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EFFECTS OF DIFFERENT SOIL TILLAGE INTENSITY ON YIELDS OF SPRING BARLEY

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Abstract

PERNICOVÁ ALENA, PROCHÁZKOVÁ BLANKA, HLEDÍK PAVEL, FILIPSKÝ TOMÁŠ. 2014. Effects of Different Soil Tillage Intensity on Yields of Spring Barley. *Acta Universitatis Agriculturae et Silviculturae Mendelianae Brunensis,* 62(5): 1071–1078.

Within the period 1990–2012, effects of different soil tillage intensity on yields of spring barley were studied in a field experiment in the sugar-beet producing region (Ivanovice na Hané, Czech Republic). The forecrop of the spring barley was always sugar beet; following in three different crop rotations, after maize for silage, winter wheat and spring barley. Four variants of tillage were evaluated: Variant 1 – ploughing to the depth of 0.22 m; Variant 2 – shallow ploughing to the depth of 0.15 m; Variant 3 – no tillage; Variant 4 – shallow loosening soil to the depth of 0.10 m.
Effect of different tillage on yields of spring barley was statistically insignificant. In all three crop rotations, the highest and the lowest average yields were obtained in Variant 2 (ploughing to the depth of 0.15 m) and Variant 1 (ploughing to the depth of 0.22 m), respectively. Average yields in variants of soil tillage were these: variant 1 – 6.42 $t.ha^{-1}$; variant 2 – 6.57 $t.ha^{-1}$, variant 3 – 6.53 $t.ha^{-1}$, variant 4 – 6.50 $t.ha^{-1}$. The obtained results indicate that in these pedo-climatic conditions reduction of intensity soil tillage represented a very suitable alternative in case of growing spring barley after sugar beet as compared with the conventional method of tillage by ploughing to the depth of 0.22 m.

Keywords: spring barley, methods of tillage, grain yield

INTRODUCTION

In recent years, some positive changes were observed in the topic of tillage; these are associated with an increased interest in sustainable agriculture and consequences of a long-term use technologies of tillage on the soil. There is a number of modified tillage methods that are determined by growing conditions existing in a given locality as well as by different crop rotations. Barley reacts sensitively on soil compaction. It is necessary to reduce the number of movements of tractors and agricultural machinery on the field. Good physical and structural conditions of soil as well as a good aeration and availability of soil nutrients are preconditions for good growth and high yields of crops (Suškevič, 1994; Arshad, 1999; Hůla, Procházková *et al.*, 2008; Hůla *et al.*, 2010).

Barley (*Hordeum vulgare L.*) is an important cereal crop, ranking fourth in the world in terms of planted area after only wheat, rice and maize. Barley production is often influenced by abiotic stress caused, for example, by salinity, drought, frost or waterlogging. (Xiao *et al.*, 2007). Drought, the result of low precipitation or high temperature, is thus one of the main problems underlying the success of modern agriculture around the globe and is one of the most important environmental factors that affect the growth, development and production of crops (Hasanuzzaman *et al.*, 2012; Hossain *et al.*, 2012a). In practice, it is very difficult for plant breeders to control the multiple environmental factors operating in a field experiment (Babu *et al.*, 2004).

As far as the spring barley is concerned, it is possible to use also methods of minimum tillage. This approach is justified above all by requirements of cereals that prefer slightly compacted soils and do not need its deeper tillage. The application of minimum tillage technologies is dependent above all on environmental conditions. The most suitable are usually medium soils with a higher degree of fertility in maize and sugar-beet producing regions. A reduction of the depth and intensity of tillage can be used also in drier regions with sandy soils, mainly due to a positive effect of minimum tillage technologies on the soil moisture regime (Zimolka *et al.*, 2006).

The introduction of minimum soil tillage technologies have influenced significantly economic results of farms. The application of minimum tillage reduces costs of soil tillage and, thus, also unit costs of production. An indispensable presumption of this is that yields will remain unchanged and/or that the reduction of the income will be lower than the cost savings (Šarapatka *et al.*, 2010). The fertility is one of the most important properties of soil. This means that we should be considerate in this respect and take care not only about soil but also of all other natural resources. It is quite clear that we cannot only exploit soil; we must also tend for it, replace nutrients, use considerate soil tillage operations, and try to improve overall soil environment (Hůla *et al.*, 2010, Köller and Linke, 2006; Hůla, Procházková *et al.*, 2008; Procházková *et al.*, 2011).

