EVALUATION OF DIFFERENT TILLAGE METHODS REGARDING SOIL PROTECTION

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1. BACKGROUND AND AIMS OF THE RESEARCH WORK

Nowadays one of the most important things is rational utilization, protection, conservation and function's maintenance of our soil resources, which is a fundamental element of sustainable development. Unfortunately this rightful expectation is not fulfilled or just occasionally realized. Soil destruction has speeded up because of human activity to such an extent that soil forming processes are no longer able to compensate the damages caused by the erosion. There are several arable sites in Hungary where the soil structure is degraded and damaged by erosion; therefore, successful farming cannot be achieved. Inspired by this fact, reduction and prevention of these harmful processes are essential. The tillage methods directly modify the structure of soil and the process of water and wind erosion. The soil conservation land use within agronomical protection provides facilities to prevent and to reduce harmful soil degradation and erosion. Hereby, the safety of agricultural activity and crop production in sloping area can be increased.

Our Earth's climate is changing continuously and human activity has a role in this changing. The effect of human activities (industry, traffic, agriculture) exercises a demonstrable influence not only on the micro- and macro-, but also on the global climate. According to the researches, one of the main reasons of global warming is that green house gases – especially carbon dioxide – get into the atmosphere where their concentration is increased. Agricultural activities contribute to the increase of atmospherical quantity of greenhouse gases. The international commitments encourage for reducing the emission of carbon dioxide. Concerning crop production, the solution could be the application of conservation and sustainable land use.

Formation of the structure of a tilled soil is a process influenced by external factors, which may be of anthropogenic (e.g. tilling instruments, treading) and natural (e.g. climate, fauna, roots) origin. These factors can lead as well to compaction as to disintegration, and to displacement of the soil; besides, characteristics determining the soil structure develop as a consequence of their complex effect. Soil structure can be directly influenced by the tillage.

Protection and improvement of the condition of the Hungarian soils, adjustment to the environment protection directives of the EU and Hungary, harmonization of the tillage technology and the environment protection together with the maintenance of this harmony account for the timeliness of the research. Study of the alterations of the soil-condition, evaluation of the tillage factors influencing the biological activity of the soil and comparison of tillage methods applicable on areas in danger of erosion grant the scientific value of the research.

Based on the research aims, I have formulated tree examination groups (examination of erosion; measurement of the carbon dioxide emission of the soil; examination of agronomical texture of soil), which are as follows:

1. Comparison of conventional and ridge tillage based on
   - the amount of runoff soil
   - the eroded humus
   - the runoff water in sloping area.

   Examination of crop yield in case of conventional and ridge tillage.

2. Evaluation of different soil tillage treatments' effect on carbon dioxide emission from the soil, in connection with the changing of the humus content of soil.

3. Justification of the relationship between different soil tillage methods and soil agronomical texture. Evaluation of the effect of catch crop on soil structure.

2. MATERIALS AND METHOD

2.1. Circumstances of the research work

The experiment was set up in Józsefmajor, not far from Hatvan (Hungary), on the experimental site of Szent Istvan University. This area is one of the most erosion-damaged lands in Hungary, along the edge of the Southern Alföld alluvial fun and the Cserhátalja. The experimental site is South-East rising ground with 100 meter above sea level. The relief conditions are various compared to the small size of the experimental field. That is why the phenomena of erosion and sedimentation are presented to a different extent. Regarding the climate, the area can be separated into two parts. The Northern part of the area is temperately cold and temperately dry, while the Southern part of the area is temperately hot and temperately dry. The climate is strongly influenced by the hilly character of the area.

The area presents a medium multi annual temperature of 9,5-10 ^{o}C, (16,3-16,8 ^{o}C in the vegetation period) and medium of multi annual precipitation of 580 mm (323 mm in the vegetation period). The mean values of precipitation in Józsefmajor are lower than the Hungarian annual average. According to the recorded data, November, May and June bring the greatest part of the rain. During the research work the measured monthly precipitation was different from the mean monthly precipitation data. However, the rainfall of the year 2003 and 2004 was less than the annual average. In 2003 the precipitation was less than the annual average with 138 mm, in the year of 2004 with 68 mm. 2005 was extreme concerning the rainfall. The precipitation rate was much higher than the annual average as it already exceeded the annual average in August with its 564 mm rainfall (compared to the annual average which is 580 mm).

The experimental site is silty soil, with the type of Calcic Chernozem. The soil has good water and nutrient supply. The organic matter content on 0-40 cm depth is 2,83%.

