SZENT ISTVÁN
UNIVERSITY

Theses of the Doctoral (PhD) Dissertation

THE SIGNIFICANCE OF SURFACE COVERING IN SOIL PROTECTION AND MITIGATION OF CLIMATE DAMAGES

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Gödöllő

2016

The Doctoral School's

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1. ANTECEDENTS OF THE WORK AND THE GOALS SET

In the development of cultivation, the progress in (agricultural, technical, biological and soil physical) sciences, the economic environment, the climate impacts, the need for practice and the customs have always played a key role. With the progress of biological and soil sciences, the protective functions of soil cultivation and its functions on which crop production can be built have become increasingly clear.

In the middle of the twentieth century, views came to the fore - with the development of the science of crop production - which considered the needs of the produced crops important in soil cultivation. In many cases, this so called crop-oriented cultivation harmed the soil - it has subsequently become clearly visible (multi-threaded cultivation, spoiled ploughing, structure degradation, trampling damage). In addition to the soil degradation, the modification of cultivation goals was influenced also by the adverse climate impacts.

Since the mid-1990's, after considering the consequences of centuries-old, multi-threaded cultivation systems with mechanical approach, recognizing the degradation of soils, the adverse climatic effects of the changing years and taking into account the economic factors and the expectations for the protection of the soil and the environment, the concept of the purpose of cultivation has become significantly broadened.

Our main task is to protect the structure and organic matter, to improve and maintain the condition, thereby influencing the moisture-, air and heat turnover in the right direction. The protection of the surface and the stimulation of the biological activity has come to the forefront. In order to achieve the objectives listed above, any cultivation intervention can be effective by which the gentle mixing of the crop and stubble remains into the soil, furthermore, the certain level of surface cover can be ensured.

Due to compulsion and foresight, the climate change has given and still gives further impetus to soil cover for protection (soil, water) purposes.

Nowadays, the effects of surface cover, the mulch preserving cultivation on the improvement and maintenance of soil quality (structure, looseness, carrying capacity, organic matter content, air-, moisture and heat flow, biological life) are known but they are not sufficiently proven domestically. This may be partly because the shorter experience (approximately 25 years) compared to the Western European one, and partly because of the partial application - e.g. it was approved earlier concerning sunflower as after cereals, rapeseed or corn, but it is not general even in stubble cultivation. There is no doubt that the practical application of the mulch preserving cultivation raises a number of agronomic, technical, plant production and other issues which support the timeliness of the research topic.

My research is aimed at the exploration of impacts of the surface cover created with residual stubble on the soil condition, crop and crop stability, furthermore, on the economic conditions and the objectives can be defined as follows:

1) Provision of evidence for the beneficial effect of mulch preserving cultivation systems with surface cover on the basis of soil condition characteristics - moisture content, penetration resistance, agronomic structure, CO_2 emissions.
2) Evidence of applicability of mulch preserving cultivation systems - on the basis of soil condition characteristics, fuel consumption and yield - in three micro-regions, in different soils.
3) Provision of evidence for the beneficial effect of mulch preservation - on the basis of residual stubble cover, the fuel consumption devoted to

cultivation and the yield - in the adaptation to climatic extremes, under domestic circumstances.

2. MATERIAL AND METHOD

2.1. The circumstances of the research work

I carried out the experimental work by way of long-term tillage experiments set in three different domestic production sites, between 2007 and 2009.

2.1.1. Characterisation of the production site in Hatvan-Józsefmajor, the experimental space and the long-term tillage experiment

The Experimental and Educational Farm in Józsefmajor, belonging to Szent István University GAK Kht. is located on the border of the alluvial plans of the Northern Great Plain and the Cserhát Region. The topographical conditions are varied and erosion is an observable phenomenon. The altitude is between 128 and 350 m with hills sloping slightly to south-east.

The mean annual temperature is 9.5-10°C. The area is characterized by rainfall below the average of many years. The annual rainfall is 580 mm, 323 mm of which falls during the vegetation period.

The soil type of the experimental area is chernozem with lime deposits, with the physical characteristics of sandy loam. Its pH value is slightly acidic. The organic matter content of the 0-40 cm layer is 2.83% on average.

The tillage experiment in Józsefmajor was started in the autumn of 2002, under the leadership of Dr. Márta Birkás. The treatments of the long-term tillage experiment of Józsefmajor were set with four repetitions, in a bandbased random layout. The parcel dimensions of the specific tillage treatments are: 13 x 158 meters.

We applied the following treatments:

1. basic cultivation with ploughing (SZ), (26-30 cm),
2. direct sowing without cultivation (DV),
3. shallow cultivation by using a cultivator (SM), (14-16 cm),
4. mulch preserving cultivation with a cultivator (KM), (22-25 cm),
5. shallow cultivation by using a traditional disc (T), (16-18 cm),
6. loosening with a plain-disc surface smoothening (L+T), (40 cm).

2.1.2. Characterisation of the production site in Peresznye, the experimental space and the long-term tillage experiment

The town of Peresznye lies in the western part of Vas County, 10 km north-northeast from Kőszeg, in Kőszeg District, next to the road connecting Kőszeg and Lövő, in a valley located between wooded hills. The GPS coordinates of the town are as follows: Northern w. 47° 25′ 25″, Eastern l. 16° 39′ 03″. Its precipitation levels are basically determined by the proximity of the foothills of the Alps. As concerns its soil conditions, the dominant soil type is the brown forest soil, with physical characteristics of clay and loam and great Arany-type cohesiveness value. The humus content of the soil at the time the experiment was set (2007), in the average of the entire table: on 10 cm: 3.01%; on 20 cm: 2.58%; on 30 cm: 1.76%; on 40 cm: 1.36% (the measurement was carried out by SZIU TALT). The soil of the experimental area is a bound, brown forest soil with the physical characteristics clay and loam. The area has a slightly north-eastern slope. The area of the table constituting the experimental area is 10.8 ha, and within the table, the soil quality is homogeneous.