MATERIAL AND METHODS

Effects of different methods of tillage on yields of spring barley were studied within the framework of a long-term field experiment performed within the period of 1990–2012. Experimental fields were situated in the Research Institute of Crop Production Praha-Ruzyně, on the land of Research Station in Ivanovice na Hané (Czech Republic). This experiment still continues.

Characteristics of Experimental Site

Research Station Ivanovice na Hané is situated in a sugar beet production region and its basic parameters are as follows: altitude 225 m a.s.l., loamy chernozem soil, depth of the humus horizon 0.40–0.50 m, neutral soil reaction, humus content 2.6%, content of available phosphorus and potassium is good.

Climatic Conditions of the Experimental Site

The municipality Ivanovice na Hané is situated in the warm and temperate dry climate subregion. The average (1990–2012) annual temperature and the average annual sum of precipitation have been 9.0 °C and 554 mm, respectively.

Experimental Variants

Different methods of soil tillage for spring barley were monitored within the framework of three different crop rotations. In all three rotations spring barley was always grown after sugar beet that followed within the framework of crop rotation either after maize for silage, or winter wheat and or spring barley.

Variants of tillage:
Variant 1 – ploughing to the depth of 0.22 m;
Variant 2 – ploughing to the depth of 0.15 m;
Variant 3 – no-tillage (direct drilling);
Variant 4 – shallow loosening to the depth of 0.10 m.

Mineral Fertilization

The doses of mineral fertilizers were the same in all experimental variants: N – 40; P – 30; K – 60 (in kg of pure nutrients per hectare).

Applied fertizers: Superphosphate (46%), ammonium-calcium nitrate (applied prior to sowing), potash salt (60%).

Spring Barley Varieties

1989–1996 – Rubín,
1997 – Akcent,
1998–2007 – Kompakt,
2008–2012 – Jersey.

Protection Against Weeds, Diseases and Pests

In the field trial plant protection is performed in accordance with the methodology recommended by the Central Institute for Supervising and Testing in Agriculture and with regard to the current crop condition and degree of its infestation.

Establishment and Design of the Experiment

The design of this experiment was based on the method of strip plots with four replications. The area of experimental plots was 300 m^2 (6 × 50 m), the area of harvested parcels was 22 m^2.

Statistical Processing

The statistical analysis of effects of different methods of tillage on yields of spring barley was performed by means of variance analysis combined with Tukey's test using the software package STATISTICA, version 7.0.

RESULTS

Results of studies about effects of different soil tillage variants on spring barley as recorded within the period 1990 to 2012 are presented in the following Tabs. I–IV and Figs. 1–4. Results from the year 2006 are not presented because the vegetation of spring barley was damaged due to the fact that the sum of precipitation in the period of ripening was too high. Spring barley was always sown after sugar beet that followed within the framework of crop rotation either after maize for silage, or winter wheat and/or spring barley. Four variants of tillage were evaluated: ploughing to the depth of 0.22 m; ploughing to the depth of 0.15 m; sowing into non-tilled soil; shallow loosening soil to the depth of 0.10 m.

I: *Yields of spring barley (t·ha^{-1}) within the framework of crop rotation maize for silage – sugar beet – spring barley (1990–2012)*

Year	Method of tillage			
	Ploughing to the depth of 0.22 m	**Ploughing to the depth of 0.15 m**	**Direct sowing**	**Shallow tillage to the depth of 0.10 m**
1990	6.14	7.18	7.33	7.78
1991	7.32	6.95	6.33	7.58
1992	5.23	5.82	5.90	6.55
1993	3.11	2.79	3.40	3.46
1994	6.54	6.36	6.89	6.31
1995	6.53	7.0	6.22	5.69
1996	6.00	5.69	6.00	6.68
1997	6.62	6.49	6.64	6.95
1998	6.40	6.15	6.55	6.63
1999	6.33	7.22	7.00	7.29
2000	4.26	4.61	3.66	3.61
2001	8.05	8.34	8.49	8.12
2002	6.31	6.30	6.37	6.54
2003	4.43	5.58	4.59	3.31
2004	9.01	8.61	8.06	7.77
2005	7.05	7.58	6.91	6.66
2007	5.26	5.88	5.97	5.76
2008	6.62	6.56	6.66	6.50
2009	9.05	9.12	8.90	8.89
2010	7.43	7.47	7.20	7.37
2011	9.42	9.65	9.34	9.58
2012	1.43	1.55	2.51	1.56
Mean	6.30	6.50	6.40	6.39