2.1.1. Layout of the tillage methods experiment

The experiment was set up by the Soil Management Department of Szent Istvan University in 2001. During two consecutive years, winter wheat was produced on the plots of the experimental site before the treatment setting up. As with the continuous wheat production the soil water retention was not accomplished, the first crop of our experiment was white mustard in order to meliorate the soil structure.

The size of the experimental site is 312 x 150 m= 4, 68 ha, with four replications in split-plot design. The size of a plot is 13 x 75 m= 975 m^2.

Each block consists of vertical strips of an *"A"* factor. These are the methods of the primary tillage, which are the followings:

a1: ploughing (26-30 cm)
a2: direct drilling
a3: shallow cultivation (12-16 cm)
a4: cultivation (16-20 cm)
a5: disking (16-20 cm)
a6: loosening (40-45 cm) + disking (16-20 cm)

In the different tillage treatments I examined the effect of plouging, direct drilling, cultivation, disking and loosening combined disking tillage methods.

The different tillage methods were chosen based on their beneficial, neutral or disadvantageous impact on soil condition.

The horizontal strips of the "Cover or no cover" refer to the *"B"* factor of the trial:

+: with catch crop
-: without catch crop

<u>Crop production data of the experiment</u>

The crop sequence is as follows:

2002: white mustard (*Sinapis alba* L.) (soil conditioner)
2002/03: winter wheat (*Triticum aestivum* L.) (main crop)
2003/04: rye (*Secale cereale* L.) (catch crop+ forage)
2004: pea (*Pisum sativum* L.) (mulch)
2004/05: winter wheat (*Triticum aestivum* L.) (main crop)
2005: white mustard (*Sinapis alba* L.), (soil conditioner)
2005/2006: winter wheat (*Triticum aestivum* L.)

Crop production data of the tillage methods experiment are represented in table 1.

Table 1. Crop production data of the experiment

	I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.	X.	XI.	XII.
2002							**White mustard (soil cond.)**				**Winter wheat**	
2003	**Winter wheat (main crop)**							**Rye**				
2004	**Rye (catch crop+forage)**					**Pea (mulch)**				**Winter wheat**		
2005	**Winter wheat (main crop)**							**White mustard (soil cond.)**		**Winter wheat**		
2006	**Winter wheat (main crop)**											

Jelmagyarázat: ■ = primary tillage

2.1.2. Layout of ridge tillage experiment

Tillage treatments:

1. Conventional tillage: (22-25/28-32 cm ploughing, yearly changed), prepare of seedbed, sowing
2. Ridge tillage (ploughing in the first year of the experiment); prepare of the ridge, sowing in the middle of ridge, destruction after harvest; in the following years: nipping the top of the ridge, sowing, hilling the ridge in growing season)

The experiment is situated in a sloping area**,** which is endangered by erosion. On the plots of the experimental site maize were produced from spring of 2003 till autumn of 2005. I started my research work in 2004. The sizes of plots were set based on the lie of the land and tillage/sowing machine. **2004**. *The size of the experimental site is 900 m^2, 0,09 ha,* the size of a plot is 15x75 m = 112,5 m^2, 0.01125 ha. **2005**: *The size of experimental site is 80 m x 16 m = 0,128 ha*, the size of a plot is 8x20m = 0,016 ha, with four replications in split-plot design, perpendicular to slope. The amount of fertilizer was chosen based on the nutrient content of soil.

2.2. Methods

Examination of the erosion

The soil erosion was examined in Józsefmajor, in a long-term experiment, which represents two different tillage treatments: a conventional and ridge tillage in a sloping area, where maize was applied. The erosion was examined in four plots, two in the top and two in the bottom of the slope. A one square meter metal frame was installed on the examined plots. Bottom of the triangular part was made of metal; therefore it did not influence the size of the frame (1 m^2). An outflow unit with an attached 20 l balloon was fixed to the lower termination of the triangular part. The surface runoff from the precipitation arrived to the enclosed area and the soil eroded by the precipitation were collected by this balloon.

Humus content of the eroded soil was determined in accordance with the TAKI.

Yield of the maize was also examined in the year of the erosion experiment.

Measurement of the carbon dioxide emission of the soil

The CO_2 emission of soil was measured between 2003 and 2005 after cultivation and after sowing. The measurements were in situ, by means of an INNOVA 1312 (Multi-gas monitor). We covered the soil surface with a plastic chamber, and we measured the changing of the CO_2 concentration after determined time. The INNOVA 1312 multi-gas monitor measure the CO_2 emission in ppm. This unit was converted at maximum CO_2 emissions from soil to flux, to calculate the maximum CO_2 emission (kg m^{-2} h^{-1}).

