**Thesis of the PhD dissertation**

# EFFECTS OF VARIOUS SOIL CULTIVATION METHODS ON WEED COMMUNITY IN MAIZE


*by*

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# 1. INTRODUCTION AND OBJECTIVES

It is an expectation derived from future needs that all the aspects of the current agriculture should meet sustainability. The reduced tillage as an up-to-date technology used in land cultivation can meet the expectation. Cultivation systems which are able to manage well soil moisture content completed with sustainable crop production are capable of producing crops in more efficient but environment friendly ways. In USA, Canada, Germany, they have been familiar with the up-to-date technologies for decades, and the technologies have been applied by specific machinery on purpose. In Hungary, however, the reduced tillage systems have been known but not come into general use. The complex evaluation of the influence of soil conservation tillage is based on many stands. Its base effect is the influence on the soil, the second one is the influence on the weed community which obviously relates to the plant protection technology used. However, farmers are interested most likely in the economic aspect.

This study focuses on testing the influence of some non-rotational tillage systems on weed communities under the climate in Hungary, applying the generic large-scale farming technologies.

The driving hypothesis is that soil conservation tillage used in maize production on large-scale farms basically influences the weed communities on those fields.

The objectives of the study are to reveal the next:

1. What are the fundamental differences between traditional and soil conservation tillage referring to weed communities?
2. Is there significant difference among the weed communities of the cultivation systems of reduced tillage?
3. Are there any differences between the applied soil cultivations referring to weed diversity?
4. Which kind of reduced tillage can meet most the requirements of practice and sustainable agriculture?

## METHODOLOGY

The research field was located next by the settlement Csárdaszállás, Békés county, Hungary, which was utilised in a research into reduced tillage application in crop production by KITE Co. and University of Debrecen. It was a research field of 11,5 hectares that comprised four plots of the same size. Machinery and service demanded by the research were rendered by KITE Co.

Under the framework of the field research, this study was to reveal the influence of maize production on weed vegetation.

Hungarian Meteorological Service (OMSZ) served the data of meteorology relevant to the area and period of research. As being a three year study, two production years were dry compared to the average of many years, while one production year out of the three was similar to that average *(Figure 1)*.

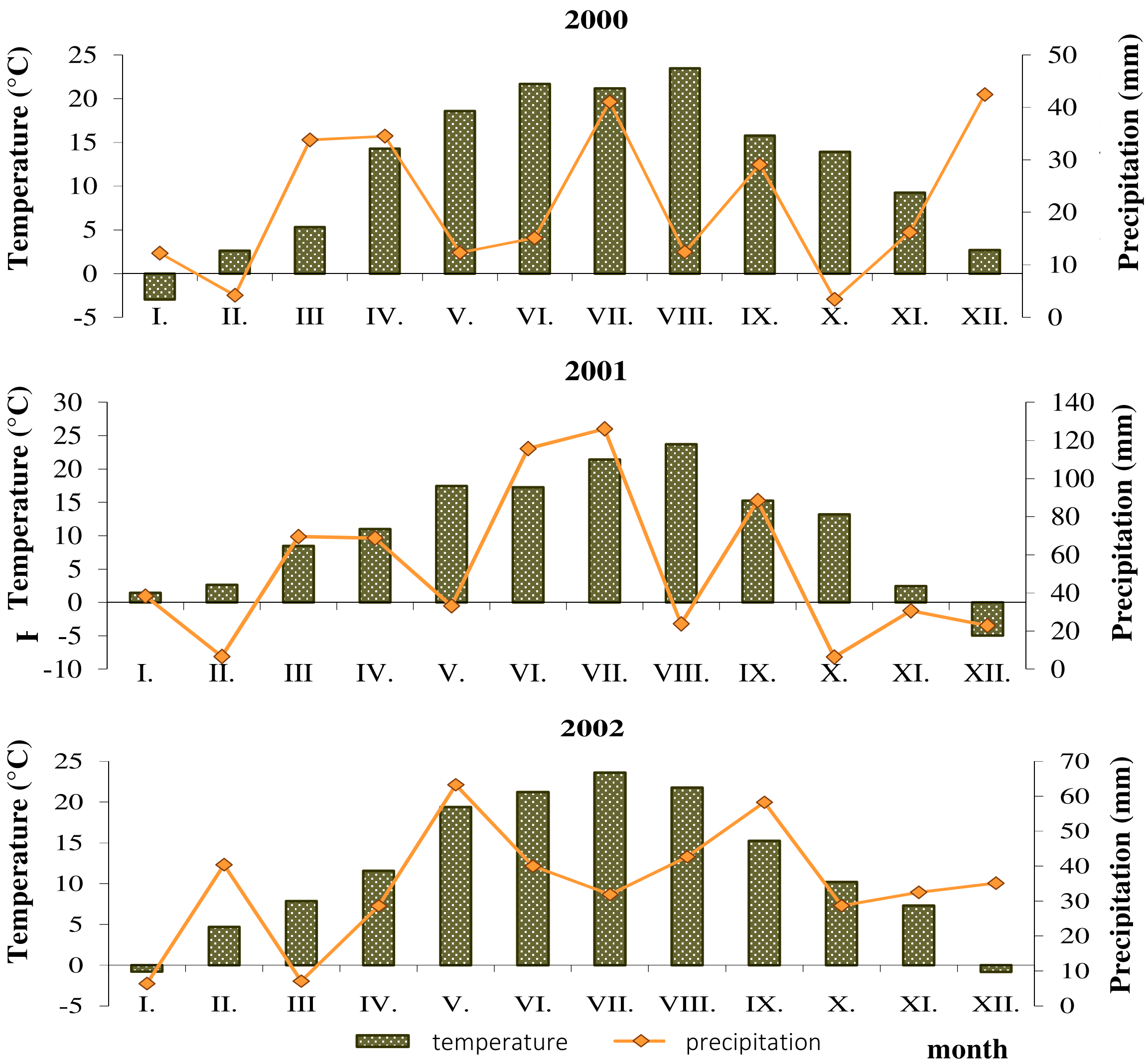


*Figure 1. Monthly temperature means and precipitation (Csárdaszállás, 2000-2002)*

According to xerothermic index by Gaussen-Bagnouls ($I_{GB}$), which was $I_{GB}<1$ in 2000 and 2002, it was the period from June to August that was critical to maize from ecological aspect, but only August was that critical in 2001. For fine tuning of meteorological data, there were potential evapotranspiration (PET), true evapotranspiration (TET), and relative evapotranspiration ($Rel_{ET}$=TET/PET) measured.

Data of soil attributes came from database of Department of Soil management, University of Debrecen. Physical attributes of soil, namely soil compactness, distribution of compact layers, and moisture content were measured by a manual penetro-meter and an instrument of deep-pipe measuring moisture content. The research field has hydromorph soil type with $CaCO_3$ (>2%) content close to the surface.

Over the three years of research, there were three maize hybrids such as Occitán SC (FAO 380) PR37M34 SC (FAO 360), Dekalb 471 SC (FAO 410) used with 75 000 seeds per hectare each.

It was an experiment set in farming condition of which three components were reduced tillage ( treatment I, II, III) and one was traditional tillage of many operations on soil (treatment IV.).