II: *Yields of spring barley (t·ha^{-1}) within the framework of crop rotation winter wheat – sugar beet – spring barley (1990–2012)*

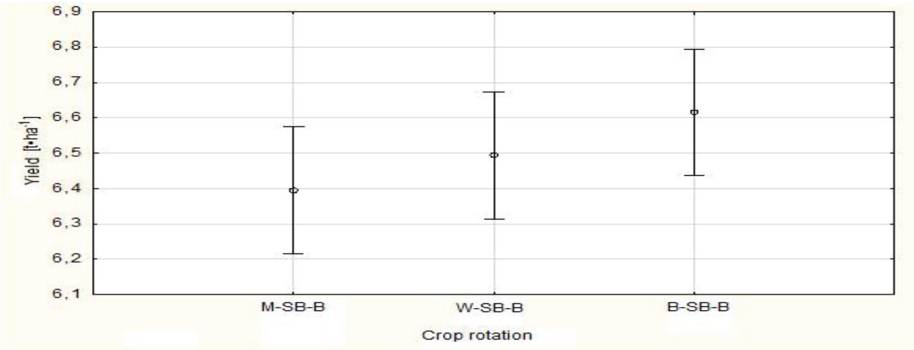
Year	Method of tillage			
	Ploughing to the depth of 0.22 m	**Ploughing to the depth of 0.15 m**	**Direct sowing**	**Shallow tillage to the depth of 0.10 m**
1990	6.95	7.83	7.84	7.81
1991	6.60	7.47	7.17	7.53
1992	6.28	6.33	6.51	6.37
1993	3.17	3.46	3.59	3.66
1994	6.64	7.19	6.87	7.06
1995	6.21	5.56	5.32	6.42
1996	6.59	6.05	6.37	6.00
1997	7.42	7.54	7.64	7.50
1998	6.01	6.03	6.55	6.31
1999	6.91	7.21	6.91	7.58
2000	4.63	4.60	3.88	3.84
2001	8.38	8.37	8.22	8.25
2002	6.51	6.75	6.41	6.32
2003	4.45	5.23	4.45	3.39
2004	8.71	8.54	8.36	7.41
2005	7.36	7.46	7.41	7.22
2007	5.05	5.55	5.94	6.09
2008	5.64	6.20	6.63	6.80
2009	9.23	7.97	8.58	8.94
2010	7.35	7.47	6.64	6.77
2011	9.04	9.19	9.20	9.02
2012	1.76	2.07	2.89	2.92
Mean	6.40	6.55	6.52	6.51

III: *Yields of spring barley (t·ha⁻¹) within the framework of crop rotation spring barley – sugar beet – spring barley (1990–2012)*