Examination of the agronomical structure of the soil

The agronomical texture was examined in a long-term experiment, which represents five different tillage treatments with and without catch crop, and in a sloping area, where conventional and ridge tillage was applied. The agronomical texture of soil was defined by dry screening. The agronomical texture is classified by the size of aggregates, which are measured and divided into three fractions (> 10 mm clod; 10-0.25 crumb; <0.25 dust). The physical condition of soil is better, if the rate of crumb fraction is higher.

2.3. Statistical analysis

Analysis of variance was conducted with the program of EXCEL.

3. RESULTS

Evaluation of different tillage methods regarding soil protection, my results will be presented in 3 points:

- Results of the erosion examination
- Results of the soil carbon dioxide emission measurement
- Results of the soil agronomical structure examination

3.1. Results of the erosion examination

Results of the measurements equally proved the soil protective effect of the ridge tillage. When ridge tillage was applied, the *amount of soil eroded* by the precipitation was smaller both at the top and at the bottom of the slope than in case of the conventional tillage. The reason for this is that during growing period different influences are acting on the soil of the maize in conventional and in ridge tillage. Splash-effect of the precipitation is observable on both soils, which leads to the disintegration of soil aggregates, facilitating the transportation of the soil from the area. In ridge tillage, current and loaming of the water are well hindered by the ridges, accordingly the amount of the soil washed away from the area can be reduced.

Difference between the effectiveness of the soil conservation and the conventional tillage can be modelled by the measurement of the *humus content of the eroded soil*. Owing to the protective effect of the ridges, the surplus of organic matter remaining on the production site is almost 10 kg/ha on steep slopes, and even 3 kg/ha on gentle slopes. This difference is significant taking into account that long years, decades are necessary for the build-up of the humic materials of the soil.

Study of the *amount of runoff water* proved that in case of the conventional tillage more water flows away from both the steep and the gentle slope sections than in case of the application of ridge tillage. This is of great significance because of two reasons: firstly, the erosion damage may be reduced by the protective effect of the ridges (down-wash of the upper productive layer, sedimentation); secondly, if the infiltration into the deeper soil strata is increased, more water is available for the plants (roots of the maize may penetrate to 2 m depth in dry soil), therefore their water-requirement can be fulfilled for more time. This advantage can be an important factor when choosing the tillage method, especially considering the more frequent periods of drought and more extreme distribution of the precipitation, both consequences of the global warming.

It was observed in our experiment, that soil and humus content conservation and water retention capacity increase resulting from ridge tillage was also demonstrated by the average yield of the maize. Both in 2004 and 2005 statistically better results were measured with ridge tillage than with the application of conventional tillage.

Results of our erosion survey suggest that with the formation of a protective surface, in our case with the application of ridge tillage, the erosion damage can be significantly reduced. Smaller amount of eroded soil, of humus in the soil and runoff water are all demonstrated as advantages of the utilization of the soil conservation surface. This positive effect was shown by the yield of the maize as well. The results call the attention on interventions of protective character (tillage perpendicular to the slope, surface cover, prevention and reduction of tillagepan compaction).

3.2. Results of the soil carbon dioxide emission measurement

The least carbon-dioxide emission was observed during the application of direct drill. This is because in the case of direct drill no intervention in the soil state occurs, the aeration of the soil is not increased, and therefore conditions of microbial activity are not fulfilled. Higher flux measured in shallow-tilled soils is most probably influenced by the soil moisture, the surface (e.g. it is not possible to close well the soils tilled by disk or cultivator) and by the undisturbedness of the digestion of residues mixed into the soil.

Significantly larger emission was measured in the tilled soil (however in all three of the years smaller than in the unclosed tilling, still widespread in Hungary). Owing to this, the humus content increased in the ploughed soil as well, which is scarcely mentioned in the literature specialised on direct drilling. Our experiment proved that immediate closing of the surface is of great significance, particularly when basic tillage is done in the summer heat, since this way not only the carbon-dioxide emission of the soil can be decreased, but the loss of organic matter can also be reduced.

Direct relationship is observable among the carbon-dioxide emission, the *humus content* and the aeration of the soil, as increased microbiological activity leads to intensive consumption of organic material. Build-up of humus materials of the soil takes years and decades; therefore selection of the proper tillage method has a great importance. Our experiment suggested that limited disturbance of the soil (direct drilling) was the most favourable for the increase of organic material, after three years 0.82% higher humus content was measured. Humus content of the soil has augmented statistically more than in the case of other tillage methods. Increase of the humus content was the smallest in case of application of disking (0.22%) and when using cultivator (0.33%). As a consequence of the ploughing and the loosening treatments the humus content increased with 0.48% and 43%. This is the result of the careful closing of the surface in these tillage methods.