The long-term tillage experiment of Peresznye was done during the period between 2007 and 2009, by applying the table-halving method. The treatments were constituted by mulch preserving cultivation variants built on rotation and without rotation of traditional character. The implementation of all the other agrotechnological and crop protection procedure took place in the same way in the entire area of the experiment.

2.1.3. Characterisation of the production site in Sarud, the experimental space and the long-term tillage experiment

The town of Sarud is located in the southern part of Heves County, in Füzesabony District, on the shore of Lake Tisza. The GPS coordinates of the town are as follows: Northern w. 47° 35′ 42″, K. h. 20° 35′ 24″. Its precipitation levels are determined by its location in the Plains, but the influencing effect of the water mass of Lake Tisza can be felt, as well. In its soil conditions, floodplain location is dominant. The soil type of the production site is a meadow chernozem prone to salination, with the characteristics of clay and loam and with a high Arany-type cohesiveness. The humus content of the soil at the time the experiment was set (2007), in the average of the entire table: on 10 cm: 4.61%; on 20 cm: 4.17%; on 30 cm: 3.78%; on 40 cm: 3.58% (the measurement was carried out by SZIU TALT).

The table constituting the experimental space is a plane, bound, saline meadow soil. The table lies at the junction point of Lake Tisza and Stream Laskó, on a floodplain area. One of its longitudinal sides is bordering with the seepage channel of the flood protection dam. It covers an area of 20 ha, and within the table, the soil quality can be considered homogeneous. I started the long-term tillage experiment in 2007 and closed in 2009, and I applied the table-halving design. In the first variant, the tillage treatments were carried out in the way typical for the traditional cultivation with a mechanical approach, while in the second variant, mulch preserving cultivation was used. The implementation of all the other agrotechnological and crop protection procedures took place in the same way in the entire area of the experiment.

In the experiments in Peresznye and Sarud, in addition to the examination of the impact of mulch-preserving cultivation on the characteristics of the soil condition, I tried to find answers also to economic, technical and suitability issues.

2.2. Methods for testing in the long-term experiments in soil cultivation

- The soil moisture test: I performed it by using a PT-I moisture meter (the product of Kapacitív Kkt., Budapest), up to a depth of 50 cm of the soil, with a scale of 10 cm, repeated five times.
- Soil resistance test: performed by using the Szarvasi spring dynamometer manufactured by Mobitech Bt. (Daróczi and Lelkes, 1999; Daróczi, 2005), up to a depth of 50 cm, with a scale of 10 cm, repeated five times.
- The CO_2 emission test: I applied the method with closed measuring cup (of a volume of 0.00385 m^3), I measured the change in the CO2 concentration by using a Testo 535-type infrared CO2 gas analyzer, at half-hour intervals, repeated five times.
- The agronomic structure test: for the test, the soil sampling took place from the upper 15 cm layer of the soil, repeated 3 times per treatment. I

distinguished between four size ranges: the fraction of clods > 10 mm, crumbs: 2.5-10 mm, small crumbs: 0.25-2.5 mm and powder < 0.25 mm.

- Stubble remains cover tests: to determine the cover level, I used a measurement framework of 0.25 m^2 and a standard photo series (according to Birkás). I expressed the surface cover (mulch) in percentage form.
- The examination of the yield and other economic indicators: I compared the fuel amount spent on the soil cultivation with the yields.
- The method of statistical analysis: for the analysis of the treatment effect, I applied the single-factor variance analysis (Sváb, 1981), while for the detection of significant differences, I used the F-statistics (Fischer LSD test), at a confidence level of 95 or 99% ($P<0,05$; or $P<0,01$). I examined the relationship between the qualitative variables with a regression analysis.

3. RESULTS

3.1. The change of surface coverage in treatments during the test period

With the exception of ploughing cultivation variant, a continuous mulch cover of variable extent is typical for all treatments. *Figure 1* shows the change in the extent of surface cover in the treatments of the long-term tillage experiment of Józsefmajor, during the entire test period. According to *Figure 1*, the depth and intensity of the disturbance is closely related to the changes of the surface cover.

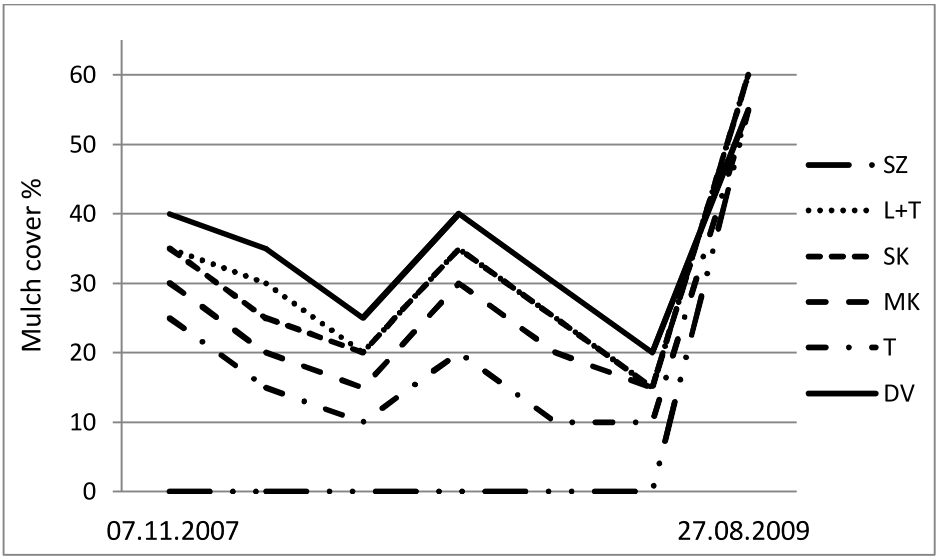

Figure 1 The change of surface cover in treatments during the entire test period (Józsefmajor)

3.2. The results of the soil moisture tests

I performed the soil moisture test with a scale of 10 cm, up to a depth of 50 cm. During the data review, I found that in the upper layer of the soil there are significant differences in the treatments. In the lower layers, the differences are reduced and blurred. After the detailed statistical analysis of the data, I found it advisable to track two soil depths.

