CROSTRO – Croatian Soil Tillage Research Organization

Proceedings of

1st International Scientific Conference

SOIL TILLAGE: :
: :OPEN APPROACH

09-11 September, 2010, Osijek, Croatia

CROSTRO – Croatian Soil Tillage Research Organization

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Under the auspice

ISTRO – International Soil Tillage Research Organization

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Conference Program

Conference topics/section:

1. Soil tillage in function of environmental protection
2. Conservation tillage – direct seeding – no-tillage
3. Soil biotic and abiotic degradations – causes and consequences
4. Soil tillage – new approach – technologies – perspectives

08 September (Wednesday) - arrival

18^{00} - 21^{00} - Registration of participants in Hotel "Osijek" at Osijek

09 September (Thursday)

10^{30} – 12^{00} - Official Opening of the Conference

Introductory words:

Prof. dr. sc. Bojan Stipešević, CROSTRO (ISTRO-Croatia Branch) president

Dr. sc. Jean Roger-Estrade [FR], ISTRO support to Croatian branch

Prof. dr. sc. Franjo Tomić [CRO], Member of Croatian Academy of Sciences and Arts, Department of Natural Sciences

13^{00} – 15^{00} – Welcome cocktail

Plenary session

Chairmen: Jug D., Birkás M., Žugec I.

15^{00} – 15^{30}	**György Várallyay, Csilla Farkas [HU]** Agrotechnical measures for reducing the risk of extreme soil moisture events
15^{30} – 16^{00}	**Márta Birkás, Danijel Jug, Ivica Kisic, Jan Kren, Márton Jolánkai [HU-CRO-CH-]** Environmentally-sound soil tillage in Central Europe - step by step
16^{00} – 16^{30}	**Ferdo Bašić, Ivica Kisić, Milan Mesić [CRO]** Framework of climate-change and soil type oriented soil tillage in agricultural regions in Croatia
16^{30} – 17^{00}	**Danijel Jug, Márta Birkás, Srđan Šeremešić, Bojan Stipešević, Irena Jug, Ivan Žugec, Ivica Djalovic [CRO-HU-SR]** Status and perspectives of soil tillage in South-East Europe

10 September (Friday)

Section:

- **Soil tillage in function of environmental protection**
- **Soil biotic and abiotic degradations – causes and consequences**

Chairmen: Macák M., Jug I., Seremesic S.

10^{00} – 10^{15}	**Macák M., Smatana J., Šimanský V., Đalović I., Demjanová E., Jug D. [SK-SR-CRO]** Soil tillage and crop management and their impact on sustainability and soil physical characteristics
10^{15} – 10^{30}	**Jug I., Jug D., Đurđević B., Horvat T., Habada V., Brozović B. [CRO]** Effect of nitrogen fertilization under reduced soil tillage on chloroplast pigments concentration in leaves of winter wheat
10^{30} – 10^{45}	**Kisic I., Basic F., Birkas M., Aleksandra J. [CRO]** Soil conservation the key role of soil tillage under actual and altered climatic conditions
10^{45} – 11^{00}	**Seremesic S., Milosev D., Manojlovic M., Djalovic I., Zeremski T., Ninkov J. [SR]** Soil organic carbon accrual in aggregates of arable soil in wheat based cropping systems
11^{00} – 11^{15}	**Cvijanović G., Dozet G., Milošević N. [SR]** Measures for increase of degraded soil biogenity
11^{15} – 11^{30}	**Tóth B., Stipešević B., Jug D., Lévai L. [HU-CRO]** Can we increase available nutrients using bacteria?

11^{30} – 12^{00} – Coffee break

Section:

- **Conservation tillage – direct seeding – no-tillage**
- **Soil tillage – new approach – technologies – perspectives**

Chairmen: Smutný V., Dumanović Z., Javůrek M.

12^{00} – 12^{15}	**Jug I., Jug D., Stipešević B., Vukadinović V., Sabo M., Grabić A., Stanić M. [CRO]** The impact of reduced tillage on the morphological and physiological parameters of soybean
12^{15} – 12^{30}	**Kornél T., Jóri J. I. [HU]** Numerical Approaches in Tillage and Soil Modeling
12^{30} – 12^{45}	**Vukadinović V., Jug D. [CRO]** Geostatistical model evaluation for soil tillage suitability on Osijek-Baranya County example
12^{45} – 13^{00}	**Smutný V., Neudert L., Dryšlová T., Birkás M. [CZ-HU]** The yield and quality of bread wheat under different agronomic factors

$13^{00} – 13^{15}$	**Stipešević B., Brozović B., Jug D., Stošić M., Jug I., Vukadinović V., Simić M., Mladenović-Drinić S., Brigita T., Laszlo L. [CRO-SR-HU]** The influence of soil tillage system at germination of buckwheat, millet and sudan grass sown as post-harvest summer crops
$13^{15} – 13^{30}$	**Cvetanovska L., Kratovalieva S., Stipesevic B., Jug D., Jug I., Klincarovska I. [MK-CRO]** Primary production at seed rice

$13^{30} – 15^{00}$ – Lunch

$15^{00} – 17^{00}$ - Poster presentation

Chairmen: Kisic I., Kornél T.

1	**Shamsi K. [IR]** Effect of Reduction of Drought Stress Using Supplementary Irrigation of Dryfarming Chickpea(Cicer arietinumL.) Varieties
2	**Javůrek M., Mikanová O., Vach M. [CZ]** Assessment of conservation tillage effect on Luvisol, loam soil, consequently on cereal production in the Central Bohemia
3	**Vach M., Javůrek M., Hýsek J. [CZ]** The role of non-chemical plant protection in conservation methods of winter wheat growing
4	**Dumanović Z., Dragičević V., Kolčar D., Ercegović Đ., Pajić M., Jug D. [SR-CRO]** Environmental aspect of nitrogen availability under subsoiling and mole drainage
5	**Winkler J., Smutný V. [CZ]** The impact of different soil tillage on weed infestation in cereals and winter oilseed rape
6	**Rátonyi T., Megyes A., Sulyok D., Harsányi E. [HU]** Evaluation of soil tillage impacts on soil physical condition in different production sites in Hungary
7	**Jug D., Jug I., Stipešević B., Stošić M., Brozović B., Đurđević B. [CRO]** Influence of different soil tillage treatments on soil compaction and nodulation of soybean root

$17^{00} – 18^{30}$ - Round table: Innovation in soil tillage systems
Moderator: prof. dr. sc. Bojan Stipešević

19^{00} - Gala dinner and closing ceremony

11 September (Saturday)

$08^{00} – 20^{00}$ Field trip - Conference tour to field experimental station (2 locations), National lipizzan farm and St. Peter's Cathedral in Đakovo (a guided conducted tour), visit of wine cellar with degustation of wines.

Information:

Registration / information desk in Hotel Osijek will be opened on:

- Wednesday 08 September from $18^{00} – 21^{00}$
- Thursday 09 September from $08^{00} – 15^{00}$
- Friday 10 September from $08^{00} – 15^{00}$

The oral presentation – plenary paper will be allocated for 30 min., the others cca 15 min. + discussion. All audio-visual equipment will be at disposal.

The poster presentation
The poster boards will be in width 90 cm and 100 cm in height.
The posters will stay on the board from Thursday 10 September during the whole conference.
Poster must be removed on Friday 10 September at 19^{00} h.

Special needs
Delegates with special needs such as diet, access, etc. are asked to complete relevant section of Registration Form. No arrangements can be made if needs are not notified via registration form.

Taxi station is near the railway and bus station and you will pay cca. 20 Kn.

Exchange rate: cca 7.2 - Kn / 1 Euro

Exchange office – an office for changing money at the railway station, at the hotels and bank in downtown on Monday – Friday from $8^{00} – 16^{00}$.

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[Plenary session]

[CHAIRMEN]

Danijel Jug

Márta Birkás

Ivan Žugec

Agrotechnical measures for reducing the risk of extreme soil moisture events

Várallyay György, Farkas Csilla

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Abstract
The most important elements of sustainable development in the Carpathian Basin are the rational use and conservation of soil and water resources, maintaining their favourable "quality" and desirable multifunctionality. In spite of the fact that agro-ecological conditions are generally favourable for multipurpose rainfed biomass production and soil is the largest **potential** natural water reservoir, the risk, probability, frequency, duration and "seriousness" of **extreme moisture events** (flood, waterlogging, over-moistening or drought) are increasing and they often happen in the same year at the same place. The two main reasons of this contradiction are the limitations of water infiltration to the soil and the storage of infiltrated water in plant available form. Consequently, the main goal of an efficient **soil moisture control** is: to help infiltration and useful storage of water in the soil profile; the establishment or maintenance of good agronomic soil structure, prevention or reduction of soil compaction with **site-specific** tillage operations; adequate land use and cropping pattern; recycling of plant residues; increasing of S.O.M. These measures reduce the risk and decrease the unfavourable consequences of extreme hydrological/soil moisture events.

Keywords: risks, waterlogging hazard, drought sensitivity, hydrophysical properties of soils, soil moisture control

Introduction
Soils are the most important **conditionally renewable natural resources** in the Carpathian Basin, with three specific/unique characteristics:

- **fertility/productivity:** soils can satisfy – to a certain extent – the main (soil) ecological requirement of living organisms (biota, natural vegetation, cultivated crops);
- **resilience:** soil may recover (renew) from various disturbances, natural or human-induced stresses;
- **multifunctionality:** ability of multipurpose biomass production; integrator of other natural resources; storage, filter buffer and detoxication functions; gene-reservoir, conservator of natural and human heritage.

Consequently, the rational use and conservation of soil and water resources, the maintenance of their favourable "quality" and desirable multifunctionality are the most important priority tasks of **sustainable development** (Várallyay, 2006b).

The most significant limiting factor of the relatively and generally favourable agro-ecological conditions in the Carpathian Basin (especially in the plains and lowlands) is the high and increasing risk and hazards of extreme hydrological and soil moisture events and their unfavourable harmful, sometimes catastrophic economical/ecological/environmental/ social consequences. Therefore, all efforts have to be taken for their prevention, elimination, or at least reduction to a tolerable level (Láng et al., 1983; Pálfai, 2000; Várallyay, 2006a, 2007a,b, 2008).

Factors of extreme moisture regime

It can be forecasted with high probability that in future **water** will be the determining (hopefully not limiting) factor of food security and environmental safety all over the world and the limited sweet-water resources of our Globe will be a strategic element of future sustainable development. The **increase in water use efficiency** will be one of the key issues of agricultural production, rural development and environment protection and the **control of soil moisture regime** will be an imperative task without any other alternatives (Várallyay, 2006a, 2008).

The increasing water demand must be satisfied from the limited water resources in the Carpathian Basin. The average 450–600 mm annual precipitation may cover the water requirement of the main crops even at high yield levels. But the average shows **extremely high territorial and temporal variability** (Figure 1) – even at micro-scale. Under such conditions a considerable part of the precipitation is lost by surface runoff, downward filtration and evaporation, increasing **drought sensitivity** (Várallyay, 2007a; Várallyay and Farkas, 2008).

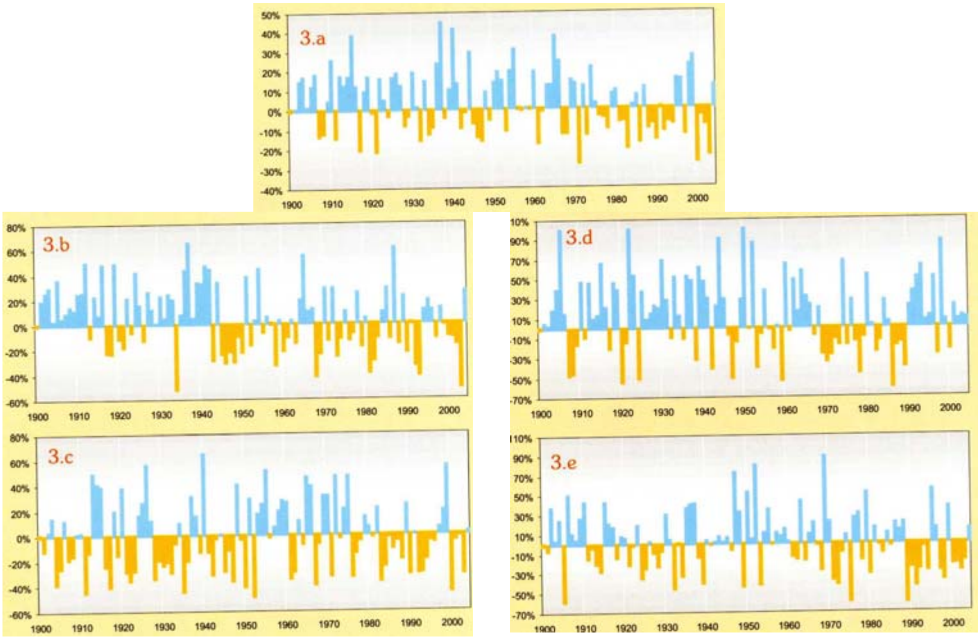

Figure 1: Anomalies in the country average annual precipitation sums, 1901–2004
a) annual, b) spring, c) summer, d) autumn, e) winter.

The available quantity of **surface waters** (rivers) will not increase, particularly in the critical low-water periods. A considerable part of the **subsurface waters** (especially in the lower parts of the Basin) cannot be used for irrigation because of their poor quality (salinity, alkalinity, sodicity). Another part is not utilizable because of environmental regulations (preventing the sink of the water table and its unfavourable ecological consequences, like the serious „desertification symptoms" in the Danube–Tisza Interfluve sand plateau.

In addition to the hardly predictable atmospheric precipitation pattern, the reasons of **extreme soil moisture regime,** the high – and increasing – hazard of waterlogging, over-moistening and droughts are:

– the heterogeneous **microrelief** of the "flat" lowland;
– the highly variable, sometimes mosaic-like **soil cover** and the unfavourable physical and hydrophysical properties of some soils (mainly due to heavy texture, high clay and swelling clay content, or high sodium saturation: ESP) (Várallyay, 1989, 2006a,b, 2007b).

According to our comprehensive assessment 43% of Hungarian soils can be characterized by unfavourable, 26% by moderately (un)favourable and 31% by favourable moisture regime, as illustrated by Figure 2, indicating the main reasons of various moisture conditions.

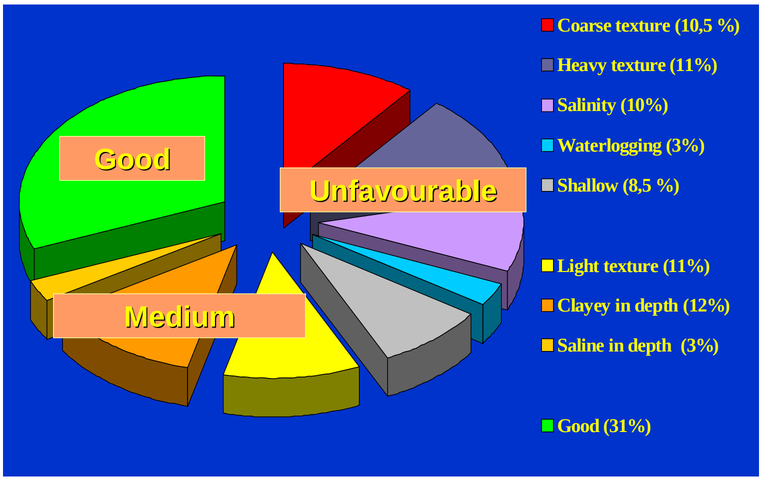

Figure 2: Hydrophysical properties of soils in Hungary (%)

We elaborated a system for the quantitative characterization of the hydrophysical properties of soil. In the system 9 main categories were distinguished according to textural class; field capacity (FC), water retention (WR), wilting percentage (WP), and available moisture range (AMR); infiltration rate (IR), permeability (P) and saturated hydraulic conductivity (HC, K). The subcategories were classified according to their layer sequence and the main reason of their limited FC, WR or IR (Várallyay et al., 1980; Várallyay, 2008).

Soil as water reservoir – extreme moisture regime

Soil is the largest **potential** natural water reservoir, water storage capacity in the Carpathian lowlands. In Hungary the 0–100 cm soil profile **may** store about 25–30 km³ water, which is more than half of the average 500–600 mm annual precipitation. About half of it is "available moisture content" (Várallyay, 2005, 2006a).

This favourable fact is quite contrary with the high and increasing risk, hazard, frequency and duration of extreme hydrological events and soil moisture situations (flood, waterlogging, over-moistening vs. drought) sometimes in the same place in the same year (Pálfai, 2000; Várallyay, 2006a,b, 2007a,b; Várallyay and Farkas, 2008).

The main reasons of this contradiction are:
(1) The pore space is not „empty": it is filled up by a previous source of water (rain, melted snow, capillary transport from groundwater, irrigation etc.): *„filled bottle effect";*

(2) *The* infiltration of water (rain, melted snow) into the soil is prevented by the frozen topsoil: *"frozen bottle effect";*
(3) The infiltration is prevented or reduced by a nearly impermeable soil layer on, or near to the soil surface: *"closed bottle effect"*;
(4) The water retention of soil is poor and the infiltrated water is not stored in the soil, it only percolates through the soil profile: *"leaking bottle effect";*
(5) The heavy-textured cracking soils result increasing *filtration* and *evaporation losses.*

(1) And (2) are not, or only partly human-controlled facts, while (3), (4) and (5) can be modified to a certain extent, by

– the establishment or maintenance of good agronomic soil structure;
– prevention or reduction of aggregate destruction and compaction;
– establishment of permanent, deeply and densely rooted vegetation cover, helping infiltration, water retention and „drainage" of surplus water simultaneously (Birkás, 2008; Birkás and Gyuricza, 2004; Várallyay, 1989).

Soil structure and soil compaction

One of the primary indicators of soil genesis is the formation of good and stable agronomic **soil structure**. The maintenance of this structure, preventing its destruction by various natural and human-induced stresses is a priority task of sustainable land use and soil management. The possibility and rate of development, and the destruction (degradation) of favourable good agronomic soil structure depend on many natural factors and human activities, especially land use practices and agrotechnics (as stress factors), and soil resilience, the sensitivity/susceptibility/vulnerability of soil structure against these stresses (as "stress receptor"). The absence or destruction of soil structure (aggregate stability) give increasing opportunity for soil compaction, which is the most extensive and most serious soil degradation process on all parts of our Globe, under various land use systems and soil management practices (Birkás, 2008; Várallyay, 1989).

The main reasons of the physical degradation of soils and the possibilities of their control are summarized in Table 1.

Table 1: Physical degradation of soils: structural damage, compaction

Main reasons		Possibilities for control
Natural factors	Human activities	
– lack of structure-forming and stabilizing agents: • inorganic and organic colloids • cementing agents • biological components (roots; microbial and earthworm activity) – natural structure destruction • heavy raining • surface runoff, flood, water-logging • chemical properties (e.g. alkalinity, etc.)	– mechanization (heavy machinery; combined operations; overtillage – tillage in improper moisture conditions – poor moisture-control practice • irrigation (intensity; method) • drainage – unfavourable changes in organic matter regime (chemical soil properties; biological degradation; improper recycling; lack of organic fertilizers)	– proper agrotechnics • tillage (time; moisture content; accuracy, "quality" and number of operations) ← technical background • cropping pattern, crop rotation • organic matter recycling • irrigation (moisture regime control) – chemical amelioration (improvement of acidic and salt-affected soils, sands, etc.) – soil conditioning

In 1989 Várallyay and Leszták elaborated a classification system expressing the susceptibility of sols to physical degradation (structure destruction and compaction). Based on the available data 8 categories were distinguished and the map of these categories was prepared I the scale of 1:500,000. The simplified version of this map is presented in Figure 3 (Várallyay and Leszták, 1990).

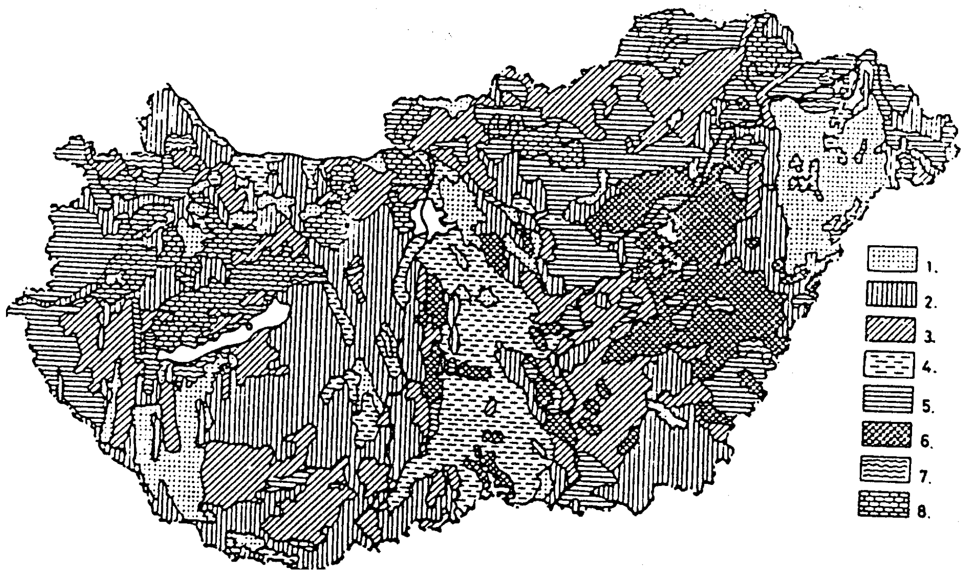

Figure 3: Map of the susceptibility of Hungarian soils to physical degradation.
1. non-susceptible soils (sandy soils without structure and with a low content of cementing compounds as carbonates or sesquioxides); 2. slightly susceptible soils (medium-textured soils with well-developed structure and high aggregate stability); 3. moderately susceptible soils (medium-textured soils with moderately developed structures and low aggregate stability); 4. soils susceptible to compaction and surface crusting but not to structural damage (sandy soils without structure but high amount of cementing compounds, mainly carbonates); 5. soils susceptible to structural damage and compaction (heavy-textured soils of swelling-shrinkage character and low structural stability); 6. soils susceptible to both structural damage and compaction due to salinity-alkalinity; 7. organic soils (peats); 8. shallow soils (solid rock or cemented layer near the surface).

Reducing the risk of extreme moisture regime

The risk reduction of the unfavourable consequences of extreme hydrological events and soil moisture situations consists of three main elements:

– the reduction of evaporation, surface runoff and filtration losses (atmospheric precipitation and irrigation water);
– the increase of the available moisture content of the soil:
    - helping infiltration into the soil;
    - the increase of the water storage capacity;
    - the reduction of the immobile moisture content;
– the improvement of the vertical and horizontal drainage condition of the soil profile or the given area (prevention of over-saturation and waterlogging).

The main possibilities and methods of this moisture control are summarized in Table 2 (Birkás, 2008; Birkás and Gyuricza, 2004; Farkas, 2004; Farkas et al., 2004; Várallyay, 2008). Most of these “moisture management actions” are – at the same time – efficient environment control measures (Várallyay, 2006b; Várallyay and Farkas, 2008; Várallyay et al., 2005, 2008).

Table 2: Elements and methods of soil moisture control with their environmental impacts

Elements		Methods	Environ-mental impacts*
Reducing	surface runoff	Increase in the duration of infiltration (moderation of slopes; terracing contour ploughing; establishment of permanent and dense vegetation cover; tillage; improvement of infiltration; soil conservation farming system)	1,1a 5a, 8
	evaporation	Helping infiltration (tillage, deep loosening) Prevention of runoff and seepage, water accumulation	2,4
	feeding of ground-water by filtration losses	Increase in the water storage capacity of soil; moderation of cracking (soil reclamation); surface and subsurface water regulation	5b, 7
	rise of the water table	Minimalization of filtration losses (↑); groundwater regulation (horizontal drainage)	2,3 5b,5c
Indreas-ing	infiltration	Minimalization of surface runoff (tillage practices, deep loosening) (↑)	1,4,5a, 7
	water storage in soil in available form	Increase in the water retention of soil; adequate cropping pattern (crop selection)	4,5b,7
Irrigation		Irrigation; groundwater table regulation	4,5c,7, 9,10
Surface } drainage Subsurface		surface } moisture control (drainage) subsurface	1,2,3,5c, 6,7, 11

* Referring numbers: See below

Favourable environmental effects		Unfavourable environmental effects
Prevention, elimination, limitation or moderation of: 1. water erosion 1a. sedimentation 2. secondary salinization, alkalization 3. peat formation, waterlogging, over-moistening 4. drought sensitivity, cracking	Plant nutrient losses by: 5.a. surface runoff (→ surface waters eutrophication) 5b. leaching (→ subsurface waters) 5.c. immobilization (5c) 6. formation of phytotoxic compounds 7. "biological degradation" 8. flood hazard	9. overmoistening, waterlogging, peat and swamp formation, secondary salinization/alkalization 10. leaching of plant nutrients 11. drought sensitivity

Soil tillage practices for the prevention or reduction of extreme soil moisture events

As an example, the main results of a field experiment are summarized, in which the influence of various tillage practices on the soil moisture regime was investigated. The long-term field experiment was established by Birkás and Gyuricza (Birkás, 2008; Birkás and Gyuricza, 2004) at the Józsefmajor Experimental Station of the Szent István University (Gödöllő) in 2002 on a medium-textured pseudomyceliar (calcic) chernozem soil with the following basic characteristics:

Depth	pH(H_2O)	pH(KCl)	Sand %	Silt %	Clay %	SOM %
0–20 cm	6.4	5.4	23	42	35	3.2
20–40 cm	7.1	6.5	24	36	40	2.5

The average annual **precipitation** is 580 mm, and 323 mm in the "vegetation season". 2002 was a medium, 2003 a dry and 2004 a wet year. The test pant was corn.

The experiment was conducted in a split-plot design on 13×200 m parcels with 4 replications, with the following treatments: L+T: loosening (35) and disking (16–20 cm); T: disking (16–20); K1: strip tillage (12–15 cm); K2: cultivator (12–15 cm); DV: minimum tillage with direct drilling; Sz: ploughing (26–30 cm).

Some of the results can be summarized as follows (Farkas, 2004; Farkas et al., 2004, 2009; Várallyay and Farkas, 2008; Várallyay et al., 2005, 2008):

1. Bulk density (Table 3)

Table 3: Bulk density (g/cm³) of soils

Treat-ment	5–10 cm			15–20 cm			45–50 cm	
	04.10.	06.30.	09.04.	04.10.	06.30.	09.04.	04.10.	06.30.
L+T	1.21 a	1.23 a	1.16 a	1.32 a	1.47 a	1.33 ac	1.45 a	1.41 a
T	1.26 a	1.27 ac	1.20 ab	1.52 bc	1.49 a	1.24 b	1.44 a	1.41 a
K1	1.33 a	1.41 bc	1.22 b	1.45 b	1.45 a	1.32 ac	1.45 a	1.36 a
K2	1.35 a	1.19 a	1.22 b	1.23 d	1.32 b	1.30 ab	1.37 a	1.43 a
DV	1.27 a	1.28 ac	1.21 ab	1.54 c	1.48 a	1.25 b	1.42 a	1.46 a

Treatments: L+T: loosening (35) and disking (16–20 cm); T: disking (16–20); K1: strip tillage (12–15 cm); K2: cultivator (12–15 cm); DV: minimum tillage with direct drilling; Sz: ploughing (26–30 cm)

In the 5–10 cm layer there were no significant differences at the beginning of the vegetation period (April). During the vegetation season (till June) some compaction was observed but it disappeared by September. In the 15–20 cm layer bulk density was lowest in the Sz and K2 treatments; practically all layers were quite seriously compacted till June; and nivelated until September. In the 45–50 cm layer there was no measurable "treatment effect".