As a result of the study of the carbon-dioxide emission of the soil it can be stated that among the studied soil conservation tillage methods the emission value may be kept at the lowest level in case of the direct drill.

Increase of the organic material content was also the largest in the direct drill and smallest in the disturbed treatment.

3.3. Results of the soil agronomical structure examination

3.3.1. Results of the tillage method experiment

The best clod:crumb:dust rate was observed in the case of the *loosening tillage* and the proportion of the crumb fraction increased with 12% and the percentage of the clod and dust fractions decreased by 7% and 5%, respectively. This result verifies again the favourable effect of loosening tillage on the soil (Fig. 1.).

Effect of ploughing on crumb fraction is also positive in our case. Results of 2005 are better than values of the 2003 measurements: proportion of clod decreased by 1%, the dust fraction by 7% and the crumb fraction increased by 8%. This cannot be generalized to ploughed soils, in our experiment the good result is a consequence of the good quality ploughing and the fast closing of the surface.

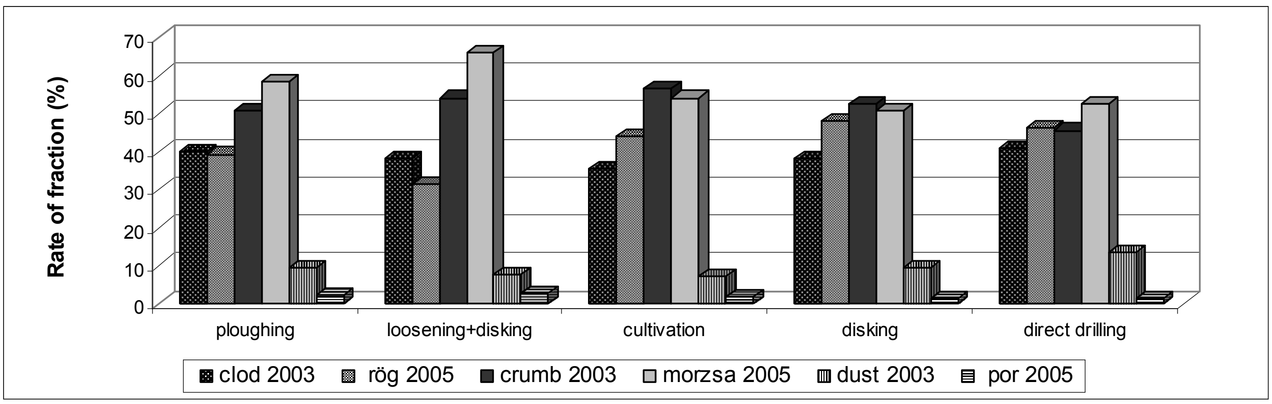

Figure 1. Trends in agronomical texture at different tillage methods between 2003 and 2005 (Józsefmajor)

During the analysis the application of *direct drilling* also led to significant improvement of the agronomic structure of the soil. However the percentage of the clod fraction increased (5%), the dust fraction decreased considerably, by 12%, and the crumb fraction got better by 7%.

In the *disking treatment* proportion of the crumbs and dust decreased by 2% and 8% respectively, while the percentage of the clods increased by 10 %. This is in agreement with results of other investigations, where smaller amount of crumbs and higher rate of clods and dust were described in soils disturbed frequently by disking (Birkás 2004; Tóth 2001).

By the application of *cultivation tillage methods*, deterioration of the soil structure was experienced during 2 years. Percentage of the clod fraction increased by 9% and the proportion of the crumb fraction decreased almost by 3%. Only the dust fraction provided a more favourable result (by 5%), but the proportion of the dust fraction decreased in all treatments. Structure conserving nature of the cultivator tillage is emphasized by Szabó (1994) and by Birkás (2002). According to their study, degradation of humus materials holding together the soil crumbs does not occur, because the ventilation, the aerobe microbial activity and the consumption of the organic material are limited as a consequence of the tillage. Cause of the opposite result of our investigations may be the imperfect loosening of the upper soil layer and the imperfect closing of the surface (the cultivator was made in 1989).

3.3.2. Results of the ridge tillage experiment

The *clod fraction* increased in both treatments during the last three years. During the experiment period the percentage of aggregates belonging to the clod fraction increased by 10% in ridge tillage, and almost by 24% in ploughing tillage method with respect to the average structure. Most probably this is the consequence of the exclusive maize production – for the sake of the experiment – during the period between the spring of 2003 and autumn of 2005. The worse result may be the outcome of the lack of rotation and monotonous production and water usage (Fig. 2.).