Figure 2 presents the soil moisture data relevant to the 0-10 cm test layer of the long-term tillage experiment in Józsefmajor registered in the year of 2008. Considering data of the spring and summer of 2008, the assumption that the surface cover helps to preserve soil moisture seems to be justified. The soil moisture test performed after the autumn basic cultivations proves that the application of mulch preserving cultivation reduces moisture loss.

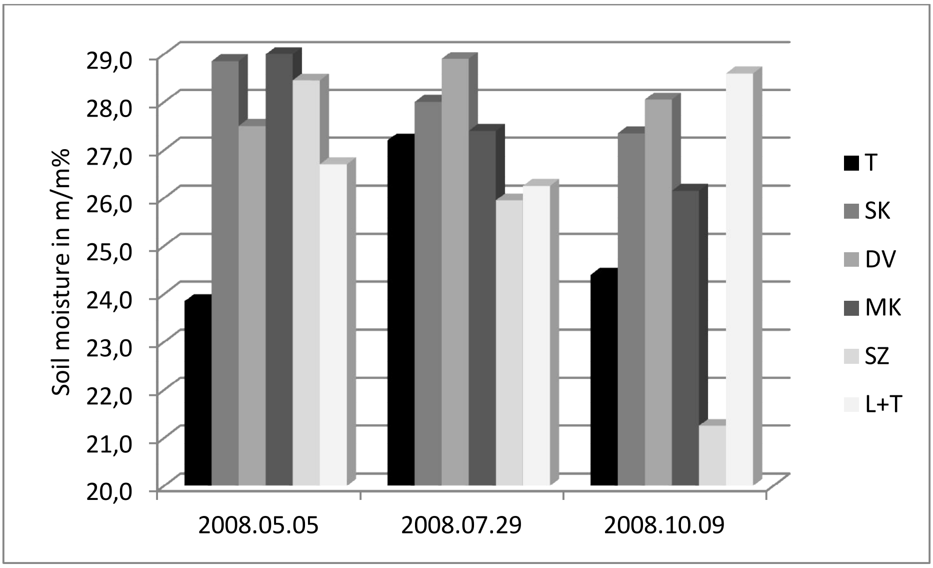

Figure 2 Moisture data of the 0-10 cm soil layer at the test dates of the long-term tillage experiment in Józsefmajor from 2008

I evaluated the relationship between the extent of surface cover and the change in the soil moisture, which did not show strong correlation between the change in the two characteristics in any of the experimental locations and any of the treatments. It means that the typical 5-35% mulch cover had only little influence on the soil moisture data emerged in the treatments.

3.3. The results of soil resistance tests

I examined the penetrometer test of soil resistance up to a depth of 50 cm, with a scale of 10 cm. After the review and detailed statistical analysis of the data I found that it was better to analyze the looseness of two typical soil layers.

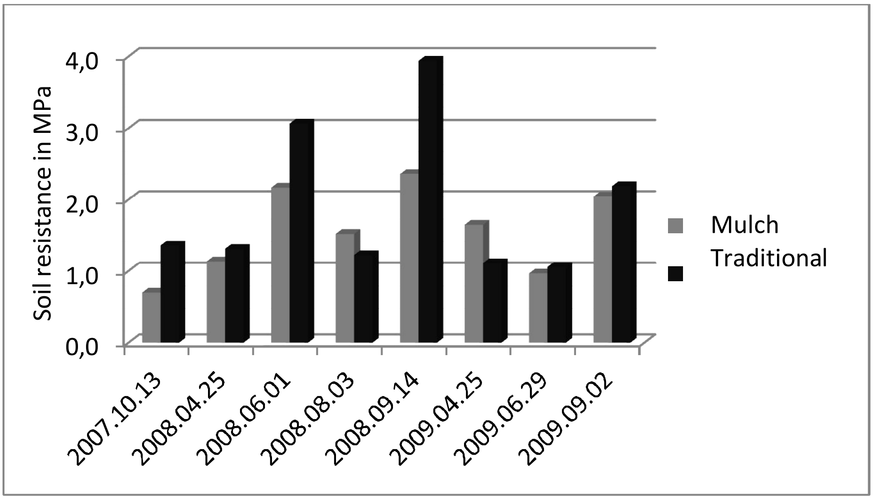

Figure 3 Penetration resistance data change of the 10-20 cm soil layer in the Peresznye experiment

Figure 3 shows the soil resistance average values measured in the 10-20 cm soil layers of the treatments of the long-term tillage experiment of Pereszinye. It can be seen that out of the eight measurement dates, the traditional cultivation variant built on ploughing showed higher penetration values six times. In the traditional variant, the extent of compaction reached the level of 3.0 MPa - which can be declared harmful - on two measurement dates: in June and September of 2008. At the same times, the values of the variant with mulch cultivation barely exceeded the level of 2.0 MPa. Thus, from the aspect of compaction, the mulch treatment can be assessed less risky. The higher compactness values of the 10-20 cm soil layer of the variant with traditional cultivation are probably the consequences of the harmful effects of multi-threaded smoothening and seedbed preparation works, furthermore, the higher-level water loss of the uncovered soil.

