INTRODUCTION

In the Great Hungarian Plain the most important ecological factor determining the development of agricultural production is the water. There is long tradition of the efforts focus on saving water in agricultural use of water. Even during the last centuries the ordinary peasants tried to use methods that ensure the safety of yield with as little amount of water as possible. The irrigation researches of the last century made it obvious that irrigation can be used only conditionally (strictly taking its environmental impacts as secondary salinization, soil degradation, etc. into consideration) on large areas due to the special ecological and soil conditions of the Great Hungarian Plain. Therefore other approaches (water saving soil cultivation, application of crops with high drought tolerance) can be the solution of this problem. Among others, these were the leading ideas of plant breeding researches at the beginning. Later the applied crop production technology researches mainly focused on the examination of the water regime of field crops and the microclimate of crop vegetation. In the early phase soil cultivation researches based on simple empirical observations and not on precise measurements, hence even in the case of the well proved and effective soil cultivation methods our knowledge is defective. This fact makes the elaboration of up-to-date technologies more difficult.

Researches focus on the control of soil water regime in order to improve the efficiency of water use are of great importance. In accordance with the combat against drought damages and soil degradation the conventional soil cultivation methods are prospectively replaced by conservation tillage, which aims the decrease of the depth of the regularly cultivated soil layer and the formation of a topsoil rich in organic matter. The scientific establishment of the hydrological impacts of these new methods can absolutely be considered actual and needs further efforts.

The determination of the effects of technological elements influencing the soil water regime (mulch layer, heat isolating soil surface, mitigation of cracking, etc.) can contribute to the elaboration of water preserving technologies as the elements of up-to-date and sustainable crop production. The control of soil water regime is an effective environmental protective process at the same time, which is of great importance to prevent soil degradation and to mitigate the pollution of our water funds.

Soil temperature has close correlation with the soil moisture content, the physical properties of the soil and the climate. As the first two factors can be influenced by soil cultivation, and the third one is independent of human activities, the determination of differences in water balance and temperature due to the effects of different soil formation and covering methods is of great importance to gain more detailed information on the impacts of sustainable soil cultivation.
The above mentioned facts were leading me when I determined the main goals of the research put in writing in this thesis. These goals can be summarised as follows:

- Examination of soil water regime processes by the operation of a measurement system that provides the possibility of permanent study of the effects of different soil cultivation methods on the soil water- and temperature regime within model (lysimeter) circumstances.

- To establish the application possibilities and limits of the weighing lysimeter system, which is unique in its type in Hungary, created in the Karcag Research Institute of Debrecen University.

- To gain more information on the effects of soil cultivation techniques suitable for the mitigation of the unproductive losses (evaporation, deep percolation) occur out of the vegetation period on the water balance components of the soil.

- To provide data about the effects of certain technological elements (mulch layer, heat isolating soil surface, mitigation of cracking, etc.) on the soil water balance in different climatic and hydrologic conditions.

2. MATERIAL AND METHOD

2.1. Description and treatments of the weighing lysimeter experiment

The experiment was carried out at the lysimeter station of the Karcag Research Institute of Debrecen University between 1993 and 2000. Fig. 1. shows the structural construction of the lysimeter system. Under the lysimeter units with plastic wall electronic scales can be found that can measure the changes of weight with the sensitivity of 0.1 kg (0.05 mm) in the measurement range of ±300 kg. The scales are connected to a data logger in pairs to measure and store the weight data every hour automatically. The data loggers have connection with a computer for data processing. The sizes of the units: surface area 2 m², depth 1 m. The lysimeters were filled with meadow chernozem soil in 1992, hence the samples are not undisturbed, but we have taken the original rates of the horizons into consideration. The soil columns contain 25 cm from the original A horizon of the sampled soil profile, 40 cm from the B, and 20 cm from the C horizon.

The results published in this thesis originate from the following treatments:

- control: bare soil surface without cultivation
- cloddy: rotated to the depth of 25 cm
- mellowed: rotated to the depth of 25 cm and mellowed
- shallowly loosened: no tillage, only after formation of crust shallowly (3-5 cm) loosened
- crust broken: like mellowed + after formation of crust shallowly (3-5 cm) loosened
- mellowed+covered: like mellowed + straw cover
- covered: straw cover without tillage
- mellowed+gypsum: like mellowed + gypsum mixed into the cultivated layer

Fig. 1. The structural construction of the lysimeter system
mellowed+rice husk: like mellowed + rice husk mixed into the cultivated layer
mulch: like mellowed + wheat or maize chaff mixed into the cultivated layer

The photos of the six most frequently applied treatments of the lysimeter experiment are shown in Fig. 2.

