alone. Comparing tillage variants, the CT system had the highest costs each year. Significant savings were achieved on MT and NT variants. During the experimental period, a profit was reached on all variants. Applying NPK alone, the highest profit was achieved in 2010 and 2012 using MT system and in 2011 with CT tillage. The variant b_2 with PRP sol in the years 2010 and 2011 was the most profitable using NT system and in 2012 using MT. Variant with HUMAC agro was the most profitable in each year using MT. The lowest income threshold for zero profitability was calculated in 2012. Using CT farming techniques at NPK fertilisation variant b_1 in 2012, the income threshold was 1.85 t/ha, at variant b_2 PRP sol it was 2.10 t/ha and at variant b_3 HUMAC agro it was 2.42 t/ha. At MT and NT systems, the income threshold values for zero profitability were lower.

Key words: soybean, fertilisation, soil tillage, costs, economic effectiveness

Soybean cultivation requires suitable growing conditions. Yield and quality parameters of soybean are affected by many factors, but the appropriate interaction of soil and climatic factors that already exist at the regional level (Anthony *et al.* 2012), is essential.

Soybean, as reported by Šariková and Fecák (2007), is sensitive to incorrect and inconsistent essential tillage. Neglected and poorly made essential tillage makes stand establishment harder and increases the risk of its cultivation. Quality essential tillage is also an arrangement that can substantially

eliminate the negative impact of such shortage and excess rainfall and reduces the variability of yields.

Conventional crop management (conventional tillage) requires a large number of operations that enormously increase the cost, but also cause soil compaction. Botta *et al.* (2007) based on their 3-year results of soybean in Argentina indicated that direct seeding reduces the number of crossings, which reduces fuel consumption by 35.5% and will be reflected in an increase in the yield of 29.2%.

Soil conservations technologies in our country so far have been proven for maize, but in the USA and

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Canada these are successfully used in the cultivation of soybeans, especially in crop rotation with corn. Triplett and Dick (2007) indicated that direct sowing in the USA was already expanded in 1980 and after that the area grew in Australia, South America and Canada. Currently, these technologies are used here for about 23% of agricultural land. Direct seeding allows cultivation of a larger area with lower energy, labour and machinery consumption. Direct sowing directly affects crop, soil, hydrology and agricultural economy.

Archer and Reicosky (2008) report the farmers concerned about the use of direct seeding due to a potential risk of yield reduction and economic risks. Also, they face risks associated with the input costs, yields and the realisation prices. Their 7-year results show that the soybean affords achieving of higher economic benefits by minimising soil tillage and direct sowing against ploughing. Risk analysis showed that minimum tillage and non-tillage are a good alternative to conventional tillage.

Lança Rodríguez *et al.* (2009) verified different types of tillage in Brazil, including conventional tillage and direct seeding. There were no significant differences in yields using different tillage systems. Duseja and Dennis (2010) reached similar results in terms of the USA. For 7 years, they monitored soybean production indicators using conventional farming techniques and direct sowing. In the monitored period, they found significant difference only in 1 year regarding the benefit of direct sowing.

Experiments with soybean were established in conditions of heavy soils in Slovakia as well. The results showed that minimum tillage was better than direct sowing for the establishment of soybean crops (Fecák *et al.* 2009).

Level of the yield is not a decisive criterion (Katsvairo & Cox 2000; Stanger *et al.* 2006) for selection of crop management. According to the authors, the dominant factor for the selection of technology is the economy of crop management. This is confirmed by their long-term studies with crops that included soybean also.

The aim of this study was to evaluate the parameters of soybean production, costs of production and the economic indicators using the three variants of fertilisation and the three variants of crop management on heavy soils.

MATERIAL AND METHODS

Field experiments with different soil cultivation were carried out between 2010 and 2012 at an experimental station in Milhostov, the unit of National Agriculture and Food Centre – Agroecology Research Institute Michalovce – on heavy Gleyic Fluvisol (WRB 2006) at an altitude of 101 m. Gleyic Fluvisol in Milhostov is characterised as heavy, clay-loamy soil with average content of clay particles higher than 53%. Gleyic Fluvisol was formed on heavy alluvial sediments during the long-time contact with groundwater and surface. The topsoil has a lump aggregate structure with high binding ability and has a weak perviousness through the whole profile. A layer of dark grey/yellow grey clay is situated at a depth of 0.7–0.8 m of soil profile. The agronomical properties of Gleyic Fluvisol are significantly influenced by the high content of clay particles. The experimental locality is characterised as a warm and very dry lowland continental climate region.