The regression tests did not show a strong correlation between the extent of the surface cover emerged in the treatments and the penetration resistance data, in either of the experimental locations. On the basis of this, the looseness of the soil was less affected by the mulch cover than the nature of disturbance, the time elapsed since the cultivation and the weather conditions. According to the results, the 5-35% surface cover emerged in treatments with mulch preserving cultivation is insufficient for the long-term maintenance of soil looseness.

3.4. Results of the carbon dioxide emission test of the soil

The aim of the study was to determine the way in which the specific cultivation variants influence the intensity of the soil's carbon dioxide emission, furthermore, whether there are any differences concerning the CO_2 emission dynamics of the specific cultivation solutions typical for longer periods, or not.

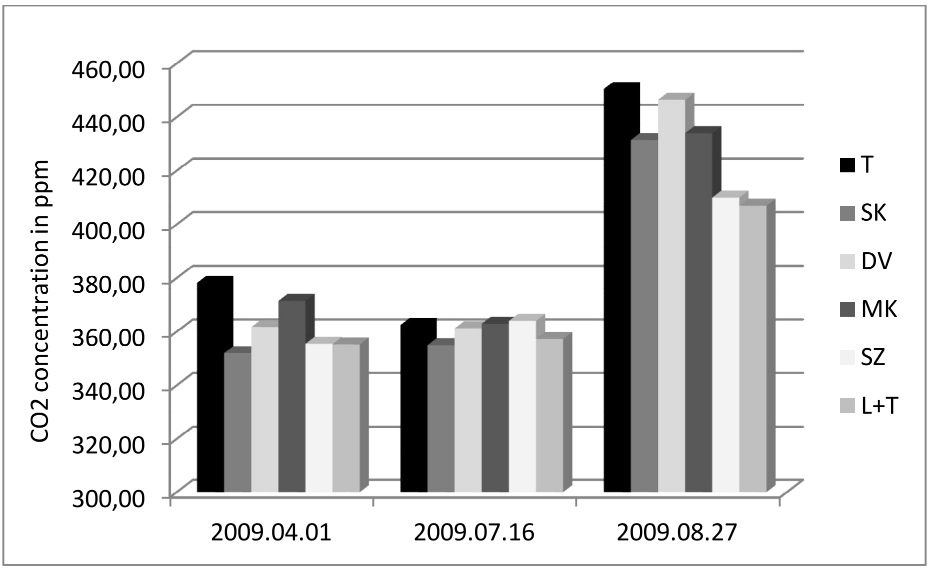

Figure 4 The CO_2 emission values in the treatments of long-term tillage experiment of Józsefmajor (2009)

According to *Figure 4*, in the treatments of the long-term tillage experiment of Józsefmajor, in the spring of 2009 - at the beginning of winter wheat tillering - high-level CO_2 emissions were not shown. I registered data barely exceeding the measured atmospheric concentration (347 ppm), although the variants T, DV and MK were slightly outstanding from among the others. I experienced a similarly low-level CO_2 emission on the summer date, on the (heat)day after stubble cultivation. The concentration data measured in the treatments barely exceeded the atmospheric concentration of 349 ppm.

On the end-of-summer measurement date of 2009 - on the matured, debarked stubble - I measured significantly higher CO_2 emission values. The highest-level emissions were in the T, DV and cultivator treatments. The values measured in the SZ and L+T treatments are lower but the carbon dioxide breathing of the soil can be regarded as intense even in these treatments. Therefore it can be said that the maturing of the debarked stubble, and the boosting soil life increase the level of CO_2 emission. Concerning the dynamics of CO_2 emissions, it was shown that with the activation of biological activities - mineralization, humification processes - the carbon dioxide emissions increase, as well.

For the analysis of the relationship between the surface cover and the carbon dioxide emissions, I performed regression tests which did not show any correlation between the surface cover and the carbon dioxide breathing of the soil in any of the experimental locations and any of the treatments. The character and depth of the disturbance, the time lapsed since the cultivation, the moisture condition of the soil and presumably the external temperature influenced the carbon dioxide emission of the soil more than the 10-35% surface cover typical for my experiments. There is a high probability that the CO_2 breathing of the soil is heavily influenced by the quantity and quality of plant residues mixed into the soil.

3.5. The results of agronomic structure tests

By the application of the agronomic structure test, the impact of the specific tillage variants on the soil structure can be clarified.

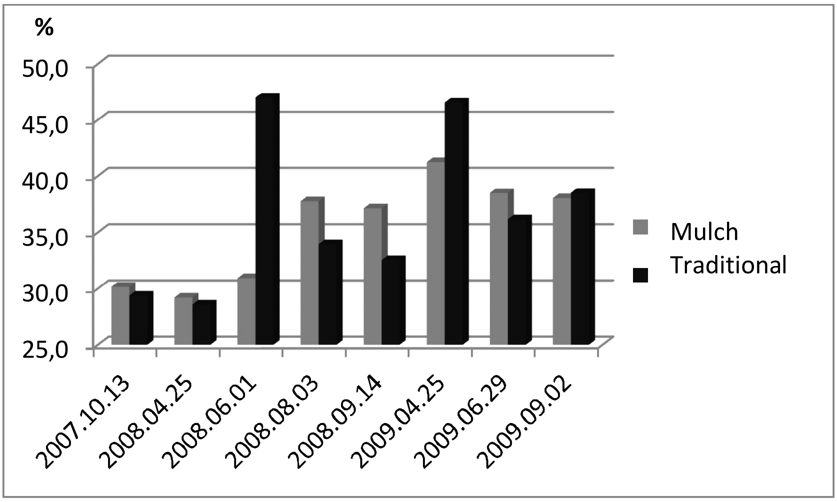

Figure 5 Change in the crumbs fraction in the treatments of the soil cultivation experiment of Peresznye

Figure 5 shows the change in the average values of the crumbs fraction in the treatments of the long-term tillage experiment of Peresznye. It can be said that five times out of the eight occasions, the mulch cultivation treatment showed a higher percentage of crumbs. In a great part of the measurement dates, a crumbs fraction proportion over 30% - that can be declared as favourable - was shown in both treatments and it approached this level also at the other two times. The figure shows that after setting the experiment, the brittle character of the soil has continuously improved in the treatments, which is the consequence of gentle cultivation.