The variants of tillage were applied as follows:

Treatment I: stubble chopping in autumn, direct drilling in spring

Treatment II. : stubble chopping, primary tillage of 30 cm depth by a Disk Ripper in autumn, seedbed formation and sowing in spring

Treatment III. : stubble chopping, stubble stripping (2 times) in autumn, narrowly (12 cm) done non-rotational tillage by a Mulch Finisher, sowing in spring

Treatment IV. : stubble chopping, stubble stripping (1 time), primary tillage by ploughing (27cm depth) in autumn, seedbed formation and sowing in spring (this is called traditional tillage)

It was active ingredients of N45, P45, K45 kg/ha applied before doing primary tillage in autumn. In spring, it was chemical fertilizer with active ingredients of ammonium nitrate of 75 kg/ha coupled with sowing. Weed control of pre-emergence was done by a combination of relevant (pre-emergent) chemicals that was followed by a post-emergent treatment, that is, (Frontier 1.5 l/ha + Gesaprim 1.4 l/ha) and (Titus 25 DF 50g/ha + Banvel 0.6l/ha), respectively, because chemical weed control is an integrated part of technology in maize production just like seed dressing. So, it is decisive on the weed community that what technology and weed control is applied on crop fields. Being given the fact that these essential elements of the technology were applied on the whole of the research field, thus the results can represent truly how weed communities changed under generic technology of maize production.

**Samples** of weed was taken in simple random ways out of ten fixed boxes of 2 times 2 metres in each treatment. As basic statistical data, abundance, dominance, vitality, and sociability data of analytical features of the species were recorded on the spot.

**Data processing** comprises meteorological and weed communities' data. Meteorological data processing was done by computing PET, TET and ($Rel_{ET}$=TET/PET). Weed communities were featured by using four aspects, such as cönotaxonomy, similarity, texture, and diversity.

*Coenotaxonomy* in the study was featured by data of frequency, life-form, and flora. All the species having frequency value of III at only one way of tillage and lower frequency values at the other ways of tillage were considered as circumstantial. At the same time, all of the differential species were identified.

*Similarity analysis* was done by two functions ignoring *d* value and two functions symmetrical to *a* and *d* values, which are Jaccard and Sorensen indices, and Sokal-Sneath and Rogers-Tanimoto indices, respectively. Hierarchical cluster analysis providing dendrograms used single-linkage method, and similarity was tested by applying euclidean distances.

*Textural characteristics* were analysed using ecological indicator values by Borhidi. Applying scales of temperature, soil moisture content, soil reaction, and soil nitrogen weed communities were evaluated by their group shares and shares of group mass.

*Diversity analysis* was done by data processing applied data matrix that was evaluated by using software DIVORD 1.9, while doing diversity ranking according to α-ranked entropy by Rényi. Data of abundance, as basic statistical data, were used to compute relative frequency figures in order to rank diversities and calculate three diversity functions with their evenness values, namely Shannon, Simpson, and Berger-Parker functions.

The weed cover and frequency data were analysed by using One-way ANOVA. Before applying ANOVA, data matrix normality and variance homogeneity (Levene-test) tests were run. The means of treatments were compared by Tukey HSD-test.

## RESULTS AND DISCUSSION

The findings of the study fall into four categories.

### *3.1. Processing data of soil and meteorology*

Based on PET and TET data it can be stated that water-saving effects of reduced tillage systems was realised right in the second year of production and sustained over the next period. In the first year the soil moisture content as to field ploughed was the highest in comparison with any fields with reduced tillage, however, the opposite was the case with moisture content of 60 mm less in the second year. The highest moisture content was provided by the field cultivated by direct drilling, followed by disk ripper and shallow ploughed fields. Higher starting moisture contents for reduced tillage systems entailed higher TET values. This is as an advantage maintained up to middle of the vegetation period, proving better water saving capability (*Figure 2*).

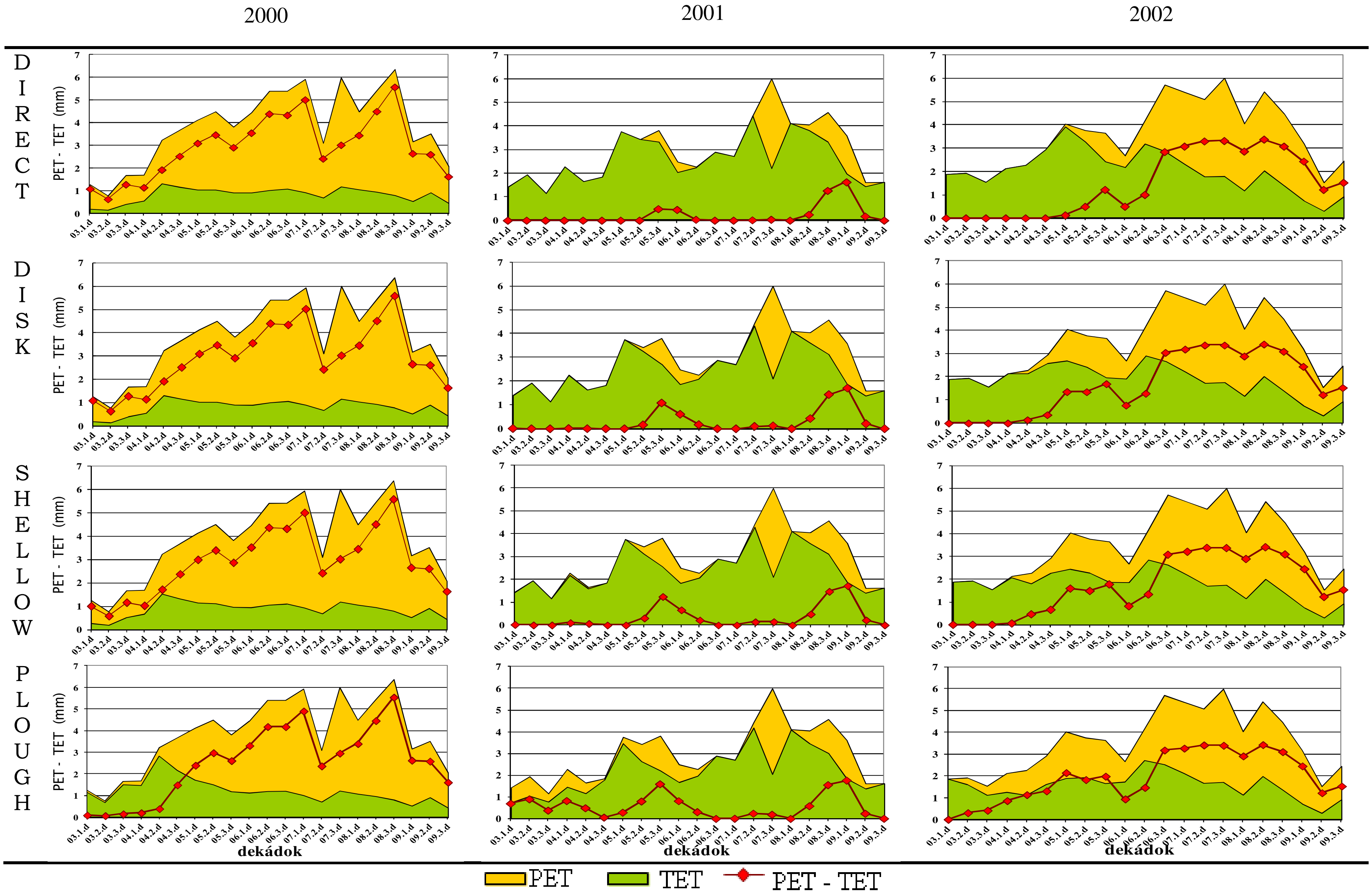


*Figure 2. Potential evapotranspiration (PET), true evapotranspiration (TET) and difference between them (PET-TET) (Csárdaszállás, 2000-2002)*

Soil moisture profiles graphed by moisture data enlighten us as to the distribution of moisture in depth. If this is coupled with data of precipitation, they can characterise well a specific soil profile.