The study was realised in Milhostov, where the field stationary experiment was founded, using the appropriate crop rotation and Cardiff soybean variety. The spring barley was a fore crop for soybean in the rotation.

The experiment was conducted by randomised blocks in four replications. Experimental factors are described in Table 1. The size of an experimental plot was 276 m² (6 m × 46 m) and the size of the whole experiment was 9936 m².

“PRP sol” and “HUMAC agro” are soil amendments, which are applied to the soil to improve its properties, increasing soil fertility and consequently the yield of agricultural crops. PRP sol is a granular soil conditioner based on calcium and magnesium carbonates and technological additives (iron, zinc, boron, sodium, manganese, etc.). It contains 35% of calcium oxide and 8% of magnesium oxide. HUMAC agro is a granulated natural stimulator of soil fertility, high in humic acids (minimum 62% of dry matter). High content of humic acids and gradual release from the granules allow it to be applied only every 4–5 years.

For all studied factors, yield of soybean was evaluated by mathematical and statistical methods. The multifactorial analysis of variance ANOVA

from statistical package STATGRAPHICS, soybean yield and the factors was used (the year, tillage and application of fertilisers and conditioners).

The costs limits with reference to Kavka (2006) and Abrham *et al.* (2007) were used for cost evaluation of the set of machines and working procedures. They were recalculated for conditions of heavy soils of the East Slovak Lowland.

The variable costs consist of:

- Personal costs of drivers and workers (data obtained from Statistical Office of the Slovak Republic 2010, 2011);
- Costs of fuel, oils and lubricants were calculated from real prices of diesel fuel purchased for experimental workplace Milhostov, increased by 10% for consumed lubricants and oils;
- Repair and maintenance costs (with reference to Abrham *et al.* 2007);
- Material costs, calculated from the prices of seed, mineral fertilisers and pesticides in that year, purchased for experimental workplace Milhostov.

The fixed costs consist of:

- Fixed costs of energetic source and connected mechanisms (depreciations, taxes and fees, insurance, warehousing mechanisms, paid interest on capital) according to norms (Abrham *et al.* 2007).

The total production was calculated on base of real production for regional processor according to approved contract price.

Economic effectiveness of production technologies was evaluated in accordance with methodology proposed by Poláčková *et al.* (2010).

The calculation of economic effectiveness:

- Revenues [€/ha] = yield [t/ha] × realisation price [€/t];
- Profit/loss [€/ha] = revenues [€/ha] – costs [€/ha];
- Profit/loss [€/t] = realisation price [€/t] – costs [€/t];
- Profitability of costs per 1 hectare [%] = [profit/loss: costs] × 100;
- Profitability of costs per 1 tone [%] = [profit/loss: costs] × 100;
- Income threshold for zero profitability [t/ha] = costs [€/ha]: realisation price [€/t].

T a b l e 1

Experimental factors

Factor	Factor level	Description	Tillage depth [m]				
A	a ₁	CT – (conventional tillage) – stubble ploughing, ploughing, smoothing, harrowing and sowing by seeder Great Plains	0.30				
	a ₂	MT – (minimum tillage) – stubble ploughing by skive cultivator, soil preparation by skive cultivator before sowing and sowing by seeder Great Plains	0.15				
	a ₃	NT – (direct sowing, no tillage) – direct sowing without ploughing by seeder Great Plains	0				
Fertilization doses [kg/ha]			N	P	K	PRP sol	HUMAC agro
B	b ₁	fertilization NPK	30	13.08	24.90	–	–
	b ₂	fertilization N + conditioner „PRP sol“	30	–	–	200	–
	b ₃	fertilization NPK + soil conditioner „HUMAC agro“	30	13.08	24.90	–	500