2. Soil moisture content (Figure 4)

The total soil moisture content strongly decreased during the vegetation season in the upper horizon of Sz, T and L+T treatments, moderately in the K1 and K2 treatments and slowly in the DV treatment. It seems to express the "water conserving" effect of minimum tillage under the given conditions. The moisture content of the deeper horizons was quite similar in each case.

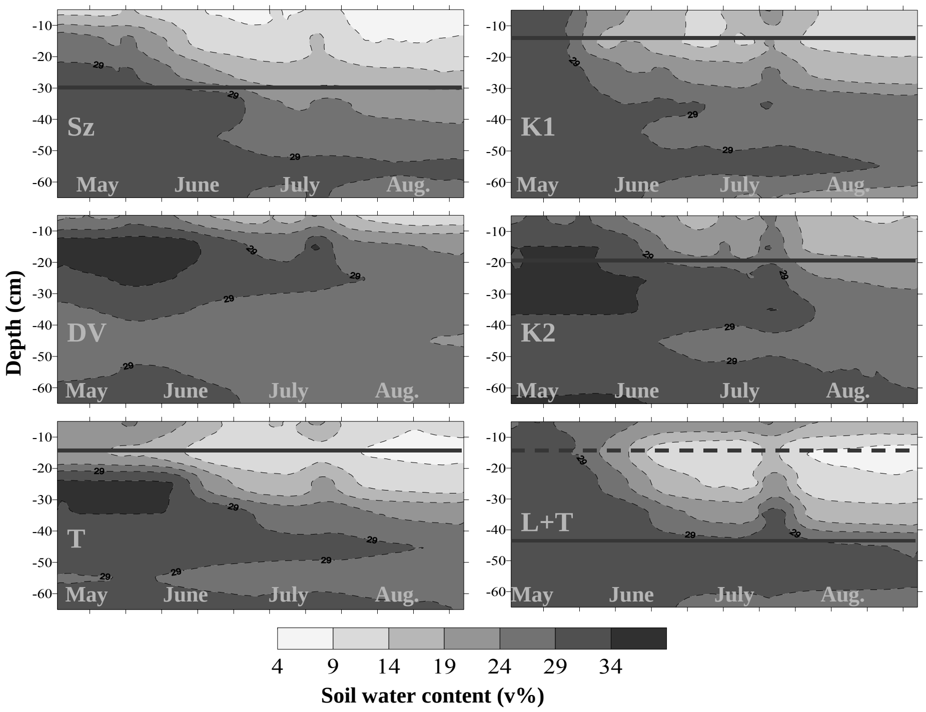

Figure 4: Spatial and temporal change of soil moisture content

3. Total water storage capacity (Figure 5)

Total water storage capacity (pF 0) was closely related to bulk density, expressing total porosity. The soil can be saturated up to this point, and after that any additional drop of water may result in oversaturation and waterlogging ("filled bottle effect"). Consequently, these data – with the infiltration rate (as an indicator of the "closed bottle effect"), and hydraulic conductivity (as an indicator of the "leaking bottle effect") – can be the scientific basis for the estimation and prediction of the **waterlogging hazard**.

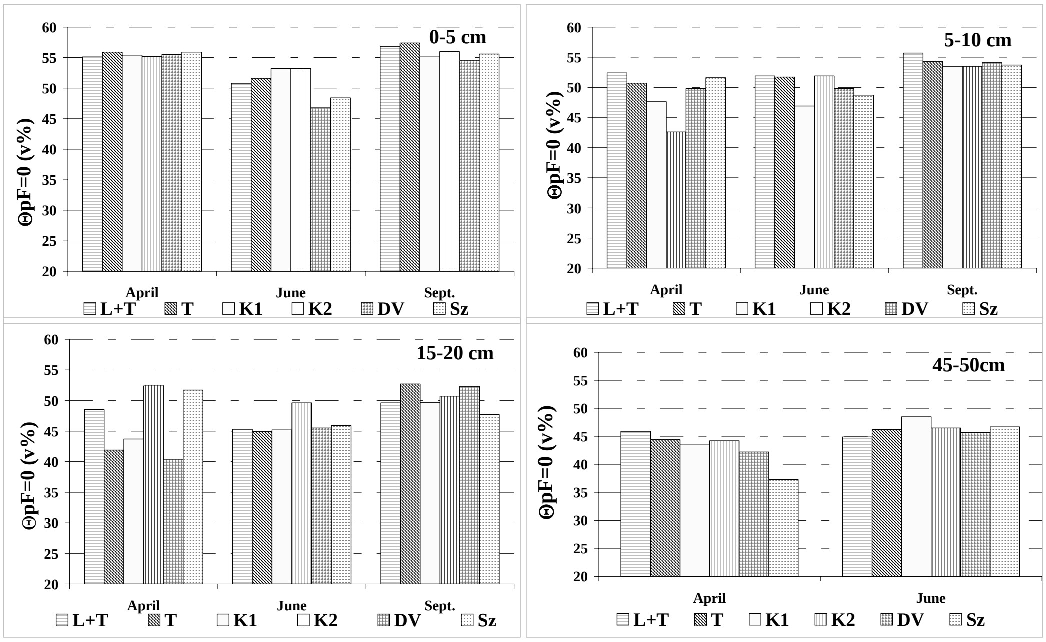

Figure 5: Total water storage capacity

4. Field capacity (Figure 6)

Field capacity (in our case pF 2) expresses the quantity of water which can be retained within the soil profile against gravity. It depends both on texture (particle size distribution, clay and organic matter content, clay minerals) and structure (aggregate state and stability, rate of compactness, swelling–shrinkage characteristics). Figure 6 shows a similar consolidation tendency in the April–June period as in the case of bulk density. However, it was favourable for water retention, especially in the near-surface layers. The treatment effect was quite randomic and did not give opportunity for drawing convincing conclusions.

5. Available moisture content (Figure 7)

In case of the potential AMC the treatment effect was limited to the 0–20 cm layer; in the 40–45 cm layer it was non-significant. Among the treatments L+T and Sz were lower than T, K1, K2 and DV, almost equally. The actual (measured) AMC results indicate an interesting (but not surprising) phenomenon. In April the soil's potential water storage capacity was almost empty, especially in the 0–5 cm layer. The whole soil profile was dried out, especially the surface horizon irrespective of the treatments.

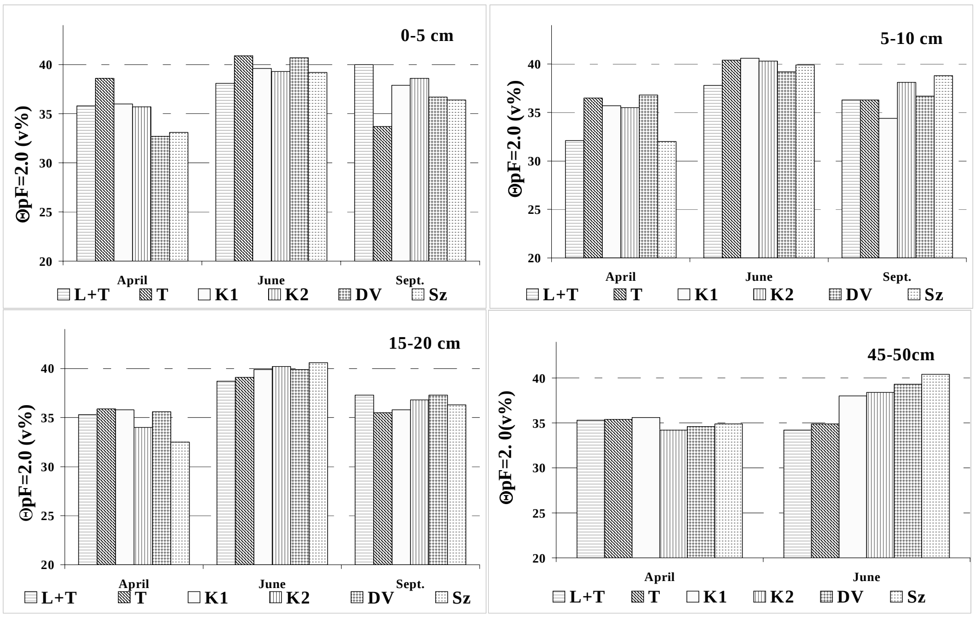

Figure 6: Field capacity

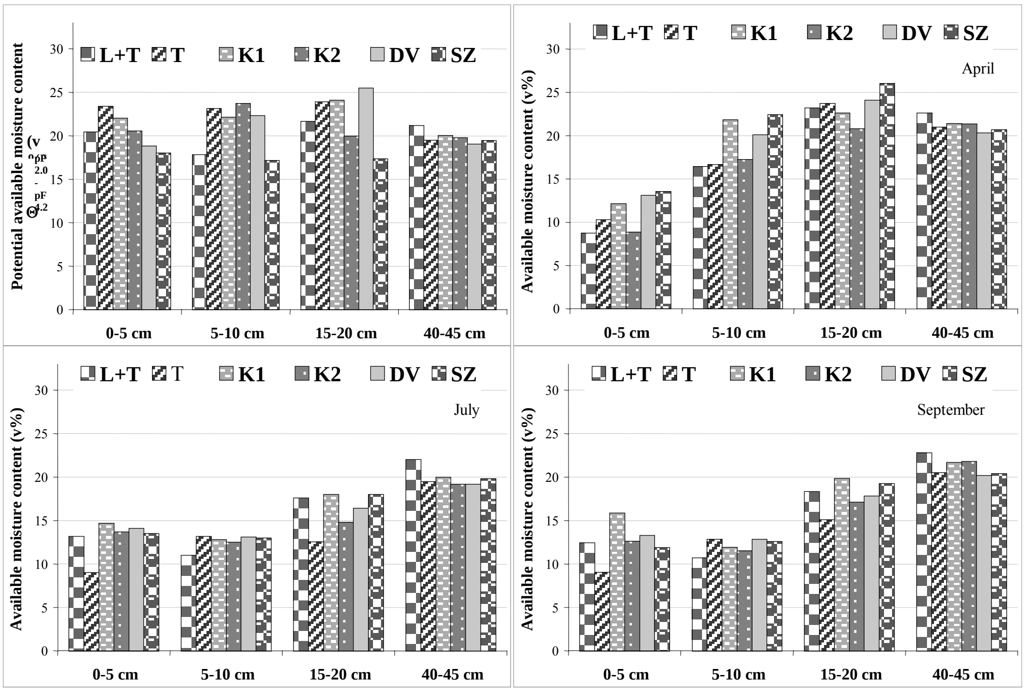

Figure 7: Potential (upper left) and actual available moisture content (AMC)

From April till June the soils became filled up step by step, and the normal summer drought changed this situation only to a certain (quite limited) extent. The AMC in the 15–20 cm, and – especially – in the 40–45 cm layer increased. In the 40–45 cm layer it almost reached the „potential”. However, in the surface layers (0–5, 5–10 cm) still a high amount of "free" soil pores remain "empty", due to the dry summer in 2003.

It was rather surprising that no significant differences were observed among the various treatments. Neither the favourable mulch + undisturbance + direct drilling effect, nor the deep tillage and ploughing were convincingly proven by our results.

Conclusions

Efficient control of the increasing hazard of extreme soil moisture situations and their consequences necessitates permanent water management activities, which are elements of sustainable land and water management, rural development, environment protection, and adaptation to or mitigation of climate change. Under the highly variable ecological conditions of the Carpathian Basin it is rather risky and hazardous to adapt technologies developed under (and for) different natural and socio-economic conditions. The "prescribed" (or even pressed) uniformization, and "over-standardization" of technologies can also be dangerous in agriculture and water management. **Site-specific precision technologies** and agrotechnical measures, however, can be used efficiently in the prevention or risk reduction of extreme soil moisture events and their undesirable consequences.

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Step-by-step adoption of environmentally-sound soil tillage in three Central European countries

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Abstract

In the last centuries, the need for tillage was to provide suitable soil conditions for plant growth (crop-focusing tillage). During the last decades, traditional goals of soil tillage have really been improved considering environmental consequences (environment-focusing tillage). In the next decade a new task is stressed, that is mitigating the climate induced losses (climate-focusing tillage). New challenges for the future is to reduce climate induced damages by the use of environmentally-sound adaptable tillage. The relationship between soil quality factors and climate effects have been studied in parallel in Croatia, in Czech Republic and in Hungary in long term tillage experiments and by field monitoring.
In the environmentally-sound tillage challenge ten important steps are suggested for this region, namely: 1) Awareness of the state of the soil to draw conclusions concerning the likely damage. 2) Preventing the development of compact layers impeding water transport. 3) Eliminating the compact layer in the soil with the aid of a suitable tillage technique. 4) Creating small surface at any time of the season, without compaction stress. 5) Covering the surface with crushed stubble residues to protect soil and moisture. 6) Preserving the soil organic C is crucial at any type of tillage. 7) Protecting the soil structure. 8) Adapting the primary tillage to the soil state improvement. 9) Causing smaller stress in over wet or dry soils. 10) Maintaining the soil's capacity to take in and to store water in irrigated soils.

Keywords: environment, conservation, tillage, water, stubble residues, carbon

Introduction

For centuries, tillage was regarded by 'classical authors' as a means of ensuring that crops' needs are met, which is why that period is referred to as the era of *crop focused* tillage. Later on, between 1975 and 2000 more and more attention was paid to soil quality, therefore that period is referred to as that of *soil focused* tillage Since the first years of the global climate change, the observation of which has been raising much concern, there is a growing need for turning tillage into a series of *climate focused* activities, as the main aim of tillage now is to alleviate climate-induced losses and damage through improving the quality of the soil (Birkás et al., 2008). This will take a radical change in the region's prevailing tillage practices, including complete abandonment of methods that are detrimental to soil and environment alike. Soil degradation caused by conventional tillage – compaction, clod and dust forming, capping, declining biological activity, organic matter loss and deteriorating workability (soils turning into 'minute soils') – have been found to be one of the main obstacles to the adoption of preserving tillage (Várallyay, 2006, Neudert, 2008, Kroulik et al., 2009). For example, no shallow loosening or direct drilling can be applied where soil has become prone to quickly settling as a consequence of the depletion of its organic matter content (Fig. 1, c.f. Badalíková and Červinka, 2008, Kisić, 2008, Birkás and Kisić et al, 2009). Soils' deteriorating quality has also been found to contribute to increasing exposure to climate damage (Kisić, 2008). Accordingly improving and maintaining soil quality are fundamental prerequisites for the adoption of both environmentally friendly and climate damage mitigating tillage practices. There is a broad range of widely known instruments for improving soil quality (Birkás et al., 2008). The first task is to show farmers how to detect tillage defects contributing to worsening soil quality and how to avoid causing such defects. The next task is to provide scientific proof of the advantages and benefits of preserving soil quality and of alleviating climate damage and to disseminate various tillage techniques that are suitable for achieving these aims, as widely as possible in the farming community.

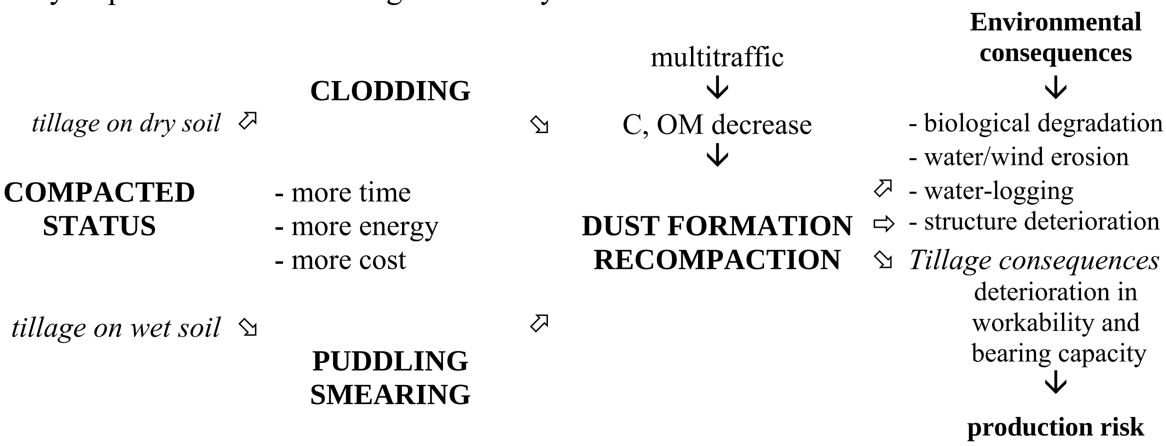

Figure 1: Tillage effects on soil condition and degradation

Materials and methods

This paper based on soil condition measuring and monitoring results in three countries. Work was started 34 years ago in Hungary, in sites of a great diversity of different soil types, in long term soil quality experiments by the Department of Soil Management at Szent István University Gödöllő (Birkás et al., 2009). In Croatia this work was started 17 years ago, on the one hand by the Department of General Agronomy at University Zagreb in the region of Daruvar and Gospić (Kisić, 2008; Mesić et al., 2008) and by the Department of Crop Production at J. J. Strossmayer University in Osijek, in the Baranja region (Jug et al., 2008). In the Czech Republic during the past 15 years long term experiments were conducted in several micro-regions (e.g. Bohuňovice, Branišovice, Praha-Ružine, Velešovice, Žabčice), where production, pedological and economic aspects of several variants of tillage technology have been studied (Badalíková and Červinka, 2008, Mikanová et al., 2009, Smutný, 2010). Research conducted in each of the three countries is aimed at achieving similar goals: to work out environmentally-sound tillage system that can be applied economically for the main field crops and to encourage the application of the techniques so developed (Hůla et al., 2005, Jug et al., 2009, Křen et al., 2009, Smutný et al., 2008). Variants adapted to the task are applied in the tests, such as conventional (ploughing, CT), reduced (RT) or shallow (ST), loosening (deep or shallow, L) and direct drilling (DD). Crops adapted to the sites are grown in the experiments, that is w. wheat (CZ, H, HR), s. barley (CZ), maize (CZ, H, HR), sugar beet (CZ, H, HR), and sunflower (H). Catch crops (phacelia, mustard) are grown in different experiment sites. Scientists also aim at providing scientific proof for the problems encountered in practice and to make cropping more reliable under extreme climate conditions as well, through their adaptable recommendations. To this end, studies on relationships between soil quality and climate effects have been added to the trials in each of the three countries. The experiments were set up, the tillage variants were arranged and the soil condition attributes and crop responses were measured at each of the three research sites in accordance with the relevant local standards and regulations (Sváb, 1981, Jug et al., 2008, Farkas et al., 2009, Birkás, 2009, Sajko et al., 2009, Smutný, 2010). The following subjects are discussed in this paper: (i) The role of soil quality in environmentally-sound tillage. (ii) Attributes and expected results of tillage adapted to local climate.

Results and discussion

The role of soil quality in environmentally friendly tillage

The soil quality factors that can be affected by tillage directly or indirectly are listed in *Table 1*. Soil protection is the key objective, since the demands of any crop can be met in a well-preserved soil. Accordingly, the factors listed in Table 1 fall in the following four categories: (i) favourable, (ii) adequate, (iii) adequate in a favourable season, (iv) unfavourable in any season. Excessive and ineffective loosening are both detrimental in the course of soil disturbance. Favourable and unfavourable *loosened* state parameters have been discussed by numerous authors (Badalíková and Červinka, 2008, 2009, Birkás and Antos et al., 2008, Sajko et al., 2009).

Table 1 Soil quality factors that can be affected by tillage

Tillage's direct impacts on soil state	Measurable parameter/state	Tillage's indirect impacts on soil state
Soil disturbance, soil looseness	bulk density (t m^{-3}), total porosity %, penetration resistance (MPa)	CO_2 release (flux), C/OM deposit or loss, aerobic/anaerobic biological processes, stubble residues decomposition
Compaction in root zone		
Extension of compacted layer	thickness (mm)	
Depth of loosen layer	rooting depth (mm), root formation/deformation	water infiltration capacity
Agronomical structure	rate of crumb (0.25-10 mm), dust (<0.25 mm), and clod (> 10 mm)	soil mellowing
Soil moisture content	w/w %, v/v %	water transport (balance of retention and loss)
Shape of surface	plane, rough, rolling etc. (differ from a determined unit ±)	
Surface coverage	area (%), mass (t ha^{-1})	earthworm number and activity

Another important aspect is whether there are tillage-induced *compaction defects* in the root zone. If there is none, the root zone is in an optimum state in terms of water intake and root growth alike, to a depth of 36-45 cm for most crops. One important requirement for this is the lack of a compact layer below the tillage depth. A 25-36 cm *root zone depth* is adequate, while 16-25 cm may be adequate only in a favourable season while a root zone of a depth of less than 15 cm may qualify as unsuitable (Birkás, Jug and Kisić 2009, Fig. 2). The depth of the loosened layer is equal to the depth that is suitable for storing water and for crops to take up water. Our field measurements and trials have proven that the closer the detrimental tillage pan to the surface, the shallower the rooting depth of the crops (Birkás and Kisić et. al., 2009). The *thickness of the compact layer* blocking water transports is indicative of the likely extent of the damage. If there is no compact layer in the root zone, there is no risk. Birkás and Kisić et al. (2009) found that if the thickness of the compact layer is between 1 and 10 mm, the risk is low, while in the case of a compact layer of 10-30 mm, in the case of an 30-50 mm or in the case of a 50-100 mm compact layer medium, high or very high risk should be expected to have to be faced (Fig. 3), when severe environmental and farming losses should be taken into account. It should be noted that over 30 mm thick compact layers are not infrequently found in soils under conventional tillage in the region of the three countries concerned.

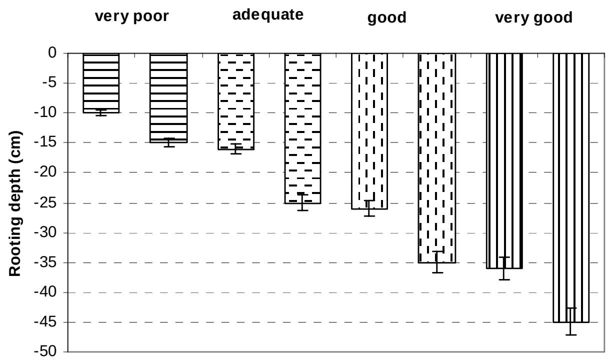

Figure 2: Depth of the loosened layer, by root growth

Risk				
no	low	mid	great	very great
0	**1-10**	**10-30**	**30-50**	**>50**
Extension (mm) in the root zone				

Figure 3: Grade of compacted layer extension

The *soil's agronomic structure* (with the exception of soils not prone to crumb forming) is indicative of the processes affecting the soil structure (*crumb forming, clod forming or dust forming)*. The preservation of the crumby structure is closely related to the protection of other soil quality attributes (Fig. 4).

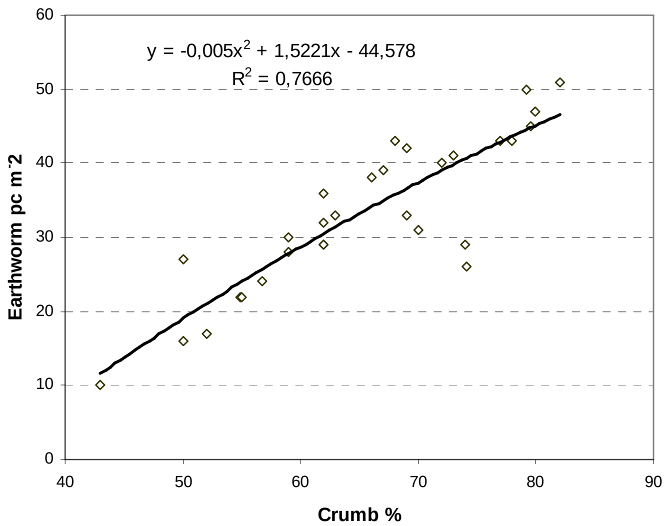

Figure 4: Relationship between crumb fraction % and earthworm count in the 18-23 m/m % soil moisture range (Hatvan, 2002-2009)

According to Birkás, Jug and Kisić (2009) there is a high (>30) dust and clod ratio in soils sensitive to climate damage, while in the case of soils not so sensitive there is a >75-80 % crumb ratio. As they found, in the case of soil conserving tillage crumb forming is mathematically proven to increase, but the production of wide-row crops has a somewhat negative impact on this trend. Moreover, that crumb forming was facilitated by preserving disturbance, the production of densely sown crops and by covering the soil during the critical periods. By contrast, insufficient coverage contributed to the forming of the dust and the clod fraction. Other authors (Bartlová and Pokorný, 2010, Kovács et al., 2010) have reported that the preservation or degradation of the soil structure is linked to disturbance, surface protection and organic matter loss.

Facilitating the process of crumb forming or the degrading of the crumb fraction is heavily affected by the shape of the tilled surface. The *form of the tilled surface* is characterised in terms of the difference in comparison to what qualifies as 'even' or to a certain expected shape (at least one control point per 2 m^2 is required in the area concerned, for the purpose of taking measurements). The shape formed by tillage is largely dependent on the given soil moisture content and the tools applied. The surface of soil remaining after harvest, not broken up by wheel ruts, was found to be the smallest surface per unit of area therefore it is taken as 100 %. The surface of shallow stubble stripping pressed by rolling is 105-110 % (>110 % may lead to losing water during the summer). The surface of the soil after ploughless tillage was found to be some 111-115 %, while after ploughing and surface forming it was 115-122 %. Favourable water retention was found in both cases. By contrast, in the case of ploughing without surface forming the surface of wet soil was found to be up to 116-126 %, while in dry soil it was as large as 118-138 % (Birkás, 2009). This latter variant results in great water loss in the summer, medium water loss in a mild and windy winter and favourable in a rainy or snowy winter.

Covering and protecting *the soil surface* during the growing season is either good or poor, depending on the crop being grown (densely grown crops provide better protection). The soil is in need of protection during the critical periods, particularly in the summer or during a dry spring after sowing. Shading removed by harvest in the summer needs to be replaced by a new protective layer, for which properly chopped and well spread field residues are highly suitable. A new coverage has to be created during the process of stubble stripping, from a mixture of straw and soil to provide protection against heat and rain stress (Birkás and Antos et al., 2008). The advantages of coverage outside the growing season include retaining soil moisture and enabling crumb forming (Fig. 5), along with that of useful biological activity in the soil (c.f. Fig. 4).

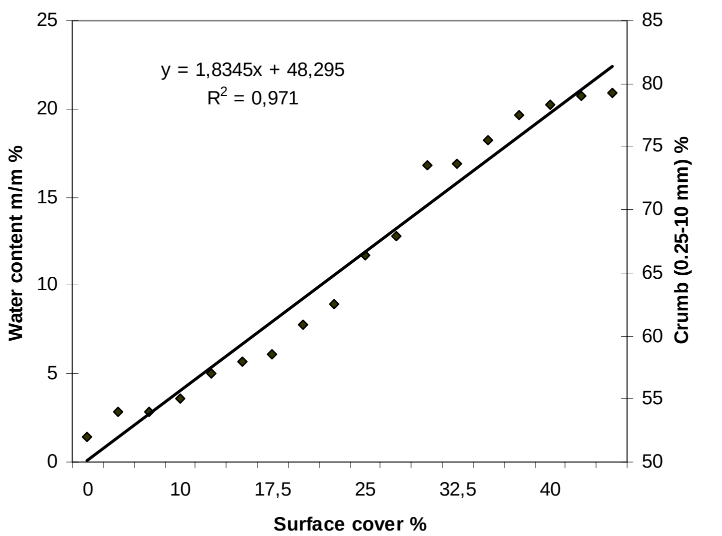

Figure 5: Impacts of surface cover and soil moisture on the ratio of the crumb fraction in an average and dry summer in a loam soil (Hatvan, 2002-2009; n = 30/measuring point/year)

The synergetic effects of these benefits improve the soil workability, for which 60-70 days are required during a dry season or 35-45 days in an average season. It should be noted that the necessity of coverage after sowing in the spring, even if through primary tillage leaving a mulch cover, is underpinned by the early heat and shortage of rain during the period concerned.