Figure 6 shows the change in the average values of the crumbs fraction in the treatments of the long-term tillage experiment of Sarud. It can be seen that eight times out of the nine sampling dates, the mulch variant showed a higher percentage of crumbs. In respect of the crumbs fraction proportions of the treatments, the differences were significant, and they were demonstrated as statistically reliable ($P<0.05$) by the variance analysis test. In the mulch treatment, I experienced a favourable, 30% or higher crumbliness of the soil even in the critical periods - after the basic cultivations and during the drought. The gentle disturbance and the evenly mixing of organic matter in the full cultivation depth had a clearly favourable effect on the crumbly character of the soil.

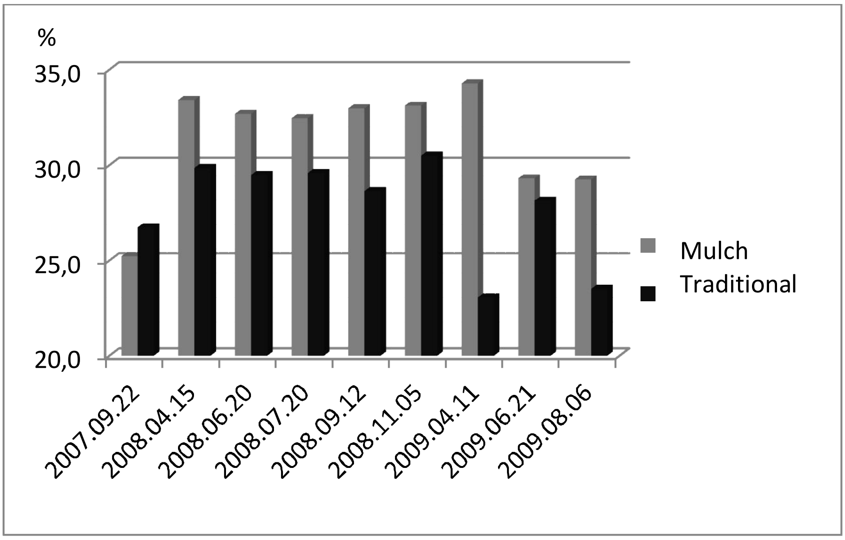

Figure 6 Change in the crumbs fraction in the treatments of the soil cultivation experiment of Sarud

To judge the correlation between the extent of surface cover and the change in the agronomic structure, I applied the regression test. According to the results, strong correlation between the mulch cover and the proportion of the given size category was not shown in either treatments of either of the experimental locations. Thus, the 5-35% surface cover, formed in the mulch preserving cultivation treatments of my experiments did not influence strongly the agronomic structure of the specific cultivation variants. This is consistent with my opinion that this mulch cover proportion is insufficient to protect the structure. In the improvement of the soil structure, soil cultivation - performed in a gentle way - and in the mulch treatment, the uniform mixing of the organic matter in the entire cultivated layer was determining.

3.6. The results of fuel consumption and crop tests

In order to be able to judge the practical applicability of mulch preserving cultivation types and traditional tillage systems, I compared the fuel consumption and yield data experienced in the two cultivation variants.

The mulch preserving cultivation proved to be more economical both in case of the experimental site of Peresznye and Sarud and also in case of all the crops produced. The omission of rotation has not involved yield decrease - what's more, even a modest extra yield was shown in the mulch preserving cultivation treatments. Based on its economical character, the mulch preserving cultivation was considered suitable for regular practical use.

3.7. New scientific results

The new scientific results of my experiments carried out in the topic of *"The significance of surface cover in soil protection and mitigation of climate damages"* are the following:

1. I proved the moisture loss reducing effect of mulch preserving cultivation at three different production sites and soils.

I determined the following decrease percentages in the test periods: 26% in the 0-10 cm layer of the medium-bound chernozem soil of Hatvan, 10% in its 20-30 cm; 7% in the 0-10 cm of the bound, brown forest soil of Peresznye and 5% in its 20-30 cm layer; 12% in the 0-10 cm of the bound, meadow soil of Sarud and 3% in its 20-30 cm layer.

2. I proved the moisture loss increasing effect of the traditional disc-based and rotation-based cultivation at three different production sites and soils compared to the mulch preserving cultivation types.

In case of cultivation by using a disc, I proved the following moisture losses: 18% in the 0-10 cm layer of the chernozem soil, 9% in its 20-30 cm layer, while it was 26% in the 0-10 cm of the ploughed soil and 10% in its 20-30 cm layer. In the ploughed soil, I proved the following moisture losses: 7% in the 0-10 cm layer of the bound, brown forest soil, 5% in its 20-30 cm layer, while it was 12% in the 0-10 cm of the bound, meadow soil of Sarud and 3% in its 20-30 cm layer. The results support the moisture loss increasing effect of the incomplete (5-10%) cover left after the traditional cultivation by using a disc and of the uncovered surface typical for ploughing.

3. I proved the direct impact of the surface cover on the looseness - related primarily to moisture protection - of the 5-35% surface cover achieved by the mulch preserving cultivation variants at three different production sites and soils.

I demonstrated the following looseness increase percentages: 40% in the 10-20 cm layer of the chernozem soil of Hatvan, 49% in its 30-40 cm layer; 38% in the 10-20 cm of the bound, brown forest soil of Pereszrnye and 19% in its 30-40 cm layer; 28% in the 10-20 cm of the bound, meadow soil of Sarud and 17% in its 30-40 cm layer.

