TILLAGE SYSTEMS OF WINTER OILSEED RAPE (*BRASSICA NAPUS L.*) PRODUCTION WITH RESPECT TO COSTS, ENERGY AND LABOUR CONSUMPTION

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Abstract
The objective of this work is to assess different systems of winter oilseed rape production, i.e. reduced (RT) and conventional (CT) tillage, mainly in terms of yields, fuel and labour consumption, machinery and material costs in the conditions of the Czech Republic. Since 2001/02, trials were accomplished in 548 fields. Over the first five years, CT yields generally surpassed RT yields. But gradually, this trend turned over. The potatoes production area proved to be the most favourable in terms of yields. Recently namely, beet production area demonstrated also good results. When excluding cases with organic fertilizer application, the average fuel consumption of RT was by 15.7 % lower than that of the CT, the overall labour consumption again lower by 18.4 %, and finally the machinery costs lower by 10.8 %. All the above mentioned differences proved statistically significant. Concerning earnings per hectare, RT results proved superior to CT in all of the production areas.

Key words: *reduced tillage; conventional tillage; ploughing; fuel, variety; fertilization.*

INTRODUCTION

Over the past decades, numerous tillage techniques have appeared substituting conventional tillage (CT) comprising ploughing. These methods, i.e. conservation or reduced tillage (RT), generally do not overturn soil and leave substantial share of crop residues on the soil surface (at least 30% of surface covered to be eligible to label 'conservation tillage'). Reduced tillage mainly helps to preserve soil moisture, to lower costs of production and to shield soils from compaction and erosion (*Holland, 2004*).

There has been extensive investigation on the effects of conservation tillage on crop yield in many zones in Europe over the last decades. Often, detailed works were carried out on the environmental and economic consequences of conservation agriculture (e.g. *Bailey et al., 2003; Hocking et al., 2003; Husnjak, Filipović & Košutić, 2002; Kisić et al., 2010; Lopez & Arrue, 1997; Răus et al, 2016; Tebrügge & During, 1999*). However, the conclusions from different works frequently appear conflicting and are therefore problematic to interpret (e.g. *Cantero-Martinez et al., 2003; Huang et al., 2011; Lopez & Arrue, 1997*). This is to be anticipated: both the agro-environmental settings as well as the method of reduced tillage applied differ substantially between individual works. The recent study of *Madarász et al.* (2016) nevertheless suggested that over the ten trial years, tillage type was a more important factor with respect to yields than the highly changeable climate of the studied years. During the first three years of changeover to RT, a reduction of 8.7% was measured, compared to CT. However, the next seven years produced a 12.7% increase of RT yields of all the crops grown.

An assessment of the particular parts of the overall costs disclosed that reduced-tillage involved herbicide costs and larger machinery, but these costs were counterweighed by lower operating costs (*Sanchez-Giron et al., 2004, 2007; Sørensen & Nielsen, 2005*). Other studies established that marginally reduced crop yields can be counter balanced by the lower fuel and labour consumption (*Gemtos et al., 1998; Bonciarelli & Archetti, 2000; Tebrügge, 2000; Šařec P. & Šařec O., 2017*). The systems with lower level of tillage intensity should be prioritized, not only for the sake of costs, but also for the sake of simpler organization due to less machinery and labour requirements (*Grubor et al., 2015*). However, the extend of benefit depends on specific situation such as farm size, cropping system etc. (*Sanchez-Giron et al., 2007*).

The objective of this work is to assess different systems of winter oilseed rape production, i.e. reduced (RT) and conventional (CT) tillage, mainly in terms of yields, fuel and labour consumption, machinery and material costs in the conditions of the Czech Republic. The assessment is based on the long-term operational monitoring of approximately 40 farms that begun in 2001. This work followed experiments carried out by the authors in Opařany in 1998 (*Šařec et al., 2002*).