In 2005 the *crumb fraction* increased by 4% in the ridge tillage, with respect to the characteristic structure of 2002. On the other hand, the crumb rate decreased almost by 10% in the ploughed soil. Though neither of the values is outstanding, the trend suggests structure conservation nature of the ridge tillage. Prevention of washing away the soil was of major importance in 2005, when more precipitation fell during the growing period.

Analysis of the *dust fraction* yielded better results in both tillage. Percentage of the dust fraction decreased by 14% both in the ploughing and ridge tillage, with respect to the average structure.

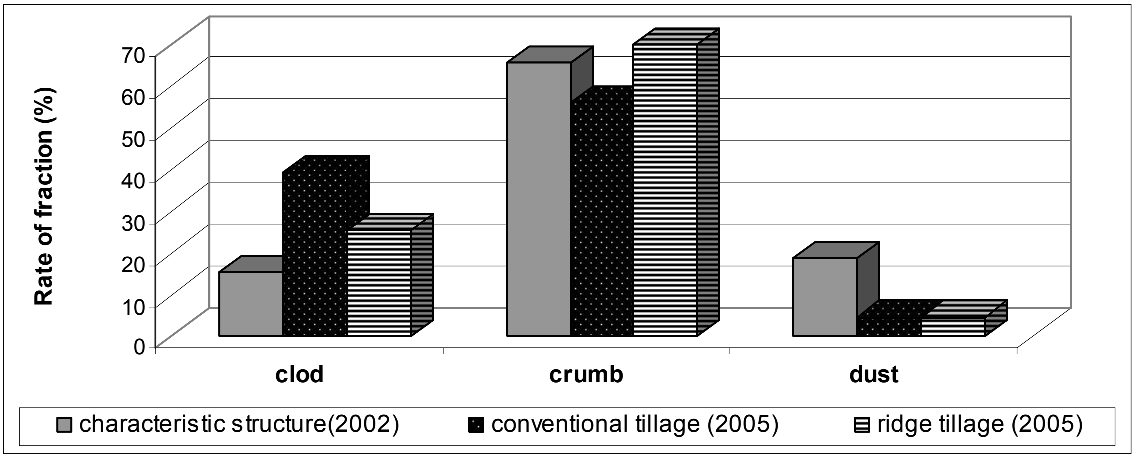

Figure 2. Trends in agronomical texture at conventional and ridge tillage methods between 2002 and 2005 (Józsefmajor)

As a result of the examination of the agronomic structure of the soil it can be stated that in tillage methods experiments disking combined with loosening not only conserved the soil crumbs, but helped their formation in the soil. At the same time percentage of the clod and dust fractions decreased significantly. The ploughing also proved to be soil conservative, which cannot be generalized as in our case the rotation was more rational in comparison with the usual practice. Minimisation of disturbance (direct drilling) also led to an improvement of the soil structure, proportion of the crumb fraction augmented and the dust fraction decreased. Frequent disking of the soil led to the reduction of the percentage of crumb fraction, while quantity of clods increased. Cultivation tillage methods provided the worst results, in our case the imperfectness of the cultivator (made in 1989) can be accounted for this.

On sloping area annually and also altogether, the *ridge tillage experiment* proved the advantages of the soil structure conservation ridge tillage with respect to the conventional tillage. In three years percentage of the crumb fraction increased significantly, while in the conventional tillage of limited conservation capacity, a decrease of the proportion of the crumb fraction was observed.

4. NOVEL SCIENTIFIC RESULTS

Novel scientific results related to my experiments carried out in the matter of *„Evaluation of different tillage methods regarding soil protection”* are as follows:

1. The amount of the soil and humus eroded by the precipitation is diminished by the ridge tillage method reduce, therefore it reduces the erosion damages on sloping cultivation area respective to the conventional tillage method, as was statistically verified.

2. On sloping area, taking the advantage of the soil conservation effect of ridge tillage, significantly major amount of water is retainable in the cultivation area with respect to ploughed, not profiled soil.

3. On tilled soil, including the ploughed soil as well, carbon-dioxide emission of the soil can be reduced by immediate closing of the surface, which makes possible the conservation and enrichment of the humus content of the soil.

4. Advantages of conservation tillage performed by different instruments on the agronomic structure of the soil were mathematically verified. The *disking combined with loosening* proved to be the most favourable regarding all the three fractions. Soil conservation effect of two tillage, which differ in the way of disturbance – ploughing and direct drilling – was proved by the advance of crumb fraction.

5. With the application of protective plant, no statistical difference in the agronomic structure of differently tilled soils was detected.

6. On a sloping area, with the application of ridge tillage conservation of the crumby structure and advanced crumbing were statistically verified. Decrease of the crumb fraction was proved in conventionally ploughed soil when no protective surface was formed.