As for the saving soil moisture content, it is direct drilling that is the most favourable. The highest loss of soil moisture was caused by traditional tillage of ploughing. At the same time there was no clear difference found between shallow and disk ripper tillage when analysing the combined three year data base. To differentiate these reduced tillage systems, it is the 10 cm layers of soil that have to be compared. Disk ripper gives higher moisture content figures in the layers of 10 cm and 40 cm, but shallow cultivation provides higher values in 20 cm and 30 cm depth (*Figure 3*).

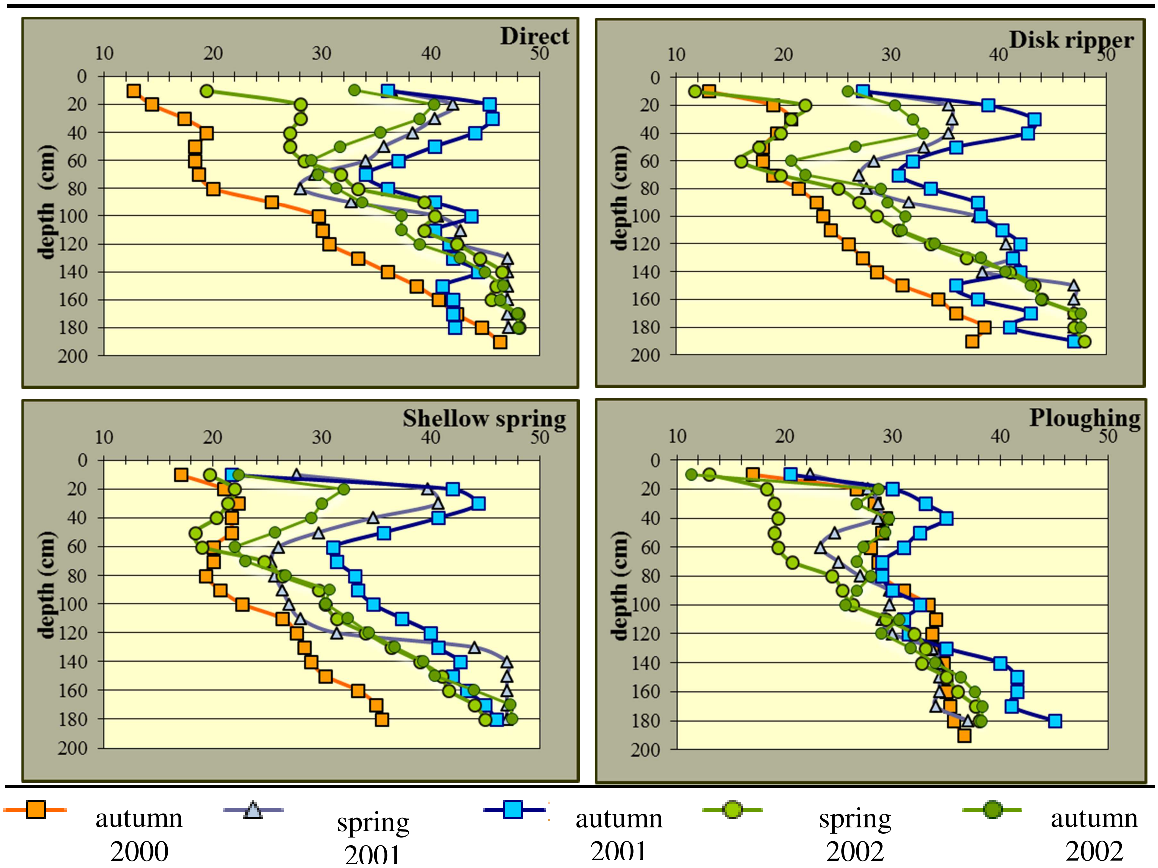


*Figure 3. Moisture content profiles by ways of tillage (Csárdaszállás, 2000-2002)*

### *3.2. Weed cover and composition of species developed by distinct treatments over the research period*

Based on the number of species it is soil conservation tillage that is more diverse with higher number of weed species compared to the ploughing. There were some decrease in number of species for each soil conservation tillage over the research period but they could keep maintaining more diverse weed flora than that of ploughing. Direct drilling had significantly higher number of species compared to any other ways of tillage. The research period was not long enough to track the changes in the assortments of species dependent on ways of tillage (Figure 4.).

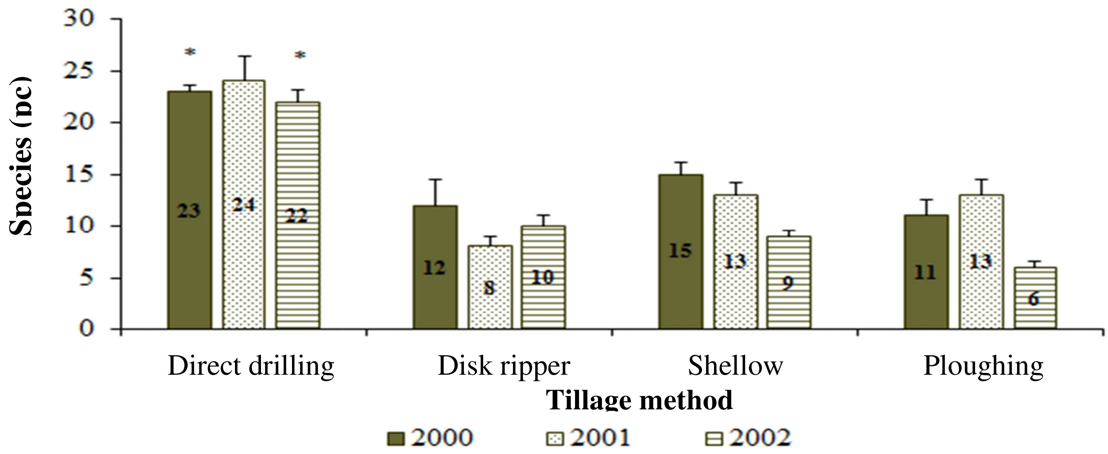


*Figure 4. Average number of species (±SE) by ways of tillage (*sign. P<0,05) (Csárdaszállás, 2000-2002)*

There are two statements concluded on similarities based on compositions of weed species, that is, (1) the use of one index to understand results right is inadequate. Under the framework of this research indices ignoring d-values could modulate the picture of the communities better than the symmetric ones, being capable of indicating the tiniest differences between communities developed by the influence of ways of tillage. (2) According to all the indices the most similar weed communities could develop on fields cultivated by disk ripper and shallow spring tillage, while direct drilling and ploughing were the less similar (*Table 1).*