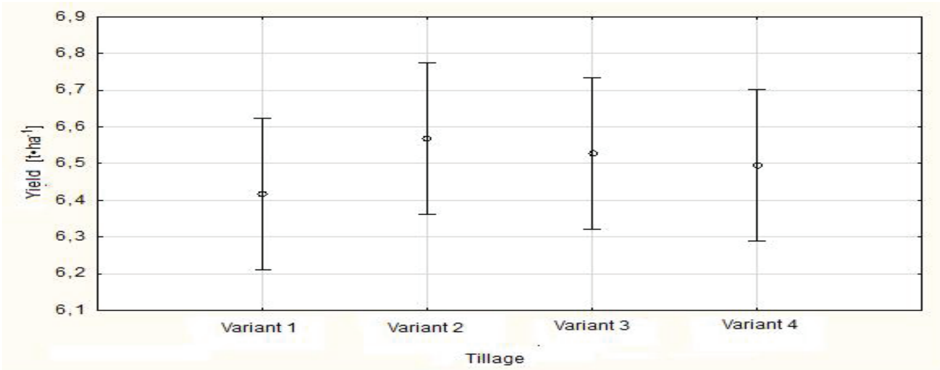
Year	Method of tillage			
	Ploughing to the depth of 0.22 m	Ploughing to the depth of 0.15 m	Direct sowing	Shallow tillage to the depth of 0.10 m
1990	7.09	7.58	7.40	7.79
1991	7.22	7.41	7.24	6.98
1992	6.32	6.42	6.55	6.35
1993	3.33	3.60	4.01	3.74
1994	6.73	7.36	7.05	6.85
1995	6.31	7.15	6.81	6.35
1996	6.20	6.02	6.13	5.78
1997	7.31	7.18	7.33	7.22
1998	6.10	5.38	6.50	6.30
1999	7.01	6.92	7.05	7.23
2000	4.73	5.06	3.96	3.86
2001	8.10	7.96	8.71	8.27
2002	6.78	6.63	6.32	6.57
2003	4.77	5.22	4.13	3.55
2004	8.32	7.99	7.83	8.24
2005	7.35	7.38	7.47	7.30
2007	5.69	6.40	6.34	6.38
2008	6.35	7.14	7.08	7.17
2009	9.34	8.53	8.63	8.90
2010	7.17	7.28	6.74	7.21
2011	9.17	9.40	9.47	9.45
2012	2.74	2.59	3.81	3.45
Mean	6.55	6.66	6.61	6.59

IV: *Average yields of spring barley (t·ha⁻¹) in individual crop rotations within the period 1990–2012*

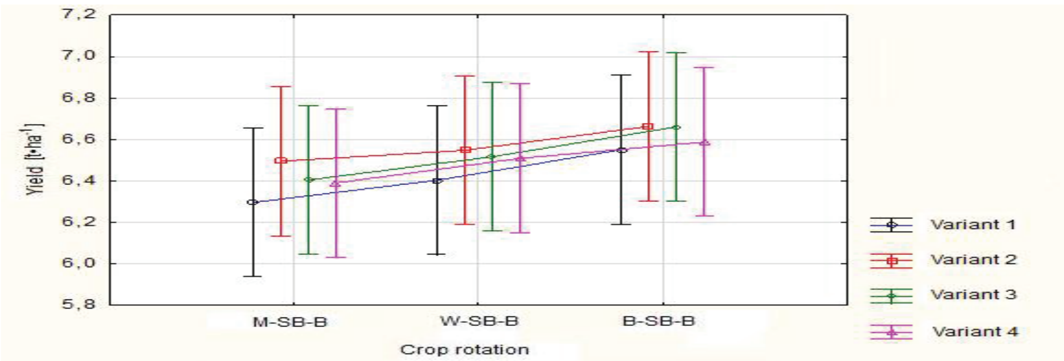
Year	Crop rotation			
	Maize – Sugar beet – Barley	Wheat – Sugar beet – Barley	Barley – Sugar beet – Barley	Mean
1990	7.11	7.61	7.46	7.39
1991	7.05	7.19	7.21	7.11
1992	5.87	6.37	6.41	6.22
1993	3.19	3.47	3.67	3.44
1994	6.52	6.94	6.99	6.82
1995	6.36	5.88	6.66	6.30
1996	6.09	6.25	6.03	6.13
1997	6.67	7.53	7.26	7.15
1998	6.43	6.22	6.07	6.24
1999	6.96	7.15	7.05	7.05
2000	4.03	4.24	4.40	4.22
2001	8.25	8.30	8.26	8.27
2002	6.38	6.50	6.57	6.48
2003	4.48	4.38	4.42	4.42
2004	8.36	8.25	8.09	8.24
2005	7.05	7.36	7.38	7.26
2007	5.72	5.66	6.20	5.86
2008	6.58	6.32	6.94	6.61
2009	8.99	8.68	8.85	8.84
2010	7.37	7.05	7.10	7.17
2011	9.50	9.11	9.37	9.33
2012	1.76	2.41	3.15	2.44
Mean	6.40	6.49	6.62	6.50