5. CONCLUSIONS AND RECOMMENDATIONS

Experiments serving as a basis of the thesis were completed in the area of the Józsefmajor Experimental and Teaching Farm of the Szent István University GAK Kht. Statements and conclusions drawn related to my surveys, as well as my suggestions are presented on the basis of my investigations.

5.1. Qualification of the tillage methods from soil- and environment protection point of view

Long-time experiment carried out on silty soil (Calcic Chernozem) in Józsefmajor made possible the evaluation of the different tillage methods based on the carbon-dioxide emission of the soil, the alteration of humus content and the change of the agronomic structure.

- As a result of the analysis of the carbon-dioxide emission of the soil it can be stated that the among the tillage methods emission can be kept at a lowest level by the application of *direct drilling*. This is because the minimised soil disturbance did not increase the aeration of the soil and consequently the conditions adequate for the microbial activity were not granted. Considerably higher emission values were measured in case of the *ploughing*, however lower than the data published in the relevant literature for the case of rotation tillage without closing the surface. Higher values measured in *the disking combined with loosening, the disking and the cultivation tillage* are most probably the consequence of the imperfect closing of the surface and the continuous disclosure of the residues merged into the soil. Being aware of the role of growing atmospheric carbon-dioxide concentration in the climate change, application of a tillage method keeping the carbon-dioxide emission of the soil at a low level is suggested, besides, in the conventional tillage the closing of the surface and the good quality execution of the soil works.
- According to our experiment examining the change of humus content in the upper 40 cm layer of the soil, during the period of the study humus content of the soil increased in all tillage methods. Major enrichment of humus content of the soil was observed in *direct drilling treatment*, which statistically proves the organic material conservative effect of limited disturbance. In case of the *ploughing* the positive effect of rotation on the organic material content of the soil is a consequence of the closing of the surface, which has been rarely mentioned in the relevant literature. As a result of the *disking and cultivation tillage* humus content of the soil decreased in a 10-20 cm layer, which can be accounted for the stronger aeration of the soil. The *disking combined with loosening* also led to a decrease of the organic material in 20-30 depth of the soil, similarly to those literature data, which suggest negative effect of intensive tillage on the natural fertility of the

soil. We propose the reduction of excessive soil disturbance and thus regulation of the aeration of the soil. Expected outcome of our suggestion is the rational control of microbial processes and conservation of the humus content of the soil.

- In agreement with the literature data direct relationship was found between the soil usage and the agronomic structure. After three years the most favourable result was observed in the case of the *disking combined with loosening*, which not only conserved but also promoted the crumb formation in the soil. According to our experiment, *ploughing* proved to be conservative of the soil structure, too. However, this result may not be generalized, in our case it occurred as a consequence of the good quality, more rational rotation. Considering the aforesaid, tillage instrument suitable for the circumstances and, if possible, the closing of the surface in the same round are suggested during ploughing. Both conditions are essential for conservation of the soil structure and humidity. By reducing the humidity loss, mechanical damages related to the tillage (clod and dust formation) may be restrained, which was proved by our experience in accordance with the literature data. In *direct drilling tillage*, where the soil disturbance was minimised, the soil structure improved as well, percentage of the crumb fraction increased, the dust fraction decreased. Application of the disking, similarly to other experiments, led to the deterioration of the soil structure, proportion of the crumb fraction decreased, while percentage of the clod fraction increased. Structure conservation effect of the *cultivation tillage*, mentioned in the literature, was not experienced in our investigation; it provided the most unfavourable result, proportion of the crumb fraction slightly decreased, and rate of the clod fraction increased. Opposite result of our observation may be the consequence of the excessive loosening of the upper soil layer and of the imperfect closing of the surface (the cultivator was made in 1989). As a conclusion it can be stated, that when choosing the adequate soil usage not only the effect of the tillage method on the soil has to be considered, but the suitability of the cultivation instrument for the given job and the quality of the surface treatment as well.

5.2. Comparison of the conventional and the ridge tillage by their influence on erosion damages

The experiment executed in Józsefmajor, on sloping area exposed to erosion made possible the investigation of erosion reductive effect of the conventional and ridge tillage, based on the amount of the eroded soil by the precipitation, of the down-washed humus and of the runoff water and on the alteration of the agronomic structure of the soil.