*Table 1. Similarity indices of the treatments based on indices ignoring* d *and those symmetrical to* a *and* d *values*

| | **Disk** | | | | **Shallow** | | | | **Ploughing** | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **J** | **S** | **RT** | **SM** | **J** | **S** | **RT** | **SM** | **J** | **S** | **RT** | **SM** |
| **Direct** | 0,44 | 0,61 | 0,3 | 0,47 | 0,48 | 0,65 | 0,33 | 0,5 | 0,39 | 0,56 | 0,24 | 0,39 |
| **Disk** | | | | | 0,5 | 0,66 | 0,53 | 0,69 | 0,47 | 0,64 | 0,53 | 0,69 |
| **Shallow** | | | | | | | | | 0,47 | 0,64 | 0,5 | 0,66 |

*J= Jaccard index, S= Sørensen index, RT= Rogers-Tanimoto index, SM= Sokal-Michener index*

*Jaccard and Sorensen indices ignoring* d, *and Sokal-Sneath and Rogers-Tanimoto indices symmetrical to* a *and* d *values*

By testing weed cover data in per cent, it was found that there was significant difference among weed covers caused by different tillage systems, therefore, way of tillage is a decisive factor to weed cover. In each year weed cover figures measured on fields ploughed were significantly lower to those figures for reduced tillage systems. At the same time, there was no significant weed cover difference found between disk ripper and shallow tillage in any year of the research, while admitting the year effect on direct drilling (*Figure 5*).

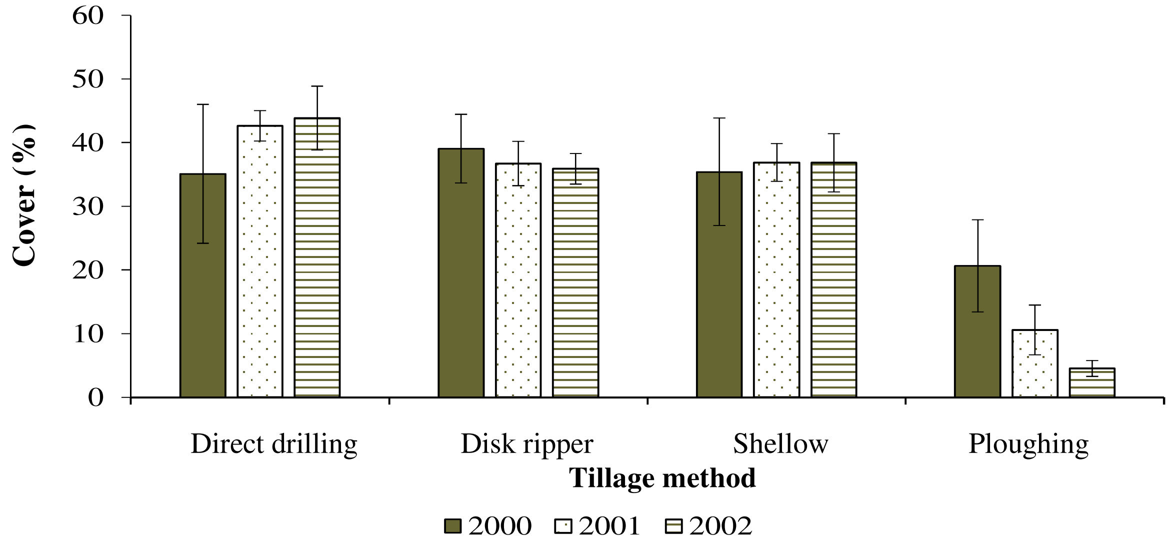


*Figure 5. Yearly weed cover averages by ways of tillage (Csárdaszállás, 2000-2002)*

### *3.3. Analysis and comparison of coenotaxonomy and texture of detected arable weeds by ways of soil cultivation*

It was Luckspur-Yellowbristle grass community identified for each way of soil cultivation (*Echinochloo-Setarietum pumilae* Felföldy 1942 corr. Mucina 1993), therefore, weed species as the components of community were not influenced by distinct cultivation.

As the components there were identified weed species as follows: *Echinochloa crus-galli*, *Setaria viridis* and *Hibiscus trionum* but there were others such as *Amaranthus retroflexus, Setaria verticillata, Stachys annua, Convolvulus arvensis, Chenopodium hybridum, Solanum nigrum.*

Unlike to the literature there was Yellow foxtail (*Setaria viridis*) instead of Yellowbristle grass (*Setaria pumilae*) as a component, which was caused by factors of soil and weed control. Yellowbristle grass prefers sour sandy clay soils, but Yellow foxtail dominates on calcareous, moreover, on calcareo-loessal soils. The soil conditions of the research field, which was carbonated soil with $CaCO_3$ (>2%) content close to the surface developed on loess, favoured towards Yellow foxtail, in addition, an active ingredient that was used for weed control fails to control *Setaria*, thus if preemergent control fails somehow the species booms.

In spite of that there was a weed community identified in the research field as independent on the way of tillage, there were differential species by which distinct tillage systems can be differentiated. Detected differential species featuring all three soil conservation tillage are such as *Amaranthus retroflexus*, *Setaria verticillata*, and *Cirsium arvense*. *Cirsium arvense* is an ideal differential species for soil conservation tillage systems as being with 80-100 per cent of frequency, while not existing on the fields ploughed.

There were, however, differences between compositions of species for soil conservation systems. It is direct drilling that only has distinctive weed species compared to the other two. These species exist with high frequency in the case of direct drilling, which is contrary to those two. These species are the next: *Amaranthus powellii*, *Sonchus asper, Conyza canadensis*, *Tripleurospermum perforatum* and *Taraxacum officinale*. Nevertheless, *Convolvulus arvensis* of G3 is a differential species for direct and shallow tillage (*Table 2*).

As for disk tiller and shallow tillage cluster analysis based on frequency data supported the resemblance and pointed out that direct drilling has a weed community cluster apart. Thus, the classification has partly confirm the traditional weed community findings (*Figure 6*).

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Dendrogram using Single Linkage

                         Rescaled Distance Cluster Combine

   C A S E      0         5        10        15        20        25
  Label     Num  +---------+---------+---------+---------+---------+

     2,00    2   -+-------------------------+
     3,00    3   -+                         +----------------------+
     4,00    4   ---------------------------+                      |
     1,00    1   --------------------------------------------------+
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1=direct drilling, 2= disk ripper, 3= shallow spring, 4= ploughing