4. I proved the looseness maintaining effect of direct sowing, which resulted in the following looseness condition percentage increases: 40% in the 10-20 cm layer of the chernozem soil of Hatvan compared with ploughing, 61% compared with the cultivation of the soil by using discs,

48% in the 30-40 cm layer compared to ploughing and 30% compared with the cultivation of the soil by using discs.

5. At three different production sites and soils, I managed to prove that the 5-35% surface cover - typical for the mulch preserving cultivation - did not affect the CO_2 respiration of the soil. This means that the CO_2 breathing of the soil is more influenced by the quantity and quality of plant residues mixed into the soil than the cover ratio.

6. I proved that by applying mulch preserving cultivation on medium-bound and bound soils - in average and dry seasons - a more favourable soil structure can be created via gentle disturbance and even mixing of residual stubble. By the application of mulch preserving cultivation, the following percentage increases were observed in the formation of soil crumbs: 5% in the chernozem soil of Hatvan compared with ploughing and 19% compared with traditional cultivation of the soil by using discs, while it was 5% on the bound, brown forest soil of Peresznye and 11% on the bound, meadow soil of Sarud. The results confirm that the 5-35% surface cover, typical for the mulch preserving cultivation types is only conditionally suitable for the longer-term preservation of crumbly soil structures.

7. Based on economic efficiency and soil condition characteristics, I justified the suitability of mulch preserving cultivation systems for their adaptation in practice. By applying a mulch preserving cultivation, the following yield increases were achievable: 2.5% with a fuel saving of 37.6% on the bound, brown forest soil of Peresznye and 7.3% with a fuel saving of 17.9% on the bound, meadow soil of Sarud.

4. CONCLUSIONS AND RECOMMENDATIONS

4.1. Consequences drawn on the basis of the examination of effects of mulch preserving cultivation systems with surface cover on the soil condition

- I experienced in all three soil cultivation experiments that the extent of the surface cover depends fundamentally on the quality of the plant remains treatment during the harvest.
- The extent of surface cover is mainly determined by the character and intensity of disturbance. According to the results, the profound disturbance - in particular, if it is an intensive mixing procedure - significantly reduces the mulch cover. In contrast, the deepening procedures not involving mixing work - e.g. the medium-deep loosening (L+T) of my experiments - reduce cover to a lower extent. The mulch cover is reduced to the most extent by the traditional cultivation by using discs, which is the result of the intensive mixing work.
- In the tillage experiments of Peresznye and Sarud, the rapid reduction of the mulch cover showed that in case of easily degrading plant residues, the establishment of a higher initial cover is justified.
- The soil moisture tests show a clear relationship between the nature of the disturbance and the soil moisture loss. In the treatments performed by a cultivator machine (SK, MK), declared as soil-friendly and in the treatments with medium-deep loosening (L+T), usually I experienced more favourable humidity values. The DV treatment, involving only a minimal level of disturbance turned out to be similarly moisture-saving. It is striking that I experienced the smallest loss of moisture in the L+T treatment after the basic cultivations performed at the end of the summer or in the autumn, which is

the combined consequence of gentle disturbance and the small water losing surface. The test results demonstrated that the traditional cultivation with discs (T) and the rotation (SZ) involves the highest risk concerning the soil moisture loss.

- It is noteworthy that the cultivations leaving a larger surface cover proportion (SK, DV) showed more favourable humidity values during dry periods. In contrast, the 5-10% cover level of the cultivation by disc (T) and the clean surface typical for ploughing (SZ) did not help to protect soil moisture.
- The soil moisture tests performed in the tillage experiment of Peresznye prove that gentle cultivation - reduced to the necessary extent and performed with great care - reduces moisture loss.
- In the long-term tillage experiment carried out in Sarud, the mulch preserving cultivation has clearly proven to be gentler from the aspect of moisture content. This was best manifested during the summer period of the year of 2009, considered to be droughty. I found that in the mulch treatment, the basic cultivation with medium-deep loosening facilitated the infiltration and storage of precipitation more effectively than the rotation in the traditional variant. The combination of the gentler disturbance and the surface cover resulted in a more favourable soil moisture turnover in the mulch preserving cultivation variant.
- It was shown at each experimental locations that the soil moisture preserving effect of the 5-35% surface cover typical for the mulch preserving cultivation variants is insufficient - especially over a long time - or rather is not statistically proven. This one of my comments is supported also by the results of regression tests.
- According to the soil resistance tests performed in the long-term tillage experiment of Józsefmajor, the soil cultivated by a disc (T) often proved to

be compacted. The cultivating base emerging during the tilling process was usually detected in the 10-20 cm soil layer. A similar risk is meant by the plough sole emerging during the rotation-based cultivation (SZ), which was usually detected in the looseness tests of the 30-40 cm soil layer. The rapid sedimentation tendency of cultivations performed by using a disc (T) and ploughing (SZ) meant an additional risk from the aspect of the reduction of the looseness of the soil.

- The mulch preserving treatments, performed by using a cultivator (SK, MK) and the treatments with medium-deep loosening (L+T) have established and maintained the loosened soil condition more efficiently, with less risk - by preventing the formation of a harmful compaction of cultivation trouble character. Usually, in the 30-40 cm soil layer of the DV treatment, sufficiently loosened soil condition was typical. This demonstrates that the minimum disturbance and the mulch keeping facilitates the natural loosening of the soil.
- In the long-term tillage experiment of Peresznye, on the basis of the results of penetration resistance tests the mulch preserving cultivation variant could be assessed less risky.
- In the long-term tillage experiment of Sarud, both cultivation variants were considered risky in the sense that in the dry period, the compaction has reached the harmful level of 3.0 MPa in both variants. According to the penetration test results of the 30-40 cm soil layer, the looseness of this soil layer was not safely founded by any of the cultivation variants, as during the entire test period, a compaction level of 3 MPa was shown in both treatments.
- On the basis of the results of the regression tests, all three experiments showed that the 5-35% surface cover - formed in the mulch preserving cultivation variants - has only indirect effect on soil looseness.