Soil moisture monitoring is a crucial prerequisite for evaluating a given tillage method or a given growing season. Although the effects of a tillage process or system can be evaluated in the moisture range in which it can be applied, results achieved under unfavourable conditions – as those occur more frequently – are more important. The optimum range of soil moisture for tillage can be established with the aid of energy input measurements and by monitoring crumb forming trends, in view of the moisture content of the semi-solid soil state. For example, the optimum soil moisture range for workability in the Chernic Calcic Chernozem soil near the town of Hatvan is 16-20 m/m % in the top 20 cm and 18-26 m/m % at 20-40 cm below the surface. A given soil is dry if it is below the limit value of 16 m/m %, it is moist if its soil moisture is 17-22 m/m % and wet over 26-28 m/m %. The soil moisture transport during a given growing season can be characterised in terms of the differences in comparison to the optimum (Farkas et al., 2009).

CO_2 respiration is affected by tillage through the resulting soil state (Birkás and Antos et al., 2008). Reports on such research and experiments have been growing increasingly important during recent year, as a consequence of the unfolding climate change (c.f. Reicosky et al., 1997). Data reported so far prove that deep tillage, leaving large soil surface behind, leads to increased soil respiration and thereby to higher carbon losses (e.g. in Figure 6 the soil was left without surface forming after ploughing (P) in 2002 and it was followed by surface forming in the next years).

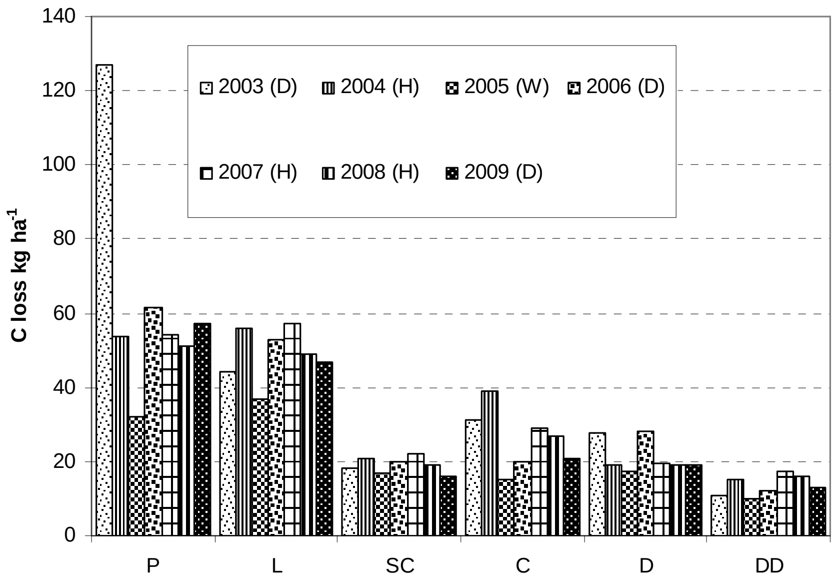

Figure 6: Example for the C loss of loam soil during the first 24 hours after ploughing under dry (D), humid (H), and W (wet) conditions (Hatvan, 2003-2009), LSD 5%: P: 14.22; L: 5.77; SC: 2.09; C: 3.46; D: 4.58; DD: 2.88

As was noted above, deep tillage leaving large soil surface aggravates the soil's exposure to climate damage by causing larger water loss. That is, the soil state causing increased soil respiration is the same as the state causing increased water loss in terms of time, temperature etc. At the same time, preserving tillage (in our example: L, SC, C and D and above all DD) causes moderate CO_2 flux, entailing a reliably lower rate of C loss. Data resulting from continuous measuring helps setting up a ranking order that makes it easier decide what tillage techniques are to be applied under the given conditions of the site, which is expected to help the farming community widely accept and adopt carbon conserving tillage.

The attributes of tillage adapted to climate and its expected results

One of the most important results of soil quality research is the identification of tillage patterns that are detrimental to the soil. The most important such techniques in the Central European region include: 1. Deep stubble stripping in the summer, leaving exposed soil surface without surface forming and coverage. 2. Ploughing in the summer, leaving soil surface without surface forming. 3. Shallow disking when the soil is compacted below the disked layer. 4. Winter ploughing of wet soil, causing and thickening plough pan. 5. Leaving soil surface after winter ploughing without surface forming when there is no (site-specific or other) reason for doing so. 6. Failing to loosen the root zone that has been compacted by tillage. 7. Deteriorating the quality of winter primary tillage by using tools that are not suitable for the soil moisture content. 8. Primary tillage in the spring in sites where there is no reason for this. 9. Creating soil with a large proportion of small crumbs and/or dust before sowing in the spring. 10. Making decisions concerning tillage for the next crop without knowledge of the status of the soil.

These habits should be dropped step by step to conserve soil quality. Tillage techniques and tricks improving the reliability of farming through preserving soil and environment have to be learned and adopted by the farming community.

Conclusions

Soil scientists of three Central European countries joined forces to help improve tillage in practice with the aid of their scientific achievements driven by environment and soil friendly motives. They identified the soil quality factors that can scientifically underpin their recommendations, put forth as follows: 1) Awareness of the state of the soil to draw conclusions concerning the likely damage. 2) Preventing the development of compact layers impeding water transport. 3) Eliminating the compact layer in the soil with the aid of a suitable tillage technique. 4) Creating small surface at any time of the season, without compaction stress. 5) Covering the surface with crushed stubble residues to protect soil and moisture. 6) Preserving the soil organic C is crucial at any type of tillage. 7) Protecting the soil structure. 8) Adapting primary tillage to soil state improvement. 9) Causing smaller stress in over wet or dry soils. 10) Maintaining the soil's capacity to take in and to store water in irrigated soils.

Acknowledgements

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Framework of climate change - and soil type - oriented tillage and land management in Croatia

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> All ethic rests upon a single premise that individual is a member of a community of interdependent parts. We are member of the land community. Therefore: we need to exercise the same constraints on our relations to the other members of the land community - soils, waters, plants and animals - as we do in our relations to people…. The oldest task in human history is to live on a piece of land without spoiling.
>
> *Leopold, A., 1991*.

Abstract

For a long time in the past research of soil tillage was one-side, exclusive soil biomass production (crop yield) – oriented, and generally not holistic but specialized, which means collecting more and more knowledge about less and less. Environmental problems, especially climate change and soil degradation as doubtless interconnected emergences are driving forces for re-orientation to respect the other, non-productive soil functions; soil as reactor, transformer and integrator of material and energy from other resources, storage, filter and buffer system, gen reservoir and medium of past and present human activities. Premise of soil tillage as component of (crop) land management will be to understand and improve efficiency of internal recycling and storage of water, carbon and plant nutrients. Creating of framework for soil-type- and climate change-oriented soil tillage, we take in account the forthcoming accession of Croatia to EU, acceptance of CAP as European model of agriculture which is at the same time market oriented, environment friendly, multifunctional and respond to all the demands which society places upon it. There are the three main policy instruments for establishment and practical realization of proposed system on farm level; mandatory measures, (EU directives and national legislation), incentive-based measures, awareness raising and possible private initiatives. Extremely important role in implementation all changes would have Croatian Agricultural Advisory Service (CAAS) in partnership relation with research institutions and Croatian Agricultural Chamber (CAC). It is necessary to clear define of set of minimum standards for to keep the land in Good Agricultural and Environmental Condition (GAES) as precondition for an efficient use of cross compliance for incentives in agriculture.

Keywords: soil-type-oriented tillage, enhancement SOC management policy, SOCSI

Introduction

Since the relationship between agriculture and environment is not static, intensification has in turn increased pressure on environment. Our awareness that are living in the world where is everything interconnected with everything else is a base of worrying about climate change, its impacts on soil properties and functions, interrelation between them and reflexion on land management - tillage practices. Just in actual year climate changes taking place at an unprecedented rate; flooded in Poland, Germany, Pakistan, but fire in Russia. Soil degradation and climate change as its cause-effect are some kind of “price or tax of progress”. The ethical side of this progress is exposed in syllogism of Leopold (1991) printed under the title of this paper. Agriculture is at the same time a cause – origin, but solution and the first and the most damaged victim of climate-change. Therefore, there is a requirement of change of farm production philosophy and adaptation towards new –

sustainable farming systems, including land management, within which tillage system. It's a "requirement of the day" of global agriculture, characterised by very efficient profit-and investment-oriented agriculture of developed countries on one, but extensive, traditional, and for any change (in spite of urgency) helpless agriculture of undeveloped world on the other side. Respecting afore-mentioned, the new farming and tillage system within it need to be set up, adapted to actual and foreseen agroecological conditions. Soil tillage system has to face these erratic changes and to be a buffer system for mitigation of negative effects on crop yield and environment – natural resources, soil and water at first. Intensification, specialisation and farmland enlargement are for a long time economic and social trends of Croatian agriculture, all trends produce with environmental effects, which is necessary to control for ensure the sustainability.

Respecting MFCAL concept, available data on agroecological conditions, especially soil type, foreseen climate changes and experiences, we analysed situation in different agricultural regions of Croatia for definition a guideline of an adaptable tillage system. Of course, tillage system is impossible to apart from farming system subordinated to demands of each crop in crop rotation. Expecting forthcoming access to EU, Croatian agriculture accept the framework of *Common Agricultural Policy (CAP),* based on principles of environmental integration through Good Agricultural Practice (GAP) as reference level based on cross compliance. It means: wherever society asks farmer to accomplish environmental objectives beyond of GAP as reference level and farmer loss part of possible income then society must pay for the environmental services provided by agri-environmental measures. A separate treatment within GAP have Mediterranean sector and Les Favoured Area (LFA) where belongs Mountainous agricultural region.

It needs research activities oriented to creation of certain standards of agricultural practices including soil tillage system within code of **G**ood **A**gricultural **P**ractices (GAP) and standards of **G**ood **A**gricultural and **E**nvironmental **C**onditions (GAEC), on which agricultural economy and rural development of Croatia would be based. It is necessary to create Croatian standards of GAEC. We believe that this, scientific-based system will broaden the old conceptual barriers of traditional technology and open new horizons.

Material and methods

Basis of this work are results of long-term investigation of University of Zagreb, Faculty of Agriculture, Department of General Agronomy and papers presented in list of references. The frame and directions of expected changes is possible to recognize from warning titles of publications of Birkas et al. (2008): *Soil tillage needs a radical change for sustainability*, and also (2008) an alarming call; *climate change is a subsequent challenge to abandon the conventional tillage ideas in Central Europe.*

In spite unpredictability IPCC (International Panel on Climate Changes) assess for the future that precipitation will increase in temperate, means Pannonian region, but decrease in subtropics, tropics and Mediterranean region. Weather conditions of last period did not affirm this prediction. The extreme precipitation events and its consequences as drought and floods are also in increasingly tendency all over the globe. Soil degradation is directly linked to climate changes by more ways; reducing capacity of soil for carbon sequestration caused at first by clearing natural vegetation of higher capacity and change by crops of lower capacity of C-sequestration. Additionally, soil erosion and loss of vegetation cover are factors of high influence on local weather patterns by impacts on albedo and evapotranspiration, lower from crop than from forest. Before mentioned means that soils of

Europe in shorter or longer time would be in a new condition. Situated partly in temperate, where is to expect higher precipitation, partly in Mediterranean region with decrease of annual precipitation Croatia is faced with really not simple challenges.

Very valuable where data on sustainable land management within EU projects (Hubertus and SoCo Project team, 2009), and Reports of the technical working groups established within The thematic strategy for soil protection published by Institute for Environment and Sustainability of JRC in Ispra (Van-Camp et al., 2004; Toth et al., 2007), as well as publications of European Soil Bureau Network (ESBN), focussed on soil resources of EU.
Framework for soil-type- and climate-change-oriented soil tillage needs to take in account the forthcoming accession of Croatia to EU respecting the three main policy instruments; mandatory measures, like EU (Nitrates, Water Framework, Habitats, Sewage Sludge and Groundwater Directive) and national legislation, incentive-based measures, as well as awareness raising measures. It can also include and private initiatives.

Results and discussion

As essential component of land soil is a natural resource (Blum, 2005; Varallyay, 2005) with decisive influence on sustainable development of global economy, especially sustainable agriculture and environmental protection. The thematic strategy for soil protection of EU (xxx 2006) recognized inadequate practices in agriculture as one of impacting factors that prevent the soil from performing its services to human society and agro- or natural ecosystems at desired - required levels. Soil is a medium or „sphere of interaction" of all spheres (atmosphere, hydrosphere, lithosphere and biosphere) with numerous functions: productive (primary production of food for the biosphere, source of row materials), regulatory (climatic regulation-source and/or sink of glasshouse gases, reactor, receptor, accumulator, and bio-transformer, universal filter for water, powerful puffer system), biological-regulatory system (starting and ending point of numerous bio-cycles, gen-reservoir and base of biodiversity), spatial (natural landscape and anthroscape, spatial conditions for all activities: agriculture, forestry, industry, transport, housing, recreation, waste disposal), a memory for natural (geological, paleontological, pedological) and archaeological heritage. EU Commissioner Stavros Dimas express importance of soil functions by words: "Soil is a prime example of the need to think global and act local!" We can ad: soil tillage within land management is a prime example of act local!

In the focus of research and economy for a long time was productive function of soil, other functions were unknown, marginalised or self-presumed as something normal. Following the same logic, tillage system in conventional agriculture was exclusively soil productive function - oriented, which means to prepare and keep the soil in a condition optimal for growing of crop, starting with germination to the harvest and finishing with post harvesting treatment - incorporation of crop residue in soil. Today is necessary to change philosophy and observe soil tillage as an environment protection-oriented practice, focussed on the soil which has to fulfil all other, non-productive soil functions.

Soil tillage of future would be sustainable, it would use of soil as natural resource on a way that does not any negative effects irreparable under rational conditions – either on the soil itself or any other systems of the environment (Toth et al., 2007). Since the sustainable management of soil resources depends on soil properties, related environmental i.e. climate conditions and farming system (crop rotation) all factors interact so that change of one factor causes alteration in the others. Means, soil is a prime object of sustainable land management in changing natural conditions.

In the background of most soil degrading processes of Croatia is decline of humus as consequence of more influences, some of which are “natural”, climate-change caused, but some are consequence of unfavourable turnover of organic matter in soil and/or inadequate tillage system, soil aeration and stimulation processes of mineralization of humus (Butorac et al., 1988). Important factor of formation of humus of high quality of agricultural soils is the use of farmyard manure, for which is necessary to have an appropriate stock density (stock units - SU/ha of agricultural land). It is possible in a balanced relation between stock breeding and arable farming on the farm, consequently in the national agriculture. Optimal structure of farming is when about 70% of farm income is from livestock production. As visible in Figure 1, the long-term situation in Croatia is bellow desirable relation.

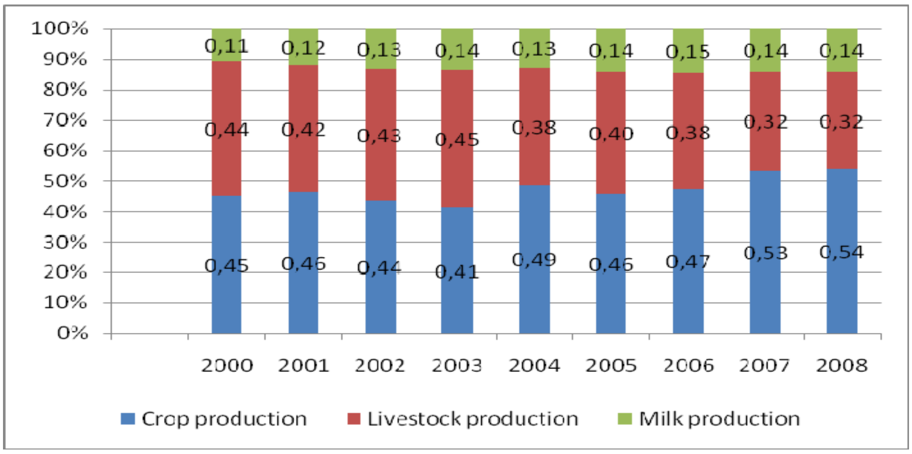

Figure 1: Production value structure of Croatian agriculture
(Source: CBS of the Republic of Croatia, prepared by Franić, 2010.)

This situation is one of consequences of long-term disorder in structure of farming system – crop growing separate of animal breeding practiced on state farms in the past. Consequence is an alarming stock density expressed as SU/ha of cultivated land, which is bellow of minimal requirements, with the tendency of constant decreasing in all agricultural regions of Croatia (Figure 2).

The only source of organic carbon of soils were crop residues plough in, and/or but infrequent green manure. There is a large area of cultivated land intensive used in arable farming but without any use of farmyard manure from the middle of past century till today! At the same time in EU there is limit of organic manure rates to the threshold of 170 kg/ha of nitrogen and problems with greater rates is spite of taxes for to high stock density – higher than 2.5 SU/ha. All in all, there is alarming necessity to change unfavourable practices, especially in Pannonian region. There is an urgent need to conceived increase livestock density, means to increase farm income and improve balance of SOC.

Very favourable effects is possible to expect if incentives would be conditioned by desired stock density, which depends on soil type and needs to be different in different agricultural regions of Croatia. This change is in primary interest of farmers. All in all, there is urgent need to create SOC accumulation-oriented farming and tillage system. Having small quantity of organic matter (farmyard manure, compost, crop residues), practiced deeper tillage we get lower content than we can in the case of incorporate it in shallower – seedbed layer. In new, changed conditions it is necessary a special care on research of status of SOC in Croatian soils and changes in this, dynamic complex. Stolbovoy and

Montanarella (2008) developed a new quantitative approach of Soil Organic Carbon Status Indicators (SOCSI). SOC properties they divided in a static group which includes indicators of SOC level (actual, maximal and minimal) and dynamic group which includes potentials and rates of SOC changes. This concept proposes principles of SOC management policy, which can be conservation (maintenance the level), enhancement and/or optimization of SOC content.

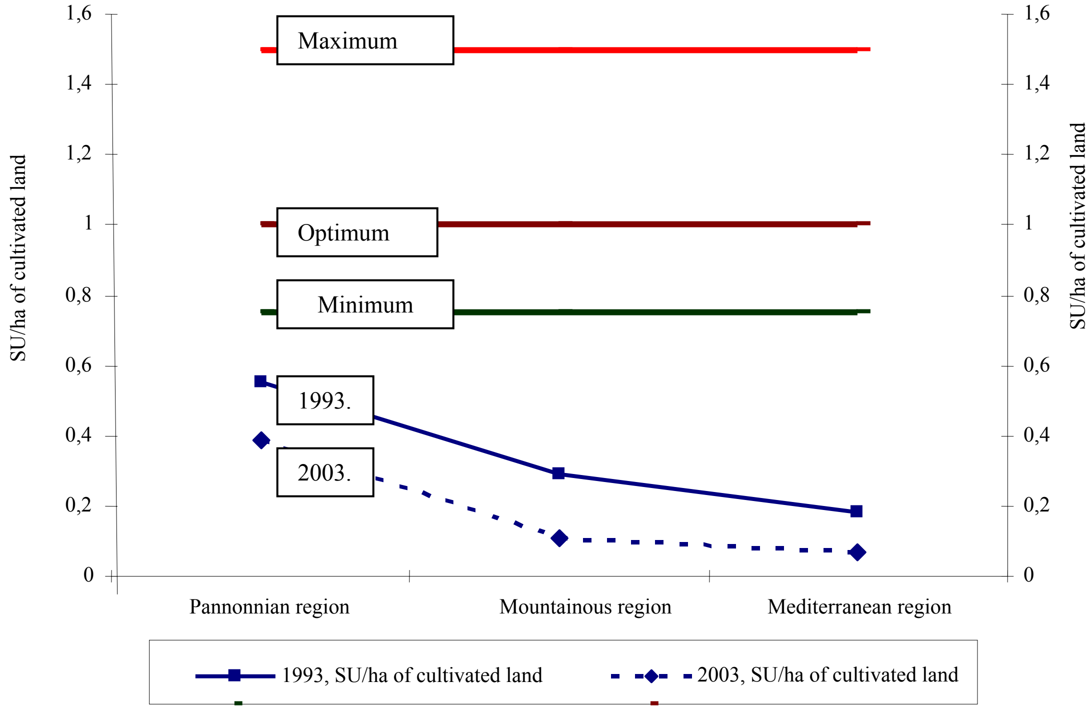

Figure 2: Alarming stock density (SU/ha) in all agricultural regions (Kisić et al., 2007)

Less well known and a separate topic is interrelation between climate changes and soil organic carbon as source of greenhouse gases (GHGs) – CO_2, CH_4 and N_2O. Sum of glasshouse gases is expressed in CO_2 eq, and calculate by this way;

$$(CO_2x1) + (CH_4x21) + (N_2O \times 310) = CO_2 \text{ eq}$$

Soil tillage operations (except of rolling) stimulate soil aeration and aerobic process of mineralisation of organic matter, means emission of CO_2. Globally, according of Lal (2000, 2003), humosphere is the third largest C-pool (2 300 Gt), after oceanic (38 000 Gt) and geologic (5 000 Gt) one. The C-pool of humosphere is directly linked with the biotic (600 Gt) and atmospheric (770 Gt) C-pools. About 9% of total emission CO_2 in EU is from agriculture, 48% of CH_4 and 52% of NO_2. According of our results (Mesić et al 2006) soils of Croatia emitted 723 thousands tones of CO_2 in 1995., but total emission from agriculture and related industry was 3,6 Gt of CO_2. At the same time, soil can be a sink of carbon through carbon sequestration. Therefore follows the task of scientists in agriculture to create and establish farming and tillage system which would open the process of CO_2 sequestration, enrichment of soil by organic carbon (humus), increase soil fertility and stabilization of yields of all crops in crop rotation on high level.

Expected changes in soil tillage

The mean foreseen change of soil tillage is reduction of: depth and/or tilled area of land surface; kind and/or number of tillage operations, which in some cases leads to exclusive no-tillage system. In every case, tillage system has to be climate-change and soil type-oriented, in some subregions and area exclusively conservation tillage system. If so, there is no place for uniform solution, because of different soil types – agroecological condition in agricultural regions and erratic – unpredictable climate changes. It is important to stress that no-tillage is possible and reasonable on very fertile soils of favourable physical, chemical and biological properties. Therefore for most soil types of Croatia we see as logical and acceptable slogan declared by Butorac (1994):

The first maximum** (investment in soil amelioration) **and then minimum** (or no-) **tillage!

In Croatian history the period in which existed some, but never maximal investment in soil amelioration (drainage) was very short, but after becoming autonomous state there is no any investment in soil amelioration, except of pre-election promises of politicians. So, the possibility for minimum or no-tillage is reduced on some naturally favourable soil types.

In soil regionalization of EU and neighbouring countries Hartwich et al. (2007) classified the territory of Croatia in three soil regions:

- Soil region with predominant temperate to warm temperate sub-continental climate, partly arid – Pannonian basin with Calcaric Fluvisol as dominant soil type in valleys of rivers, but Stagnic Luvisols and Stagnic Albeluvisol as dominant soil type of basin, with rainfed arable land, Distric, Eutri-stagnic Cambisol and Mollic gleysolos, as associated soil types.
- Soil region with predominant temperate continental climate influenced by mountains with Chromic and Calcaric Cambisols, Lithic and Rendzic Leptosols as dominant, Chromic and Stagnic Luvisols as associated soils, with mixed forest type pattern and low mountain to mountain relief.
- Soil region with predominant Mediterranean sub-oceanic climate, with Rendzic and Calcaric Leptosols as dominant but Chromic Cambisols and Chromic Luvisols as associated soil-types, with mixed cultivation pattern and hill to mountain relief.

Of course, in every region, even for smaller area it is necessary to create site-specific tillage practices in different agricultural regions of Croatia presented in Figure 3.

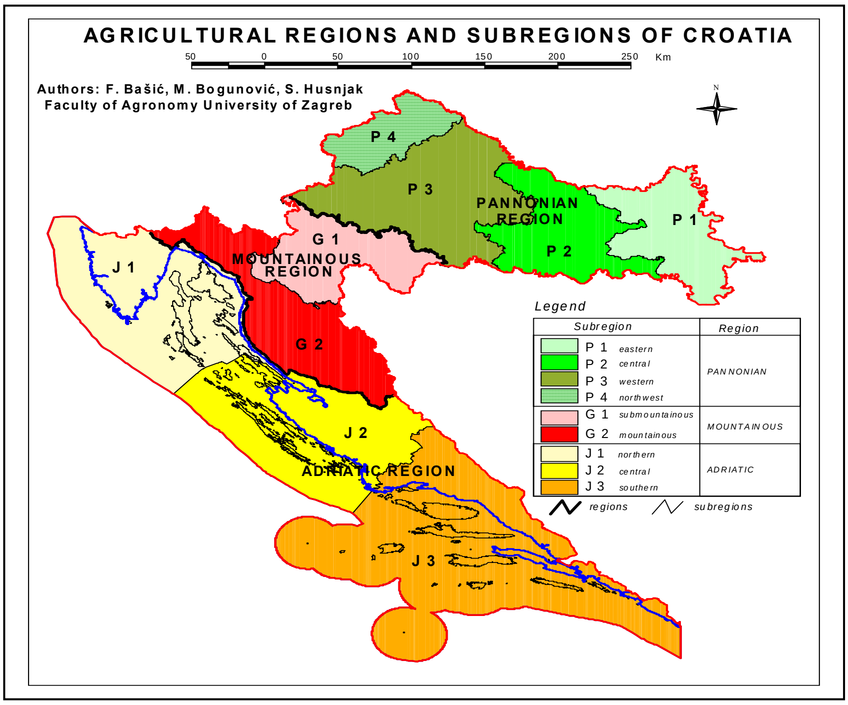

Figure 3: Regionalisation of Croatian agriculture (Bašić, Bogunović, Husnjak, 2001)

The Pannonian agricultural region

As the most densely populated, for agricultural production potentials the richest and most valuable Pannonian region is the southern part of the Pannonian plain. It is commonly divided into the dry semiarid (about 600 mm annually) lowland eastern and humid (900 mm) hilly western part.

There are three well marked geomorphologic units: Holocene terrace with multi-layer fluvial sediments, Pleistocene terrace built from loess (calcareous on eastern, leached in central, and compacted by fluvioglacial processes in western part), and Central Pannonian hills built from metamorphic rocks as third unit.

Because of practise of intensive profit-oriented agriculture with narrow crop rotation in the whole Pannonian region central problem is SOC at unacceptable low. Research according of SOCSI concept would show the real situation but all results suggest that SOC level is minimal and SOC management policy should be enhance-oriented. It means that is not acceptable no any remove or burn of any straw grown in this agricultural region. All crop residue has to stay where grown and be incorporated in cycling in the soil. Accumulation of SOC is soil type-depending property which is leading factor of soil type-oriented tillage practice. Very important task of Croatian Agricultural Advisory System (CAAS) is raise farmers and public awareness on importance of this system for sustainability of agriculture.