MATERIALS AND METHODS

Starting in 2001/02, operational experiment has been carried out in the Czech Republic where around 40 farms growing winter oilseed rape took part in. The farms were chosen in order to represent various production zones, i.e. pedoclimatic conditions, and different soil tillage technologies. According to the tillage system used, observations were sorted into one of the two key groups, i.e. conventional tillage (CT) and reduced tillage (RT) group. Other sorting criteria, besides production year, were:

- production area: forage, potato, cereal, beet, maize;
- winter oilseed rape variety: conventional, hybrid, mixed (both types of varieties used in a field);
- application of organic fertilizers (manure, slurry, compost, sugar cane boiling residues etc.);
- application of fertilizers at sowing.

Within the experiment, the following values were monitored or measured:

- characteristics of soil: bulk density (Kopecky's cylinders of a volume of 100 cm3), gravimetric moisture, cone index (registered penetrometer PEN 70 developed at the CULS Prague);
- characteristics of individual fields: size, system of soil tillage and stand establishment, previous crop, manner of crop residue management, year of previous application of farmyard manure;
- data on conducted filed operations: machinery used, fuel and labour consumption, material applied and its rate, costs and other supplementary information;
- characteristics of crop stand: the number of plants per m2, the weight of roots, hybrid / conventional variety, yield.

Machinery costs were determined in a customary way and consisted of ownership (financing costs, depreciation, insurance and taxes, housing) and operation costs (fuel and oil costs, repair and maintenance costs, labour costs). At every farm, the amount of expenses spent, i.e. machinery and material costs, was evaluated compared to the attained seed yield, respectively revenues. Earnings from one hectare were calculated as total costs deducted from revenues, i.e. average annual farm price one ton of oilseeds multiplied by seed yield. Costs related to agricultural land and overhead costs were not comprised.

RESULTS AND DISCUSSION

During seventeen production years since 2001/02, trials were accomplished in 548 fields. Reduced tillage (RT) system of oilseed rape production was employed in 304 cases, conventional tillage (CT) in 244 cases only. This inequity developed over the monitored period, when some of the farms changed their system from CT to RT.

RT prevailed on heavy-textured soils in arid regions, i.e. in maize production area and in most of the beet production area. The most frequent tillage operations consisted of two soil cultivations, followed in some cases by a seedbed preparation. Under RT, deeper (20 cm and more) soil cultivation became regular in the course of time, and has been employed by nearly every farm recently.

CT was used predominantly by farms with lighter soils and higher annual precipitation rates that could be found in potato and marginally beet production area. The common tillage procedures consisted of a stubble cultivation followed by ploughing, and a seedbed preparation done once or twice.

Choice of the tillage system was influenced also by the equipment that a particular agricultural business owned. Disc cultivators prevailed within CT, whereas within RT, where two stubble cultivations were usual, tine cultivators were common, particularly for the second cultivation.

Application of organic fertilizers is another factor influencing costs and operational characteristics. Manure was applied mainly in forage and potato production areas, where the production of manure was sufficient and potatoes production decreasing. Therefore, manure could have been applied prior to oilseed rape. On the other hand in cereal, beet and maize production areas, where manure was applied primarily prior to sugar beet or corn maize, the application prior to oilseed rape displayed lower frequencies.

Over the monitored period of seventeen years, the average oilseed rape yield from all 548 fields was $3.74\ t \cdot ha^{-1}$. Tab. 1 shows average seed yields according to several sorting criteria. Average yield attained by RT slightly surpassed the one attained by CT.

Over the first five years of the monitoring, CT yields generally surpassed RT yields (Fig. 1). But gradually, this trend turned over and RT reached higher yields. One of the reasons might be that farmers got used to the specific requirements and opportunities of RT system and may have improved it over time,

e.g. by employing the deeper soil loosening. Favorable effect of RT may have been gradual and required time to arise. Yet another reason may relate to recent weather development with higher temperatures and lower precipitations, where RT may have helped with better soil moisture management.
Concerning regionalization, potato production area demonstrated the highest average yield, followed by beet production area, while maize production area, where only RT was used, proved inferior results. Seed yields attained by RT exceeded those produced using CT in all of the production areas except the forage one.
Relatively small frequencies and uneven distribution of cases into individual categories may have influenced the results. For example RT was the only tillage system employed in maize production area. Results of CT were therefore not harmed due to unsuitability of maize production area in terms of winter oilseed rape growing.