- I experienced the soil life enhancing effect of the plant residues mixed into the soil. The organic matter mixed into the soil by the mulch-based cultivation reduced the settling process, which phenomenon was mainly observed in the long-term tillage experiment of Józsefmajor. In the long-term tillage experiments of Peresznye and Sarud, this favourable effect of the mulch preserving cultivation types could be detected less, which can be explained by the short period of the experiment and the harder soil conditions.
- On the basis of the results of the carbon dioxide emission tests, there is a clear relationship between the character and depth of the disturbance and the emission values.
- According to the measurement data, there is a relationship between the degradation and transformation processes of plant residues mixed into the soil and the CO_2 breathing of the soil. The CO_2 emissions were intensified in all treatments when the digestion of the mixed organic matter took place intensively.
- In the long-term tillage experiment carried out in Peresznye, the results of the CO_2 emission tests clearly prove that soil-friendly disturbance reduces the carbon dioxide emissions.
- In the long-term tillage experiment of Sarud, the intensive disturbances - resulting in excessive aeration of the soil - increased the CO_2 emissions.
- During the regression tests, I have concluded that the 5-35% surface cover typical in the mulch preserving cultivation variants in the experiments does not have a direct effect on the carbon dioxide emission of the soil. The quantity, quality and digestion opportunities of the plant residues mixed into the soil, furthermore, the quality of the soil condition can have a greater impact on the carbon dioxide respiration of the soil.

- In the long-term tillage experiment of Józsefmajor, the agronomic structure test drew attention to the danger of structure degradation during the vegetation period. With the progress of time, the proportion of clod and powder fraction has increased during both years in all treatments. From the above data I concluded that the mulch preserving treatments performed by using a cultivator (SK, MK), the DV treatment involving minimum disturbance and the gentle deep cultivation (L+T) have provided a slightly better crumbly character of the soil during the entire test period. The gentle disturbance and the mulch preservation has facilitated the formation and maintenance of a more brittle soil structure.
- In the long-term tillage experiment of Peresznye, after setting the experiment, the brittle character of the soil has continuously improved in the treatments. In the traditional cultivation variant, in most of the cases, all the crumbs ratios were 10-20% lower than the one typical in the mulch variant. On the basis of this, the mulch preserving cultivation has proved to be more soil structure-friendly. That is, the gentle disturbance and the continuous organic matter input facilitated the formation of a more crumbly structure.
- In the long-term tillage experiment of Sarud, after the autumn basic cultivations an extremely high proportion of clods was observed. Regarding the crumbly character, the differences were significant. In the mulch treatment, I experienced a favourable, 30% or higher crumbliness of the soil even in the critical periods - after the basic cultivations and during the drought. The gentle disturbance and the evenly mixing of organic matter in the full cultivation depth had a clearly favourable effect on the crumbly character of the soil.
- The regression test applied for the evaluation of the relationship between the surface cover and the change of the agronomic structure did not show a strong relationship between the two properties. The 5-35% mulch

cover, typical for the experiments had only little impact on the changes in the soil structure. Nevertheless, the combination of the organic matter mixing and gentle disturbance, typical for the mulch preserving cultivation has a beneficial effect on the soil structure, facilitates the formation of crumbs and maintains a more favourable structure.

4.2. Recommendations concerning the domestic application of mulch preserving cultivation systems without rotation

- Based on the fuel consumption and yield tests performed in the long-term tillage experiments of Peresznye and Sarud, the application of the mulch preserving cultivation systems has clearly proven to be more economical.
- Despite fuel savings, the mulch preserving cultivation variant was not associated with yield decrease in any of the experimental locations. Moreover, the detected modest yield increase may refer to a higher yield safety.
- The long-term tillage experiments set in three locations with different endowments highlighted a number of technical and technological problems related to mulch preserving cultivation. It has been shown that the surface cover is able to fulfil soil and climate protection functions only if the cover has a proper ratio and is evenly distributed. In addition to this, the perfect crushing of the plant remains (so small size) is a basic expectation, too. Only the harvesting machines of the highest technical quality are able to meet these requirements.

During my experiments, I have reached the opinion that the successful applicability of the mulch preserving cultivation assumes a complex system-based approach. The mulch preserving cultivation starts with the harvesting technology, during which the plant residues become chopped and homogeneously spread.

In the tillage system, all operations must be carried out by means which are the most suitable for the given purpose. This requires the existence of the necessary special-purpose machines. For the stubble cultivation tasks, the planar disc - applied also in the experiments of Józsefmajor and Pereszny e - has proven to be the most appropriate. For stubble cultivation and care, the use of the planar disc involved more gentle disturbance than the application of the arable cultivator machine in the Sarud experiment. The traditional (spherical) disc does not meet the soil protection expectations of the mulch preserving cultivation.

In the mulch preserving soil cultivation system, thee tillage cultivator and the medium-deep loosener has proven to be the most successful for the execution of the basic cultivation. In case of deeper work (under 30 cm), the medium-deep loosening implied more gentle disturbance. In addition to this, loosening reduces surface cover less, as it does not have any mixing effect.

The excessive proportion of clods and the aeration experienced in the Sarud experiment highlights that it is justified to apply a medium-deep loosener that has a surface smoother unit. This way it is possible to avoid all the soil condition damaging effects of the separate-threaded treatment, together with its extra costs; however, at the same time, the excessive aeration - harmful from soil and climate protection aspects - can be eliminated.