The Eastern Pannonian subregion (P-1) – Chernozem-oriented tillage

This subregion is naturally a semiarid transitional zone between step and forest region, covered by calcareous loess, provided the bases for soil forming processes resulted by Chernozem, Regosol, and Cambisol Eutric (Bogunović et al., 1996; Bašić, 2005). These soils provide conditions for dry farming of all arable crops, as well as vine, fruit and vegetables. Deep involved in tradition of husbandry for a long period was original crop rotation established in “horse-epoch”, known as “Old Slavonic three-field crop rotation”. The sequence of crops was; Row crop (maize) - Grain crop (winter wheat) – Legume (common vetch). It’s a balanced crop sequence, in which there is enough time for any desired tillage practice without time straits; legume as a base of animal breeding enriches humus content in soil, with positive effects on soil fertility, biodiversity, pedo-hygienic condition and ecological functions of soil. Tendency to narrowing crop rotation as; maize – winter wheat, or monoculture of maize in modern, profit-oriented agriculture was very unfavourable, because of humus decline, loss of structure, increases soil compaction and soil crusting, both incentives soil erosion. Sugar beat growing in rainy autumns, ordinary in previous century, resulted by soil compaction. Decline of soil fertility as consequence of this practice was compensated and “masked” by higher rates of mineral fertilizers. Soil degradation has a direct impact on water including groundwater, and air quality.

Implementation of Nitrate Directive of EU as well as domestic legislation means restrictions; in period of application of organic (liquid manure) and inorganic fertilizers; apply on steep slopes, frozen, flooded, snow covered and water saturated condition of soil. Also, the rate and uniform distribution is restricted and clearly defined. Plant Protection Directive regulates use (or no) of pesticides. Practical implement of those measures, including arising awareness of public and farmers on importance and cross compliance on efficient implementation these measures would be in competence of Croatian Agricultural Advisory System (CAAS) as well as Croatian Agricultural Chamber (CAC).

Investment in Danube-Sava canal and infrastructure for irrigation would guarantee desired extended arable crop rotation and/or reorientation of farming to vegetable growing, economic revival and stable development (Tomić, et al, 1998). Chernozem is a soil type with the SOC distribution and favourable soil structure in the whole soil profile. For a favourable recycling and storage function of this soil type it is very important to avoid any pass of mechanization, even on dry soil, and any soil compaction. In sugar beet growing year part of parcel used for storing of beet needs separate treatment to reduce negative effects of compaction to minimum. Transport and any pass is allowed on Respecting this fact As known, the main priority of soil tillage practice in dry farming is accumulation maximal rain and snow water during autumn-winter wet period and save it for the dry one (Butorac, 1993, 1994; Jurić et al., 1998; Žugec et al., 1984). Because of registered climate change and the tendency to desertification of this subregion (Bašić and Bašić, 2007; Mađar et al., 1998), there is to expect adaptation of tillage practices to new, changed conditions. At first place – more and regularly use no-tillage practices, especially on Chernozem and Fluvisol. The second change would be generally shallower ploughing, except of for sugar beet and other root-crops and vegetables. The main principle would be: deep loosening – by chisel plough (actual plough layer) shallow tillage top layer, practically seed bed and organic fertilizers or crop residue incorporation, with the aim to increase SOC (humus) in surface - top layer. For the same aim we recommend green manure whenever possible, but after harvesting of cereals obligate. Effect of no-tillage in the first years of practices is usually bellow of expectation, but stepwise increases till 5-6 years of continuous no-tillage. It is necessary to stimulate farmers for transition from conventional to no-tillage system within Code of good agricultural practices (GAP) by special incentives tailored within cross-compliance.

A specific question is land management in intensive plantation. At first, traditional practice of very deep ploughing for establishment of intensive vineyard or orchard plantation on hilly slopes of Fruška gora and Baranjsko brdo is better to change by subsoiling, because of calcareous loess bringing to surface cause disorders in plant nutrition, especially ferrous chlorosis. Of the same importance is a need to protect the soil of the inter-row space of vineyards of Syrmium and Baranja by grass cover. In winter period we recommend subsoiling of interrow space every year, but in case of dry vegetation period, means minimal compaction, this practice can be omitted. There is more protected and very sensitive areas, especially drinking-water protected areas, where is obligate to establish and maintenance green cover, by growing catch crops or grass cover.

We see as necessary to stress the necessity of "selective tillage" on Vukovar loess terrace with specific aeolian geomorphology and soil sequence. Namely, aeolian dunes cause very specific redistribution of rain water and soil forming processes; on flat area is formed Chernozem, on top of "slope" of depression there is formed Regosol as consequence of runoff and tillage erosion, in direction to the bottom follows Cambisol Eutric but on the bottom there is Cambisol, luvic and/or Luvisol on loess. In this case chiselling or deep loosening is a promising tillage operation of area of depression and around it, because of this operation increases permeability of soil and decreases surface run off of rain water, erosion and leaching of soil on the bottom of aeolian dune. Leaching of calcium carbonate is a favourable process on Regosol which can cause its evolution to Leptosol and Cambisol. This practice would be efficient in both scenarios of climate change; decreasing or increasing of annual precipitation. Mollic Gleysols with typical hydromorphic regime – very high variability of underground water level is the most favourable soil type for a very successful no-tillage system in this subregion.

The Central Pannonian subregion (P-2) – Luvisol-oriented tillage

Prevalent soil types of this subregion are hydromorphic soils, but the most spread cultivated soil type is Luvisol on loess, follows by Stagnosol, Gleysol, Cambisol eutric, Leptosol on marl, but in Drava and Sava valley Fluvisol Calcaric. Prevalent in agriculture is intensive farming, especially in the flat eastern part of subregion and Drava river valley (Bašić et al., 2001). Compared to the previous, this subregion is semihumid with water erosion of higher intensity, especially in the spring and on land sown by row crops (maize, sugar beet, soya bean).

Precondition for an efficient use, agricultural soils of this subregion is land consolidation, enlargement of farmland following of land reclamation – irrigation and drainage (Tomić et al., 1993; Šimunić et al., 2006), as well as liming and enrichment by SOC (humus content). Similar as in previous – P-1 subregion, to implement Nitrate Directive there are restrictions in period of application of organic and inorganic fertilizers, it's apply on steeply slopes of Middle-Slavonian hills, on frozen, flooded, snow covered and water saturated condition of soil. Also, the rate and uniform distribution is restricted and clearly defined. Plant Protection Directive regulates use (or no) of pesticides.

Following GAEC demands it will be defined establishment and maintenance of permanent grass cover on some land, which is actually marginal practice.

Because of intensive leaching, low pH, low humus and high silt content, structure of soils is unstable and well-disposed to soil crust formation. Combined with rains of high intensity, especially in spring maximum period and on maize as row crop, water erosion is very respectable process of soil damage. Intensity of erosion demands conservative contour line tillage and permanent green cover (crop, catch crop, stubble mulch) on soil. Stubble and crop residue burning is according national legislation prohibited.

Soil tillage pattern on Luvisol has to respect three facts, at first; because of high silt content structure is unstable and soil is crust-liable, second; SOC is accumulated in shallow surface horizon, and third; compacted, deep (40-60 cm) less permeable (for water and crop root penetration) horizon. Folowing natural properties of soil type, any compaction (by passes of mechanization) is risky, also to much chopping, especially bare soil, usual in seedbed preparation is very risky, soil has to be covered by any vegetation (crop or weed), incorporation of organic fertilizers and crop residue should be in upper, practically seedbed layer, but deeper layer is necessary to loose by subsoiling, which would be operation number one in this soil type. And very important; for and efficient transformation of organic matter in humus of high quality liming is precondition.

In Drava River valley there is registered initial wind erosion on sandy soils in dry summer period or early spring when is surface of soil not protected by crop biomass cover. In conventional tillage of this soil traditionally the central role has very shallow ploughing, just after harvesting of cereals and deep winter ploughing for spring crops. In professional circles there is a wrong conviction that Luvisol on loess is not convenient for no-tillage because of unstable structure and high silt content.

The Western Pannonian subregion (P-3) – Stagnosol-oriented tillage

The most common soil type of this subregion is Stagnosol on Pleistocene plateau and hills but Fluvisol Calcaric widespread along the Drava and Sava River. Soil tillage pattern on

Stagnosol is similar as for Luvisol, because of high silt content structure is unstable and soil is crust-liable, SOC is accumulated in shallow surface horizon, and compacted deep less permeable horizon at 40-60 cm. Any compaction (by passes of mechanization) is risky, also to much chopping in seedbed preparation is very risky, soil has to be covered, incorporation of organic fertilizers and crop residue should be in upper, practically seedbed layer. For deeper layer subsoiling is obvious, practically operation number one. Liming is a precondition of favourable properties and an efficient transformation of organic matter in humus of fair quality.

Because of high silt content, practically all types of soil in this subregion are very erodible, especially on slopes and under maize as dominant arable crop. With eroded soil nitrate and other nutrients and residues of pesticides are transported to water bodies and to numerous fishponds of this area (Mesić et al., 2002). One of characteristics of this subregion is widespread of freshwater fishponds. In catchment area of fishponds and drinking water protected area is necessary to manage by strong following all restriction on rates and time of application of nitrogen fertilizers and liquid manure according Nitrate Directive. The valuable practice is growing cover crops, which reduce nutrient leaching especially nitrate and provide additional organic matter (about 150 kg of C/ha).

This subregion is just a typical one for soil tillage according the slogan of Butorac (1994): the first maximum and then minimum, which suggests investment in land reclamation (drainage, liming, and humus enrichment) as the most reliable way to establish stable and reliable farming and tillage system. Without an efficient drainage there is no any way for reduced or no-tillage practice. All experiences in drainage of Stagnosol by method of "three step amelioration"; the first – pipe drainage, the second - deep loosening, the third – liming and stable structure forming-oriented measures are very affirmative. The same is with no-tillage in such ameliorated soil. Investments in soil amelioration last twenty years are stopped. This situation is necessary to break and find an efficient way for financial support of this investment, especially irrigation, because of most scenarios predict increased frequency of drought in future.

Soil erosion is the main process of degradation of soils generally but Stagnosol especially. To quantify this process and looking for a sustainable tillage treatment on Stagnosol we established the project of stationary field measuring of soil erosion in six conventional tillage treatments normally practised in this area in arable land management in the period of 15 years (1994-2009) near Daruvar on the slope of 9%. Results of this, long-term research is visible in Table 1.

The table shows soil loss (cm/ha/year) under different soil tillage treatments, as well as the time period in which the plough layer in spring or winter crops growing, as test crops, would be completely eroded away.

As expected, in all investigated years, soil loss was the highest in the control treatment and it varies within the disastrous values. If row-crops were grown on this soil type with up-down the slope ploughing and sowing tillage treatment, the plough layer of 25 cm would be completely eroded away in 147 years only.

Table 1: Soil loss and erosion risk during 15 years (1994-2009) different tillage treatments in crop rotation: maize - double crop - winter wheat – soybean

Tillage treatment	Standard plot according of USLE	Ploughing up/down the slope	No-tillage	Ploughing	Very deep ploughing	Subsoiling + ploughing
				across the slope		
SPRING - ROW CROPS (MAIZE AND SOYBEAN)						
Soil loss, cm/ha/year	0,714	0,170	0,038	0,044	0,046	0,023
Loss of arable layer of 25 cm in …years	35	147	661	574	548	1.086
Erosion risk	Disastrous	Extreme	Moderate	Moderate	Moderate	Small
WINTER CROPS OF HIGH DENSITY (WINTER WHEAT AND OIL SEED RAPE)						
Soil loss, cm/ha/year	0,352	0,009	0,001	0,003	0,001	0,002
Loss of arable layer of 25 cm in…. years	71	2.863	25.333	8.780	16.905	13.036
Erosion risk	Disastrous	Insignificant	Insignificant	Insignificant	Insignific.	Insignific.
DOUBLE CROPS – SPRING CROPS (SOYBEAN) + WINTER CROPS (BARLEY OR WHEAT)						
Soil loss, cm/ha/year	0,307	0,094	0,002	0,036	0,030	0,023
Loss of arable layer of 25 cm in… years	81	267	12.258	699	847	1.071
Erosion risk	Disastrous	High	Insignificant	Moderate	Small	Small
TOTAL CROP SEQUENCE IN 15 YEARS (1994-2009)						
Soil loss, cm/ha/year	0,455	0,092	0,014	0,028	0,025	0,016
Loss of arable layer of 25 cm in… years	55	273	1.745	896	986	1.545
Erosion risk	Disastrous	High	Small	Small	Small	Small

Source: Kisić et al. (2010)

According of efficiency in soil conservation the used tillage variants form the next sequence:
No-tillage > **Subsoiling** (contour) > **Very deep ploughing** (contour) > **Contour tillage** > **Tillage up/down the slope** > **Black fallow** (standard variant according of USLE).

According of our field observation, without collection of exact data, last climate change, especially drying and warming (high temperature in deeper layer – luvic horizon), caused some changes in structure of these horizons, which consequently increases soil permeability. After strong rains there is no water stagnation, as it was in past time.

In starting and second year of use, no-tillage was not superior to conventional tillage, in the period of first five years effects where better but increased gradually. After 10 years of practice no-tillage variant shows all advantages. On the line of principles of good agricultural practice (GAP) and cross compliance it is advisable to support - stimulate farmers by special, selective incentives in the period of transition from conventional to no-tillage system. After the transition phase no-tillage result in a higher macroporosity with vertical orientation of the pores as influence of earthworm activity. There are and other positive effects of no-tillage; increase of humus content, annual increase of SOC 3-120 g of C/m^2, increase of water holding capacity, reduced mineralization rate, increase of nitrogen and phosphorus content.

Based on results and taking in account that soil loss tolerant (T value) of this soil type is 10t/ha/year, we calculated erosion risk and in which period plough layer – topsoil, would be completely eroded in a crop rotation with maize and soybean as row crops and winter wheat, oil rape and double crop, as crops of high density.

Taking in account that there is no statistically significant difference in yields, no- and contour tillage are absolutely recommended tillage variants, subsoiling is too expensive but recommended for inter-row space of plantations. In spite of high efficiency, very deep ploughing is too expensive for regular use in arable farming. Crop rotation is of special importance, especially if includes legume and fodder crops, because of more positive effects on weed control, which reduces use of pesticides, nitrate leaching and risk of water pollution, and increases SOC content.

The Northwestern Pannonian subregion (P-4) – Leptosol- and Stagnosol-oriented tillage
Due to heterogeneity of parent material and very different relief, this subregion abounds in very different soil types. Prevalent soil types are Gleysols, widespread in numerous valleys that have been formed by rivers, streams and brooks, follows by Leptosol on marl, Regosol, Anthrosol and Stagnosol. Most important for growth of crops and plantations of orchards and vineyards are Regosol, Anthrosol and Leptosol as shallow soil on marl. The common characteristic of soils in this subregion is intensive water erosion, mostly due to limited permeability of the soils and intensive runoff of rain-water.

Therefore this subregion needs a separate treatment – using cross compliance principles incentives system to be created for use Conservative agriculture (CA) – resource-saving agricultural crop production that strives to achieve acceptable profit together with high and sustained production level and conserving the environment. This subregion is convenient for test agroforestry as potentially favourable land use system.

One of problems is the fact that the most farms are mixed part-time and/or hobby farms, with no interests for investment in machinery and equipment. This subregion is favourable for organic farming.

Characteristics of the climate also contribute to the erosion, but the key factor is anthropogenic influence – high percentage of perennial plants – vineyards and orchards, with rows mostly oriented up-down the slope – from top to the bottom, without grass cover in inter-row space. Water erosion stimulates high frequency of row crops, especially maize and tillage up-down the slope. The eroded soil material washed away through erosion causes eutrophisation and leads to pollution of underground drinking water by nitrates. Because of traditional small parcels are up-down oriented it is a factor of stimulation of erosion. Therefore it is necessary in standard of Good agricultural practice to include conservation buffers–strips of land maintained under permanent vegetation and hedgerows. For an efficient long-term tillage system there is necessary at first land consolidation, which would open the door for enlargement of farmland and contour line tillage or terracing. Also, an efficient practice is subsoiling for increase of infiltration and water holding capacity of loosened soil layer, especially in plantation. For tillage practices on Stagnosol it is advisable to follow the same recommendation as for previous subregion.

The mountainous agricultural region
This region is a natural barrier between Pannonian and Mediterranean region of Croatia, characterized by very heterogeneous parent materials – mesosoic (triasic and jurrasic) limestone and dolomite as well as metamorphic rocks, all covered by loess which was mostly eroded and removed.

The area is depopulated to the level of semidesert, the main branch of economy is forestry. Agricultural holdings are mixed livestock oriented. The region fulfils main criteria of EU for treatment as vulnerable, less favoured area (LFA), in which natural handicaps (shallow acid soils, intensive erosion, short vegetation period), cause lower agricultural productivity. Farmers get support for to continue farming activities and are obliged to adhere to the standards of Good farming practices. They help to maintain the scenic landscape as well as environmentally valuable habitats on vulnerable rural areas. Catchment areas of drinking water in this region would be designate as Nitrates Vulnerable Zones (NVZ).

The submountainous subregion (G-1) – Stagnosol- and Luvisol Acric-oriented tillage

This subregion rises gradually from the Pannonian plane towards the massif of the Dinara mountain range. It covers a territory populated by 30 inhabitants per km^2 only. The subregion is situated on a large karst plateau with very prominent and developed karst, with specific feature of landscape as numerous karst holes, known in the geological literature as "pock-pitted karst". Its other characteristic is that is covered by deep layers of well-developed soil (Bašić, 2005).

On flatter and lower parts of the subregion prevalent is red soil, which has been described in our literature as the so called relict Cambisol Rhodic (Terra rossa), as well as Luvisol Acric and Cambisol Distric formed on relict Terra rossa. On limestone and dolomites dominate Cambisol and Leptosol on limestone and dolomite. This subregion offers very favourable conditions for all arable crops, especially fodder crops and pastures for an efficient livestock breeding.

Cattle breeding have a long tradition and all economic measures for development of cattle breeding are of high priority. There are very favourable conditions for organic agriculture. Our experiences in growing of vegetable for row material in baby-food production on clean soils of this subregion are very affirmative. Because of some very valuable rivers like Dobra River, Mrežnica River and Kupa River and drinking water needs a special care. The only risk can be livestock breeding on large farms with high concentration of liquid manure. It is necessary to define standards of land management in plant growing on water protected area of Croatia.

The Mountainous subregion (G-2) – Acrisol-oriented tillage

This is a prominently forest subregion, with 61% of the area under the forest, and 38.3% of agricultural land. From the point of view of agriculture this is the most backward and least populated area of Croatia, with only 10 persons per km^2 – practically semi desert, but very high potential in all branches of agriculture. Although lithological rather homogenous, due to a series of other factors that bear on formation of soil, especially the relief and the vegetation, this area is pedologically very heterogeneous. The dominant agricultural soil type is Acrisol, but generally Cambisol and Leptosol on limestone and dolomite and relict Cambisol Rhodic (Terra rossa). Common characteristic of soil types is a good and favourable physical but unfavourable chemical properties, especially extremely high acidity of soils.

The subregion lacks good arable land. There are some karst fields (Krbavsko, Gacko, Ličko) as potentially good farmland – Leptosols, favourable for tuber and root crops, as well as vegetable. Farming systems in this subregion is dominantly based on cattle breeding, especially pastoral farming on natural pasture.

Advisable is according of EU rules this subregion to declare as Less Favoured Area (LFA), which means area where agriculture is hampered by permanent natural handicaps.

The major objective is to ensure the continuation of farming, thereby maintaining a minimum population level and preserving scenic landscapes and environmentally valuable habitats. The LFA measure is used as an additional payment, to compensate farmers for negative economic effects due to the conservation of these natural handicaps.

Our investigations show as the most important and absolutely profitable land reclamation measure is liming. Namely, combining liming with bacterization by nitrogen-fixing bacteria – *Rhizobium* on Acrisol near Plitvice lakes we prepared favourable condition for Alfa-alfa as very demanded but valuable fodder crop (Butorac et al., 1998).

The Adriatic agricultural region

Adriatic region is a typical karst area, with all, well known karst-phenomenon very populated in narrow Coastal zone, where constant pressure of soil is sealing – building urban structures with all consequences of this process. The dominant parent rocks are Mesozoic limestone and dolomite, as hard rocks, and flysh as soft and permeable material of high water holding capacity, which cause erosion and landslides. The main process of soil genesis on hard rock is dissolution of rock and accumulation of non-soluble residue on topographic stable position; highlands, depression, karst fields and holes and river valleys. The process is very slow and soils are shallow, because of for a soil layer of 1 cm deep is necessary 8 000 till 10 000 years, means for 1m deep soil one million years. Of course, it illustrates the responsibility of actual generation of soil users to care about soil and to save this valuable heritage for next generation. The next particularity of region is karst hydrology, with absolutely dominant underground flows of water of high quality for drinking and irrigation. Shallow soil layer can't fulfil natural function to be an efficient filter for water and protect water from pollution. In the karst landscape some rivers, called "karst beauties" cut waterbed deep into limestone. The most famous is Krka River – Croatian national park and Neretva River, with specific delta mouth. There are two interesting lakes; Vransko on Cres-island, positioned 70 m below of sea level with drinking water of high quality and Vransko near Zadar, which is connected with sea water and partly saline.

Spatial changes imposed by urbanization, construction of highways, exploitation of stone, and mostly continuing growth of tourism, intensive agriculture along the coastlines are causes of particular stress, especially focussed on soils. Agriculture is concentrated on proportionally small areas – karst fields and river valleys.

Separate problem of this region is a practice of preparing a specific Anthrosol by grinding and mixing top-layer of land with some soil, vegetation – maquis, pasture, bushes, trees, roots of bushes or trees and stone – limestone, for establishment of substratum for establishment of permanent plantations – vineyards and/or orchards. It is very risky, sometimes agricultural production-, but sometimes "space occupation"- motivated practice. Of course, there are substrates convenient for grinding, for instance; very deep soft limestone with high participation of soil mass (minimum 30%); soil on very deep layer regolites of limestone and/or dolomite; deep, only locally stony soils. But there is also such one without or with symbolic content of soil and vegetative mass which in every case can't give satisfactory results. Generally, all Anthrosols prepared by describing way are liable to erosion and/or land-flowing and landslides. Therefore, to protect the soil is necessary, at first; rows of plantation and all practices have to be contour line-oriented, second; tillage of inter-row space first years after establishment have to be shallow tilled, and third;

vegetation cover in inter-row space before, or as soon as possible after establishment of plantation.

The North Adriatic subregion (J-1) – Cambisol Rhodic (Terra rossa)-oriented tillage

This subregion covers Istria and Kvarner with related islands. On islands there is permanent tendency of depopulation, abandonment of land and agriculture as profession. Average annual precipitation is ranging 875-1215 mm, average summer period water deficiency is 120-140 mm, but in dry years 300-400 mm, but sufficiency is over 450 mm. The dominant parent rock, especially in Istria is Mesozoic – Cretaceous limestone on which is formed the most known and widespread soil type Cambisol Rhodic (Terra rossa), very fertile soil with typical red colour and favourable physical, chemical and biological properties and fertility. On higher topographic positions on Triassic and Jurassic limestone and dolomite there is formed Cambisol Calcic on limestone and dolomites, Leptosol on hard limestone.

On flysh (mix of marl and sandstone) are formed Leptosol, Regosol and Anthrosol. In this subregion there is enormous soil erosion shown in Table 2.

Table 2: Erosion of soils on flysh of istria

Watercourse	Catchm. area ha				Water erosion – classes (ha)				
					Excessive	Strong	Moderate	Weak	Very weak
		min	max	aver.	I	II	III	IV	V
Mirna	54 100	0,98	35,8	12,6	2 164	2 706	16 230	19 480	13 530
Raša	31 400	1,05	35,3	21,3	942	1 570	7 850	10 990	10 050
Boljunčica	22 990	7,29	20,9	14,1	916	1 145	6 870	870	5 270

Generally, the climate in Istria, especially high average annual precipitation and high maximal daily precipitation, are conductive to erosion. Our research has proved that the annual average erosion of soil in the basin of the Mirna river is 18.84 t/ha, of the Rasa river 31.97 t/ha and of the Boljuncica river 21.20 t/ha annually, which is more times over a tolerant annual erosion (Bašić et al., 2001, 2003). Consequences of such extremely high erosion in Istria are manifold. Besides of generally known and described a special one is eutrophisation of drinking water in accumulation of drinking water Butoniga, as well as sedimentation of eroded soil and reduction of useable volume of accumulation. Sedimentation of eroded soil material to Adriatic sea by Mirna River caused it's accumulation on the bottom of sea in coastal zone, which consequence is shallow water for use as harbour for larger ships.

On Regosol and Anthrosol as main flysh soils of Central Istria the only way for a sustainable management is Conservation agriculture, which means integral measures for reducing of erosion; soil cover (green cover of main crop and/or intercrop or weed) for alleviation of effect of blow of rain drops; reducing surface runoff by increasing of infiltration of water forming clods on arable land surface, forming grassed waterways in contour line direction. Catchment area of accumulation is necessary to declare as Nitrate vulnerable zone in which is advisable to practice Catchment Sensitive Farming scheme (CSF), as practised in UK, with the aim to reduce diffuse pollution.

In management of Cambisol Rhodic it is important to avoid bare soil. A favourable tillage system of this soil type depends on deepness of soil. In very deep varieties subsoiling is advisable, especially in dry and hot summer period, expected effects of irreversible coagulation of colloids important for stable structure formation. The same practice is favourable for establishment of permanent plantations. Permanent grass cover of inter-row space is an advisable practice in permanent plantations.

The Central Adriatic subregion (J-2) – Cambisol Calcic and Anthrosol-oriented tillage
This subregion is situated in central part of Croatian littoral, i.e. the area of Zadar and its hinterlands, as well as the related islands. In spite of quite populated with an agricultural land per capita of 1.53 ha (including extensive karst pasture) in practice of this subregion is traditionally very efficient agriculture, especially viticulture and horticulture; vine and vegetable, Mediterranean as well as continental fruit growing, all of the highest quality.

The subregion is a karst highland rather low and flat. It consists of a variety of limestone, mostly from the Cretaceous age. The prevalent soil type is Cambisol Calcic formed on limestone and dolomite, following by Cambisol Rhodic (Terra rossa), Leptosol on hard limestone and Leptosol Calcaric. Less prevalent are soils on flysh. All agricultural soils are under intensive anthropogenic influence, most of which is Anthrosol, originated from different soil types.
Separate, very sensitive question is the first Anthrosol “grindic” in Croatia becoming by grinding of soft Eocene limestone and soil material from Leptosol Calcaric with famous vineyard plantation Korlat near Benkovac city. Situated in protected catchment area of Park of nature Vransko Lake, this soil shows very high permeability for water, which means high risk of pollution of water in the lake by agrochemicals used in plantation. Main characteristic of water balance is a regular annual sufficiency in winter (more than 300 mm) and deficiency of about 550 mm in summer - vegetation period.

The Karst plateau is crossed by water valleys of three Karst beauties – Zrmanja, Cikola and Krka River. The Krka River valley is nominated as national park, which means that all commercial activities are restricted and strongly regulated. This subregion also features the largest fresh water lake in Croatia - Vransko Lake, mixing with the seawater, so is only partly and limited usable for irrigation. Around of lake, declared as Park on nature with restricted use of agrochemicals, there is a wide Vransko field with very fertile soil intensive used in vegetable growing.