*Figure 6. Clusters based on frequency of species in each treatment of four*

*Table 2. Combined table of weed communities of distinct soil cultivation tillage and the differential species (boxes in bold)*

| SPECIES (36 pcs) | DIRECT DRILLING | | | DISK RIPPER | | | SHALLOW SPRING | | | PLOUGHING | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Fr | cover % | | Fr | cover % | | Fr | cover % | | Fr | cover % | |
| | | min | max | | min | max | | min | max | | min | max |
| **Community components** | | | | | | | | | | | | |
| Echinochloa crus-galli | V | 1,24 | 18,75 | V | 1,24 | 37,50 | V | 1,24 | 18,75 | V | 0,62 | 18,75 |
| Setaria viridis | V | 1,24 | 9,37 | V | 1,24 | 12,50 | V | 1,24 | 37,50 | IV | 0,36 | 1,24 |
| Hibiscus trionum | IV | 0,36 | 4,68 | IV | 0,36 | 9,37 | V | 0,36 | 4,68 | V | 0,36 | 5,46 |
| **Diff. direct + disk + shallow spring** | | | | | | | | | | | | |
| Amaranthus retroflexus | V | 1,24 | 25 | V | 1,24 | 31,35 | V | 0,62 | 31,35 | III | 1,24 | 4,68 |
| Setaria verticillata | V | 1,87 | 12,50 | V | 1,24 | 3,12 | V | 1,24 | 15,62 | II | 1,24 | 7,81 |
| Cirsium arvense | V | 1,87 | 18,75 | IV | 1,24 | 4,68 | V | 0,62 | 18,75 | 0 | – | – |
| **Differential to direct + shallow spring + ploughing** | | | | | | | | | | | | |
| Stachys annua | IV | 1,24 | 12,50 | III | 0,36 | 4,68 | IV | 0,62 | 9,37 | V | 0,36 | 31,35 |
| **Differential to direct + shallow spring** | | | | | | | | | | | | |
| Convolvulus arvensis | IV | 1,24 | 15,62 | I | 1,24 | 1,24 | V | 0,62 | 3,12 | II | 1,87 | 4,68 |
| **Differential to direct + ploughing** | | | | | | | | | | | | |
| Chenopodium hybridum | V | 0,62 | 7,81 | 0 | – | – | II | 1,24 | 3,12 | V | 0,62 | 4,68 |
| Solanum nigrum | V | 1,24 | 5,46 | 0 | – | – | I | 1,24 | 1,24 | IV | 1,24 | 3,12 |
| **Differential to direct drilling** | | | | | | | | | | | | |
| Amaranthus powellii | V | 0,62 | 4,68 | II | 1,24 | 4,68 | I | 1,24 | 1,87 | 0 | – | – |
| Sonchus asper | IV | 0,62 | 15,62 | I | 0,37 | 4,68 | I | 9,37 | 2 | 0 | – | – |
| Conyza canadensis | V | 1,24 | 4,68 | 0 | – | – | 0 | – | – | 0 | – | – |
| Tripleurospermum perforatum | IV | 0,62 | 9,37 | 0 | – | – | I | 1,24 | 18,75 | 0 | – | – |
| Taraxacum officinale | III | 1,24 | 1,24 | 0 | – | – | 0 | – | – | 0 | – | – |
| **Requisite species** | | | | | | | | | | | | |
| Abutilon theophrasti | II | 1,24 | 1,24 | III | 1,24 | 4,68 | III | 0,62 | 4,68 | I | 1,24 | 1,24 |
| Fallopia convolvulus | III | 0,36 | 3,12 | III | 0,36 | 1,24 | 0 | – | – | III | 1,24 | 4,68 |
| **Accidental species** | | | | | | | | | | | | |
| Chenopodium album | III | 0,62 | 4,68 | 0 | – | – | 0 | – | – | II | 1,24 | 1,24 |
| Lathyrus tuberosus | III | 1,24 | 3,12 | 0 | – | – | II | 1,24 | 3,12 | 0 | – | – |
| Conium maculatum | II | 1,24 | 18,75 | 0 | – | – | 0 | – | – | 0 | – | – |
| Persicaria lapathifolia | 0 | – | – | 0 | – | – | II | 1,24 | 6,25 | II | 1,24 | 15,62 |
| Reseda lutea | I | 0,62 | 1,24 | II | 4,68 | 10,93 | 0 | – | – | 0 | – | – |
| Atriplex tatarica | II | 1,24 | 6,25 | 0 | – | – | I | 7,81 | 9,37 | 0 | – | – |
| Ambrosia artemisiifolia | II | 1,24 | 7,81 | 0 | – | – | 0 | – | – | I | 1,24 | 1,24 |
| Datura stramonium | I | 0,62 | 0,62 | I | 1,24 | 1,24 | 0 | – | – | II | 1,24 | 9,37 |
| Anagallis arvensis | II | 1,24 | 3,90 | 0 | – | – | I | 1,24 | 1,87 | 0 | – | – |
| Sonchus oleraceus | I | 1,24 | 2,49 | I | 1,87 | 3,12 | 0 | – | – | 0 | – | – |
| Artemisia vulgaris | II | 1,24 | 1,24 | 0 | – | – | 0 | – | – | 0 | – | – |
| Chenopodium ficifolium | II | 1,87 | 5,46 | 0 | – | – | 0 | – | – | 0 | – | – |
| Malva pusilla | II | 1,24 | 1,87 | 0 | – | – | 0 | – | – | 0 | – | – |
| Lactuca serriola | I | 1,24 | 1,24 | 0 | – | – | 0 | – | – | 0 | – | – |
| Malva sylvestris | I | 1,24 | 1,24 | 0 | – | – | 0 | – | – | 0 | – | – |
| Odontites vernus ssp.serotinus | I | 1,24 | 4,68 | 0 | – | – | 0 | – | – | 0 | – | – |
| Polygonum arenastrum | I | 1,87 | 1,87 | 0 | – | – | 0 | – | – | 0 | – | – |
| Xanthium italicum | I | 2,49 | 6,25 | 0 | – | – | 0 | – | – | 0 | – | – |
| Ajuga chamaepitys | 0 | – | – | 0 | – | – | 0 | – | – | I | 1,24 | 1,24 |

There were quantitative features of weed communities analysed such as life-form spectrum, ecological indices, monocotyledon and dicotyledon, distribution of invasive species and $C_3/C_4$ ratios.

It was the ploughing which had the most homogenous life-form spectra with weeds of $T_4$ on the field. The most diverse life-form spectra including weeds of $T_4$, $G_1$, $G_3$, $H_3$, $H_4$, $H_5$, HT appertains to direct drilling followed by disk ripper and shallow tillage with 7, 3, and 3 life-forms, respectively. The proportion of weeds of $T_4$ will probably decrease, but there will be an increase in weed cover of $G_3$ in line with that, resulting in twice and treble as much of the portions for direct drilling and shallow tillage, respectively. Creeping thistle (*Cirsium arvense, Convulvulus arvensis*) of $G_3$ may dominate, but *Lathyrus tuberosus* of $G_1$ in fields cultivated by direct drilling and shallow tillage may occur with low cover and short existence (*Figure 7*).

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Dendrogram using Single Linkage

                         Rescaled Distance Cluster Combine

   C A S E      0         5        10        15        20        25
  Label     Num  +---------+---------+---------+---------+---------+

         3    3   -+-----+
         4    4   -+     +-----------------------------------------+
         2    2   -------+                                         |
         1    1   -------------------------------------------------+
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1=direct drilling, 2= disk ripper, 3= shallow spring, 4= ploughing

*Figure 7. Clusters based on life-forms of species in each treatment*

According to the *ecological indices* on fields with traditional tillage over the three years of research weeds that are plants in accordance with submontane broad-leaved forest belt, semi-humid habitats, neutral, and moderately nutrient rich habitats accrued. Disk tiller preferred weeds that are basiphylous plants in accorrdance with woodland belt, N-idicators of fresh, fertilized soils to accrue. There was no notable difference between direct and shallow tillage, both preferring basifrequent plants of semi-humid habitats with soils rich in mineral nitrogen. As for the medians they were lower compared to each mean of indicator.