In the experiments, the mulch preserving basic cultivation types usually resulted in favourable soil conditions which have allowed single-thread seedbed preparation. From the aspect of disturbance reduction, the seedbed preparing machines - to which the seedbed preparation and seeding can be connected - have an indisputable advantage.

SCIENTIFIC PUBLICATIONS WRITTEN ON THE SUBJECT OF THE DISSERTATION

Foreign-language, peer-reviewed scientific publications:

1. **Bottlik, L. –** Csorba, Sz. – Gyuricza, C. – Kende, Z. – Birkás, M. 2014. Climate challenges and solutions in soil tillage. Applied Ecology and Environmental Research 12:(1) 13-23. (IF: 0,586)
2. Kalmár, T. – **Bottlik, L. –** Kisic, I. – Gyuricza, C. – Birkás, M. 2013. Soil protecting effect of the surface cover in extreme summer periods. Plant, Soil and Environment, 59. 9. 404-409. (IF 2012: 1,113)
3. Birkás M. – **Bottlik, L. –** Stingli, A. – Gyuricza, C. – Jolánkai, M. 2010. Effect of Soil Physical State on the Earthworms in Hungary. Hindawi Publishing Corporation, Applied and Environmental Soil Science. Vol. 2010, Article ID 830853, 7 pages, doi:10.1155/2010/830853
4. Birkás, M. – Kisic, I. – **Bottlik, L. –** Jolánkai, M. – Mesic, M. – Kalmár T. 2009. Subsoil compaction as a climate damage indicator. Agriculturae Conspectus Scientificus, 74: (2) 1-7.
5. Birkás, M. – Kalmár, T. – **Bottlik, L. –** Takács, T. 2007. Importance of soil quality in environment protection. Agriculturae Conspectus Scientificus, 71: (1) 21-26.

Hungarian-language, peer-reviewed scientific publications:

1. **Bottlik, L.** – Kalmár, T. – Csorba, Sz. – Szemők, A. – Birkás, M. 2012. Talajművelés új szemlélete – a precíziós növénytermesztés alapjai. (A new approach to tillage - the basics of precision crop production.) „Fork to Farm” „Asztaltól a szántóföldig” Fenntartható mezőgazdaság Konferencia,

Debrecen. (Sustainable Agriculture Conference, Debrecen). 06 September, 2012 *Acta Agraria Debreceniensis*. 49. 123-127.

2. Birkás, M. – **Bottlik, L.** – Csorba, Sz. – Mesic, M. 2010. Soil Quality Improving and Climate Stress Mitigating Tillage – The Hungarian Solutions. Hung. Agr. Res., 19: (3) 4-8.

3. Birkás, M. – Stingli, A. – Farkas, C. – **Bottlik, L.** 2009. Összefüggés a művelés eredetű tömörödés és a klímakárok között. (Relationship between compaction originating from cultivation and the climate damages.) Crop production, 58: (3) 5-26.

4. Birkás, M. – Jolánkai, M. – Stingli, A. – **Bottlik, L.** 2007. The significance of adaptive cultivation in soil and climate protection. „KLÍMA-21” Füzetek (CLIMATE-21 Booklets), 51: 34-47.

Other scientific works

Scientific book chapter:

1. Tóth, E. – Barcza, Z. – Birkás, M. – Gelybó, G. – Zsembeli. J. – **Bottlik, L.** – Davis, K., J. – Haszpra. L. – Kern, A. – Kljun, N. – Koós, S. – Kovács, G. – Stingli, A. – Farkas, C. 2011. Measurements and estimations of biosphere-atmosphere exchange of greenhouse gases - Arable lands. In: Atmospheric Greenhouse Gases: The Hungarian Perspective (Ed.: Haszpra, L.), pp. 157-197. Springer, Dordrecht - Heidelberg – London – New York. ISBN 978-90481-9949-5, e-ISBN 978-90-481-9950-1, DOI 10.1007/978-90-481-9950-1.

Foreign-language conference publications:

1. Birkás, M. – Kisic, I. – Jug, D. – **Bottlik, L. –** Pósa, B. 2012. Soil

phenomena and soil tillage defects in the past two years – A scientific approach. 5th Internat. Scientific Conf., Agriculture in nature and environment protection, Vukovar, 4-6 June, 2012. Proceedings&Abstracts (Eds. Stipesevic, B., Soric, R.), Glas Slavonije d.d.Osijek, pp.11-23. ISBN: 978-953-7858-01-8

2. **Bottlik, L. –** Stingli, A. – Birkás, M. – Percze, A. 2008. Soil quality improvement under extreme climatic conditions. 10th International Congress on Mechanization and Energy in Agriculture Antalya, Turkey, 14.-17. October, 2008. Proc. Book, pp. 209-214.

Hungarian-language conference publications:

1. Birkás, M. – **Bottlik, L. –** Kisic, I. – Jug, D. – Mesic, M. 2010. Talajművelési feladatok a fenntartható szántóföldi növénytermesztésben (Soil tillage tasks in the sustainable crop production). „Termesztési tényezők a fenntartható növénytermesztésben" ("Production factors in sustainable crop production", edited by Pepó P.), DE AGTC Debrecen, pp. 31-38. ISBN 978-963-9732-93-3.

2. Birkás, M. – Stingli, A. – **Bottlik, L.** 2008. Possibilities of climate damage reducing tillage in Hungary. Vajdasági Magyar Tudományos Társaság „A Magyar Tudomány Napja Délvidéken" (plenáris előadás)/Hungarian Scientific Society of Vojvodina, "Hungarian Science Day in Vojvodina" (plenary lecture), Novi Sad, 8 November, 2008; Publication (edited by Szalma J.), Atlantis Publisher House, Novi Sad, pp. 14-23.