It is advisable the whole subregion to declare as Nitrate sensitive area. Especially sensitive, because of specific karst hydrology are karst fields in coastal zone, hinterland and islands. All are in practically direct contact with fresh or sea water, which means that risk of eutrophisation and/or pollution, especially from soil of intensive plantations is very high. In the subregion hydrotechnical land reclamation has already been carried out by installation of draining pipe system on state farms. Furthermore, in the Karst fields stable water levels should be ensured by prevention of flooding and by pipe drainage. Yet, the need for irrigation is much more pressing.

This subregion abounds in high quality water for irrigation but the pressing needs for irrigation have not been met due to impermissible lack of investment. The multipurpose water accumulation would prevent flooding, stabilize the chaotic and unfavourable water regime, embellish the landscape and guarantee stable and reliable supply of high quality water for the annual crops and the plantations.

The South Adriatic subregion (J-3) - Anthrosol-oriented tillage
This subregion comprises the rest of the coast down to Dubrovnik and Konavle, i.e. to the state border, including the respective islands. It is karst territory, with two larger and very

specific agricultural area; Neretva River valley and Konavle – hinterland of Dubrovnik. The subregion is mostly built from limestone and dolomites, except of Konavle, where is flysh the dominant parent material. Prevalent area is a bare karst, but soil types are Cambisol Calcic formed on limestone and dolomite, following by shallow Leptosol Calcaric, but there are also large areas under hydromorphic soil – Fluvisol and Gleysol, both in the Neretva valley and in the karst fields, as well as Leptosol calcaric, Regosol and Anthrosol originated from soil on flysh.

Neretva valley is in many ways a special and extraordinary natural complex – a unique marsh habitat, one of the last remaining in Europe. There are also in continental part as well as on islands karst fields like most valuable oasis of agriculture within bare karst. There is also increasing area of Anthrosol “grindic”, as result of grinding different limestone and/or dolomites.

Given the characteristics of soils, for stable production and high and stable yields it will be necessary to carry out hydro and agro technical land reclamation. It is necessary to renovate, expand and repair the old systems, in karst fields of Imotski and Vrgorac water level should be regulated. Yet, much more important and economically more productive would be irrigation, for which should ensure a sufficient quantity of water, build accumulations and obtain appropriate infrastructure and equipment for irrigation. Revitalization of islands is a special and very complex problem, in centre of which is irrigation. It would be advisable to build reservoirs for collection of rainwater during the wet season.

The most important agricultural area is undoubtedly the valley of the Neretva River. Soils in the valley are very high quality, it abounds in water, but due to seawater penetration quality of the water is dubious. Seawater penetrates even further upstream than the town of Metkovic. Also salinized are underground waters, where the degree of salinity varies. Because of specific karst hydrology, very valuable and vulnerable water resources – (underground and on surface) the whole subregion needs a special treatment. Advisable is some parts of subregion of higher credibility and sensitive areas like karst fields to declare as Nitrate vulnerable zone in which is advisable to practice Catchment Sensitive Farming scheme (CSF), as practised in UK, with the aim to reduce diffuse pollution.

Conclusions

Taking in account the multifunctionality of soil, soil type, foreseen climate changes, means increasing of annual precipitation in continental part, but decreasing in Mediterranean and own experiences, we analysed situation in agricultural regions of Croatia for a framework of an efficient, adapted tillage system, and exclude some conclusions:

- Research in soil tillage for a long time was production (yield)-oriented. Environmental problems, especially natural resources pollution and climate change extort re-orientation to other, non-productive functions. The new farming and tillage system need to be set up, adapted to the erratic changes, to be a buffer system for mitigation of negative effects of climate changes.
- Precondition for any change and efficient use of tillage system is an accustomed land management policy which includes land consolidation, enlargement of farmland (farms), follows land reclamation – irrigation and/or drainage, liming and enrichment of humus content.
- The mean foreseen change of soil tillage is reduction of: depth and/or tilled area of land surface; kind and/or number of tillage operations, which in some cases leads to

exclusive no-tillage system. The leading principle would be: deep loosening – shallow tillage of seed bed and organic fertilizers or crop residue incorporation, as SOC accumulation-oriented practice. In some agricultural regions or specific areas it would be exclusively conservation tillage system.

- As the most radical change, no-tillage is possible to practice on very fertile soils of favourable physical, chemical and biological properties. Therefore, for most soil types of Croatia we see as reasonable and acceptable slogan: The first maximum (investment in soil amelioration) and then minimum (or no-) tillage!
- Creating the proposal of framework for soil-type- and climate-change-oriented tillage system we take in account the forthcoming accession of Croatia to EU i.e. respecting the accustomed policy instruments for establishment and practical realization of proposed system to the farm level.
- In new, changed conditions it is necessary to research to define Soil Organic Carbon Status Indicators (SOCSI), which means actual, minimal and maximal content and management policy - conservation (maintenance the level) or enhancement.
- Obligation of Croatia as future new member state is to establish the set of minimum standards for to keep the land in **G**ood Agricultural and **E**nvironmental **C**ondition (GAES) as precondition for an efficient use of incentives in agriculture.

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Status and perspectives of soil tillage in South-East Europe

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"Application of reduced / conservation soil tillage will make a good farmer is better, and the poor even poorer".

Abstract
Conservation or reduced soil tillage in different European Countries are mainly specific. This specific arise from different ecological conditions and from possibilities of acceptance a new scientific approaches and technological innovation, and partially of course from different conceptions in soil tillage approaches. However, in most countries conservation tillage are not accepted in proportions which are expected according their natural conditions and possibilities. It should not be forgotten subjective difficulties that require a higher level of education and greater sense of scientific approach to conservation tillage. The aim of this study was to determine the state of soil tillage in Croatia, Hungary and Serbia, and to determine the development prospects of conservation / reduced tillage systems.

Introduction

The agroecological conditions (climate, water, soil and biological resources) of the Carpathian Basin are generally favourable for arable crop production. According to the old paradigm, "…intensive crop production in tending to higher and stabile yields, need intensive and deep soil tillage and implementation high technological inputs…". However, this concept entails a number of issues, primarily, and especially at the present time, everything becomes more dominant equilibrium relationship between quality and quantity of products and ever more pronounced ecological and economic sustainability in crop production. Conventional or standard soil tillage, on which our farmers are accustomed, has a great advantages and great disadvantages. It is usually cited as advantages: ploughing (incorporation) of crop residues and weeds, chiseling the root zone (easier rooting of plants), incorporation of organic and mineral fertilizers, the accumulation of moisture in the autumn-winter period, control of diseases and pests, etc.

However, this traditional approach to conventional tillage, with all the advantages for growing crops, has its negative sides, especially in the domains of physical, chemical and biological complexes of soil fertility, causing increasing degradation and pollution of soil and environment. Regarding this, the most important changes that occur using conventional crop production, primarily tillage may be the following: anthropogenic soil compaction, loss of humus and stable soil structure, undesirable changes in soil reaction, cation exchange capacity and soil microbial activity, external and internal erosion, etc. (Table 1). Furthermore, conventional tillage is expensive (40% of the cost of agricultural production is attributed to the soil tillage, of which 80% of ploughing), it requires a lot of time, human and machine involvement, more rigorous organization of work in the optimum period, etc. Based on the foregoing, it is clear that the agriculture of today's increasingly understood from an ecological point of view, or environmental pollution, but also the economic aspect, and find solutions that can help in prevention, and improvement of soil degradation, and thus the environment.

One of the possible ways to solve these problems is in the domain of soil tillage, which is presented as a concept of *reduced tillage*, in which the so-called *”Conservation tillage”, ”minimum tillage”, ”rational tillage”* and *”no-tillage” (or “direct seeding”, or ”omitted tillage”).*

Table 1: Main characteristics of conventional and conservation (climate stress mitigation) tillage (Birkás et al., 2008a)

Factor	Conventional	Conservation
Purpose of tillage	Meeting plant requirements	Soil quality conserving or improving
Depth	Excesses (deep or shallow)	Depending on soil condition
Mode	Inverting	Ploughless
Surface	Free of residues	Covered to various degrees
Field residues	Something impeding tillage	Valuable material
Organic material	Diminishing	Preserving
Carbon balance	Input in soil < loss	Input in soil > loss
Tillage tool	Subordinated to tillage concept	Adapted to soil condition
Energy input	Excessive	Realistic
Adaptability to soil	Limited	Wide
Risks	Soil quality deterioration	Weeds, pests, pathogens
Impact on soil	Varying	Protection, renewal
Impact on plants	Sometimes positive	Positive
Long term impacts	Increasing climate-induced sensitiveness	Alleviating climate-induced threats

Different conceptions of reduced soil tillage occurred because of the settlement, primarily soil erosion by wind and water, the problem of accumulation of soil and water conservation in dry areas, preventing groundwater pollution, and reducing the consumption of energy, primarily oil and oil products, etc.

Farmers started to use reduced tillage and direct seeding, practiced since the beginning of the conscious cultivation of plants, but not in ways what we today perceive under reduced tillage and/or direct seeding. Invention of the first efficient ploughs in the 18th century marked a revolution in agriculture, with whom it had also come to the partial abandonment of "reduced tillage". Farmers were then thought: “*more intensive treatment - higher yields*, but the truth was *more intensive treatment - more soil degradation”*. Only after dozens of years, for the first time they observed also negative aspects associated with deep-ploughing of the soil. Plough, who had saved humanity from hunger, opened the way for many degradation processes in soil. In the modern and mechanized agriculture, there were several attempts to introduce reduced tillage and no-tillage technology in crop production, but without major success before the advent of modern herbicides. Only during the 40-ies of the last century, the discovery of effective herbicides and effective weed control, we were able to think about replacing the plough, as a basic tool in the soil tillage. The present areas under reduced tillage in the cultivation of crops in the world are not negligible and as example should include information pertaining to areas under direct seeding. It is estimated that the total global area under no-tillage cultivation technology of approximately 100 million hectares (Table 2, 3). It should be noted that in the applying of the no-tillage technology in the world, America (North and South) dominated with up to 96%, while the rest of the world, covering only 4%.

Table 2: Total area under No-tillage in different countries (hectares) 2000/2001, 2004/2005 and 2007/2008

Country [Source 1]	2000/2001 year
U.S.A.	21.120.000
Brazil	13.470.000
Argentina	9.250.000
Australia	8.640.000
Canada	4.080.000
Paraguay	960.000
México	650.000
Bolivia	350.000
Venezuela	150.000
Chile	100.000
Colombia	70.000
Uruguay	50.000
Others	1.000.000
Total	59.890.000
Country [Source 2]	2004/ 2005 year
U.S.A.	25.304.000
Brazil	23.600.000
Argentina	18.269.000
Canada	12.522.000
Australia	9.000.000
Paraguay	1.700.000
India, Pakistan, Bangladesh, Nepal	1.900.000
Bolivia	550.000
South Africa	300.000
Spain	300.000
Venezuela	300.000
Uruguay	263.000
France	150.000
Chile	120.000
Columbia	102.000
China	100.000
Others	1.000.000
Total	95.480.000
Country [Source 3]	2004/ 2005 year
U.S.A.	25.304.000
Brazil	23.600.000
Argentina	18.269.000
Canada	12.522.000
Australia	9.000.000
Paraguay	1.700.000
China	1.900.000
Kazakhstan	550.000
Bolivia	300.000
Uruguay	300.000
Spain	300.000
South Africa	263.000
Venezuela	
France	150.000
Finland	
Chile	120.000
New Zeland	
Columbia	102.000
Ukraine	
Russia	100.000
Others (estimate)	1.000.000
Total	95.480.000

Source 1: Derpsch i Benites (2003);Source 2: www.rolf-derpsch.com/profile.htm
Source 3: Derpsch, R. and Friedrich, T., 2008, unpublished data

From the foregoing it follows that the more developed countries were willing and open to acceptance of reduced tillage technologies. Such approaches have made a big step forward in resolving its large and accumulated problems concerning the ecology, energetic, production, organization, and economic aspects.

Also it should be noted that in most European countries, reduced tillage is not accepted in proportions that were realistic to expect based on their climatic and soil conditions. For such a state partially "culprit" are economic ability of individual countries in adopting new scientific knowledge and new technical and technological achievements, and partly a different approach to the treatment of soil, as well as the burden of tradition. Europe, especially Eastern, has the greatest potential for expansion of this technology.

In order to apply new technologies for soil tillage (and beyond) and successful as accepted, much greater openness and connection between farmers and scientific institutions are required.

Unfortunately, it is often the case that production is going ahead of the scientific practice of verification possibilities of a technology without a sufficiently strong experimental basis, given the great diversity of agroecological conditions and opportunities.

Table 3: Area under No-tillage by continent

Continent	Area (hectares)	Percent of total
South America	49.579.000	46.8
North America	40.074.000	37.8
Australia & New Zealand	12.162.000	11.5
Asia	2.530.000	2.3
Europe	1.150.000	1.1
Africa	368.000	0.3
World total	105.863.000	100%

We have witnessed major climatic changes (primarily changes in the water and temperature regime), which have large and perhaps the greatest impact on crop production. Regarding this, the soil tillage is necessary to be changed in order to achieve a safer and more stable production. Simplified, cheaper, more rational conservation and reduced tillage is one of the possibilities of overcoming the upcoming unfavorable climate (all the more extreme vegetation years), economic, market, organizational, socio-economic and other changes.

Soil tillage development in Pannonian region

Eras of soil tillage (as our tillage history)

On the basis of both land and machinery use the development of soil tillage can be divided into seven eras. Features and experiences characterized the theory and the practice of the soil tillage earlier gave a chance to determine the new tasks. The different periods cannot be exactly separated in time. The length of transition depends on progressive and depressive factors (Table 4).

The first era was characterized by the use of shallow working implements, deforestation, meadows changed to arable land. Land use and soil fertility were based on grazing, waste-land and woodland alternating systems, later fallow farming took place. Finally the two- and three – field fallow systems were widely used. The regeneration of soil condition was only influenced by the climate and during the fallow periods.

The low intensive farming techniques was enhanced by the food demand of increasing population, as well as the West-European demand for regional agricultural products. (The fallow system could not guarantee these demands). The change into crop rotations gave more advantageous in farming efficiency. Widening of tillage tools and propagation of better constructions occurred in West-Europe from the 1600s. In the middle of the 18th century, plough development started, inspired by the Brabantian and Hohenheim types. Owing to the well-constructed ploughs, tillage culture developed, and a deeper tillage ensured crop yield increase.

The **multi-ploughing system** was thought to-be modern only at the start. Ploughing 3-5 times a year – increasing the aeration of the soil –, the lack of fertilization, simplified rotations (maize-wheat) proved to damage soil structure. Authors called attention to the negative effects of inappropriate cultivation. The “multi-ploughing” system strengthened the traditional use of the plough and ploughing that was hard to change even nowadays.

Table 4: Soil tillage development in Pannonian region (Birkás et al., 2008a)

Eras of soil tillage development	Impacts on soil tillage quality (negative-positive)
1. Early (-1600)	Lack of tools and expertise (-)
2. Introduction of low intensive farming techniques (1600-1800)	New demands of crop production (+)
3. Multi-ploughing systems (1750-1900)	Soil structure deterioration (-)
4. Early adaptable tillage (1860-1930)	Adoption to soil (+)
5. Conventional tillage (1900-1988)	
5.1. Classic, based on draught animal (1900-1960)	Dependence weather conditions and draught power (-)
5.2. Temporary, partially mechanized (1920-1970)	Improvement in soil state (+)
5.3. Technology focused, fully mechanized (1975-1988)	Improvement in mechanization (+), Overestimation of the importance of mechanization (-)
6. Energy saving and soil conservation tillage (1975-1988)	Harmony between energy saving and soil conservation (+)
7. Modern Adaptable tillage (1988-2015)	
7.1. Declining period (1988-2000)	Economic resource shortages (-), Scarce supply of machinery and implements (-), Deteriorating soil condition (-), Land size (-)
7.2. Period of transition (2000-2015)	Climatic harms (-), New tasks and challenges in soil and environment conservation (+)
7.3. Soil and environment conservation period (?2015-)	Recognition of sustainability principles (+), Improvement in soil quality (+)

Early adaptable tillage aimed at carrying out only those procedures which were inevitable for crop production and at conserving the biological condition of the soil, thus to slowing down the process of soil degradation. Ploughing was reduced to one/year, deeper tillage was done when it was needed and proper soil state was maintained. At the beginning of the 20th century the disk, cultivator and other new tools gave good background for this last activity.

The first decades of "reasonable tillage" can be characterized as the classical period of "*dry farming*" as well. Dry years required more efficient tillage methods to survive under unfavourable ecological conditions. Between 1907-1914 and 1920-1930 (the years of Campbell's fever) many farmers tried and applied his method, used his disk and special roll that has been rediscovered nowadays (however, the Campbell' system based on a multi-traffics tillage, and damaged the soils in 6-8 years). In the 1920s the "*movement against the plough*" by Bippart, from Germany had only theoretical influence in the region. The era of "reasonable tillage" was the period of different powered machinery (animal, steam-engine and tractor) too. The steam-engine which had no traffic in the field was really a protective method in soil conservation. The simple ideas "*the deeper the better*" and "*better with plough*" reflected the negation of the "movement against the plough".

The roots of the **conventional systems** go back to the “multi-ploughing” system. The main characteristic, ploughing in the primary tillage operation originated from there, but plough was used only once or twice a year. The other characteristic still remained and it was the “multi traffic”. Conventional tillage cultivates the total surface, and the deepest operation is based on the plough. New and more operations are used to get the proper soil condition. In such a way this system is a “multi-traffic” one, the required soil state can be reached by high energy, cost and time.

In the first stage of the conventional systems *animal-drawn power* was general with the single use of ploughs and other simple tillage tools. In the *temporary, partially-mechanized systems* tillage operations that required deeper depth, more power or shorter working time were done by engine draught. “Partial” means the parallel existence of animal and engine draught power in the different sized farms. In these systems engine draught power had two faces: it meant better efficiency and in some cases, destruction of soil structure.

There was a conference on soil tillage in Wageningen in 1962 where answers had been given to the questions as follows: “*Is there a need to loosen the soil with high costs when it is necessary to compact it later, according to the need of crops*?” In the conclusion of the conference criticism of the conventional system could be found too; since it was not able to reduce processes causing soil damage.

In our region the conception of deep ploughing was forced and disputable at the beginning of the 1950s, although it had not lasted long, but almost until the mid-1970s there were no new tendencies in cultivation. The *periodical deepening tillage* had only temporary success (e.g. with the state subsidy of deep loosening) and the results of minimum tillage experiments (including direct drilling) were not as popular as it could have been thought. Thus in this important period of agricultural development almost the conventional tillage systems ruled, based on the plough (non-reversible plough).

The stage of technology focused, fully mechanized tillage systems took place from the mid-seventies till the end of the eighties. The use of high powered machinery became general; besides the evident economic benefits, disadvantages e.g. deeper soil compaction could also be seen. However, advantages became more and more over-estimated, while the biological life of the soil was disregarded. Over-mechanization refers only to the number of traffic that remained unchanged or showed only a slight decrease. Although there was wide choice in soil and crop specific technologies, the chances in soil conservation were only partly utilized. Due to development of machinery and wide variety of equipment at this stage of conventional tillage, there was the possibility of reducing traffic in the fields and give more attention to soil conservation. This fully mechanized tillage had real technical advantage, compared to previous ones, but less attention was given to the biological life of the soil and the utilization of good workability.

Energy saving tillage practices gained place because of external and internal pressure. The most important factors were as follows: increase of oil costs, dry years, competition of Western-European and North-American technologies and equipment. *Minimum tillage* included elements of soil conservation because of the effect of dry years as it had happened in the beginning of the century. Stubble and straw burning was prohibited thus manufacturers and farmers were forced to look for new technical and management practices which solved the incorporation of straw and other crop residues.

The most important task of *conservation tillage* was to minimize the losses of soil and soil moisture. Unfortunately the special conservation tools were developed only at the end of the period. Farmers could not try earlier these tools thus the need for wider use did not grow. The “era” was too short to make radical changes in soil and environment conservation. On the other hand, the strength of convention gave always safety in case of uncertainty. In the early years of the eighties a part of new investment was focused on conservation tillage but the change of machinery and the need for soil conservation did not last long.

The task of **adaptable tillage** is the harmonization of soil conservation and demand of crops with ecological and economic conditions. The latter determines more the tillage possibilities of the first stage – *declining* – of the era. Production and development decreased because of loss of markets and lack of capital and they indirectly influenced cultivation as well. Demand on high level and conservation tillage has decreased, the choice of equipment got narrower (because farmers are unable to buy spare parts) where it may cause direct risk in production (compacted layers, frequent shallow tillage).

During the *period of transition* – that is: today – new opportunities for improvements in tillage are offered by encouraging the production of high quality produce, by a new appreciation of expertise and recognition of the need for soil conservation and environmental protection as well as by a rich great variety of machinery and equipment available in the market. A growing demand for machines suitable for soil conserving tillage and improvements in soil conditions at quite a number of holdings are signs of progress. A *phase of soil conservation and environmental protection* should begin depending on the effectiveness of the Community and national soil conservation endeavours and efforts and its duration should be determined by the extent to which such practices are adopted across the farming community.

Soil tillage in Croatia

Croatia has a total land area of 5,660,000 ha, of which 1,289,000 ha (22.8%) is agricultural land, and 836,000 ha (14.8%) is arable land. Owners of total arable land are approx. 80% private family farm and approx. 20% is a legal entity (*Statistical Yearbook, 2009).

Table 5: Harvested area and production of some important crops

Crop	Harvested area (000 ha)	Yield per ha (t)
Maize	314	8.0
Wheat	157	5.5
Barley	66	4.3
Sunflower	39	3.1
Soybean	36	3.0

*Statistical Yearbook, 2009

Pannonia region (Croatian part) has 48% of agricultural land and 75% of arable land in total land of Croatia (Bašić et al. 2001). Average yields of major crops in Croatia are relatively low (Table 5), a proper application of appropriate soil tillage systems yields could be significantly improved. Such low yields are most of the farmers' “main argument” for not accepting the new soil tillage technology - *“... if these low yields with application of ploughing, how low would have been with application of reduced soil tillage ?! ..."*.

In the Croatian region, reduced tillage is not a novelty (the first survey conducted in the mid-70s of last century). Unfortunately, this technology is still used very occasionally and in small areas, with rarely examples in practice. Such soil tillage involves ploughing at 25-30-35 cm (depending on the crop farming), disc harrowing, soil seed preparation, etc. (Jug et al., 2010). The reasons for our big delays for the developed world in terms of reduced soil tillage are numerous, and the main reason is the great burden of tradition, which is difficulty for accepting new concepts, especially if they fundamentally change the established (traditional) norms. Following reason is the low technical and technological development of our farms, and low level of knowledge required in the continuous application of this technology.

At the present time in the Republic of Croatia in the crop production almost always used conventional tillage (Jug et al., 2006), and reduced soil tillage in most cases the only economically feasible for reasons of production (Kanisek et al., 1999; Košutić et al., 2001), or as an alternative system (Jug et al., 2007).

In the region of Slavonia and Baranja are still ploughing as a primary soil tillage treatment, applied to about 94% of the area (Košutić et al., 2005). However, the estimate is that at last few years some form of reduced tillage is applied to more than 10%.

In Croatia in the last 10 years of intensive research carried out the applicability of reduced soil tillage systems, but still very limited (Jug et al., 2010) and with divergent results (Butorac et al., 2006). One of the most important reasons is that the scientific research is often delaying after practical agriculture.

As a confirmation of earlier report, in Croatia we have no official statistical data about land area under reduced soil tillage.

Croatian trends in soil tillage

As already stated, the development and adoption of reduced / conservation tillage systems in Croatia are relatively slow. However, the past few years the acceptance of other tillage systems (primarily of reduced tillage), which exclude ploughing is experiencing significant changes. This acceptance is the result of significant joint involvement of scientists and farmers, but it is probably the most important reason is that the detected positive financial effect of reduced tillage systems compared to conventional tillage system. Unfortunately, the other positive effects arising from the application of conservation tillage systems are still in the background, such as: reduction of soil erosion (Kisić et al., 2005), increase biogenity and quality of soil (Jug et al., 2008; Šeremešić et al., 2009), less traffic and soil compaction alleviation (Jug et al., 2009; Birkás et al., 2009), nutritional status an quality traits of crops (Jug et al. 2006; Sabo et al., 2006; Jug et al., 2007; Stipešević et al., 2009; Jug et al., 2010), weed infestation (Knežević et al., 2006; Jug et al., 2009) etc.

The most common and most applied reduced tillage system is diskharrowing as basic tillage treatment for winter wheat, and the period of application of reduced tillage on a field is usually one growing season, and then re-applies system with conventional ploughing. For this reason, in Pannonian region is very "popular" *discontinuous* tillage systems (Jug, 2006), which include the application of the reduced system in the inning with a conventional system every two years. However, some farmers applied *continuous* reduced tillage systems with variable success.

Example of 8-year long experiment with soil tillage for w. wheat and soybean in continuity and discontinuity systems: four of them with continued soil tillages: I) Conventional tillage based on ploughing; II) Diskharrowing; III) Chiseling and diskharrowing; IV) No-tillage; and four of them with discontinuity soil tillage: V) Conventional tillage for soybean (odd years) and diskharrowing for winter wheat (even years); VI) Conventional tillage for winter wheat (odd years) and diskharrowing for soybean (even years); VII) Conventional tillage for soybean (odd years) and No-till for winter wheat (even years); VIII) Conventional tillage for winter wheat (odd years) and No-till for soybean (even years).

Soil loosening applied instead ploughing is usually performed as a measure of repair of compacted soil mainly breaking tillage pan, which followed by diskharrowing. Soil loosening as a measure or treatment of reduced tillage is applied only sporadically. Other applied tillage systems which exclude ploughing are more in the domain of rational tillage systems (few tillage operation in one pass), and less in the domain of reduced and/or conservation tillage.

No-tillage is applicable in Croatia on a very small area, which is primarily the result of insufficient knowledge of farmers, but also the lack of quality tools and machinery for direct sowing. And in these smaller areas, where applicable no-tillage technology the usually applies discontinuous tillage systems, and there is no continuity in the application of technologies required in the cultivation of field crops.

With regard to reduced / conservation tillage systems, especially on a large number of soil types on which the production of crops takes place in Croatia, is still a lot of unknowns, primarily with the physical, chemical and biological aspects.

In Croatia there are a lot of negative examples of unsuitable application tillage systems, but Croatia has great potential to be used. In this regard, investigations of conservation / reduced tillage should be extended to all the main soil types and all crops, especially to those who are expecteing a positive response from conservation tillage.

Soil tillage in Hungary

The total area of Hungary is 9,303,000 ha, of which 60% or 5,585,000 ha is agricultural land, while 48.4% or 4,500,000 ha is arable land. Soils can be characterised as follows: sand 15%, sandy loam 12%, loam 47% and silty clay and clay 26%. 34.8% of soils are sensitive to degradation and compaction, 13.9% non-sensitive, 23.0% slightly and 28.3% has moderate sensitivity (Birkás et al., 2008b).

Hungarian trends in soil tillage

Trends in soil tillage systems were compared to the standards and estimated on the basis of data-collection and self-analysis of observed farms. Factors of the estimation were: results and/or defects in soil conservation according to physical state, level of machinery and knowledge, execution level of tillage operations, impact of tillage systems on soils, number of tillage traffics, and soil physical condition on their fields (Table 6).

Conventional - developing

Soil conservation by a conventional way and using up-to-date equipment, (reversible ploughs, combined surface preparation tools) and apply the subsoiling periodically.
Soils are free from degradation processes, disregarding a light degree of dustiness in the plough layer. Soil is usually maintained in a good condition.