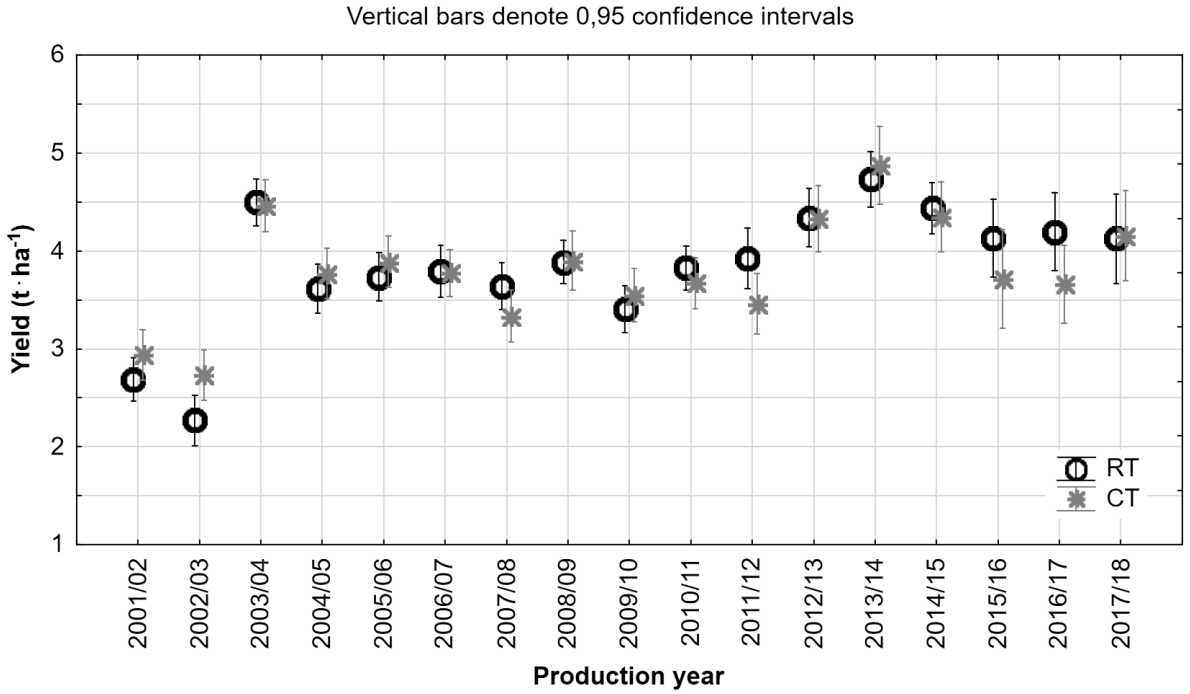

Fig. 1 Graph of time development of oilseed rape yields produced by reduced (RT) and conventional (CT) tillage systems

Statistical analysis of seed yields showed no significant differences with regard to the tillage system used, to fertilizer application at sowing, and to organic fertilizer application. Oilseed rape variety type (*t*-Test, $n = 538$ – mixed varieties excluded, $p = 0{,}037449$), and production area (*Turkey HSD* test) were the two sorting criteria where significant differences were demonstrated between the average rape yields. The trials thus correspond only partly with what *Madarász et al.* (2016) proved, i.e. by 12.6 % significantly higher rape yield of conservation compared to ploughing technology over ten-year period. One reason might be the monitoring and operational character of the trials, another one the differences in local climatic and other conditions.
Technological and economic variables, i.e. fuel consumption, labour consumption, machinery, material and total costs, unit costs per ton of production and earnings per hectare, were statistically significantly influenced by the application of organic fertilizers. This operation is demanding in terms of fuel, labour as well as costs. In order to avoid its influence, observations with organic fertilizer involved were excluded from further analysis. Tab. 2 thus presents the effect of soil tillage systems on the above mentioned technological and economic variables in the cases, where no organic fertilizers were used. Statistically significant differences between RT and CT were proved in terms of fuel and labour consumption, and machinery costs.