Fig. 2. The most frequently applied treatments of the lysimeter experiment

2.3. Determination of the water balance components

According to the principle of weighing lysimetry the facility is suitable for the calculation of the water balance of each unit. The adequate water balance equation valid for the given situation is as follows:

\[ P + I = E + D + WB \]

where \( P \) = precipitation (mm), \( I \) = irrigation water (mm), \( E \) = evaporation (mm), \( D \) = drain water (mm), \( WB \) = water balance, change of soil moisture content (mm). As \( WB = \Delta W \), water balance equals the change of the weight of the soil column, its value can be expressed by reducing the input and output factors:

\[ \Delta W = P + I - E - D \]

As all the factors of the water balance equation, except for evaporation, can be measured and expressed in mm, the evaporation value can be calculated as follows:

\[ E = P + I - D + \Delta W \]

The accuracy of the calculation depends on the measurement accuracy of the components, which is 0.05 mm in the case of the change of weight. This accuracy ranges the lysimeter system to the category of high precision lysimeters.
2.3. Determination of moisture and temperature profiles

The first five units of the sampling set (probes) suitable for the soil moisture and temperature measurements were completed by January of 1998, and built in the lysimeters. The probes (type TTN-M by Sinóros and Szőlősi) measure the soil moisture content according to the principle of hydropolarisation at four different soil layers (0-10, 10-20, 20-30 and 30-40 cm respectively). The measurement frequency is optional, and the detected data are directly sent by the probes to the linked computer.

3. RESULTS

3.1. Determination of water balance components with weighing lysimeters

During the determination of water balance components with weighing lysimeters I elaborated the measurement and calculation methods based on the water balance equation valid for the investigated measurement system. I analysed the temporal frames that are the most suitable for the processing and assessment of the gained data. I established that within the given experimental circumstances water balance results calculated for a half-year (May-October), for a month and for short drying out periods are the most suitable for the determination of the dynamics and characteristics of water balance components influenced by the different soil cultivation methods and for the determination of the effects of different climatic and hydrological situations.

3.2. Results of the half–year water balances

For the investigated period (1993-2000.) I numerically determined the half-year water balances (and their components) of the soil columns with different surfaces created by the modelling of various soil surface formation and covering methods.

I figured out the probable reasons of the experienced differences and the effects of different periods, especially of the extremely dry or wet periods, on the water regime of the soil.

On the base of the half-year results I evaluated the effect of different soil surfaces created by the examined soil cultivation treatments on the soil water balance. By means of the method of regression analyses I tried to find a correlation between the amount of water input (precipitation, irrigation) and output by evaporation of the soil columns. I found close exponential correlation between the examined variables (Fig. 3.). According to the results I ranged the examined five treatments into three different groups. I established that probably there is a certain amount of water input, where practically there is no difference in the amount of water evaporated from the soil columns of the cultivated treatments. I also figured out that the treatments that have evaporation decreasing effect in the lower water input range, in case of water load higher than the average, loose more water by evaporation. I elaborated a new method for the assessment of evaporation decreasing and infiltration increasing effect of the investigated treatments (Table 1.).

![Graph showing water input vs. evaporation for different treatments]

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Equation</th>
<th>R²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>( y = 105.7e^{0.007x} )</td>
<td>0.8873</td>
</tr>
<tr>
<td>Cloddy</td>
<td>( y = 142.57e^{0.0016x} )</td>
<td>0.9233</td>
</tr>
<tr>
<td>Mellowed</td>
<td>( y = 138.92e^{0.0017x} )</td>
<td>0.9968</td>
</tr>
<tr>
<td>Crust broken</td>
<td>( y = 87.87e^{0.0028x} )</td>
<td>0.8768</td>
</tr>
<tr>
<td>Mellowed+covered</td>
<td>( y = 70.517e^{0.0032x} )</td>
<td>0.9476</td>
</tr>
</tbody>
</table>
Fig. 3. Correlation between water input and evaporation on the base of the half-year water balance data

Table 1. Assessment of the effect of five treatments on the water balance of the soil column

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Evaporation mitigating effect</th>
<th>Infiltration increasing effect</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>evap./input</td>
<td>category</td>
</tr>
<tr>
<td>control</td>
<td>94 %</td>
<td>poor</td>
</tr>
<tr>
<td>cloddy</td>
<td>85 %</td>
<td>medium</td>
</tr>
<tr>
<td>mellowed</td>
<td>84 %</td>
<td>medium</td>
</tr>
<tr>
<td>mellowed + crust br.</td>
<td>77 %</td>
<td>good</td>
</tr>
<tr>
<td>mellowed + covered</td>
<td>77 %</td>
<td>good</td>
</tr>
</tbody>
</table>

3.3. Results of the monthly water balances

For the investigated period (1993-2000) I numerically determined the monthly water balances (May-October) of the soil columns with different surfaces. On the base of these result I figured out the seasonal diversity of the soil water balances and the duration of the effect of the treatments.