RESULTS AND DISCUSSION

Evaluation of grain production parameters

Yield of soybean grains observed between 2010 and 2012 is shown in Table 2. Yield achieved in experiments greatly exceeded the yield achieved in agricultural practice (Rozborilová 2012). In the monitored period, the final yield was significantly affected by the year (the course of meteorological factors). Year 2011 statistically significantly affected the soybean crop compared with 2010 and 2012 (Table 3). In 2011, soya was seeded on 26th of April (Figures 1, 2). In this year, weather conditions were more favourable than in 2010 and 2012. Sufficient rainfall in June and July favourably impacted pro-

duction of soybean, which was harvested on 22nd of September. In 2010, soya was seeded on 27th of April. A lower yield in 2010 resulted from a higher total rainfall after sowing in the month of May, which amounted to 219 mm that significantly exceeded long-term normal of May, which is 57 mm. High rainfall and wet soil negatively influenced the initial development of soybean crop, which was reflected in the resulting yield. Rainfall above normal in August and September and temperatures lower than average delayed the ripening of soya, which was harvested on 6th October. Compared with cultivation year 2010, 2012 influenced significantly less the final grain yield of soybean. Soya was seeded on 2nd of May and the year 2012 was extremely dry and

T a b l e 2

Soybean seed yield in experimental years [t/ha]

Factor	Fertilisation								
	b ₁			b ₂			b ₃		
Tillage	a ₁	a ₂	a ₃	a ₁	a ₂	a ₃	a ₁	a ₂	a ₃
2010	4.40	4.45	3.95	3.99	4.33	4.30	4.75	4.65	3.71
2011	5.54	4.69	4.57	4.64	4.71	4.83	4.98	5.12	4.62
2012	4.64	4.73	2.92	4.06	4.78	3.35	4.15	4.45	3.55

Abbreviations see Table 1

T a b l e 3

Multifactor analysis and multiple comparison test of monitored parameters of soybean seed

Source of variation		Degree of freedom	F-value	P-value	Yield [t/ha]	Homogeneous groups		
Fertilization	PRP sol	2	1.18	0.31	4.33	x		
	NPK				4.43	x		
	HUMAC agro				4.44	x		
Tillage	NT	2	44.47	0.00	3.98	x		
	CT				4.57		x	
	MT				4.65		x	
Year	2012	2	54.02	0.00	4.07	x		
	2010				4.28		x	
	2011				4.86			x
Residual		98						
Total		102						

Abbreviations see Table 1

warm as well. The average temperature during the growing season increased by 2.1°C compared with long-term normal and rainfall was lower by 41 mm. The average yield in 2012 was lowest in the stud-

ied years. In this year, soya was harvested on 13th of September.

The lowest yields were achieved at variants of fertilisation b_1 (NPK) and b_3 (HUMAC agro) by