Tab. 1 Oilseed rape yields and frequencies of cases with respect to tillage system, production area and other factors

	Tillage system				Aggregate	
	Reduced tillage (RT)		Conventional tillage (CT)			
	Yield ($t \cdot ha^{-1}$)	Frequency	Yield ($t \cdot ha^{-1}$)	Frequency	Yield ($t \cdot ha^{-1}$)	Frequency
Production area						
Forage	3.45	32	3.62	12	3.49 [ab]	44
Potato	4.21	22	3.82	71	3.91 [c]	93
Cereal	3.56	92	3.54	51	3.55 [a]	143
Beet	3.93	142	3.73	110	3.84 [bc]	252
Maize	3.33	16	—	—	3.33 [ab]	16
Variety						
Conventional	3.68	123	3.62	88	3.65 [b]	211
Hybrid	3.82	179	3.77	148	3.80 [a]	327
Mixed	2.33	2	3.58	8	3.33	10
Organic fertilizers						
No	3.72	221	3.70	137	3.71 [a]	358
Yes	3.85	83	3.73	107	3.78 [a]	190
Fertilizers at sowing						
No	3.75	188	3.70	239	3.72 [a]	427
Yes	3.76	116	4.07	5	3.77 [a]	121
Aggregate	3.75 [a]	304	3.71 [a]	244	3.74	548

The findings of *Sanchez-Giron et al.* (2004, 2007) on higher herbicide, i.e. material, costs of RT was thus not verified, contrary to the conclusion on lower machinery costs. Decrease in fuel and labour consumption (*Bailey et al., 2003; Bonciarelli and Archetti, 2000; Gemtos et al., 1998; Tebrügge, 2000; Grubor et al., 2015*) was validated entirely.

Tab. 2 Effect of reduced (RT) and conventional (CT) tillage systems on yield, technological and economic variables of oilseed rape production excluding cases with organic fertilizer application (*t*-Test)

Variable	RT	CT	p-value
Frequency	221 [a]	137 [a]	—
Yield ($t \cdot ha^{-1}$)	3.72 [a]	3.70 [a]	0.814660
Fuel consumption ($l \cdot ha^{-1}$)	66.02 [a]	78.29 [b]	<0.000001
Labour consumption of stand establishment ($hrs \cdot ha^{-1}$)	1.16 [a]	1.86 [b]	<0.000001
Labour consumption ($hrs \cdot ha^{-1}$)	3.32 [a]	4.06 [b]	<0.000001
Machinery costs ($CZK \cdot ha^{-1}$)	5,983.22 [a]	6,706.03 [b]	0.000002
Material costs ($CZK \cdot ha^{-1}$)	12,177.81 [a]	11,613.22 [a]	0.062611
Total costs ($CZK \cdot ha^{-1}$)	18,321.67 [a]	18,542.60 [a]	0.533736
Unit costs ($CZK \cdot t^{-1}$)	5,249.68 [a]	5,244.37 [a]	0.978239
Revenues per ha ($CZK \cdot ha^{-1}$)	31,538.84 [a]	31,294.48 [a]	0.833348
Earnings per ha ($CZK \cdot ha^{-1}$)	13,217.17 [a]	12,751.88 [a]	0.660559

With respect to the earnings per hectare (Fig. 2), the best results were reached in potato and beet production areas with RT in both, followed by CT in potato zone, and by cereal production area with both RT and CT.