By means of the monthly water balance data I calculated the difference of the monthly average evaporation of the most frequently applied treatments compared to the control (Fig. 4.). I established that the evaporation of the soil column can be mitigated with the regular crust breaking treatment during the whole half a year period. In the case of the other treatments the evaporation mitigating effect was decreasing with the time, by September-October practically it came to an end. This tendency is especially characteristic for the mulch treatment. The characteristic of the soil columns with cloddy and mellowed surfaces is the high evaporation loss in May (month following the set of the treatments). The evaporation of straw covered surfaces showed similar seasonal tendencies, independent of cultivation. As a summary it can be established that the lower evaporation values, comparing to the control, occurred mainly during the two-three months after the set of the treatments, the only exception is the regular crust breaking treatment that ensures a permanent evaporation decreasing effect.

3.4. Results of the short drying out periods

As a case-study I calculated the water balances of the soil columns with different surfaces for short (100 hours) periods as well. I used this temporal frame for those periods, when significant amount of precipitation or irrigation water got on the surface of the soil columns but there was no drain water by deep percolation. I figured out that the evaporation values calculated for the longer temporal frames (half-year, month) are not in accordance with the values of the short drying out periods. On the base of these results it can be can be concluded that the investigated surface formation and covering treatments have soil moisture saving effect only in case of dry periods. But as the climate of our region tends to dryness, this effect is the dominant.
3.5. Methodological assessment of water balance measurements by weighing lysimeters

I determined the advantages and disadvantages of the weighing lysimeter system, and figured out its application possibilities and limits for the examination of soil water balance. My conclusion is that this weighing lysimeter system, with its given size parameters, provides very accurate data for the comparison analysis of the differences arising in the water balance of soil columns with different surface formation and covering treatments. But I also established that this system is not, or only with very limited conditions, suitable for the examination of the water regime of soils covered by crops.

3.6. Examination of the moisture profile of soil columns with different surfaces

In the course of the moisture content measurements I established that even in those cases when no differences of the moisture fund of the soil columns could be detected by means of the lysimeter measurement system, the vertical moisture profiles showed significant differences. In periods with average or high amount of precipitation only the upper 20 cm deep soil layer lost moisture. But in case of long dry periods I experienced the decrease of the moisture content in the soil layers under 20 cm too.

I figured out the stratification characteristics of the soil moisture profile in the soil columns with different surfaces (Fig. 5.). The characteristic of the untreated surface (control) is the high amount of water remaining close to the soil surface, but the deeper layers are not saturated to field capacity. In the case of the crust breaking treatment only the upper 10 cm layer dries out, but in accordance with the literature data, this isolation layer impedes the spreading of drying deeper. The mulch layer also dries out to the depth of cultivation, but the water can infiltrate effectively into the mulched soil surface, hence the soil with this treatment showed very good water regime properties. Unambiguously the soil columns covered with straw preserved the highest amount of water content, nevertheless some differences could be detected in the stratification due to the presence or lack of cultivation. The uncultivated version (similarly to the control) preserves more moisture close to the surface, but less in the deeper layers, the situation is exactly the opposite in the case of the cultivated version.
3.7. Examination of the temperature profile of soil columns with different surfaces

I also measured the temperature at the 0-40 cm layer of the soil columns with different surfaces created with the examined soil surface formation and covering methods (Fig. 6.). I established that straw cover has temperature decreasing effect independently of the presence or lack of soil cultivation. The highest temperature values were detected in the case of the regular crust breaking treatment, which can be explained with the low heat capacity of its dry surface layer. I figured out the characteristic of the mulched surface: its temperature influencing effect has a certain duration. I measured relatively low temperature data after the set of the treatment, but later higher temperature can be expected, as the heat capacity is decreasing due to the drying out of the topsoil with high porosity. I also established that the heat concentration of the soil columns moderately decreased by the depth, but no differences of heat mass stored in the examined soil layers could be detected.