Considering the influence of soil conservation tillage on *mono- and dicotyledon* distributions, an increase in the portion of monocotyledons compared to that of dicotyledons may be expected. Monocotyledones was represented by three species of grasses (*Poaceae)* such as *Echinochloa crus-galli, Setaria viridis, Setaria verticillata.* Accrual of the monocotyledonous is not favoured by ploughing as rotational tillage, but then again grasses can accrue under conditions of soil conservation tillage, even if there is a technology including weed control to produce maize in large-scale farming. In addition, there are detectable differences between ways of soil tillage even at species level. Direct drilling supported communities of *Echinochloa crus-galli* and *Setaria verticillata* to increase but at low cover level, at the same time direct drilling favoured *Echinochloa crus-galli* to spread aggressively up to 20-30% of cover from year two, shallow tillage although served fast spreading especially for *Setaria viridis*.

Based on the three year averages, ranking of soil conservation tillage is as follows: disk ripper (23,9%) → shallow (21,9%) → direct drilling (11,4%), of which difference as to direct drilling was significant. It is direct drilling of soil conservation tillage which may keep grasses within bounds because of higher number of species and more diverse life-forms spectrum generating higher competition between weed species (*Figure 8*).

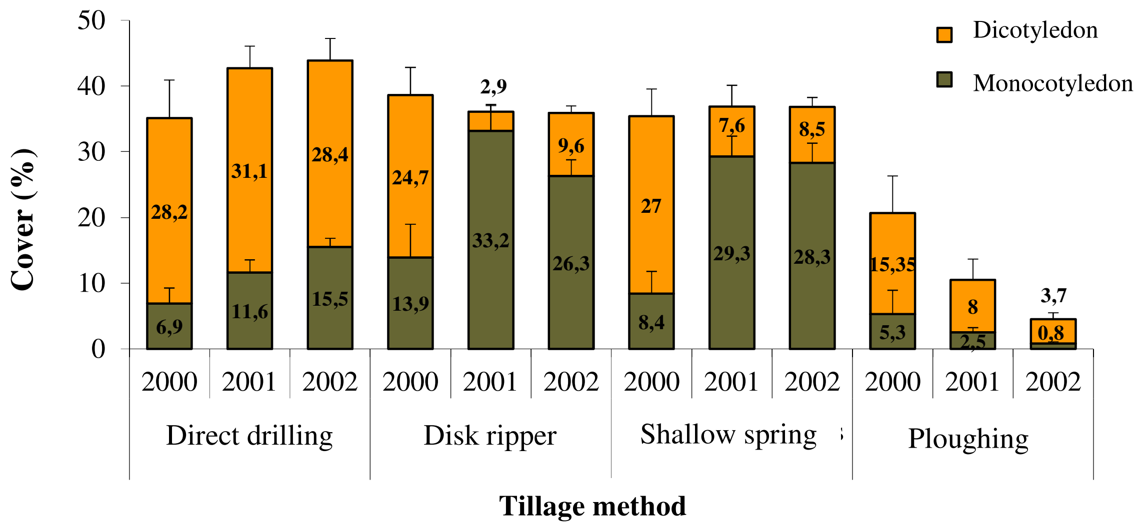


*Figure 8. Covers of the monocotyledonous and dicotyledonous weeds by tillage methods (±SE)*
*(Csárdaszállás, 2000-2002)*

Analysing *weeds of $C_3$ and $C_4$* it is clear that soil conservation tillage obviously favours spreading of weeds of C4, which is shown by the ranking based on average covers, that is, disk ripper (32,6%) → shallow spring (27,1%) → direct drilling (17,6) → traditional (3,2%). There were significant differences found between traditional tillage and direct drilling in each year, moreover, traditional tillage significantly differed from each conservation tillage by the third year of research. In the meanwhile, difference was found only between direct drilling and disk ripper. In the research field three dicotyledonous species of $C_4$ (*Amaranthus retroflexus, Amaranthus powelii, Atriplex tatarica*) and three monocotyledonous species of $C_4$ (*Echinochloa crus-galli, Setaria viridis, Setaria verticillata)* were identified. In line with the former findings within the total cover of $C_4$ it is the monocotyledonous that have the highest share, which may be notably high cover of $C_4$ dominated by the monocotyledonous as to primary tillage by disk ripper (*Figure 9*).

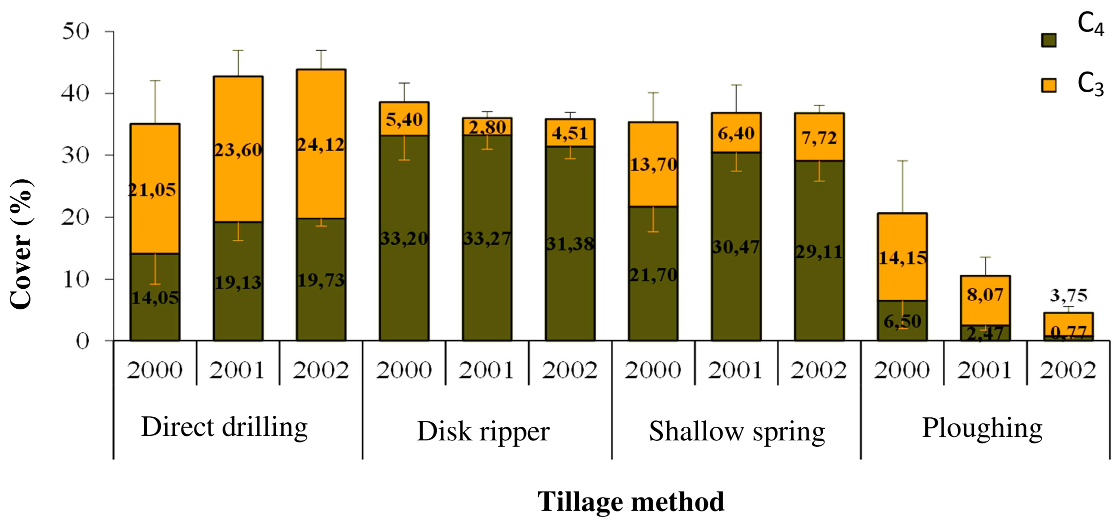


*Figure 9. Average covers of weeds of $C_3$ and $C_4$ by tillage methods (± SE) (Csárdaszállás, 2000-2002)*

In the research field five ones of invasive species appeared, namely *Amaranthus retroflexus* L., *Amaranthus powelii* L., *Ambrosia artemisiifolia* L., *Conyza canadensis* L, *Xanthium italicum* L. and all of them falls into the invasive neophyte weeds. It can be stated that for non-rotational tillage higher covers of invasive species may be projected, however, this invasion will be retarded by the maize production technology using herbicides (*Figure 10*).