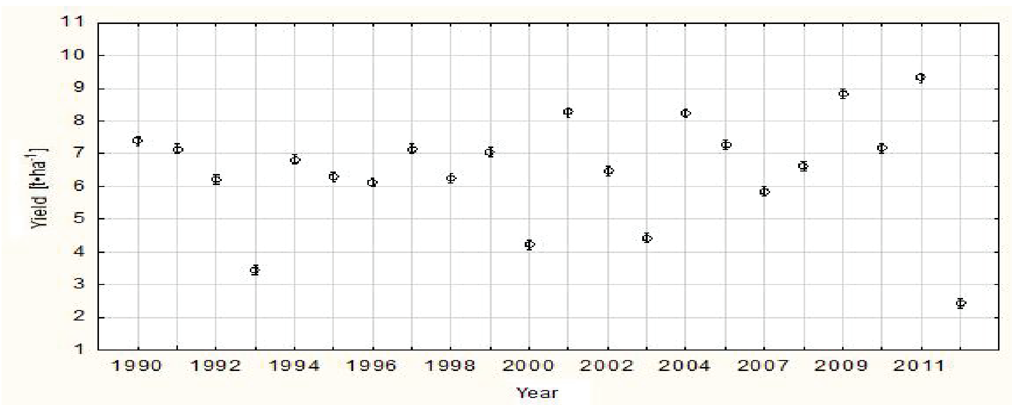
1: *Statistical evaluation of the effect of crop rotation on yields of spring barley*
Note: B = spring barley; M = maize for silage; SB = sugar beet; W = winter wheat



2: *Statistical evaluation of the effect of soil tillage on yields of spring barley*



3: *Statistical evaluation of the combined effect of crop rotation and method of soil tillage on yields of spring barley*



4: *Statistical evaluation of average yields of spring barley within the period of 1990–2012*

DISCUSSION

The aim of this study was to evaluate effects of different methods of tillage on yields of spring barley grown on loamy chernozem soil in the sugar beet producing region (Ivanovice na Hané). Within the period of 1990–2012, four different variants of tillage were evaluated.

Yields of spring barley were more influenced by its placement in the crop rotation. As mentioned above, spring barley was grown within the framework of three crop rotations. The effect of barley sequence in the crop rotations was statistically insignificant in all three cases. Similarly, statistically insignificant differences were found out also among all four variants of tillage. The highest average yield of grain (6.62 t·ha^{-1}) was recorded within the crop rotation spring barley – sugar beet – spring barley. In the crop rotation winter wheat – sugar beet – spring barley the average grain yield was a little lower (6.49 t·ha^{-1}) and the lowest one (6.40 t·ha^{-1}) was recorded in the crop rotation maize for silage – sugar beet – spring barley.

As far as the whole experimental period was concerned, the highest average yield (9.65 t·ha^{-1}) was obtained in Variant 2 (ploughing to the depth of 0.15 m) of the crop rotation maize for silage – sugar beet – spring barley in the year 2011; on the other hand, the lowest one (1.43 t·ha^{-1}) was recorded in Variant 1 (ploughing to the depth of 0.22 m) of the same crop rotation in the year 2012. The highest average yields were recorded in 2011; in this year, the average yield obtained in all four variants of tillage was higher than nine tons. Within the whole experimental period and regardless to the crop rotation, the highest average yield (6.57 t·ha^{-1}) was obtained in Variant 2; the second and the third places were occupied by Variants 3 and 4 (6.53 t·ha^{-1} and 6.50 t·ha^{-1}, respectively). The lowest average grain yield (6.42 t·ha^{-1}) was obtained on Variant 1. The lowest yields were obtained in extremely dry year 2012 (average of variants was 2.44 t.ha^{-1}), when a higher intensity of soil tillage resulted in higher decline of yields.

Results of this long-term experiment indicate that in drier and warmer regions, a reduced intensity of tillage showed a positive effect on yields of spring barley cultivated after sugar beet on fields with chernozem soil.