3.8. Evaluation of the moisture and temperature profile measurements

I established that the measurement of the moisture and temperature profile of the soil, taking the utilisation limits into consideration, provides useful complementary information for the evaluation of the water balance results gained by the lysimeter system. I figured out that, within the given investigation circumstances, the different soil surface influences only the water regime of the topsoil directly, hence the effects of the various soil cultivation treatments can be well characterised by the determination of the water balance of the upper 40 cm layer of the soil column. To prove this establishment I compared...
the water balances determined by means of the lysimeter system and the balances calculated from the soil moisture data measured with TTN-M probes, which are valid for the upper 40 cm layer of the soil columns. This examination had two objectives: beyond to prove the establishment mentioned above, I intended to test the authenticity of the probes. I used the monthly water balance data determined in 1998-2000, for this comparison. The differences expressed in mm are shown in Table 2. On the base of the differences I established that the water balances calculated by the probe measurements do not diverge so much from the data determined by the lysimeter measurements: the differences were only 0.16-2.39 mm for the averages of the treatments.

![Fig. 5. The average temperature profiles of the soil columns on the base of the daily values (1998-2000, May-October)](image)

Table 2. The differences of the monthly soil water balances determined with the lysimeter system and with the TTN-M probes (mm)

<table>
<thead>
<tr>
<th>YEAR</th>
<th>MONTH</th>
<th>TREATMENTS</th>
<th>control</th>
<th>mellowed +crust broken</th>
<th>mulch</th>
<th>covered</th>
<th>mellowed +covered</th>
</tr>
</thead>
<tbody>
<tr>
<td>1998</td>
<td>6</td>
<td>-2.50</td>
<td>+3.90</td>
<td>+2.30</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td></td>
<td>7</td>
<td>-0.25</td>
<td>-0.50</td>
<td>+0.50</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td></td>
<td>8</td>
<td>-0.15</td>
<td>+1.25</td>
<td>+1.0</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td></td>
<td>9</td>
<td>+2.90</td>
<td>+4.90</td>
<td>+9.65</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>+0.75</td>
<td>-</td>
<td>-0.70</td>
<td>+0.40</td>
<td>+0.40</td>
<td></td>
</tr>
</tbody>
</table>
NEW SCIENTIFIC ACHIEVEMENTS

1. I established that within the given experimental circumstances the half-year, the month and the short drying out periods are the most suitable temporal frames of the water balance measurements. For these periods I numerically determined the water balances (and their components) of the soil columns with different surfaces created by the modelling of various soil surface formation and covering methods. I figured out the probable reasons of the experienced differences and the effects of different periods, especially of the extremely dry or wet periods, on the water regime of the soil.

2. I determined the correlation between the amount of water input (precipitation, irrigation) and output by evaporation of the soil columns. I elaborated a new method for the assessment of evaporation decreasing and infiltration increasing effect of the investigated treatments.

3. I figured out the advantages and disadvantages of the weighing lysimeter system, and figured out its application possibilities and limits for the examination of soil water balance. I concluded that this weighing lysimeter system, with its given size parameters, provides very accurate data for the comparison analysis of the differences arising in the water balance of soil columns with different surface formation and covering treatments, but is not, or only with very limited conditions, suitable for the examination of water regime of soil covered by crops.

4. I established that the determination of the moisture and temperature profile of the soil, taking the utilisation limits into consideration, provides useful complementary information for the evaluation of the water balance results gained by the lysimeter system. I figured out that, within the given investigation circumstances, the effects of the various soil cultivation treatments can be well characterised by the determination of the water balance of the upper 40 cm layer of the soil column.

5. I established that the moisture preserving effect of the different soil formation and covering methods does not concern the whole soil profile, but the rearrangement of the moisture profile and the accumulation and preservation of water in the cultivated layer are the dominant processes in this respect. I figured out the stratification characteristics of the soil moisture profile in the soil columns with different surfaces.

6. In accordance with other authors I proved that fallowing, which aims the regeneration of the soil, has moisture preserving effect only in cultivated state, as the undisturbed soil has the highest evaporation loss and the lowest infiltration.

7. I figured out that the soil moisture and temperature influencing effect of the mulched surface has a certain duration. As the mulch layer keeps the soil surface loose for a certain period, it has an important role in the mitigation of evaporation loss, but in re-compacted state its water- and heat regime gets less favourable.

8. I established that the heat concentration of the soil columns of the investigated treatments moderately decreased by the depth, but no differences of heat mass stored in the certain soil layers could be detected.
LIST OF SCIENTIFIC PUBLICATIONS ISSUED IN THE TOPIC OF THE DISSERTATION

Scientific studies


Presentations and posters at conferences