Conventional - stagnating
It can be characterised ambitions for soil conservation with a poorer assortment of tillage tools. Soil degradation (compaction, dustiness) covers up to 25%, or less of the fields.

Conservation - fully
The number of traffics is limited rationally by the help of knowledge and tillage tools (heavy-duty cultivators, seedbed preparation and plant combination, chisels etc.) and technique. The most important features of tillage are the carbon and water conservation, the energy save and the adaptation to the soil condition. Tillage is omitted on too dry or wet soils to eliminate the harmful clodding, dusting, smearing or puddling.

Conservation -partially
Applying the soil conservation tillage and having a medium or a high level of machinery with an imperfect level of the knowledge. The level of conservation is equal to damage of the soils.

Reduced of constraints
It forced to save in energy and tillage traffic because of the lack of capital and appropriate equipment. A greater problem is the imperfect level of the knowledge. Deterioration in soil physical (the diskpan compaction and/or the dustiness of topsoil are typically) and biological state are observed.

Table 6 Trends in soil tillage in Hungary in the end of the 1990s and in 2009

Tillage method and percent adoption (in the 1990s)	Requirements of soil tillage	Impact on soil quality	Percent adoption in 2009
Conventional: 50			45
Developing: 10	soil state maintenance	favourable	35
Stagnating: 40	cost saving only	unfavourable	10
Conservation/sustainable: 25			48
Fully: 5	long-term conservation	improving/ maintaining	35
Partially: 20	occasional conservation	favourable	13
Reduced of constraints: 25	over-minimum	harmful	7

The development of tillage is determined by the following factors in the first decade of the 21st century:

- *separation of mass production from the production of high quality produce* by production site or in accordance with land use (intensive, extensive, integrated, ecological),
- local and regional tasks of *soil conservation and environmental protection*,
- reduction of energy and cost input,
- *mitigating adverse or harmful impacts of local* (site) *conditions and circumstances* (drought, severe rainfalls) that have long been or that have become unfavourable,
- transformation of land use, *new demands* to be met by tillage,
- adaptation to *landscape production*,
- improved *utilisation* of the results of scientific progress,

- expanding range of machines on offer that are *adaptable to specific conditions and circumstances* in addition to those that are suitable for a larger variety of tasks,
- *development of extension and control network* to prevent environmental damage, with the aim of improving the standards of farming.

Soil tillage in Serbia

The state and development of tillage in Serbia

Scientific and technological development world-wide also resulted with an intensification of agricultural sector. Continuous demand for the soil to create the best conditions for growing plants could be fulfilled only with the effective cultivation. Organized research on cultivation of R. Serbia started in 1957 and in the framework of these activities; special attention has been devoted to the study of plough depth and methods of primary tillage, the application of different fertilizers, and the amount of organic and mineral fertilizers in the primary tillage and seedbed preparation.

For developing a principals of soil tillage for each crop, theoretical achievements of different countries were used, but the research was based primarily on scientific concepts elaborated by Todorovic, who was first developed basis of creating a deep, fertile and homogeneous soil surface with method "establishing the plowlayer". Further research was based upon the prolonged effects of deep tillage treatment and the possibility of introducing the different reductions in the process of soil preparation. This research involved the research of interaction of depth and intensity of organic and mineral fertilization (Molnar, 1995).

In our country from the beginning of practical introduction of scientific results soil tillage developed in two directions: towards greater depth and in increasing the number machinery passes (intensification). Today the conventional (traditional, classical) tillage method is based on the mouldboard ploughs, or ploughing. Primary tillage is mainly performed by ploughs regardless of soil moisture content, follow by the secondary tillage with tools for additional seedbed preparation. The conventional tillage of soils with heavy mechanical composition (high content of clay) is more demanding with many difficulties in terms of maintaining favourable mechanical and physical properties of water-efficient land and energy consumption in terms of intensive farming and irrigation applications. Considering the fact that only the ploughing consumes 50-55% of the total energy in the soil preparation, or 38-42% of the total production of some crops, it was logical to assume that in this segment must be the solutions for rationalization (Kovacevic, 2003).

Currently, relatively poor state of research on cultivation imposed alternative, first of all to intensify research in this area.

Serbian trends in soil tillage

Rapid technical development of tools for soil tillage in recent decades allowed the modernization and development of cultivation in Serbia, as well as the introduction of new simplified system of tillage. Revision the tillage system goes towards the reduction and minimization of soil treatment. The first experiments with systems of cultivation in our country started 1963. During the 1981 experimental trials with conservation tillage based on harrow are set at 17 locations across Vojvodina. This study lasted for 5 years and total of 125 experiments were carried out in all regions of Vojvodina. At that time, disposable equipment, and therefore possible options and the quality of the performance of certain operations were at much lower level than today (Škrbić and Garalejić, 2002).

In recent years, in Vojvodina, conservation tillage for small grains became the dominant system of treatment, even though the sowing is still done mostly with conventional seeding machines. The focus of the application of new technologies in sowing small grain is on the reduction of work operations, reducing the number of applied working machine and spending hours, as well as the implementation of new standards in environmental protection. The main soil conservation tillage systems applied in Serbia are: (i) **reduced tillage system**, which means any process that ensures that at least 30% of the land is covered with the remains of harvest; (ii) **mulch tillage** in which sowing precede treatment without the soil turning (often with chisel, disk ploughs or cultivators with various constructions) that provides loosen and fragmented soil; (iii) **partial width till**: just before planting soil tillage is performed in the sowing zone, up to one third of the total area (strip tillage) or planting in the raw bank, which are performed in the same pass (ridge tillage, beeding system) and (iv) **no-tillage** that encompasses the use of no-till seeders with the removal of harvest residues and loosening tools in the area of planting up to 5 cm, with the system disk or coulters of a different design. Each of these systems has its subsystems, which are applied in dependence on agroecological conditions and requirements of the grown crop. Systems and subsystems of conservation tillage are implemented with tractors or independent mechanical units and machines. The working parts of the units are individual tools and machines, and their appropriate combinations.

A key factor in the selection of the appropriate conservation system lies in the choice of tools for tillage and seeding. However, research in this area is quite modest in our country (Momirović, 1998; Kovacevic et al., 1999; Molnar et al., 1999). Kovacevic et al. (1999) performed a comparative study of conventional and conservation tillage influence on chernozem soil type. Conservation tillage system compared to conventional, decrease yields of winter wheat (25-30%), spring barley (5.7-51.9%), maize (24.6-24.9%) and soybean (35.0-39.4%), (Table 7).

Table 7: The effects of tillage systems on yields of maize and soybean (t ha^{-1}), (Kovačević, 2003)

Tillage systems	Maize		Soybean	
	(t ha^{-1})	(%)	(t ha^{-1})	(%)
Conventional tillage	7.11	100.0	3.92	100.0
Reduced tillage	5.44			
No-till system	5.25			
Reduced tillage total	5.34	75.1		
Protective tillage > 30% mulch	5.21			
No till system > 30% mulch	5.50		2.55	65.0
Conservation tillage total	5.36	75.4	2.37	60.6

Recent research is directed towards the adaptation of minimal tillage with positive effects on physical properties of soil, particularly the structural stability of aggregates, the possibility of direct seeding and finding the most desirable features of direct seeding using special, for this purpose constructed seeding machines (Milosev et al., 2010). Soil tillage could be completed with an omission of soil intervention and completely reliant to direct seeding machines and the efficient protection with herbicides. When all this occurs, a number of problems will appear which are related to the inability to achieve effects that is only possible to achieve with plough (fertilization, control of perennial weeds, etc.). For these reasons, various difficulties and obstacles emerged due to regional character and aims that we want to achieve with tillage. Numerous predictions and studies indicate that reduced cultivation systems in Europe in the future will occupy vast areas, while the share of regular conventional areas is in a significant degree of decrease (Molnar, 2002; Jug, 2005; Birkas, 2008).

Conclusion

In three countries of Pannonian region: Croatia, Hungary and Serbia as a main problem in acceptance of temporary trends of reduced / conservation soil tillage is impropriety level of knowledge.

Changes in tillage systems are oriented towards the following goals: to stop land degradation, the revitalization of the structure and improving water and air properties of soil, reducing soil erosion (caused by wind and water), improving soil biogeny, reducing energy consumption, reducing emissions of carbon dioxide and the risk of global pollution; reduce the required number of machines, reducing time for tillage operations; achieve maximum profits and other conservation tillage and intercropping aggregates for soil tillage and planting in a significant degree may reduce investment, with regard to environmental requirements in land use.

Greater or lesser effectiveness of a particular tillage system depends on many elements, and some of the most important are: the climate (weather conditions, soil), the availability of appropriate machinery, appropriate cultivars (varieties), etc. If it is a known fact that in most developed countries of the world area under reduced tillage, and direct seeding without tillage, measures millions of acres, it is clear that reducing the depth and intensity of tillage is not only going in the less developed countries. Reduced tillage is a result of serious scientific research and practical testing, and it is the result of better and more comprehensive observation and understanding of the natural environment.

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[Session:]

[1. Soil tillage in function of environmental protection]
[2. Soil biotic and abiotic degradations – causes and consequences]

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Soil tillage and crop management and their impact on sustainability and soil physical characteristics

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Abstract
There is the strong decline of mouldboard ploughing during transition period from 90% to 60% of arable land in Slovakia due to economic, marketing and environmental reasons. For adoption of environmental sound tillage systems the research and dissemination is needed. The aim of research was to evaluate the influence of conventional and reduced tillage, FYM and residue management on soil bulk density (SBD) and porosity. The field trial was carried out over the period 2004-2006 at the experimental farm PD Kalná nad Hronom in south-western Slovakia. The sugar beet-spring barley-sunflower crop sequence was evaluated. The soil tillage treatments as follows: T1 conventional mould board ploughing with farm yard manure (FYM) application to sugar beet and incorporation of aboveground biomass of growing crops; T2 conventional mould board ploughing without organic fertilization; T3 no-till Horsch CONCORD CO 9. During June the soil samples were taken from 0.05-0.10m, 0.1-0.20m, 0.2-0.3m. The SBD and total porosity was highly significantly influenced by growing crops and weather conditions of evaluated years and SBD was also significantly influenced by tillage system. The positive effect of FYM on total porosity was noted in 2004 during sugar beet phase which is in relationship with SBD 1.266 t m^3-1.279 t m^3 in topsoil layers 0.5-0.20m. In subsequent evaluated years 2005-2006 the topsoil layers 0.5-0.20 m were more compacted with comparison to 2004 after first year of FYM application. In three year average, the conventional mould board ploughing with farm yard manure and incorporation of aboveground biomass form the most suitable soil environment (SBD 1.395 m^3, total porosity 43.65%) but we also recommended the no-till (SBD 1.455 m^3, total porosity 42.31%) for Haplic Chernozems in this specific area of Slovak region.

Keywords: soil bulk density, straw management, tillage systems, total porosity

Introduction
Reduce tillage techniques indicate a positive impact on environmental components, as reduced energy needs and greenhouse gas emissions, reduced erosion along with reduced run-off of nutrients and pesticides subsequently affecting water quality, and farm management aspects like reduced time and cost of production. As negative side-effects, we recognised crop protection aspects (use of herbicides, pesticides), and the specialised knowledge required to apply conservation agriculture. Despite the overall positive balance, we nevertheless emphasised the gap between the outcome of experiments and daily farming practice (SoCo, 2010).

The evaluation of man-induced (secondary) susceptibility of soils to compaction focuses primarily on soils that are intensively cultivated, mainly with root crops. These soils are continuously ploughed and the crop requires repeated machinery use among others for the application of fertilisers or pesticides. Secondary susceptibility is expected to be higher in big fields (typical for the countries of Central Europe) where the use of heavy machinery is indispensable.

In the Central Europe, from the end of the 1990s, new requirements have also been introduced because of the rise in energy prices and because of the need to cut production costs (Birkás et al., 2008a).

Economic changes and environmental policy are driving forces for reduced tillage systems also in Slovakia. Share of mouldboard ploughing decrease from 90% to 60% during the transition period (Table 1).

Table 1: Share (%) of primary soil tillage systems on arable land in Slovakia during 1970-2009*

Period	Mouldboard ploughing			Reduced tillage without plough		
	deep ≥0.24 m	medium 0.18-24 m	shallow ≤0.18 m	stubble tillage ≤ 0.18 m (disking, loosening)	before sowing ≤ 0.10 m	direct drill
1970-1989 socialist period	35	50	5	7	3	0
1990-1999 transition period	15	28	17	18	13	9
2000-2009 post-transition period	15	40	8	23	10	4
Outlook 2010-2019	12	28	10	35	10	5

*Smatana 2010. Own investigation.

Soil condition is assessed in terms of aspects of workability, suitability for crop production and the soils impacts on the environment. Tillage-induced subsoil compaction has often occurred in the Pannonian region in relation to traffic-induced compaction and has become a soil management problem (Birkás et al., 2009).

The increasing of soil density is implemented by self-weight of soil or it is caused by intensive rainfalls during a growing season. In winter time the changes of soil bulk density (SBD) are activated by the ploughing effect of winter frosts (Franzluebbers, 2002). The SBD and total porosity is considered to be an integral indicator of the soil habitat quality (Logsdon and Karlen, 2004). Good soil storage water depends upon appropriate tillage management (Kováč and Švančárková, 2003; Kvaternjak et al., 2008). The importance and influence of tillage systems on physical and environmental characteristics is broadly recognized (Jug et al., 2008; Birkás et al., 2008b; Boja et al., 2008).

The aim of this work was to evaluate the influence of tillage (conventional and reduced) FYM and residue management on the on soil bulk density (SBD) and porosity.

Material and methods

The field trial was conducted at the experimental farm Kalná nad Hronom (south-west Slovakia) in 2004-2006. Experimental farm is situated in warm and moderate arid climatic region. The average annual rainfall is 539.0 mm. The average annual rainfall during the growing season is 320.3 mm. The mean annual temperature is 10.2˚C. The mean temperature during growing season is 16.3˚C. Soil in the area was developed on loess and it is according to FAO classification as silt loam Haplic Chernozems (FAO, 2006). The particle-size distribution is 280.3 g kg^{-1} of sand, 533.7 g kg^{-1} of silt and 186.0 g kg^{-1} of clay. Some chemical and physical characteristics of the soil profile (0–0.3 m) determined in 2004 before the start of the present study are given in Table 2.

Table 2: Chemical and physical properties before experiment

pH	6.30
Organic carbon (g kg^{-1})	15.3
Total nitrogen (mg kg^{-1})	1400
Hydrolytic acidity (mmol kg^{-1})	9.15
Sum of basic cations (mmol kg^{-1})	390.8
Total sorptive capacity (mmol kg^{-1})	399.9
Base saturation (%)	97.7
Bulk density (t m^{-3})	1.51
Porosity (%)	40.1
Maximum capillary water capacity (%)	34.,7
Wilting point	10.3
Available water capacity	21.8

Selected soil physical properties – soil sampling were set by the Kopecky method with cylinders with the cubic content 0.001m^3 in four replicates. Soil samples for measuring the soil bulk density (SBD) and total porosity were always taken in the layers from 0.05 up to 0.30 m. The spring and summer weather conditions are documented in the Table 3.

Table 3: Spring and summer weather conditions at the farm Kalná nad Hronom during the experimental years 2004-2006

Month	N30 (1960-1990)		2004		2005		2006	
	ºC	mm	ºC	mm	ºC	mm	ºC	mm
IV.	9.6	46	11.8	39.6	11.7	71.7	12.7	43.2
V.	15.1	67	14.2	50.2	16.5	45.2	15.1	84.9
VI.	18.3	64	18.1	88.7	18.8	46.1	19.7	90.3
Average for spring (IV.-VI.)	17.6	-	14.7	-	15.7	-	15.8	-
Sum for spring (IV.-VI.)		177.0	-	178.5	-	163.0	-	218.4
VII.	20.3	63	20.2	25.8	20.9	75.4	24.0	14.3
VIII.	19.6	56	20.5	13.8	18.7	114.9	18.6	114.1
IX.	15.8	54	15.3	46.5	16.9	40.1	17.7	30.8
Average for summer (VII.-IX.)	18.6	-	18.7	-	18.8	-	20.1	-
Sum for summer (VII.-IX.)	-	173.0	-	86.1	-	230.4	-	159.2

Three tillage practices on selected physical soil characteristics were evaluated. The sugar beet-spring barley-sunflower crop sequence was evaluated. The main plot with four replicates was 10 m by 550 m. The soil tillage treatments as follows: T1 conventional mould board ploughing with 40 t ha^{-1} farm yard manure (FYM) application to sugar beet and incorporation of aboveground biomass of sugar beet, spring barley and sunflower; T2 conventional mould board ploughing; T3 no-till Horsch CONCORD CO 9. During June the soil samples were taken from 0.05-0.10 m, 0.1-0.20 m, 0.2-0.3 m. The total porosity and soil bulk density was determined by core samples of 0,001m^3.

Results and discussions

The experimental years 2004-2006 were largely different from the aspect of weather conditions. The effect of tillage and crop residue management on total porosity and SBD is documented in tables 4-6 in different soil layers. The positive effect of FYM was noted in 2004 during sugar beet phase of rotation in first and second soil layers 0.05-0.10 m (T1 47.47%) and 0.10-0.20m (46.93%) which is in relationship with SBD 1.266 t m^3 and 1.279 t m^3 in topsoil layers 0.5-0.20 m. In subsequent evaluated years 2005-2006 the topsoil layers 0.5-0.20 m were more compacted with comparison to 2004 after first year of FYM application.

Table 4: Effect of tillage systems on soil physical properties in soil layer 0.05–0.10 m at Kalná nad Hronom, 2004–2006

Tillage	Total porosity in %			Soil bulk density in t m^3		
	2004	2005	2006	2004	2005	2006
T1	47.47	43.39	41.54	1.266	1.438	1.485
T2	40.20	42.52	41.61	1.513	1.460	1.483
T3	44.65	46.92	34.17	1.406	1.400	1.672

The wet spring support the water balance of soil under sunflower, expressed by water content 27.7-29.3% in 2006. The most compacted soil layers were noted in 2006 under canopy of sunflower. No till treatment (T3) influenced the less infiltration rate of soil profile (24.3-21.6-19.36%) with comparison to mouldboard ploughing treatments. The same tendency concerning infiltration rate noted also Kováč et al. (2005) on Luvi-Haplic Chernozem with loamy to clay-loamy texture.

Table 5: Effect of tillage systems on soil physical properties in soil layer 0.10 – 0.20 m at Kalná nad Hronom, 2004–2006

Tillage	Total porosity in %			Soil bulk density t m^3		
	2004	2005	2006	2004	2005	2006
T1	46.93	44.4	42.82	1.279	1.340	1.427
T2	40.32	41.38	42.93	1.510	1.485	1.448
T3	47.17	41.3	37.66	1.342	1.400	1.579

The effect of precipitation influenced also the less total porosity in 2006 in all soil layers from 34.17 to 38.5%. SBD in no till treatment, range from 1.43-1.49 t m^{-3} in all evaluated layers.

Table 6: Effect of tillage systems on soil physical properties in soil layer 0.20 – 0.30 m at Kalná nad Hronom, 2004–2006

Tillage	Total porosity in %			Soil bulk density in t m^3		
	2004	2005	2006	2004	2005	2006
T1	39.42	46.92	40.00	1.460	1.343	1.518
T2	39.61	41.91	40.00	1.528	1.485	1.518
T3	44.10	47.83	38.50	1.420	1.320	1.556

The knowledge of the soil porosity is of the highest importance because the whole dynamics of soil depends on it (Boja et al., 2008). We evaluated temporal and spatial dynamics of porosity. The incorporation of FYM and aboveground residues significantly influence the increasing of total porosity with comparison to lack of organic matter incorporation. No differences between soil layers were noted. Due to wet conditions and secondary predisposition to compaction we noted insufficient porosity in 2006 under canopy of sunflower. The soil bulk density has inverse relationship to porosity in evaluated years.

The effect of tillage and growing crops on total porosity and soil bulk density is documented in the Tables 7 and 8.

Table 7: Effect of tillage systems and growing crops on total porosity (%) in evaluated soil layers at Kalná nad Hronom, 2004–2006

Tillage		Depth		Crops	
T1	43.65b	0.05-0.10 m	42.27a	Sugar beet	43.31b
T2	41.09a	0.10-0.20 m	42.83a	Barley	43.83b
T3	42.31ab	0.20-0.30 m	41.96a	Sunflower	39.91a
$LSD_{0.05}$	2.07208		2.07208		2.07208
$LSD_{0.01}$	3.01488		3.01488		3.01488

Means followed by the same letter are not significantly different at the P<0.05 probability level within tillage treatments, depth and crops respectively

Weather conditions with tillage treatments create specific physical conditions. This is in accord with the information about differences of soil physical properties caused by different tillage, published by Skukla et al. (2003) and Kováč et al. (2010).

Soil compaction is the rearrangement of soil aggregates and/or particles by reducing or even eliminating voids and pores between aggregates and particles, causing the soil to become denser. The porosity of the internal aggregates is also influenced (Birkás, et al., 2008a).

Table 8: Effect of tillage systems and growing crops on soil bulk density (t m^3) in evaluated soil layers at Kalná nad Hronom, 2004–2006

Tillage		Depth		Crops	
T1	1.3951a	0.05-0.10 m	1.4581a	Sugar beet	1.4137a
T2	1.4922b	0.10-0.20 m	1.4233a	Barley	1.4078a
T3	1.455ab	0.20-0.30 m	1.4608a	Sunflower	1.5206b
$LSD_{0.05}$	0.04746		0.04746		0.04746
$LSD_{0.01}$	0.06905		0.06905		0.06905

Means followed by the same letter are not significantly different at the P<0.05 probability level within tillage treatments, depth and crops respectively

Conventional mouldboard ploughing with appropriate residue management (T1) creates significantly better soil condition but no significant differences between soils layers were noted (Table 8). The further investigation for adoption of appropriate tillage technique is needed.

Conclusions

The results present characteristics which are binding with soil tillage and climate conditions. The pressure of the reform of CAP EÚ on soil environment protection will lead to more intensive implementation of environmentally friendly and conservation soil management which can be qualified as having sustainable effect on environment quality. According three years study the conventional mould board ploughing with farm yard manure, and incorporation of aboveground biomass of growing crops, form the most suitable soil environment (SBD, total porosity) but we also recommended the no-till for this specific area of Slovak region.

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Effect of nitrogen fertilization under reduced soil tillage on chloroplast pigments concentration in leaves of winter wheat

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Abstract
The scope of this research was to determine concentration of chloroplast pigments in the winter wheat leaves influenced nitrogen fertilization under reduced soil tillage. The research for winter-wheat has been conducted at the Virovitica-Podravina County in 2008/2009 , with six different nitrogen rate (controla-0 kg N ha^{-1}, 30 kg N ha^{-1}, 60 kg N ha^{-1}, 90 kg N ha^{-1}, 120 kg N ha^{-1}, 150 kg N ha^{-1}, respectively) with following continuous soil tillage treatments: CT – conventional soil tillage, based on mouldboard ploughing; DH – multiple pass diskharrowing; and NT – No-tillage. The chloroplast pigments have been measured in stem extension (after Feekes: 6.0). This research showed that chlorophylls are very sensitive to changes in nitrogen content: concentration of chlorophyll a, chlorophyll b, chlorophyll (a+b) and carotenoids increased with higher fertilization rate. Tillage did not significantly effect on concentration of chloroplast pigments.

Keywords: soil tillage, nitrogen fertilization, chloroplast pigments

Introduction
Chlorophyll content is one of the indices of photosynthetic activity (Larcher, 1995). Many authors have established that chlorophyll synthesis is dependent upon mineral nutrition. Mineral nutrition significantly affects the dynamics of leaf surface formation and the extent of leaf surface, which is reflected in the sum total of leaf area, photosynthetic potential and photosynthetic productivity. Of all macroelements the greatest influence on development of plants is general and their leaf area is exerted by nitrogen. Nitrogen is an integral part of many compounds essential for life processes of plants and different plant nitrogen supply is reflected primarily in the synthesis of proteins and enzymes, many of which participate in the construction of the photosynthetic apparatus in the reactions of photosynthesis. Nitrogen beneficial effect on the development of leaf area while, also extending the physiological activity of leaves. According to numerous authors nitrogen content is closely correlated with chlorophyll content in leaves of wheat (Karele, 2001). Reduced nitrate assimilation by plants causes decreased synthesis of pigments, and lower net photosynthesis. The external factors with their variability and intensity significantly impact plant's growth and development, and yield quantity is determined not only by crop's genome, but also with different agroecological conditions and applied agrotechnology (Vukadinović et al. 1989). The photosynthesis is determined by numerous internal and external factor, such as: plant's development conditions, degree of adaptability to environmental conditions, water and nutrient supply, temperature, quality and quantity of the light, CO_2 and O_2 concentration, etc. (Jug et al., 2008). Numerous researches have been pointing out dependency of chloroplast pigments concentrations by growth and

development of the crop, and pigment concentration and photosynthesis intensity are in close dependency with ontogenetic winter wheat growth (Jug et al., 2010).

In recent years, many investigations showed the need to reduce conventional tillage systems in the production of crops, including wheat (Jug, 2006; Kovačević et al., 2007,). The necessity of reducing tillage occurred for a number of negatives that have caused the continued implementation of conventional tillage (Jug, 2005). An increasing number of studies directly related to the production of wheat under various unfavourable agroecological and production conditions, with the main objective of increasing yields, with the least investment in production.

No-tillage methods can affect the soils physical structure. Surface residue greatly reduces erosion and evaporative water loss, increasing water retention in the field. However, long-term continuous no-till soil profiles also have a greater number of macropores and wormholes, increasing water infiltration rates compared to conventional tillage (Edwards et al, 1988; Eck and Jones, 1992). No-till also affects soil nitrogen dynamics, potentially altering optimum nitrogen fertilizer inputs compared to conventionally tilled soils. Producers have traditionally used more nitrogen fertilizer on no-till fields because of increased N immobilization. Microbial immobilization of inorganic nitrogen during the decomposition of previous crop residues is dependent on the C:N ratio. Carter and Rennie (1982) reported wheat under 12 to 16 year continuous no-till had 20 to 30 % greater potentially mineralizable nitrogen compared to similar conventionally tilled soils. However, immobilization is the primary process responsible for the need for additional early season nitrogen fertilization of no-till wheat compared to conventional tillage methods (Gaidos, 2001).

The main objective of this research was to establish the influence of different dose of nitrogen fertilization and reduced soil tillage systems at the chloroplast pigments concentration in winter wheat at the Virovitica-Podravina County. This investigation should contribute toward better understanding of each soil tillage system on growth, development and yield of winter wheat.

Materials and methods

Field trials were established at two sites and two types of soil, which according to the classification of soils (Škorić, 1985) belong to a class of automorphic (AS) and hydromorphic soils (HS), with the following chemical properties:

Table 1: Soils properties

soil type	pH (H_2O)	pH (KCl)	mg P_2O_5/100 g soil	mg K_2O/100 g soil	humus (%)	$CaCO_3$(%)
HS	8,13	7,05	12,1	16,25	3,9	2,5
AS	6,16	5,44	18,5	18,5	1,36	3,68

The main experimental set-up was a complete randomized block design in three replications, with six nitrogen fertilization treatments and with three continuing soil tillage systems:

CT – conventional tillage with ploughing up to the 30 cm as a primary tillage, followed by diskharrowing, sowing preparation and sowing with no-till driller John Deere 750A;

DH – diskharrowing only up to the 15 cm and sowing as for CT
NT – No-tillage sowing without any primary tillage operation.