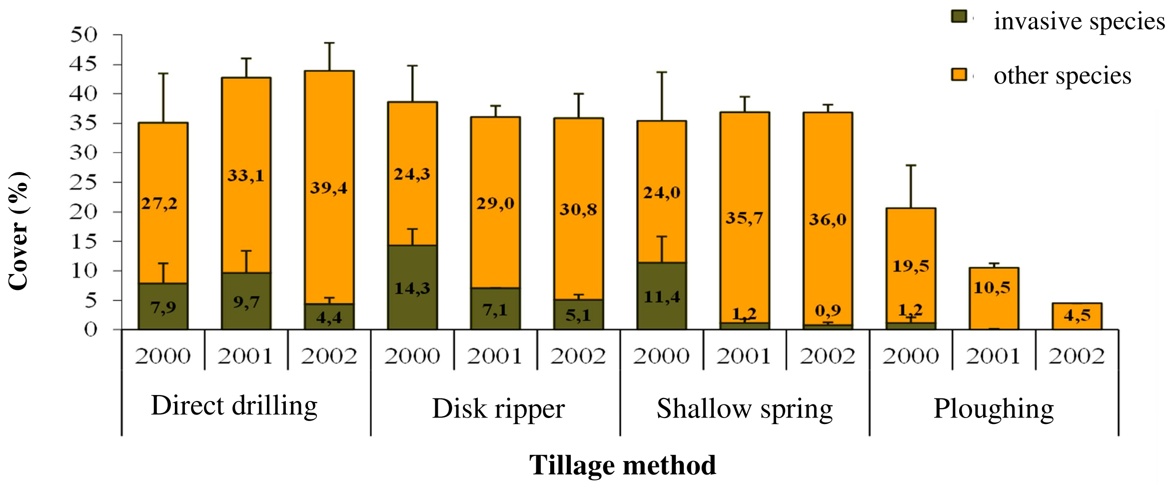


*Figure 10. Average covers of invasive species by tillage methods (± SE) (Csárdaszállás,2000-2002)*

### *3.4. Diversity measures to evaluate weed communities of ways of soil tillage*

Chapter dedicated to diversity in the thesis addresses methodology. Its goal is to reveal that what calculations as to arable weed communities can provide the results mostly being in accordance with true situations on the fields. Using numbers (pcs) of individuals as basic data, there were diversity measures, classical diversity functions, and diversity orderings computed.

Diversity measures (ST, $S_{mean,}$ Me, N, $N_{mean,}$ ST/N) are recommended to differentiate weed diversities provided that more measures are used together, but even this is the case results have to be checked by specific diversity calculations. If there is no way to do that, terms such as more diverse or less diverse cannot be used. Applying measures together there was an order of weed diversity independent on precipitation such as direct drilling followed by shallow tillage in spring.

Classical diversity indices can be more precise and clearer than diversity measures as to true relations among weed communities, indicating tinier differences within communities. Sometimes they provided different orders to those based on diversity measures. Shannon and Simpson indices gave similar posture, while Berger-Parker measure gave an order in contrary as to the first two place. As for the diversity order based on the last year data of research, all the orders were different set by each index, which is also true for Shannon and Simpson indices, but they were in accordance only with indicating the same diversity (first place) as to direct drilling. Weed diversities of the other two ways of soil conservation tillage could not be evaluated unequivocally based on the indices.

The rationale of diversity ordering is that it is community A considered as being more diverse compared to community B, provided that diversity profile of A runs over that of B spanning over the whole range of the scale factor (A> B). If curves of profile cross, communities cannot be ordered (A╫B). It was generalised entropy by Rényi out of one-parameter diversity functions that was used to measure diversity, which was coupled with RTS-diversity and thus being adapted for evaluating weed communities in each aspects and year. Considering the combined data of the three year of research it can be stated that homogenising effect of ploughing on weed community was developed by the end of the third year only. In drier years (2000, 2002) this could develop weed communities with low cover but they were more diverse than those by disk ripper and shallow tillage (*Figure 11.*).

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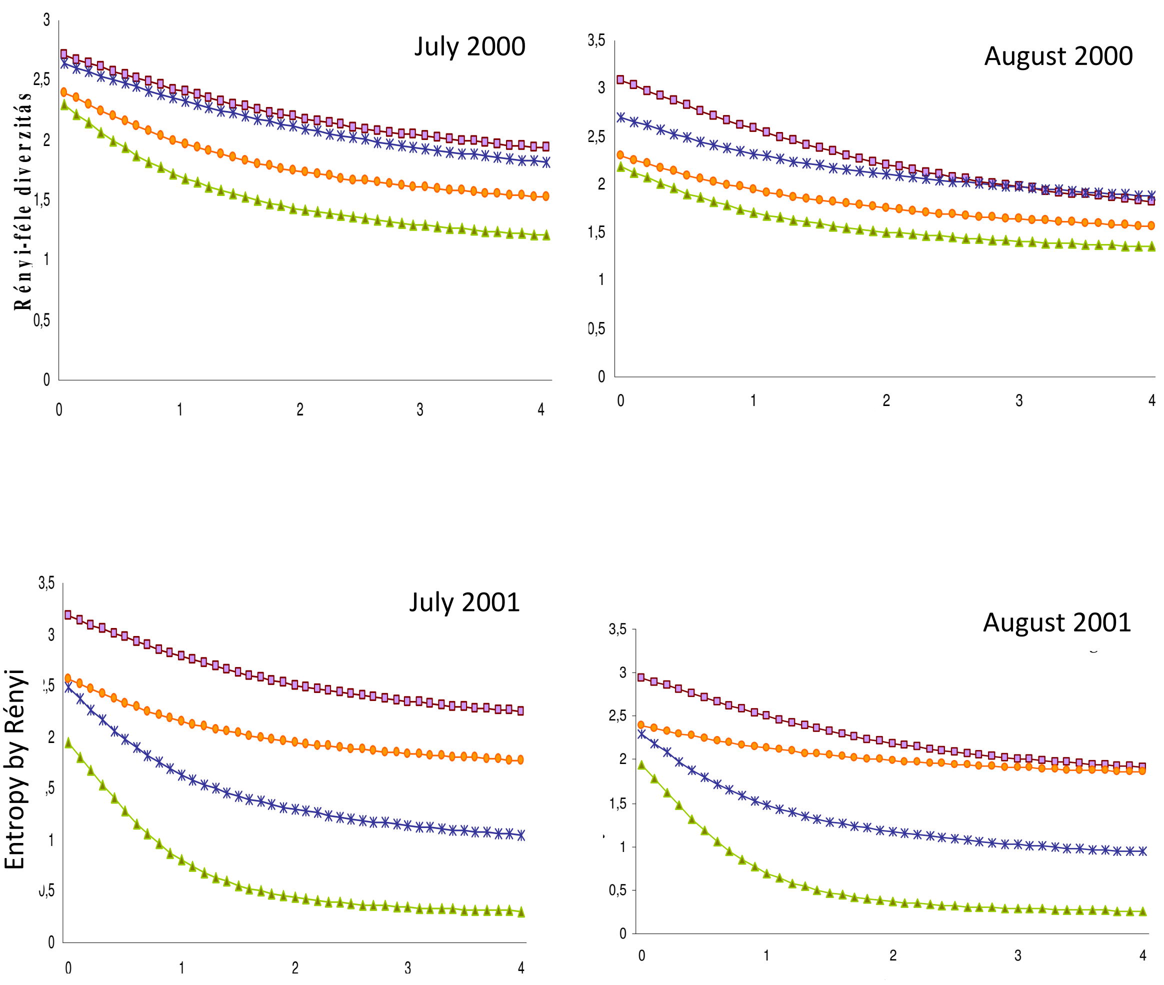