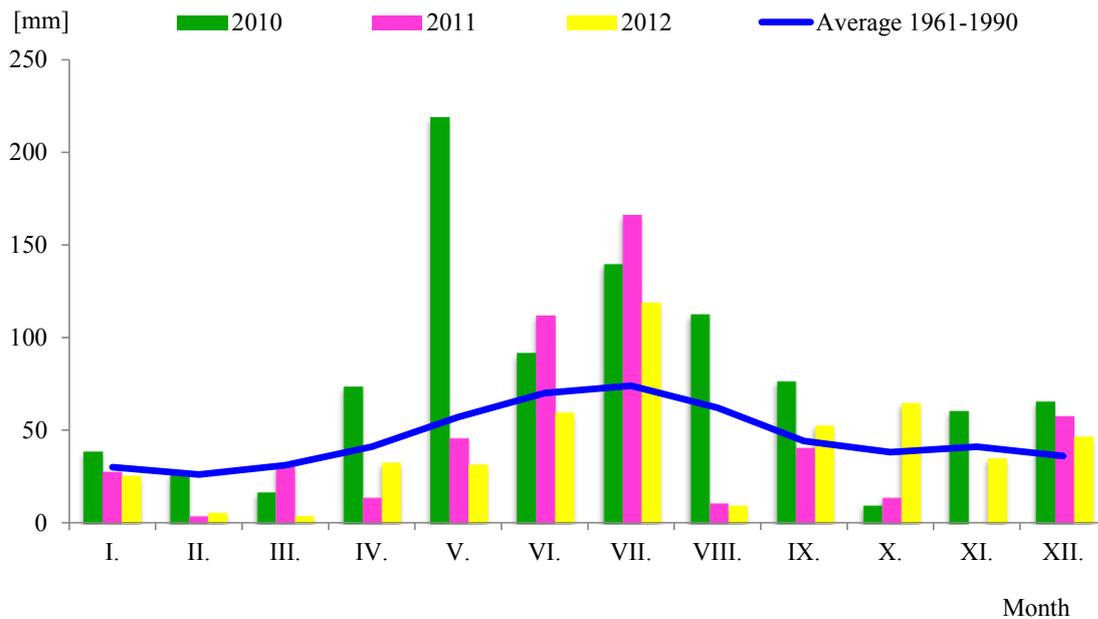


Figure 1. Rainfall for the years 2010–2012 and the long-term normal

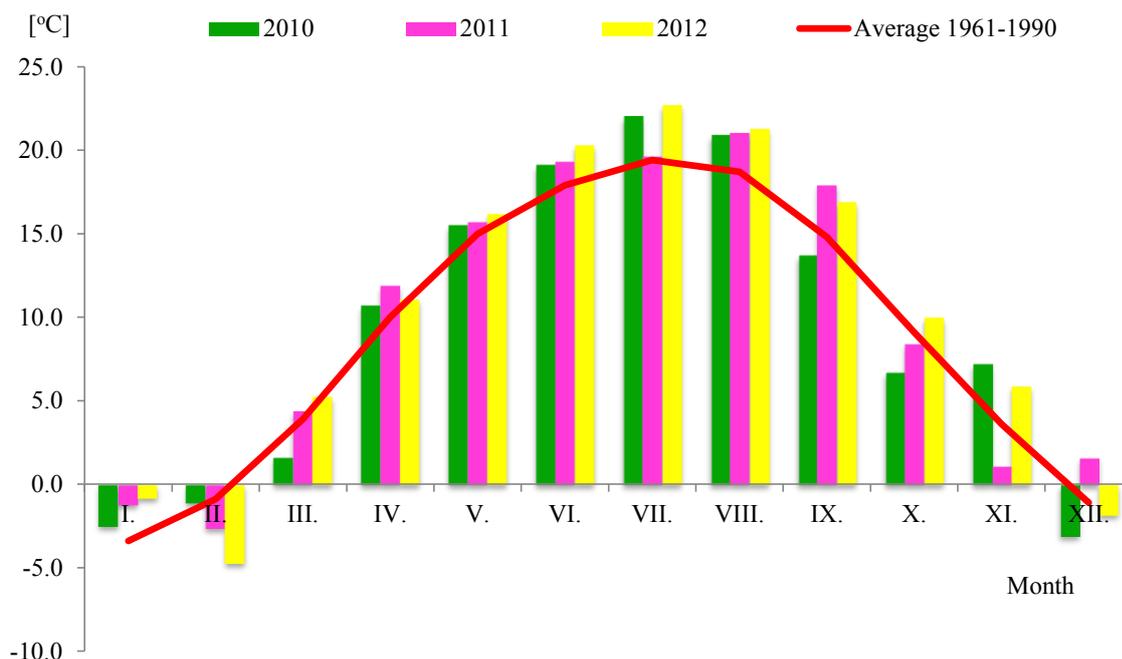


Figure 2. Temperatures for the years 2010–2012 and the long-term average

direct sowing in each of the studied years. The lowest yield was at the variant b_2 (PRP sol) by direct sowing only in 2012. In 2011, in this fertilisation variant, the highest yield of 4.83 t/ha was achieved by direct sowing. The highest yield in the experiment (5.54 t/ha) was in 2011 using the conventional variant of tillage and the application of NPK (Table 2).

Statistical comparison of tillage technologies in the studied years confirmed that no-tillage technology has a non-significant effect on the soybean yield. Significantly, the yields were affected by conventional and minimum tillage. Similar results reached in experiments with soybeans on heavy soils between 2006 and 2008 (Fecák *et al.* 2010). These evaluations, however, do not correspond to the results given for soybean by Lança Rodríguez *et al.* (2009) and Duseja and Dennis (2010). The results of these authors indicate no signification in crop yields using different soybean cropping practices.

Statistical evaluation of the various applications of fertiliser and soil conditioner did not show a significant difference in yields between the different variants. Soil conditioners in the experiment did not significantly influence the yield of soybean, but it is known to significantly affect the soil characteristics.