Size fertilizer plot was 120 m^2 (4 x 30 m). Fertilizer treatments were as follows:

N1 – control (0 kg N ha^{-1})
N2 – 30 kg N ha^{-1}
N3 – 60 kg N ha^{-1}
N4 – 90 kg N ha^{-1}
N5 – 120 kg N ha^{-1}
N6 – 150 kg N ha^{-1}

Basic fertilization was done with NPK 7:20:30, in the amount of 350 kg ha^{-1}. The control treatment with 0 kg N ha^{-1} was carried out only individual phosphoric and potassium fertilizers. Were performed and two top dressing as follows: 1st top dressing - 12 March 2009; 2nd top dressing - 20 April 2009.

The winter wheat cultivar "*Gabi*" ("Agrigenetics", Osijek) was sown at the planned rate of 500 germinating seeds m^{-2}, at the inter-row distance of 15 cm.

The samples of winter wheat for chloroplast pigment analysis were sampled in stem extension phenological stage (according to Feekes: 6.0). The positions for leaf collection were chosen by the appearance and condition of the crop, with precautions needed for proper average sample collection. For chloroplast pigments analysis the 0.1 g of fresh weight of the most developed leaf was taken. The concentration of chlorophyll a, chlorophyll b, chlorophyll a+b and carotenoids were determined spectro-photometrically (at wave lengths 662, 644 and 440 nm) from an acetone extract using the methods of Holm and Wettstain and expressed in mg g^{-1} of fresh weight (FW) (Arsenijević and Pajević, 2002).

Leaf greenness (SPAD readings) or relative concentration chlorophyll in leaves of winter wheat was measured with chlorophyll meter (SPAD 502, Minolta) on the same phenological stage and on the same places where was taken samples for determine chlorophyll concentration. The chlorophyll meter makes instantaneous and non-destructive readings on plant based on the quantification of light intensity absorbed by the tissue sample (Minolta Camera Co, Ltd., 1989).

Results and discussion

On AS concentration of chloroplast pigments were under significant influence of fertilizer treatment (Table 2). The highest value was detected on N6 treatment (1.631 mg chlorophyll a g^{-1} FW), and lowest on N1 treatment (1.010 mg chlorophyll a g^{-1} FW).

By split-plot method it was determined that varying of chlorophyll a on HS was strongly influenced by amount of nitrogen (Table 2). The average concentration of chlorophyll a on HS was 1.419 mg g^{-1} FW. The highest chlorophyll a concentration was recorded on N6 treatment (1.778 mg g^{-1} FW), and the lowest on control (1.203 mg g^{-1} FW). Interaction Tillage x Fertilizer was very significant.

The concentration of chlorophyll a increased with the amount of nitrogen amount, because nitrogen is component of photosynthetic pigments. According Vukadinovic et al. (1987)

mineral nutrition stimulates the development of the photosynthetic apparatus and the intensity of its action, whereby the efficiency of the photosynthetic apparatus directly determines the speed of accumulation of organic matter, and nitrogen nutrition has a significant impact on the development of the leaf area.

Table 2: Chlorophyll a concentration (mg g^{-1} FW) for three different soil tillage systems and six different N fertilizer treatments

		N1	N2	N3	N4	N5	N6	average
AS	CT	1.016	1.093	1.183	1.216	1.482	1.596	1.264
	DH	1.218	1.069	1.082	1.229	1.299	1.621	1.253
	NT	0.795	0.991	1.007	1.136	1.345	1.675	1.158
	average	1.010 d	1.051 cd	1.091 cd	1.194c	1.375 b	1.631 a	1.225
HS	CT	1.253	1.364	1.374	1.418	1.437	1.681	1.421
	DH	1.386	1.202	1.308	1.499	1.633	1.740	1.461
	NT	0.970	1.074	1.399	1.433	1.461	1.912	1.375
	average	1.203	1.213	1.360	1.450	1.511	1.778	1.419

Very close link between chlorophyll and nitrogen content many investigators proved (Evans, 1983; Filed and Moony, 1986; Amaliotis et al., 2004). It is understandable, because nitrogen is a structural element of chlorophyll and protein molecules, and thereby affects formation of chloroplasts and accumulation of chlorophyll in them (Tucker, 2004; Daughtry, 2000).

Table 3: Chlorophyll b concentration (mg g^{-1} FW) for three different soil tillage systems and six different N fertilizer treatments

		N1	N2	N3	N4	N5	N6	average
AS	CT	0.270	0.276	0.312	0.338	0.333	0.435	0.327
	DH	0.314	0.281	0.282	0.326	0.346	0.431	0.330
	NT	0.198	0.246	0.230	0.301	0.354	0.439	0.295
	average	0.261	0.268	0.275	0.322	0.344	0.435	0.317
HS	CT	0.450	0.403	0.387	0.395	0.382	0.375	0.399
	DH	0.306	0.322	0.358	0.438	0.471	0.483	0.396
	NT	0.378	0.388	0.473	0.281	0.377	0.373	0.378
	average	0.378	0.371	0.406	0.371	0.410	0.410	0.391

The chlorophyll b concentration on AS was significantly influenced by fertilize treatments (Table 3). As was expected, the lowest chlorophyll b concentration was recorded on control (0.261 mg g^{-1}FW). The greatest chlorophyll b concentration was measured on N6 treatment (0.435 mg g^{-1}FW). All differences in fertilizer treatments were statistically significant, except differences between N3, N2 and N1, respectively.

Bojović and Marković (2009) were studied relation between nitrogen and chlorophyll content at some wheat cultivars, and their found very close correlation between nitrogen content and total chlorophyll content.

The ANOVA for chlorophyll concentration (a+b) (Table 4) on AS showed very significant impact of fertilizer treatment. The highest chlorophyll concentration (a+b) winter wheat had on N6 treatment (2.062 mg g^{-1} FW) and the lowest on control (1.267 mg g^{-1} FW).

Table 4: Chlorophyll (a+b) concentration (mg g $^{-1}$FW) for three different soil tillage systems and six different N fertilizer treatments

		N1	N2	N3	N4	N5	N6	average
AS	CT	1.283	1.366	1.492	1.550	1.811	2.027	1.588
	DH	1.528	1.347	1.361	1.552	1.641	2.049	1.580
	NT	0.990	1.234	1.234	1.434	1.695	2.111	1.450
	average	1.267	1.316	1.362	1.512	1.716	2.062	1.539
HS	CT	1.593	1.743	1.770	1.819	1.835	2.142	1.817
	DH	1.444	1.521	1.670	1.913	2.068	2.267	1.814
	NT	1.215	1.380	1.789	1.817	1.856	2.443	1.750
	average	1.417	1.548	1.743	1.849	1.920	2.284	1.793

On HS chlorophyll concentration (a+b) was under significant influence of fertilizer treatment and interaction Tillage x Fertilizer. The highest value of chlorophyll (a+b) concentration was detected on N6 treatment (2.284 mg g^{-1} FW), and the lowest on N1 treatment (1.417 mg g^{-1} FW).

Carotenoids play an important role in the light harvesting complex and in the photo protection of the photosystem. Biosynthesis of carotenoids in winter wheat is genetic characteristic, but environmental conditions also have an essential role. Concentration of carotenoids, on both type of soil, was under significant influence of fertilizer treatments (Table 5).

Table 5: Carotenoids concentration (mg g^{-1} FW) for three different soil tillage systems and six different N fertilizer treatments

		N1	N2	N3	N4	N5	N6	average
AS	CT	0.388	0.488	0.466	0.457	0.570	0.601	0.495
	DH	0.460	0.430	0.442	0.495	0.508	0.621	0.493
	NT	0.333	0.419	0.449	0.457	0.558	0.611	0.471
	average	0.394	0.446	0.453	0.470	0.545	0.611	0.486
HS	CT	0.473	0.547	0.524	0.564	0.547	0.637	0.549
	DH	0.441	0.488	0.518	0.581	0.648	0.662	0.556
	NT	0.361	0.427	0.547	0.549	0.570	0.763	0.536
	average	0.425	0.487	0.530	0.564	0.588	0.688	0.547

The highest value was recorded on N6 treatment (AS - 0.611 mg g^{-1} FW; HS – 0.688 mg g^{-1} FW), and the lowest on control (AS - 0.394 mg g^{-1} FW; HS – 0.425 mg g^{-1} FW). The same results were obtained by Bojović and Stojanović (2005). According to their results lowest carotenoid content was measured on unfertilized soil.

SPAD reading was affected by fertilizer treatment and varying from 25.2 to 44.4. Soil tillage did not effect on SPAD readings. On both soil types, highest SPAD reading was measured on N6 treatment (AS - 40.8 and HS – 44.4), and the lowest on control (AS - 25.2 and HS – 30.1). All differences between fertilizer treatments were significant, except between N4 and N3 fertilizer treatment, and between N3, N2 and N1 treatment.

Table 6: SPAD values for three different soil tillage systems and six different N fertilizer treatments

		N1	N2	N3	N4	N5	N6	average
AS	CT	25.4	27.3	29.6	30.4	37.0	39.9	31.6
	DH	30.5	26.7	27.0	30.7	32.5	40.5	31.3
	NT	19.9	24.8	25.2	28.4	33.6	41.9	28.9
	average	25.2	26.3	27.3	29.8	34.4	40.8	30.6
HS	CT	31.32	34.1	34.3	35.5	35.9	42.0	35.5
	DH	34.6	30.1	32.7	37.5	40.8	43.5	36.5
	NT	24.2	26.8	34.9	35.8	36.5	47.8	34.4
	average	30.1	30.3	34.0	36.3	37.8	44.4	35.5

Conclusions

One of the important factors indicating the efficiency of nitrogen fertilization is the performance of the photosynthetic apparatus that determines photosynthetic pigment contents in leaves. Chlorophylls are very sensitive to changes in nitrogen content. According to our results, concentration of chlorophyll a, chlorophyll b, chlorophyll (a+b), carotenoids and SPAD readings increased with higher fertilization rate. Fertilization with nitrogen enables to manage physiological indices during wheat vegetation. Nitrogen metabolism affects wheat photosynthesis and controls plant development. Tillage did not significantly effect on concentration of chloroplast pigments.

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Soil tillage as the key issue in soil preservation under actual and altered climatic conditions

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Abstract
Changes in climatic conditions in both possible directions - increase or decrease of annual precipitation and mean annual temperature, will actualize the issue of soil conservation by tillage. I order to estimate the effect of the current climatic conditions, soil loss was measured on Stagnic Luvisol of sloping terrain in the Daruvar area in six different tillage treatments and the following crop rotation: maize – soybean - winter wheat - oilseed rape – double crop (barley + soybean). The highest erosion in the 15-year period was recorded in the control treatment. Following was the treatment that involved ploughing and sowing up and down the slope. Lower soil losses were recorded in no-tillage treatments and treatments with ploughing and sowing across the slope. Higher soil losses were recorded in spring row crops growing (Maize and Soybean) than in winter crops (Wheat and Oilseed rape). In the current climatic conditions an average loss of 0.45 cm of the plough layer was recorded in the control treatment, which means that the entire plough layer be completely eroded away in a period of 57 years. In ploughing and sowing up and down the slope treatment average soil loss was 0.08 cm and plough layer would be completely eroded away in a period of approximately 300 years. In all other treatments which we recommend for the area of Stagnic Luvisol the soil could be preserved for the next several thousands of years. The primary goal of this investigation was to define the amount of soil that would be eroded under different tillage treatments in altered climatic conditions.

Keywords: soil tillage, soil loss, climatic change

Introduction and objectives of investigation

Water induced soil erosion is influenced by tillage (especially by the ploughing direction in relation to slope), crop selection, planting direction or orientation, and the amount, distribution, and intensity of rainfall. The primary objective of this investigation is to determine the characteristics of water erosion on Stagnic Luvisols (ISSS-ISRIC-FAO, 2006) and then to find the answer to the question whether it is possible, and to which extent, to reduce erosion to an acceptable level (soil loss tolerance – T values) by applying different soil tillage treatments in growing agricultural crops. Based on the obtained results, the optimal tillage for Stagnic Luvisols, a soil very prone to water erosion, should be determined. The physical composition (i.e. high content of fine sand), chemical properties (i.e. low pH value, calcium carbonate deficiency, low content of soil organic matter) and very low structural stability make those soils highly susceptible to water erosion on slopes. The results should provide guidelines for recommending the optimal method of tillage on Stagnic Luvisols, as a remarkably widespread soil type in this part of Europe.

Materials and methods

The experimental field was located near Darvuvar in central Croatia (N: 45°33' 48" E: 17°02' 06") and was initiated on Stagnic Luvisols following the oil-seed rape crop harvest in the summer of 1994. Erosion was measured on six plots, according to the USLE (Universal soil loss equation - Wischmeier and Smith, 1978) protocol, which specifies a plot area of 41.3 m^2 (22.1 m long and 1.87 m wide) on a 9 % slope. Sheet metal borders were used to fence off the plots, and were removed before each tillage operation and then ~ ⸝ 4 11½2 !¼4 1À!¿ ∘Â! ¾½ÄÂ¿ !for the remainder of the growing season. Filtration equipment was set up at the lower end of each plot and clean water was collected in a container. To facilitate the use of agricultural machinery, the plots were set 15 m apart to allow the tractor with the longest trailing implement to easily turn at the ends. Mechanical operations, tillage direction (with respect to slope), and the row orientation or planting direction for the six treatments are described in Table 1.

Table 1: Tillage treatments on experimental field

Description	Tillage direction	Planting direction
Control treatment - bare fallow (USLE protocol)*	Up and down	No crop
Plowed to 30 cm; disked and harrowed	Up and down	Up and down
No-tillage, seed drilled into mulch 2-3 cm, weeks after applying total herbicides	Up and down	Up and down
Plowed to 30 cm, disked and harrowed	Across the slope	Across the slope
Plowed to 60 cm, disked and harrowed	Across the slope	Across the slope
Subsoiled to 60 cm with tines spaced at 70 cm, plowed to 30 cm, disked and harrowed	Across the slope	Across the slope

**Maximum runoff and soil loss was expect in this treatment*

The crops on each experimental plot (apart from the control treatment) were grown in a rotation that is typical for this agricultural area: maize (1995; 2000 and 2008), soybean (1996; 2001; 2005 and 2009), winter wheat (1996/97; 2001/02 and 2005/06), oilseed rape (1997/98; 2002/03 and 2006/07) and double crop – spring barley with soybean (1999 and 2004). Erosion risk was calculated by comparing soil loss per treatment with soil loss tolerance (T), according to the following equation:

Erosion risk = Soil loss (t/ha/year) : Soil loss tolerance (10 t/ha/year)

Soil loss tolerance (T value) for this soil type has been estimated at 10 t/ha/year (Kisic et al., 2003). Based on the difference between the tolerance value and the recorded erosion in particular treatment, erosion risk has been evaluated for the studied tillage practices using the criteria of Auerswald and Schmidt (1986): insignificant ≤0,20; small 0,21-0,50; moderate 0,51-1,00; high 1,01-2,00; extreme 2,01-4,00 and disastrous >4,01.

To elucidate the extent to which the studied tillage practices present a hazard to their sustainability, annual soil losses were calculated in centimetres of soil loss recorded in the growing of the test crops. For this calculation the bulk density (Table 2) and depth of arable layer of 25 cm were used. Relating the weight of such arable layer to the weight of the recorded soil loss renders data on annual soil loss in centimetres in different tillage practices applied in growing tested crops. The time period, i.e. the number of years in which the plough layer would be completely eroded away if a particular test crop was grown, was estimated.

Results and discussion

Soil properties

Parent material at this site is loess of Upper Pleistocene origin - Riß, Würm (i.e. loess transformed into mottled, non-carbonate loam). Soil texture throughout the profile is more or less sandy loam. The soil was acidic throughout the profile and there was very little soil organic matter. Phosphorus availability was classified as medium and potassium availability was classified as good (Table 2).

Table 2: Physical and chemical characteristics of Stagnic Luvisols evaluated on the experimental plots

Soil horizon	Depth of horizon (cm)	Particle size distribution ($g\ kg^{-1}$)[a] Coarse sand (2-0.2 mm)	Fine sand (0.2-0.02 mm)	Silt (0.02-0.002mm)	Clay (< 0.002 mm)	Texture class
Ap + Eg[b]	0 – 24	18[c] ± 4.7	586 ± 37	242 ± 35	154 ± 25	Sandy loam
Eg + Btg	24 – 35	21 ± 5.5	571 ± 59	260 ± 54	148 ± 44	Sandy loam
Btg	35 – 95	5 ± 2.3	545 ± 69	254 ± 32	196 ± 40	Sandy loam
Average value of soil bulk density (ρ_b)[d] after 15 years of investigation, $Mg\ m^{-3}$, 0-10; 10–20 and 20 -30 cm						
Control treatment	Plowed to 25 cm, up/down	No tillage	Plowed to 25 cm, across the slope	Plowed to 60 cm, across the slope	Subsoiled to 60 cm, across the slope	
1.57 ± 0.10	1.57 ± 0.15	1.53 ± 0.10	1.50 ± 0.13	1.54 ± 0.10	1.46 ± 0.10	
1.61 ± 0.10	1.64 ± 0.15	1.54 ± 0.10	1.65 ± 0.13	1.70 ± 0.10	1.66 ± 0.10	
1.67 ± 0.10	1.66 ± 0.10	1.58 ± 0.10	1.66 ± 0.10	1.63 ± 0.10	1.61 ± 0.10	
Soil horizon	Depth of horizon (cm)	pH, KCl	Soil organic matter ($g\ kg^{-1}$)	Available P ($kg\ ha^{-1}$)	Available K ($kg\ ha^{-1}$)	
Ap + Eg	0 – 24	4.21[c] ± 0.15	16 ± 3.3	172 ± 18	308 ± 6	
Eg + Btg	24 – 35	4.20 ± 0.18	14 ± 4.2	65 ± 4	123 ± 8	
Btg	35 – 95	4.81 ± 0.23	6 ± 3.8	244 ± 24	502 ± 12	

[a]Average of all treatments; [b]according to ISSS… (2006); [c]data expressed as average of all treatments, four replications ± standard deviation

Figure 1 shows soil loss in relation to the crops that were grown. Low density spring row crops (maize and soybean), had a significantly higher soil loss compared to high density winter crops in all treatments.

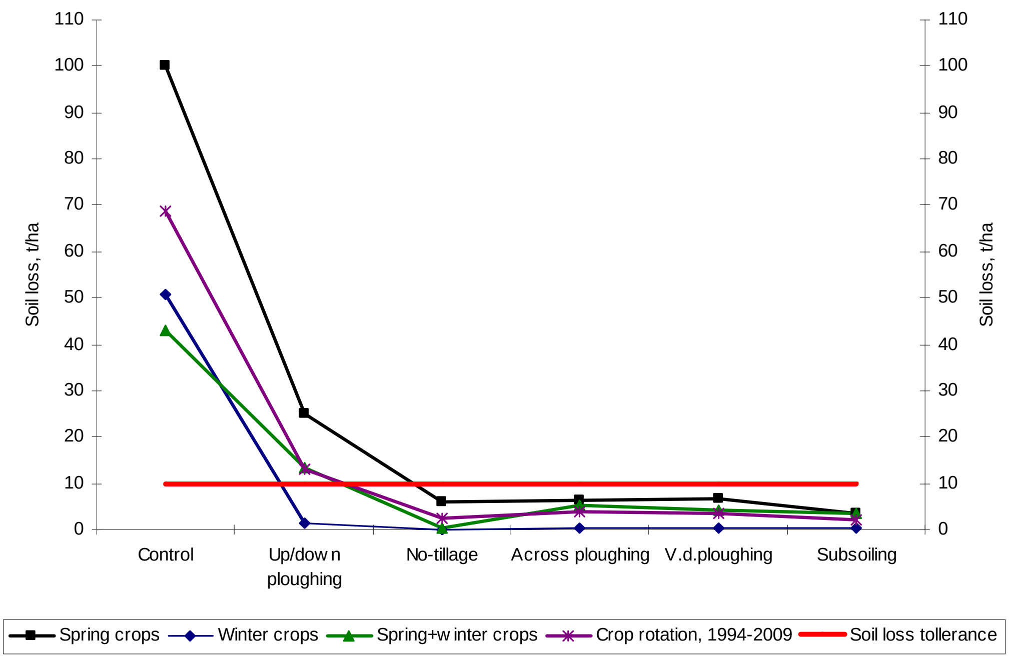

Figure 1: Soil loss under different tillage treatments and crops

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Likewise, a significantly higher soil loss in growing of spring row crops was observed in treatment with ploughing up and down the slope in comparison with the no-tillage and the treatment with ploughing and sowing across the slope. In low density spring row crops growing, in up and down the slope tillage treatment the soil loss exceeded the soil loss tolerance level. In winter crops of high density growing (winter wheat and oilseed rape) significant differences between the investigated tillage treatments were not observed. Soil loss in high density winter crops growing, in all soil tillage treatments, was by far below the soil loss tolerance level.

Table 3: Soil loss and erosion risk under different tillage treatments and crops

Treatment	Control treatment	Up/down the slope ploughing	No-tillage	Ploughing	Very deep ploughing	Subsoiling+ ploughing
				across the slope		
Spring row crops (maize and soybean)						
Soil loss, cm/ha/year	0,714	0,170	0,038	0,044	0,046	0,023
Loss of arable layer of 25 cm, in years	35	147	661	574	548	1.086
Erosion risk	Disastrous	Extreme	Moderate	Moderate	Moderate	Small
Winter high density crops (winter wheat and oil seed rape)						
Soil loss, cm/ha/year	0,352	0,009	0,001	0,003	0,001	0,002
Loss of arable layer of 25 cm, in years	71	2.863	25.333	8.780	16.905	13.036
Erosion risk	Disastrous	Insignificant	Insignificant	Insignificant	Insignificant	Insignificant
Double crops – spring crops (soybean) + winter crops (barley or wheat)						
Soil loss, cm/ha/year	0,307	0,094	0,002	0,036	0,030	0,023
Loss of arable layer of 25 cm, in years	81	267	12.258	699	847	1.071
Erosion risk	Disastrous	High	Insignificant	Moderate	Small	Small
Total crop sequence, 1994-2009						
Soil loss, cm/ha/year	0,455	0,092	0,014	0,028	0,025	0,016
Loss of arable layer of 25 cm in years	55	273	1.745	896	986	1.545
Erosion risk	Disastrous	High	Small	Small	Small	Small

Table 3 shows the soil loss (cm/ha/year) under different soil tillage treatments, as well as the time period in which the plough layer in spring or winter crops growing, as test crops, would be completely eroded away. As expected, in all investigated years, the soil loss was the highest in the control treatment and it varies within the disastrous values. Extreme soil loss was also observed in low density winter crops growing. If low density spring crops were grown on this type of soil every year, with up and down the slope ploughing and sowing tillage treatment, the plough layer of 25 cm would be completely eroded away in 147 years. In all other treatments the plough layer would be lost in more than 500 years. In high density winter crops growing the annual loss of the plough layer amounts to less than 1 millimetre, which means that there is absolutely no danger of plough layer complete erosion, not even in the distant future. Similar results were observed in double crops regarding the average soil loss during the investigated period (1994-2009). Somewhat below the sustainability level (320 years) was only the up and down the slope tillage treatment. Soil erosion protection considers every tillage treatment as unacceptable if it enables a complete loss of plough layer in the period shorter than 320 years (Njøs, 1994). The observed results obviously show that in row crops growing - maize and soybean, ploughing up and down the slope is unacceptable, even though it is a common practice in

this area. There is no doubt: this practice should be abandoned. The results recorded for tillage treatments of high density winter crops in any direction and investigated methods were within the tolerance levels.
Based on soil loss tolerance level and the amount of actual soil loss in growing investigated crops under different treatments, the erosion risk was calculated. For ploughing up and down the slope treatment, in low density spring crops growing, the erosion risk is extremely high, and for no-tillage treatment it is moderate. For tillage treatment across the slope in spring crops growing the erosion risk is moderate to small. For all tillage treatments of winter high density crops (apart from control treatment) the erosion risk is insignificant. When the whole period of 15 years of crop rotation is taken into consideration, the erosion risk for control treatment is disastrous, for up and down the slope tillage treatment it is high, and for all other treatments the risk is small.

These results point to the conclusion that during the year, the soil should be kept bare for the shortest period possible (Birkas, 2008). Ploughing and sowing spring crops of low density on sloping fields is unsustainable method of soil management in this area.

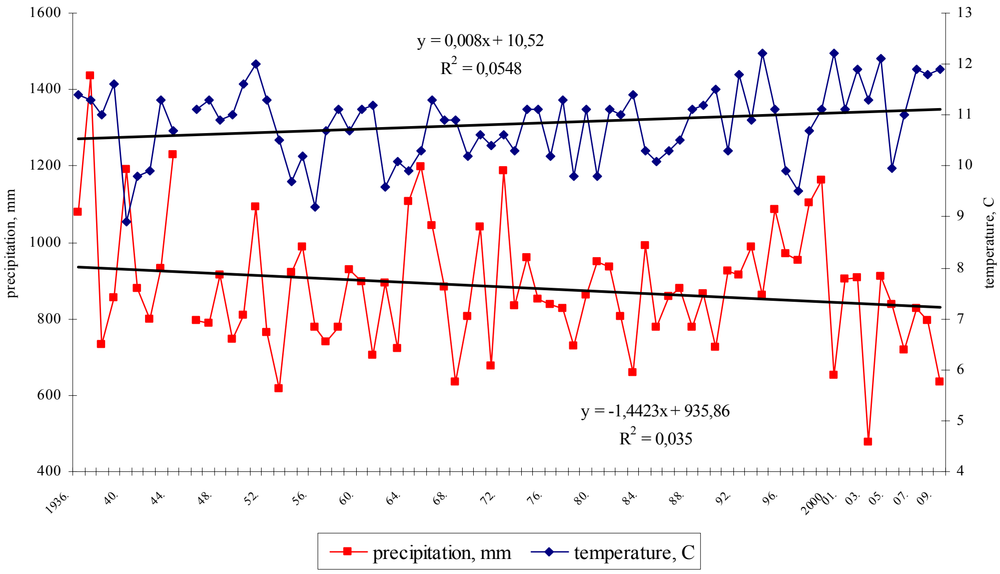

Figure 2: Rainfall and temperature trends in Daruvar, from 1936 until 2009

The observations of this investigation apply to the actual climate conditions recorded during the investigation period. Figure 2 shows the amount of annual precipitation and mean annual temperature from 1936 until 2009. The trends that are shown in the above chart point to the significant changes of climate conditions. The decreasing trend in rainfall and the temperature increase in the investigated period from 1936 until 2009 can clearly be noticed. Based on a 15-year survey of erosion and the daily half-hour rain intensity, the following preliminary conclusion can be derived. Although the investigated period (1994 - 2009) is relatively short, there are visible changes in total annual rainfall. In the last decade of the last century (1990-1999) the annual amount of precipitation increased, while in the first decade of this century (2000-2009) the annual amount of precipitation is much lower. However, a greater problem is what cannot be seen in Figure 2, and that is the changes of the intensity of rainfall. The rains more often occur in short and intensive form, causing, among other things, the erosion of the sloping terrain. When their total monthly or annual amount is summed up, they do not differ from the average of many years, but, once again, significant differences in the intensity of rainfall have been noted.

The direction that the erosion trends will take in the future is difficult to predict at the moment, but it is assumed that extreme climatic conditions will occur more often, which will among other things, cause more frequent extreme consequential phenomena such as floods and torrential flows on one side and the dry period, on the other side. Natural disasters that used to have a 50-year probability of occurrence now have a 10-year probability, what was happening in the climatic conditions every ten years, happens almost every third or fourth year and what used to happen every three or four years, now happens every year.