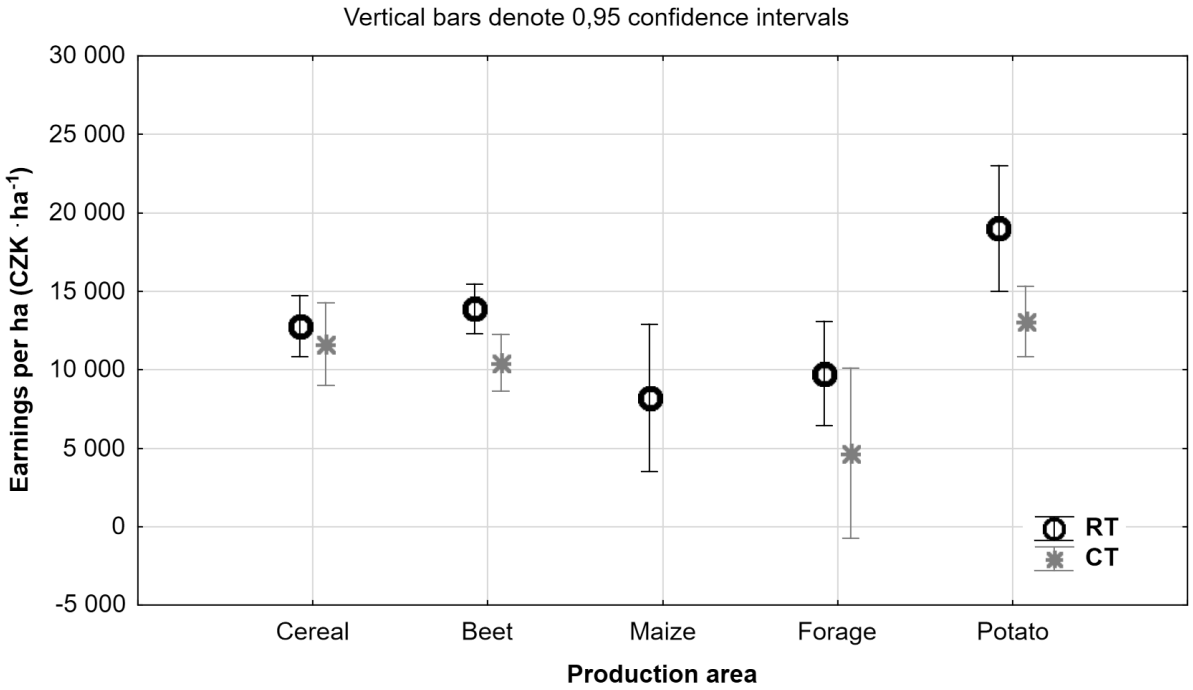

Fig. 2 Graph of earnings per hectare of oilseed rape regarding production areas and reduced (RT) and conventional (CT) tillage systems

CONCLUSIONS

When excluding cases with organic fertilizer application, the average fuel consumption of RT was by 15.7 % lower than that of the CT, the labour consumption of stand establishment was lower by 37.7 %, the overall labour consumption again lower by 18.4 %, and finally the machinery costs lower by 10.8 %. All the above mentioned differences proved statistically significant. The total costs were lower by mere 1.2 %. On the other hand, yields reached by RT were slightly higher, i.e. by 0.6%. The resulting unit costs of seed production were nearly identical. The potatoes production area proved to be the most favourable in terms of oilseed rape yields. Beet production area demonstrated also good results, namely over the recent years. In all of the production areas except the forage one, average seed yields reached by RT surpassed those produced using CT. Concerning earnings per hectare, RT results proved outstanding with regard to CT in all of the production areas.

RT confirmed to be an adequate alternative to CT from the viewpoint of oilseed yields, of economics as well as of fuel and labour consumption, particularly when employed on purpose and systematically. Lately, RT with deeper soil loosening has spread increasingly, namely in order to ensure the disruption of compacted layers.

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