According to Šoltysová (2012), application of soil conditioner PRP sol allowed stabilising of soil reaction and increasing its average value. It worked to increase the humus and soil organic carbon content in the soil. Similar results have been reached by Balla *et al.* (2012) as well. As per Kotorová (2012), application of PRP sol promoters affected the physical properties of soil. It contributed to a reduction in density and an increase in total soil porosity. Tóth (2012) states that the product HUMAC agro is a soil improver carbon type and affects the improvement of soil structure, improving conditions for the development of micro-organisms, sorption and buffering capacity of the soil and so on.

Assessment of costs for soybean planting

Costs of soybean crop management in 2010 are shown in Figure 3. The highest costs were achieved at conventional tillage a_1 and using all three variants of fertilisation. At minimum tillage, the total cost compared with conventional technology was reduced by €110.49/ha and for direct sowing of €128.30/ha. Comparing variants of fertilisation, the lowest costs were determined for variant option b_1 (NPK fertiliser only). The fertilisation variant b_2 (PRP sol and N) costs were higher at €91.98/ha and

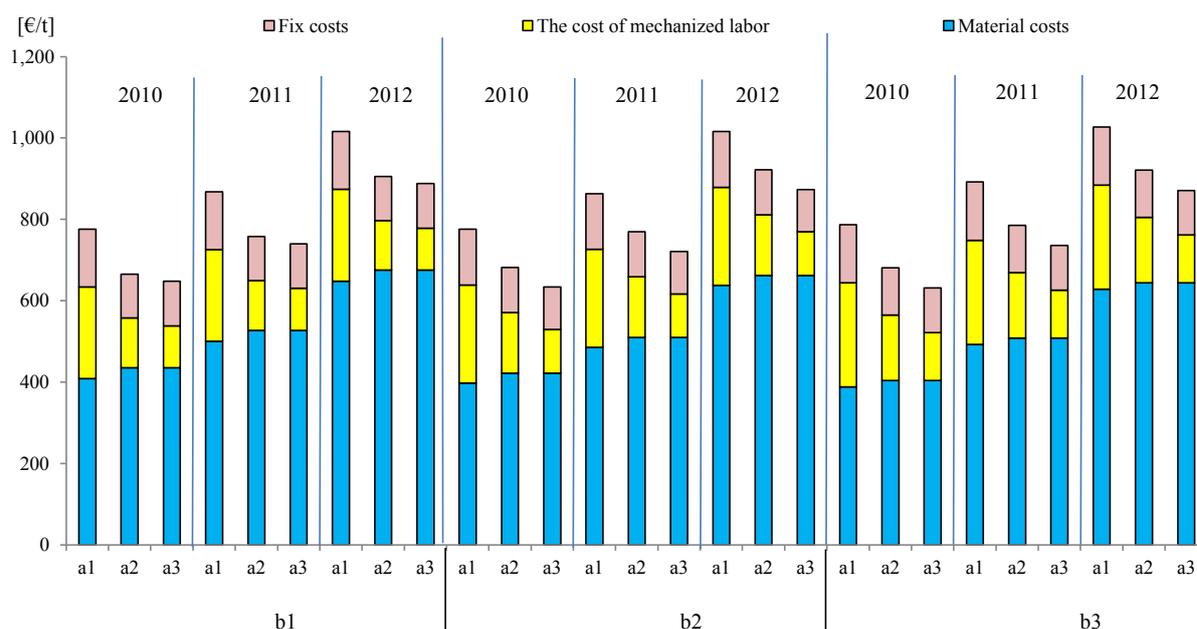


Figure 3. The costs of soybean cultivation in 2010–2012 – €/ha (Abbreviations see Table 1)

the variant of fertilisation b_3 (HUMAC agro and NPK) €240/ha. More than 50% of costs in all experimental variants were material costs.

In 2011, due to lower prices of NPK fertiliser, material costs slightly decreased (by €10.39–€17.52/ha). This resulted in the total cost reduction on all variants except variant with minimum tillage (a_2), where the total costs increase in the application of PRP sol (b_2) for €11.75/ha and in the application of NPK alone (b_1) and HUMAC agro (b_3) for €16.21/ha. The cost structure and the relationships between the different variants were analogous as in 2010.

Costs of growing soybean in 2012 are shown in Figure 3. In 2012, compared with 2011, the cost of mechanised labour and fixed costs increased for all scenarios. With further decrease in prices of mineral fertilisers, material costs reduced for alternatives with NPK application alone (b_1) and the application of HUMAC agro (b_3). The increase in total cost was for all variants of conventional soil tillage (a_1) and

all versions of the application of soil conditioner PRP sol.