- Examining the effect of the conventional and ridge tillage on sloping surface, it can be stated that the *amount of the eroded soil* is statistically lower when ridge tillage is applied, than without the formation of the soil protective surface. Humus content of the eroded soil was also analysed. According to our observations, taking the advantage of the conservative effect of ridge tillage, the *amount of eroded humus content* was significantly lower than by the application of conventional tillage. Amount of *water running off* the area is statistically lower in case of the ridge tillage, than in the conventional tillage. This is of great significance because of two reasons: firstly, the erosion damage may be reduced by the protective effect of the ridges (down-wash of the upper productive layer, sedimentation); secondly, if the infiltration into the deeper soil strata is increased, more water is available for the plants (roots of the maize may penetrate to 2 m depth in dry soil), therefore their water-requirement can be fulfilled for more time. This advantage may be an important factor when choosing the tillage method, especially considering the more frequent periods of drought and more extreme distribution of the precipitation, both consequences of the global warming. Significantly larger yield achieved by the application of soil conservation tillage compared to the conventional tillage also accounts for the protective effect of ridge ploughing. On sloping area the application of soil protective ridge tillage is suggested, which conserves (keeps in place) the upper productive layer of the soil and reduces the amount of water running off the area, therefore it may increase the success of plant cultivation. In case of application of traditional tillage it is advised to strive for interventions of protective nature, like for example tillage perpendicular to the slope, surface cover, formation of loosened layer devoid of tillagepan compaction.

- The *agronomic structure of the soil* influences the magnitude of erosion damage. The more structured is the soil, the better it resists the splash-effect of the precipitation and the aggregates of larger size (crumb fraction) are more difficult to transport by the water than the soil-grains belonging to the dust fraction. Our experiment proved that percentage of the crumb fraction increased statistically in ridge tillage. In the course of our investigation decrease of the crumb fraction was observed in conventional tillage. Proportion of the clod fraction also provided better values in the ridge tillage. Larger dust fraction was measured in ridge tillage, which may be caused by the different influences arriving to the soil in growing period in conventional and in ridge tillage. Both soils are affected by the splash-effect of the precipitation, but the current and loaming of the water is well dammed by the ridges. The dust is the grain size fraction most easily swept away by the water, accordingly, its proportion most probably decreases in rainy periods where the runoff is unimpeded. On conventionally tilled soil no such obstacles existed, therefore percentage of the dust fraction became slightly lower. In case of ridge tillage the protective function of the ridges worked, thus all fractions, including also the dust fraction, kept in place. The ridge tillage method is suggested for sloping cultivation areas, as by its application conservation and improvement of the soil structure to some extent is achievable.

SCIENTIFIC PUBLICATIONS

Scientific articles in refereed journals

1. Ujj A., **Bencsik K.,** Mikó P. 2004. Soil penetration resistance influenced by rye as a catch crop under semi-arid climate of Hungary. Agricultura (Buletinul Universitatii de Stiinte Agricole Si Medicina Veterinara), Cluj-Napoca, 2004/60: 81-86.

2. **Bencsik K.,** Ujj A., Stingli A., Mikó P. 2005. The connection between the physical and agronomical texture of soil. Cereal Research Communications, 33, 1. 157-160**.**

3. **Bencsik K.,** Ujj A., Stingli A., Percze A. 2006. Determining various soil tillage and nutrient loss in soil protection methodology. Cereal Research Comm., 34, 1. 123-126.

5. **Bencsik K.** Ujj A., Mikó P. 2007. Evaluation of different soil tillage methods regarding sustainibility and soil protection. Cereal Research Communications 35, 2. 233-236.

6. **Bencsik, K.,** Gyuricza, C., Mikó, P., Nagy, L., Földesi, P. 2007. Evaluation of different soil tillage methods regarding soil protection. Environment and Progress, 9. 77-80.

7. Mikó, P., Gyuricza, C., Földesi, P., Szita, B., **Bencsik, K.,** Nagy, L. 2007. Green manuring plants as main crops under unfavourable field conditions in 2005. Environment and Progress, 9. 329-332.

8. **Bencsik K.,** Ujj A. 2008. Evaluation of different soil tillage methods regarding soil-plant interrelations. Cereal Research Communications, 36. Suppl. 1559-1562.

9. **Bencsik K.** 2009. Soil conservation tillage methods. Acta Agronomica Óváriensis (megjelenés alatt)

Scientific articles in Hungarian refereed journals

1. **Bencsik K.** 2004. A talajok fizikai kondíciója és az agronómiai szerkezet összefüggései. In: Talajhasználat – Műveléshatás – Talajnedvesség (Szerk. Birkás M. – Gyuricza Cs.), Quality-Press Nyomda & Kiadó Kft., pp. 126-132.

2. **Bencsik K.** 2007. Talajművelési módok és a talaj agronómiai szerkezetének összefüggései. Agrokémia és Talajtan 56, 1. 21-28.

3. Birkás M., **Bencsik K.,** Stingli A. 2007. A talajminőség jelentősége a klímaváltozásokkal összefüggésben. Acta Agronomica Ovariensis, 49. 2. 135-140.