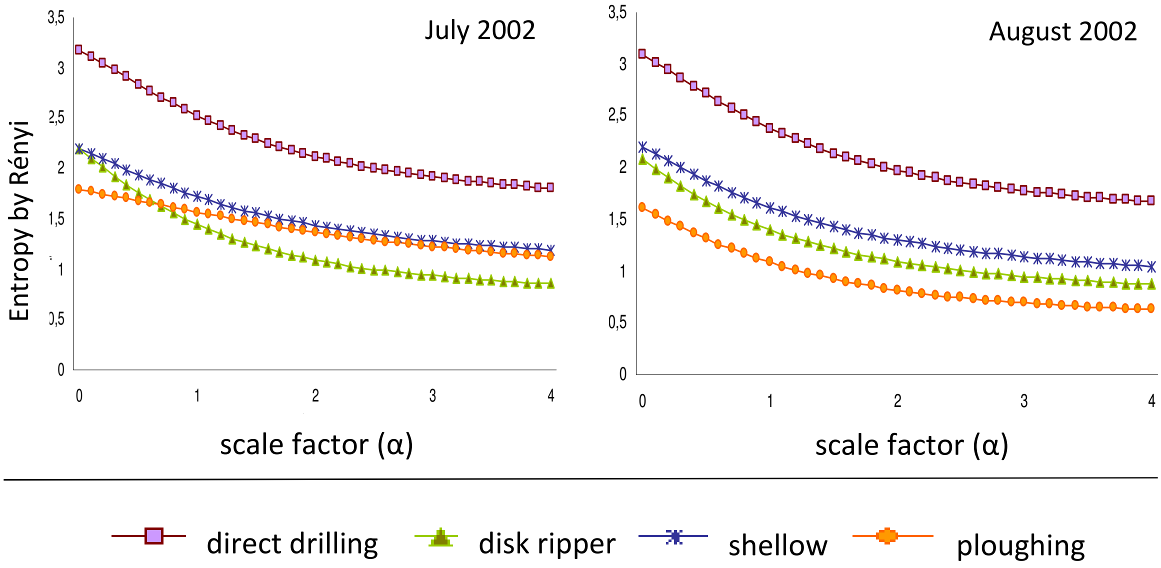


*Figure 11. Weed community diversity rankings by ways of tillage according to $\alpha$-ranked entropy by Rényi*

Weed communities of soil conservation tillage could be unequivocally ordered by their profiles of diversity (except in August in 2000). Their ranking was unchanged, that is, direct drilling had the most diverse weed community, as second one was shallow tillage followed by disk ripper in the third place (*Table 3.*)

*Table 3. Weed community diversity rankings according to α-ranked entropy by Rényi*

| | 2000 | | 2001 | | 2002 | |
|---|---|---|---|---|---|---|
| | July | August | July | August | July | August |
| 1. | Direct | Direct* | Direct | Direct* | Direct | Direct |
| 2. | Shallow | Shallow* | Ploughing | Ploughing* | Shallow* | Shallow |
| 3. | Ploughing | Ploughing | Shallow | Shallow | Ploughing* | Disk ripper |
| 4. | Disk ripper | Disk ripper | Disk ripper | Disk ripper | Disk ripper* | Ploughing |
| Ordering | **yes** | **partly** | **yes** | **yes** | **partly** | **yes** |

* Profiles of diversity crossed

## NEW SCIENTIFIC RESULTS

1. It was Luckspur-Yellowbristle grass community identified for each way of soil cultivation (*Echinochloo-Setarietum pumilae* Felföldy 1942 corr. Mucina 1993), therefore, weed species as the components of community were not influenced by distinct cultivations. Detected differential species featuring all three ways of soil conservation tillage are such as *Amaranthus retroflexus*, *Setaria verticillata*, and *Cirsium arvense*. Ways of soil conservation tillage can be differentiated by specific ones of differential species.

2. Through applying soil conservation tillage *life-form diversity reduces*. The proportion of weeds of T4 will gradually decrease, but there will be an increase in weed cover of G3 in line with that, resulting in spreading of *Cirsium arvense* as the most dangerous one.

3. Ways of soil conservation tillage have *higher average values* of ecological indices (TB, RB, WB, NB). The highest values appertain to disk ripper which is followed by shallow tillage then direct drilling, while traditional rotational tillage has average indicator values falling into indifferent range or close to that.

4. Constant use of soil conservation tillage obviously favours *spreading of weeds of monocotyledonous species of C4*, resulting in significantly higher cover than that develops when applying traditional tillage. As for ways of soil conservation tillage, it is disk ripper that develops significantly higher weed cover compared to that of direct drilling.

5. Significantly *higher covers of invasive species* may be *expected* when applying ways of soil conservation tillage, of which disk ripper and direct drilling show favour toward invasive species better than shallow tillage in spring. The invasion will be retarded by the maize production technology using herbicides.

6. For analysing diversity of arable weed communities diversity measures are not appropriate. Using these measures false conclusions may be drawn, therefore, their application is wakefully recommended only. Reliable results can be obtained by parallel usage of more indices, checking that results critically. Diversity measures cannot capable of indicating tiny differences between weed communities, thus disk ripper and shallow tillage cannot be differentiated by diversity indices.

7. To compare diversities of arable weed communities, it is the use of diversity orderings that is the most adequate. Using generalised entropy by Rényi coupled with RTS-diversity can be utilised for evaluating weed communities in a toned way, also being suitable for realising changes in diversity at species level in distinct aspects. Weed communities of soil conservation tillage could be unequivocally ordered by their profiles of diversity. Direct drilling had the most diverse weed community, the next was shallow tillage followed by disk ripper. The homogenising effect of ploughing on weed community can be constant from the third year only.

## FINDINGS USEFUL FOR PRACTICE

1. Ways of non-rotational tillage save more water in the soil but their compactions are more disfavourable than that of ploughing.
2. Constant use of non-rotational tillage may result in high weed cover and weed flora rich in species.
3. Using non-rotational tillage, it is the monocotyledonous that can be expected to accrual in short time, mainly such as *Echinochloa crus-galli, Setaria viridis* and *Setaria verticillata.* They will boom in years with high precipitation.
4. There will be a decrease in the proportion of late summer annual weeds, but parallel with that the perennial geophyte increase in their proportions, such as *Cirsium arvense* (Creeping thistle) which is a dangerous species.
5. Of the three reduced tillage methods, based both on soil and weed communities, shallow spring tillage and dirk ripper are recommended because of the more favourable soil conditions left by their usage.

# 6. PUBLICATIONS

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Registry number: DEENK/1/2017.PL
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Candidate: Szilvia Kovács
Neptun ID: FJZ7LR
Doctoral School: Kálmán Kerpely Doctoral School
MTMT ID: 10027723

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Tel.: +36 52 410 443 Fax: +36 52 512 900/63847 E-mail: publikaciok@lib.unideb.hu, ¤ Web: www.lib.unideb.hu

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