In the studied period, the highest total costs of soybean cultivation were achieved for variant application of HUMAC agro (variant b_3). It corresponds with the high-dosage 500 kg/ha of this conditioner. The soil fertility stimulator would gradually release nutrients for a period of 4–5 years. Using conventional tillage (a_1), the total cost of this option exceeded €1000/ha (€1015.86–€1027.29/ha). With minimum tillage (variant a_2), the total costs decreased significantly to €905.62–€921.83/ha and for direct sowing (a_3) fell below €900/ha (€871.20–€887.81/ha). The option with the application of NPK alone (b_1) had costs under €787.29/ha at a_1 , under €681.83/ha at a_2 and under €647.81/ha at a_3 .

Evaluation of economic indicators

The economic indicators per hectare of soybean cultivation are assessed in Tables 4–6. Differences

T a b l e 4

Economy of soybean growing in 2010

Parameter	Unit of measure	b_1			b_2			b_3		
		a_1	a_2	a_3	a_1	a_2	a_3	a_1	a_2	a_3
Total production*	[€/ha]	1,452.00	1,468.50	1,303.50	1,316.70	1,428.90	1,419.00	1,567.50	1,534.50	1,224.30
Economy result	[€/ha]	660.18	802.88	655.69	432.90	671.30	679.21	535.68	628.88	336.49
Profitability per ha	[%]	83.38	120.62	101.22	48.98	88.61	91.81	51.92	69.44	37.90
Income threshold for zero profitability	[t/ha]	2.40	2.02	1.96	2.68	2.30	2.24	3.13	2.74	2.69

*Exercise price of production: 330.- €/t
Abbreviations see Table 1

T a b l e 5

Economy of soybean growing in 2011

Parameter	Unit of measure	b_1			b_2			b_3		
		a_1	a_2	a_3	a_1	a_2	a_3	a_1	a_2	a_3
Total production*	[€/ha]	1,662.00	1,407.00	1,371.00	1,392.00	1,413.00	1,449.00	1,494.00	1,536.00	1,386.00
Economy result	[€/ha]	886.14	725.17	737.40	528.62	643.65	727.88	478.14	614.17	512.40
Profitability per ha	[%]	114.21	106.35	116.38	61.23	83.66	100.94	47.07	66.62	58.65
Income threshold for zero profitability	[t/ha]	2.59	2.27	2.11	2.88	2.56	2.40	3.39	3.07	2.91

*Exercise price of production: 300.- €/t
Abbreviations see Table 1

T a b l e 6

Economy of soybean growing in 2012

Parameter	Unit of measure	b ₁			b ₂			b ₃		
		a ₁	a ₂	a ₃	a ₁	a ₂	a ₃	a ₁	a ₂	a ₃
Total production*	[€/ha]	1,972.00	2,010.25	1,241.00	1,725.50	2,031.50	1,423.75	1,763.75	1,891.25	1,508.75
Economy result	[€/ha]	1,184.71	1,329.22	609.80	833.80	1,246.06	688.14	736.46	970.22	637.55
Profitability per ha	[%]	150.48	195.18	96.61	93.51	158.64	93.55	71.69	105.34	73.18
Income threshold for zero profitability	[t/ha]	1.85	1.60	1.49	2.10	1.85	1.73	2.42	2.17	2.05

*Exercise price of production: 425.- €/t
Abbreviations see Table 1

in overall production in each year were significantly affected by realisation price, which especially in 2012 has grown enormously to €425/t. Compared with 2010, the increase was €95/t and compared with 2011 €125/t. The significant differences between the prices at soybean marketing are pointed out by Vyn (2012). His findings highlight the risks that this entails for soybean growers. Marketing strategies for long-term monitoring showed lower net prices after crop harvesting. Katsvairo and Cox (2000) and Stanger *et al.* (2006) state that annually changing realisation prices and production costs as major risk factors are critical for evaluations of the economy in soybeans. They found the experiments were profitable, when soybean was cultivated in crop rotation with corn, using all tillage and maximal fertilisation.