4. Kalmár T., Birkás M., Stingi A., **Bencsik K.** 2007. Tarlóművelési módszerek hatékonysága szélsőséges idényekben. Növénytermelés, 56. 5-6. 263-279.

Books

Birkás M., Szemők A., **Bencsik K.,** Ujj A. 2004. Talajművelés, talajvédelem. In: Alkalmazkodó növénytermesztés, környezet- és tájgazdálkodás (Szerk. Ángyán J.- Menyhért Z.) Szaktudás Kiadó Ház, Budapest, pp. 181-189.

Scientific papers in international conferences

1. Ujj, A., **Bencsik, K.** 2004. Studies on soil condition on brown forest soil in a long-term experiment. III. Alps-Adria Scientific Workshop, 1-6 March, 2004, Dubrovnik, Croatia. Proceedings (Eds. Hidvégi, S., Gyuricza, C.), pp.333-337.

2. Birkás M., Ujj A., **Bencsik K.** 2004. Factors affecting the production loss under drought. The 13th conference on nutrition of domestic animals, 4-5 November, 2004. Radenci. Proceedings (Ed. A. Pen), pp. 47-53.

3. Ujj A., **Bencsik K.,** Mikó P. 2004. Soil penetration resistance influenced by rye, as a catch crop under semi-arid climate of Hungary. Scientific Workshop, 20-23 October, Cluj-Napoca, Romania. Buletinul, pp. 81-86.

4. Gyuricza C., Rosner J., **Bencsik K**., Ujj A. 2005. Conservation soil tillage effects on selected environmental parameters. ISTRO-Conference, Brno, 29 June-1 July 2005. Abstract book, p. 78. CD Proc. pp. 341-350.

5. Stingli, A., **Bencsik, K.,** Percze, A., Ujj, A. 2005. Monitoring of pests and their natural enemies under different tillage systems. 13th International Poster Day, Institute of Hydrology of the

Slovak Academy of Sciences, 10 November, 2005, Bratislava, Slovakia. pp. 509-514. CD Proc. (Eds. Čelkova, A. Matejka, F.)

Scientific papers in Hungarian conferences

1. Birkás M.- Ujj A. Gyuricza Cs.- **Bencsik K.**-Percze A., 2004. A talajállapot javító és kímélő művelés jelentősége az aszálykárok (*The role of the soil condition improvment and maintenance in drough harms*). „Innováció, a tudomány és a gyakorlat egysége az ezredforduló agráriumában" DE ATC MTK, SZIE MKK Konferencia, Debrecen, 2004. ápr. 16. Összfogl.Kiadvány, Növénytermesztés (szerk. Jávor A.), 105-106.

2. Birkás M., **Bencsik K.,** Ujj A., Gyuricza Cs., Percze A. 2004. A talajtömörödés értékelése összefüggésben az aszálykárokkal. Talajtani Vándorgyűlés, Kecskemét, 2004. aug. 24-26. Talajvédelem különszám (szerk. Antal K., Michéli E., Sz. Kele G.), SZIE Egyetemi Nyomda, Gödöllő, pp. 45-55.

3. Birkás M., Ujj A., Gyuricza Cs., **Bencsik K.**, Percze A. 2004. A talajállapot javító és kímélő művelés jelentősége az aszálykárok csökkentésében. Innováció, a tudomány és a gyakorlat egysége az ezredforduló agráriumában konferencia, Debrecen, 2004. április 16. Öfogl. Kiadvány, pp. 105-106.

4. Birkás M., Kalmár T., **Bencsik K**., Perce A. 2005. A tarlóművelés minőségének hatása a talaj állapotára. MTA AMB 29. Kutatási és Fejlesztési Tanácskozás, Gödöllő, 2005 jan. 18-19. Kiadv. (szerk. Tóth L., V. Jeney K.), 1. kötet, pp. 13-17.

5. **Bencsik K.**, Stingli A., Ujj A. 2005. Talajművelési módok értékelése a talaj agronómiai szerkezete alapján. XLVII. Georgikon Napok és 15. ÖGA találkozó, Keszthely, 2005. szept. 29-30. Öfogl. Kiadvány 220 p.

6. Birkás M., Kalmár T., **Bencsik K**., Stingli A. 2006. Tarlógondozás változóan csapadékos idényekben. MTA AMB 30. Kutatási és Fejlesztési Tanácskozása, Gödöllő, január 24-25. Összefoglalók (szerk. Tóth L., Magó L.), pp. 28. Kiadvány (szerk. Tóth L., Magó L.), 2. kötet, 11-15.