In the Czech Republic, long-term studies about application of minimum tillage technologies have been performed already since 1960s. The importance of the depth of tillage and its effects on crops and soil was evaluated in experiments performed within the period 1961–1967 on fields with the chernozem soil in the maize producing region. It was found out that in the majority of crops the yield response to the depth and intensity of tillage was inexpressive (Nováček, 1970). Systems of tillage and crop establishment are an important component of cereal growing technologies. They influence the basic elements of yield, i.e. future conditions for yield formation and quality. In case of spring cereals, the possible compensation of mistakes done during the growth establishment by means of further agrotechnical interventions is very small and for that reason it is necessary to pay great attention to this problem because it is a basis of their future successful growing. As far as the spring barley is concerned, there is a wide spectrum available of possible technologies of tillage and crop establishment. The selection of working operations should be carried out with regard to existing site conditions, sequence of spring barley in the crop rotation (including the management of post-harvest residues of the forecrop), condition of soil after the harvest of the forecrop, availability of machinery etc. (Zimolka *et al.*, 2006). Using methods of the minimum tillage, the volume of plant residues and biomass accumulate in the topsoil layer that is relatively thinner than in case of conventional soil tillage. It is possible that during their decomposition can be produced some substancies whose higher concentrations could have en inhibiting effects. This is possible in case that these residues are in high concentration either inside or in the close neighbourhood of the seedbed. If they are below it, they prevent the contact of seeds with the capillary system and this can cause problems associated with the lack of moisture (Richter and Hlušek, 2003).

Yield response of individual crops on the depth and intensity of soil tillage, considerably dependents on pedo-climatic conditions. Due to a considerable variability of weather conditions in individual years and also possible cumulative effects of pedological processes it can be concluded that the evaluation of effects of different methods of tillage gives more reliable results only when performed within the framework of long-term experiments (Procházková *et al.*, 2004).

Results of experiments performed on chernozem fields in maize and sugar beet producing regions in years 1989–1994 and 1989–2000, respectively, indicate that the application of methods of minimum tillage in case of spring barley is suitable and prospective (Procházková *et al.*, 1998; Hrubý and Procházková, 2000).

In an experiment performed in Scotland in years 1977–1978, there were no differences in yields of spring barley grown in systems with a different intensity of tillage. This experiment was performed on plots with sandy-loamy soil (Pidgeon, 1980).

In a five-year experiment performed in Norway, yields of spring barley and oats grown in a system of sowing into the non-tilled soil decreased while the degree of weed infestation increased as compared with the ploughed variant (Torresen *et al.*, 1999).

In experiments performed on fields with brown soil in the sugar beet producing region within the period of 1996–2000, Rotrekl *et al.* (2001) observed a positive yield response of the spring barley crop to a reduced intensity of tillage.

Procházková and Míša (2004) present results of assessment effect different soil tillage on yields spring barley. Results obtained in this study indicate that in maize and sugar beet producing regions it is possible to apply minimum technologies when growing spring barley not only after sugar beet but also after cereals. However, a proper treatment of post-harvest residues (that enables their quicker decomposition) becomes an important part of these measures.

SUMMARY

Effects of different methods of tillage on spring barley yields were studied in a field experiment established on a field with fertile loamy chernozem in the sugar beet producing region in the Field Trial Station Ivanovice na Hané within the period of 1990–2012. The year 2006 was not involved into the evaluation of this experiment because the stand of spring barley was damaged by a too high sum of precipitation in the period of ripening and the subsequent sprouting of grain in the standing crop. Altogether four variants of tillage were evaluated: Variant 1 – ploughing to the depth of 0.22 m; Variant 2 – shallow ploughing to the depth of 0.15 m; Variant 3 – sowing into non-tilled soil; Variant 4 – shallow loosening soil to the depth of 0.10 m.

The highest and the lowest average yields of grain spring barley were obtained in crop rotations spring barley – sugar beet – spring barley and maize for silage – sugar beet – spring barley, respectively.

In the crop rotation maize for silage – sugar beet – spring barley, the highest and the lowest average yield of grain were obtained in Variant 2 (ploughing to the depth of 0.15 m) and Variant 1 (ploughing to the depth of 0.22 m), respectively.

In the crop rotation winter wheat – sugar beet – spring barley the highest and the lowest average yield of grain were obtained also in Variant 2 (ploughing to the depth of 0.15 m) and Variant 1 (ploughing to the depth of 0.22 m), respectively.

Finally, in the crop rotation spring barley – sugar beet – spring barley the highest and the lowest average yield of grain were obtained again in Variant 2 (ploughing to the depth of 0.15 m) and Variant 1 (ploughing to the depth of 0.22 m), respectively.

As shown above, the highest average yields of grain were obtained in Variant 2 while the lowest ones were obtained in Variant 1.

The obtained results indicate that under the given pedo-climatic conditions the reduction of tillage intensity for spring barley grown after sugar beet represents a suitable alternative to the conventional method of tillage.

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