High yields on experimental variations meant that during the whole experimental period the total production per hectare falls below €1200/ha. In 2010 (Table 4), production per hectare ranged from €1224.30/ha to €1567.50/ha. For each variant, a profit was achieved. The highest profit €802.88/ha was achieved at minimum tillage variant with application of NPK alone (variant b₁), before direct sowing and minimum tillage variant b₂ applying conditioner PRP sol (€679.21/ha and €671.30/ha, respectively). The variant of direct sowing in the application of soil fertility stimulator HUMAC agro (variant b₃) was the least profitable at €336.49/ha. The lowest profitability per hectare at 37.90% was in this variant. In the previous section, soybean yield parameters were evaluated. Based on statisti-

cal evaluation between conventional tillage technology and minimum tillage, grain yield was not significantly different, indicating an advantage of this technology. Using the minimisation with the fertilisation variant b₁ in 2010, a sufficient yield to get a profit was higher than 2.02 t/ha. The variant b₂ (PRP sol) needs to achieve a yield higher than 2.30 t/ha and the b₃ variant (HUMAC agro) higher than 2.74 t/ha.

In 2011 (Table 5), the high profit gain was also seen in all variants of experiment variations. When applying NPK (variant b₁), the highest profit €886.14/ha was achieved at conventional tillage. When applying conditioner PRP sol (b₂), the direct sowing was most profitable at €727.88/ha and in the application of HUMAC agro (b₃), it was minimum tillage at €614.17/ha. The highest profitability per hectare was calculated for b₁ variants of fertilisation (154.62%–161.36%), then b₂ variants (61.23%–100.94%) and finally b₃ variants (47.07%–66.62%). Mainly due to lower exercise price of €300/t, the income threshold for zero profitability was higher for all variants, compared with 2010. It follows that the higher yield is necessary to achieve profitable soybean cultivation.

Using minimum and conventional tillage technology, the highest total production was reached in 2012 (Table 6). Simultaneously, these tillage variants in 2012 were more profitable than in 2010 and 2011. In 2012, in all variants of fertilisation, the highest profit was achieved at minimum technology (b₁ – €1329.22/ha, b₂ – €1246.06/ha and b₃ – €970.22/ha). The direct sowing was the least

profitable (b_1 – €609.80/ha, b_2 – €688.14/ha and b_3 – €637.55/ha). In 2012, the profitability per hectare of the experiment was 195.18% at b_1 fertilisation with minimum tillage. At a higher realisation price of €425/t, the lowest income threshold for zero profitability was calculated in 2012. Using the minimal tillage and the fertilisation variant b_1 in 2012, the sufficient yield to get the profit was higher than 1.60 t/ha, for the variant b_2 (PRP sol) it was necessary to achieve a yield higher than 1.85 t/ha and for the variant b_3 (HUMAC agro) it was higher than 2.17 t/ha.

CONCLUSIONS

From the results of experiments with soybean in the years 2010–2012 the following conclusions can be formulated.

The weather events during the year significantly affected soybean grain yield. There were statistically significant differences in yields from the highest average yield for 2011 to 2010 and 2012. Differentiated application of soil conditioners and fertilisers non-significantly influenced soybean grain yield. Statistically significantly higher yields were achieved at conventional and minimum tillage variant. For direct sowing variants, the grain yield of soybean was significantly lower.

The total costs of soybean crop management in comparison years have not changed significantly. The highest costs were at variants of fertilisation (with the application HUMAC agro + NPK). The lowest costs were at variants of fertilisation (with the application NPK alone). When comparing variants of tillage, significantly highest costs were at conventional variant each year. Significant savings occurred at minimum and direct sowing variants.

The exercise price of grain significantly affected the differences in total production for each year, which was the highest in 2012 (€425/t) and the lowest in 2011 (€300/t).

Using applied NPK alone, the highest profit in the years 2010 and 2012 was achieved at minimum tillage (€802.88/ha and €1329.22/ha, respectively) and in 2011 at conventional variant (€886.16/ha). On a variant with PRP sol, the most profitable was

direct sowing between 2010 and 2011 (€679.21/ha and €727.88/ha, respectively), and in 2012 at minimisation of €1246.06/ha. Variant with HUMAC agro was the most profitable each year at minimum tillage. In 2010, the profit was €628.88/ha, in 2011 it was €614.17/ha and in 2012 it was €970.22/ha.

The highest profitability per hectare was achieved in the experiment in 2012.

The lowest income threshold for zero profitability was detected in 2012 when there was the largest grain price.

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