Conclusion

The results obtained during the 15 years of investigation lead to the following conclusions regarding the optimal soil tillage method for the rolling country in Central Croatia, on the Stagnic Luvisols:

- in the annual crops growing, winter or spring crops of high density must prevail in crop rotation
- in spring row crops of low density growing, up and down the slope tillage treatment should by no means be applied
- in winter crops growing, up and down the slope tillage treatment can be applied, but with a certain risk of erosion exceeding the tolerance level
- the procedures of reduced tillage should be applied as much as possible, that is the number of procedures should be kept to a minimum
- on slopes with angles higher than 15% growing spring row crops of low density should be forbidden
- conservation tillage and sustainable crop rotation are the most powerful tool for controlling erosion in the altered climatic conditions

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Soil organic carbon accrual in aggregates of arable soil in wheat based cropping systems

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Abstract
In order to investigate effects of cropping technology on content of soil organic carbon (SOC) and distribution of particle size fractions of soil, different cropping systems of winter wheat were analyzed. Arable soil samples were collected from the long-term experiments carried out at the Rimski Sancevi experimental station, Novi Sad. Soils from nine different cropping systems were analyzed and adjacent land (control) in depths: 0-20, 20-40 and 40-60cm. Particle size fractions (<2000 µm, 2000-250 µm, 250-53 µm and < 53 µm) were obtained by dispersion in water with series of sieves. Organic carbon content was determined by CHNS analyzer. Differences in SOC content among treatments were associated with the below-ground biomass quantity of crops in rotation and fertilization. The results indicate that the addition of manure without crop residue was not sufficient for soil structure preservation. The content of aggregates among fertilized treatments, in 0-20 and 20-40 cm soil layer showed similar distribution, whereas 40-60 cm depth have had higher proportion of the macroaggregates as clay fraction predominates. SOC increase with increased particle size, accordingly, macroaggregates turnover was found to be important in the processes of soil organic matter stabilization.

Keywords: soil organic carbon, particle size fractions, cropping systems

Introduction
Soil organic matter (SOM) is the central indicator of soil quality and health, which is strongly affected by agricultural management (Lal et al., 1995). SOM is a major terrestrial pool for C, N, P, and S, and the cycling and availability of these elements are constantly being changed by microbial immobilization and mineralization (Hillel, 1991). The importance of increased SOM or soil organic carbon (SOC) is its effect on improving soil physical properties, conserving water, and increasing available nutrients. These improvements should ultimately lead to greater biomass production and crop yield (Bauer and Black, 1994; Berzsenyi et al., 2000). There is considerable concern that if SOM concentrations in soils are allowed to decrease, the productive capacity of soil will be then compromised by deterioration in soil physical properties and by impairment of soil nutrient cycling mechanisms (Loveland and Webb, 2003).

Long-term experiments are often required to predict soil management impacts on soil carbon storage and provide leading indicators of sustainability, which can serve as an early warning system to detect impairments that threaten future productivity (Clapp et al., 2000). Generally, properly managed long-term experiments (over 30 years) could contribute to accesses in SOM dynamic depending on crop or rotation, duration of experiments, and other site-specific conditions (Jarecki and Lal, 2003). Crop rotation is an important subject in SOC dynamic due to soil ecological interactions and processes that occur with time which are followed with the improvement of soil structure, increased water use efficiency weed suppression, balanced nutrient utilization (Carter et al., 2003). Beare et al. (1994) indicated that tillage enhanced short-term CO_2 evolution and microbial biomass turnover, and accelerated organic C oxidation to CO_2 not only by improving soil aeration, but also by increasing contact between soil and crop residues, and by exposing aggregate-protected organic matter to microbial attack. Several experiments have confirmed an increase in SOC concentration by application of N or NPK fertilization in winter wheat production (Franzluebbers et al., 1994; Robinson et al., 1996). Manojlovic et al., (2008) evaluated SOC content in the long-term experiment of the Southern Panonnian Basin and found that organic fertilizers rather than mineral fertilizers could display beneficial effects on SOC content in soil. The effects of mineral fertilizer interact with the new crop varieties, improved cultivation techniques, increased fertilizer use, climate and initial SOM concentration. According to Rickman et al. (2002), the options available for rotation, tillage, fertilization or machinery often have cultural, environmental or economic restrictions. With these limitations, it could be difficult to predict the magnitude of SOM change.

The aim of this study was to evaluate effects of cropping technology on SOC content and distribution of particle size soil fraction in winter wheat production.

Materials and methods

The study was conducted at the crop rotation experiment ("Plodoredi") and the IOSDV Experiment (International organic nitrogen long-term Fertilization experiment) located at the Rimski Šančevi Experimental Station of the Institute of Field and Vegetable Crops in Novi Sad (N:45°19`, E:19°50`). The following treatments were analyzed: 4-year rotation (sugar beet/spring barley/corn/wheat) with manure 40t ha^{-1} (BØ); 4-year rotation + 100 kg N ha^{-1} (B2), 4-year rotation NPK + 200 kg N ha^{-1} without crop residues (A4), 4-year rotation NPK + 200 kg N ha^{-1} with crop residues (C4), unfertilized 2-year rotation (N2), unfertilized 3-year rotation (N3), wheat monoculture + 100 kg N ha^{-1} (MO), fertilized 2-year rotation + 100 kg N ha^{-1} (Đ2), fertilized 2-year rotation (Đ3), native vegetation (control) (NV).

The trials were established on a chernozem soil. Soil analysis (0-20cm depth) indicates that investigated plots have alkali pH reaction, they differ in SOM concentration, content of available phosphorus, potassium and $CaCO_3$ (Table 1), as well as physical properties. The soil samples were taken in 2007-2009 period, after winter wheat harvest.

Table 1: Soil chemical properties of the investigated treatments (0-20 cm)

Treatments	pH_{KCl}	pH_{H2O}	$CaCO_3$ (%)	Al-P_2O_5 mg 100 soil $^{-1}$	Al-K_2O mg 100 soil $^{-1}$	SOM (%)
BO	7.61	8.16	3.41	47.96	109.03	3.10
B2	7.56	8.24	2.94	47.16	111.13	3.03
A4	7.58	8.21	2.65	42.50	135.83	2.76
C4	7.74	8.24	4.83	44.83	151.50	2.48
N2	7.83	8.47	9.09	13.96	5.36	1.93
N3	7.84	8.37	5.54	17.40	5.60	2.33
MO	7.77	8.26	3.55	32.43	27.50	2.83
Đ2	7.07	7.97	0.35	34.10	32.90	2.54
Đ3	7.63	8.23	3.40	41.03	93.16	2.62
NV	7.73	8.21	7.08	90.83	167.00	3.22

The methodology for soil fractionation was adapted from Cambardella and Elliot (1993) and Six et al. (1998). Soils from nine different cropping systems were analyzed and adjacent land (control) in depths: 0-20, 20-40 and 40-60cm. From the each plot, soil samples were collected for wet sieving to obtain four aggregate size fractions (µm diameter): (i) >2000 (ii) 250 to 2000, (iii) 53 to 250, (iv) < 53. Prior to sieving soil samples have were placed on the largest sieve and suspend for 2 min in water at the room temperature. Soils were slaked and sieved in water by moving the sieve 3 cm vertically 30 times during a period of 2 min, breaking the surface of the water with each stroke. The material retained on the sieve was backwash into an aluminum pan. Soil and water that passes through the sieve was put on to the next sieve and the process repeated. For the next fraction the number of vertical movements was reduced to 20 times and 10 times for the 53 sieve. The soil slurry that passed through the 53µm sieve was poured in a receiving aluminum pan. Different size fractions were dried at 50°C and measured for calculation of aggregate quantity in total sample. Organic carbon content was determined by CHNS analyzer.

Results and disscusion

An average distribution of the soil aggregates showed lower SOC content in the smaller soil fraction, respectively (Figure 1). On the contrary, addition of manure (BØ and B2) increases the concentration of SOC in a smallest fraction <53 µm. SOC increase with increased particle size, accordingly, macroaggregates turnover was found to be important in the processes of soil organic matter stabilization. The higher SOC content was found in the >2000 µm fraction of the C4 treatment that included incorporation of crop residue and mineral N addition (Figure 1). The potential of the biomass utilization after incorporation is related with microbiological activity in soil, placement climatic conditions (Amézketa, 1999). Lowest SOC content was observed in the unfertilized treatments. Kong et al. (2005) also found that a majority of the accumulated SOC was preferentially sequestered in the macroaggregates.

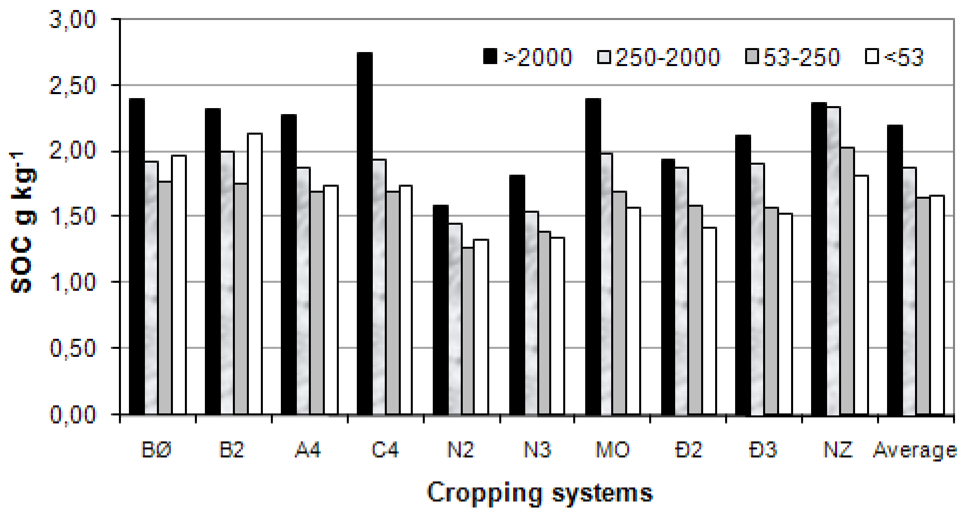

Figure 1: Distribution of aggregate size fraction in different cropping systems

Macroaggregates are dynamic in nature and the size distribution of macroaggregates fluctuates seasonally as a result of changes in weather, land use and management. During the process of slaking they broke in a stepwise fashion to smaller aggregates rather than directly to primary particles, thus aggregates of cultivated soil have a hierarchical organization. The hierarchical model proposed by Tisdall and Oades (1982) in which stable macroaggregates are microaggregates bound together by some additional organic matter has been recognized in our study. Repeated tillage or cultivation in conditions when optimal water content in soil is not attained could led to rapid breakdown of macroaggregates that expose previously protected SOM to decomposition. Balesdant et al. (2000) also found that total SOM concentration is weakly changed by tillage practice, whereas SOM location is dramatically altered.

Significantly higher content of macroaggregates in 0-20 cm soil layer was found in soil samples from control plots compared with arable land (Figure 2). Accordingly, moldboard plowing with following management practices significantly contributes to deterioration of a soil structure. Shepard et al. (2001) also found that conventional cultivation decreased proportion of the macroaggregates in soil proportional to the intensity of cultivation. The unfertilized treatments had the higher content of the aggregates >2000 µm originated from the presence of carbonates (Table 1) since their plow layer was depleted and thinned which allowed parent material to reallocate in the plow layer. In addition to that texture of the unfertilized plots was characterized with the higher total sand fraction compared with the treatments with regular fertilization. Šeremešić (2005) on the same experiment also found that the concentration of the water stable aggregates in the unfertilized treatments was linked with the soil texture. Moreover it could be estimated that loss of SOM and a reduced amount of biomass incorporation resulted with in partial Ca governance of aggregation processes (Tisdal and Oades, 1982). The stability of aggregates in the fertilized treatments indicates that the addition of manure without crop residue was not sufficient for soil structure preservation. Lower content of the <53µm aggregates was fond in the control plot (natural vegetation) with the higher proportion of the macroaggregates.

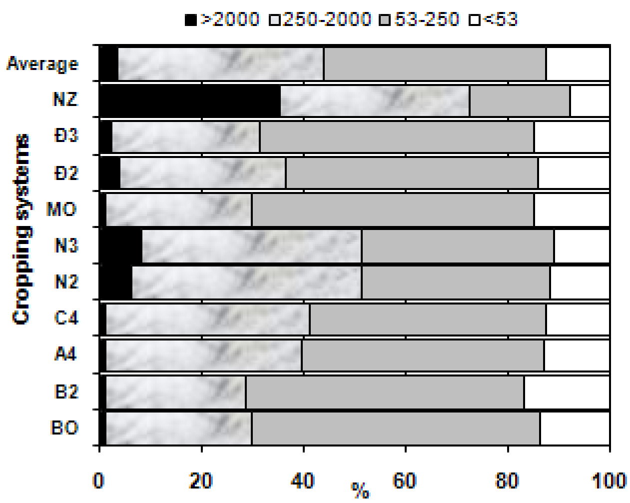

Figure 2: Stability of soil aggregate (0-20cm) of different cropping system on dispersion in water

Distribution of soil aggregate after conventional tillage elaborated in Tan et al. (2007) showed that aggregate 53-250 µm dominated in plow layer. In our study similar distribution of aggregates 250-2000 µm and 53-250 µm, among arable soils, was found in 0-20 and 20-40 cm soil layer, whereas 40-60 cm depth have had higher proportion of macroaggregates (Figure 3). Concomitantly, the fertilized treatment (BØ, B2, C4, A4 Đ2, Đ3 and MO) in the 0-40 cm soil layer were similar in distribution of aggregate size fractions which could be explained by tillage. Six et al. (2000) obtain similar result of slaked aggregate distribution for convention tillage from long-term experiment and native vegetation. In the 40-60 cm clay texture provided batter aggregation though lower content of SOC was found. The negative aspects associated with conventional tillage with plowing are formation of surface crusts and plough pan at the lower cultivation limit (Pagliai at al., 2004). Long-term observation of experimental field revealed that the concentration of smaller aggregates 53-250 µm and <53 µm is sufficient for formation of the surface crusts.

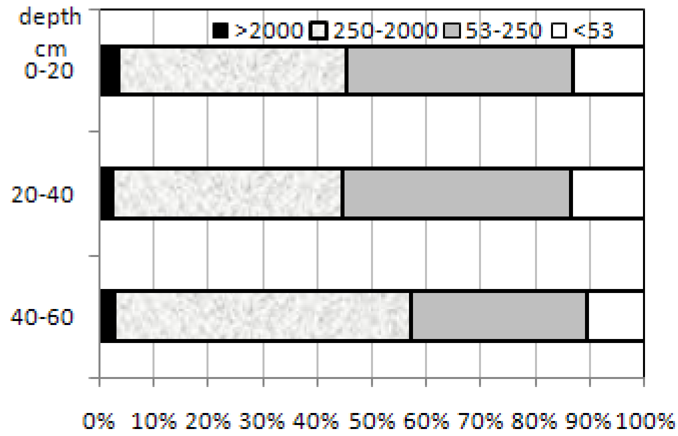

Figure 3: Distribution of soil aggregate among different soil layers (%) in the fertilized treatments (BØ, B2, C4, A4 Đ2, Đ3 and MO)

Conclusion

The maintenance of a favorable soil structure is critical for agricultural sustainability, and depends on the stability of the aggregates. Significantly higher content of macroaggregates in 0-20 cm soil layer was found in soil samples from control plots compared with arable land following the intensive cropping that affected the distribution of aggregate size classes. Crop residue is found to be important in the preservation of SOM since biomass could provide the substrate for microorganisms that produce substance for binding soil particles. Accordingly, when soil aggregation is affected with SOM concentration management practices that control the soil structure could help in preservation of SOM.

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Measures for increase of degraded soil biogenity

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Abstract
The intensive agricultural production comes to contamination and degradation of land, and urban land degradation activity was greatest in the mining surface. One of the main problems to be solved in the future is how to maintain, increase the level of organic matter in soil. Tracking biogenity of land as the first prerequisite of productive properties are used to certain physiological and systematic groups of microorganisms and enzyme activity. The aim of this study was to determine the types of fertilizers and technology of growing plants influenced the increase of soil elements biogenity. Research was conducted on soil type deposol. Fertilization was done with organic manure fertilizers, celuflorom, microbial fertilizer and mineral fertilizer as a control. Experiment was performed with sowing maize and sorghum as monocrops crop and in a joint with soya bean. It was found to increase the number of microorganisms using organic fertilizers, in a joint crop. Also within the larger crops biogenity was established in joint of maize and soybeans.

Keywords: soil, organic fertilizer, microorganisms, maize

Introduction

Losses of soil annually are great. They have not only created but also the degradation of large areas of agricultural land excluded from agricultural production operations of various anthropogenic factors (urban expansion, industrial settlements, infrastructure and mining industry). Under the pressure of soil degradation and contamination of different sources doubt that the level of environmental awareness has developed continuously. This certainly includes the care of any part of land in which any wing grow plants that represents a source of food for humans. More fifties of last century in American professional literature, raised the question: “Are we gardens or miners of soil?“ (Vučić, 1992). This did not seriously because agriculture was to intensify the expansion of application of chemical means to achieve higher profits. Agriculture is increasingly moving to an industrial form of food production which caused side effects such as loss of organic matter in soil, contamination by pesticides and their degradation products, heavy metals (Milanovic et al., 2008). This approach, agricultural production, did not Monograph land, but its exploitation. So there is a gap between the theory that the land renewable natural resource and practice in the wider sense. Because the greatest losses of agricultural land in the mining industry, with surface mining. In order to avoid any harmful effects and preserve the properties of soil production must take measures to achieve the ultimate goal and that is the formation, preservation of organic matter in soil. Planned measures must be related to the provision of favourable soil conditions for growth and development of plants by creating favourable biological properties of soil. This is certainly achieved the way of growing plants, especially eating and breeding system.

The concept of soil organic matter, which defines the fertility of soil, humus, which means the most stable part of the organic matter originated in process of creating humus, microbial degradation and new synthesis of complex organic matter.

Undoubtedly the fact that the soil humus balance does not take sufficient account and the production of humus soil with biological component affects its fertility. The biological component of soil microorganisms are involved in 60-90% of the total land activities the metabolism and represent its mercury component (Lee 1994). Otherwise, the number and activity of microbes depends on the type of land use agro ameliorative measures (Jarak et al., 2005). Representation and biomass of microorganisms is usually in direct correlation with the amount of plant residues and the share of organic matter in soil (Bo Liu et al., 2007), because the amount and composition of organic matter affects the formation of microbiological communities in soil. Therefore, it is necessary to apply those measures to establish symbiotic relation of microbiological processes and systems for growing plants in order to increase biogenity land, especially those that are degraded or made the work of people.

Materials and methods

The degraded soil type is set deposol essay by split-plot system in three replications. Surface sample plots under each culture were 5.6m x 83m = 464.8 m^2 (one repetition). The trials were applied to different types of fertilizers. The total area of experiment was conducted with the basic fertilizer. Surface parcels in fertilization rate were 15m x 51.2m = 768 m^2.

• Complex mineral NPK fertilizer in which the content of nutrients was compared 15:15:15. Mineral NPK is incorporated into the soil in quantity of 600 kg / ha in the interpretation of the results was used or control. Further fertilization is done in the following way:

• Celuflora - in quantities of 40 t/ha. Celuflora substrate is used as organic fertilizer produced in the company for processing and trade of "Humus Co" doo Loznica. Based on the physical properties can be said that the semirigid material, well homogenized organic matter, dark-brown to brown, crumb structure, without the characteristic smell. Celuflora is semirigid, because it contains about 50% moisture, although the maximum capacity of about85%

• Manure - in quantities of 40 t/ha

• Microbiology-just before the inoculation was performed sowing seeds of all plant species-specific bacteria that are capable of fixed atmospheric nitrogen and to:

a) symbiotic nitrogen-fixing bacteria *Bradyrhizobim japonicum* for soya bean, and

b) associative nitrogen-fixing bacteria *Azotobacter chroococcum, Azotobacter vineland* for maize, sorghum.

Finally, vegetation samples were taken from the rhizosphere of plants and roots were determined and systematic physiological groups of microorganisms that are indicators of changes in soil and are the parameter of biogenity of land. Standard microbiological methods were determined number of important groups of microorganisms (the total number of microorganisms, number *Azotobacter*, of ammonifiers, fungi, *Actinomicetes*) (Pochon and Tardieux, 1962). Also as a good indicator of enzyme activity performed dehydrogenase activity (Thalman, 1968).

Results and discussion

Microorganisms as the most common components of biological soil give information potentially assessing its fertility as well as evaluating the health and quality of land (Milosević et al., 2010; Cvijanović et al., 2006). With its dynamic changes and the number of enzyme activities respond to any changes in the soil, because the main participants in the cycle of matter and the necessary elements and flow of energy.

Table 1: Dynamic changes of soil parameters biogenity at the beginning of vegetation

Fertility	*Azotobacter*		Total number		Fungi		*Actinomicetes*		DHA	
	$x10^1$	I.L.	$x10^6$	I.L.	$x10^3$	I.L.	$x10^3$	I.L.	gTPF	I.L.
Maize+ Soya bean										
Manure 30 t/ha	2.9	37	684.3	135	37.8	122	9.5	500	26	51
Celuflora40t/ha	8.5	109	582.1	115	60.0	193	50.6	821	186	365
Microbiology	27.4	351	668.9	132	76.6	246	6.08	320	128	251
NPK 600 kg/ha	47.8	100	507.6	100	31.1	100	1.9	100	51	100
Average	11.7	149	610.7	120	51.4	165	8.3	435	98	191
Sorghum+Soya bean										
Manure 30 t/ha	34.4	91	772.9	156	2.36	3	7.1	120	17	38
Celuflora40t/ha	5.84	15	551.1	111	65.4	87	59.5	100	99	220
Microbiology	57.7	152	555.2	112	94.7	126	15.8	268	131	291
NPK 600 kg/ha	37.8	100	494.9	100	75.4	100	5.9	100	45	100
Average	33.9	89	593.5	120	59.5	79	22.1	374	73	162
Soya bean										
Manure 30 t/ha	2.9	74	445.9	100	39.4	51	39.4	150	351	281
Celuflora40t/ha	6.0	153	660.1	149	16.9	22	50.7	193	106	85
Microbiology	6.3	161	721.3	162	42.9	55	2.4	9	186	149
NPK 600 kg/ha	3.9	100	444.1	100	77.6	100	26.3	100	125	100
Average	4.8	122	567.9	128	44.2	57	29.7	113	192	154
Maize										
Manure 30 t/ha	20.2	91	743.1	150	55.9	127	15.5	218	223	251
Celuflora40t/ha	166	758	695.6	140	10.7	24	5.9	83	286	321
Microbiology	29.7	135	548.8	111	54.6	124	2.4	34	104	117
NPK 600 kg/ha	22.0	100	495.1	100	44.1	100	7.1	100	89	100
Average	59.7	271	620.7	125	41.3	94	7.7	109	176	197
Sorghum										
Manure 30 t/ha	2.9	14	544.9	94	98.3	197	11.8	22	91	253
Celuflora40t/ha	64.5	317	478.5	82	60.9	122	89.1	167	66	183
Microbiology	10.0	49	702.5	121	93.8	188	12.7	24	47	131
NPK 600 kg/ha	20.3	100	580.1	100	49.9	100	53.3	100	36	100
Average	24.4	120	576.5	99	75.7	152	41.7	78	60	167

I.L. Index Level

Production of soil properties directly depend on the number and activity of microorganisms, because they are the main participants in the formation and synthesis of humus. Based on the results was observed changes in the dynamics of the number of investigated groups of microorganisms. These changes are different, which depended on the type and quantity of fertilizer and the planting method and type of plant culture.

Table 1 presents the results of the condition number of the examined parameters in the development of plants phenophases 3-5 leaves and the first trefoil. The total number of microorganisms dehydrogenase activity (μTPF.10 g soil^{-1}) are reliable indicators of the welfare aspects of the assessment of quality and production capacity of soil (Kastori et al., 2006; Milosevic, 2008). At the beginning of the vegetation in maize is found the largest number of microorganisms in pure crops (620.7x10^{6} g^{-1}) and in a joint with soya bean (610.7x10^{6} g^{-1}).

Table 2: Dynamic changes of soil parameters biogenity at the end of vegetation

Fertilizers	*Azotobacter*		Total number		Fungi		*Actinomicetes*		DHA	
	x10^{1}	I.L.	x10^{6}	I.L.	x10^{3}	I.L.	x10^{3}	I.L.	μgTPF	I.L.
Maize + Soya bean										
Manure 30 t/ha	15.7	151	217.4	121	7.5	109	2.5	31	80	73
Celuflora40t/ha	64.3	618	137.3	76	7.3	106	3.7	46	219	199
Microbiology	67.7	651	197.1	109	9.5	138	10.8	135	110	100
NPK 600 kg/ha	10.4	100	180.1	100	6.9	100	8.0	100	110	100
Average	39.5	380	183.0	102	7.8	113	6.3	78	129	118
Sorghum + Soya bea										
Manure 30 t/ha	6.3	70	196.5	67	10.1	128	11.4	67	170	309
Celuflora40t/ha	41.2	462	367.9	126	10.4	132	29.2	171	52	95
Microbiology	21.8	244	384.4	132	4.75	60	15.4	90	77	140
NPK 600 kg/ha	8.9	100	291.3	100	7.90	100	17.1	100	55	100
Average	19.6	219	310.0	106	8.3	105	18.3	107	88.5	161
Soya bea										
Manure 30 t/ha	12.6	129	460.9	108	21.5	226	6.3	83	170	143
Celuflora40t/ha	12.9	133	431.4	101	20.9	220	33.8	445	148	124
Microbiology	21.7	223	436.9	103	8.7	92	13.6	179	152	128
NPK 600 kg/ha	9.7	100	426.2	100	9.5	100	7.6	100	119	100
Average	14.2	146	438.9	103	15.2	159	15.3	202	147.3	124
Maize										
Manure 30 t/ha	32.6	34	328.6	210	7.8	134	9.2	196	126	210
Celuflora40t/ha	113.3	121	307.6	197	6.8	117	31.8	677	100	167
Microbiology	110.5	118	414.1	265	6.3	109	20.2	430	84	140
NPK 600 kg/ha	93.3	100	156.3	100	5.8	100	4.7	100	60	100
Average	87.4	94	301.7	193	6.7	115	16.5	351	92.5	154
Sorghum										
Manure 30 t/ha	3.2	52	340.4	221	19.4	294	3.9	156	27	77
Celuflora40t/ha	3.5	57	460.9	299	13.0	197	23.4	936	91	260
Microbiology	0	0.0	356.8	232	7.5	114	7.9	316	50	143
NPK 600 kg/ha	6.1	100	153.9	100	6.6	100	2.5	100	35	100
Average	3.2	52	328.0	213	11.6	176	9.4	377	50.8	145

I.L. Index Level

Since the roots of plants with their secretion, congestion affects the composition and number of microbes in the rhizosphere thus a large number of microorganisms is justified because corn has a large and ramified root system. Activity dehydrogenase enzyme that catalyzes all oxyreductive processes in the soil was highest in these systems growing. At the end of the growing total number of microorganisms and enzyme activity had less value.

However, it is very significant percentage increase in the total number of microorganisms is established in the organic fertilizer. Increasing the total number of microorganisms increases with quantity microbiological protein that is released after breaking cells and directly affects the increase of organic matter in soil.

Azotobacter is the most distributed genus of the associative nitrogen-fixing bacteria dwelling in the rhizosphere zone. They are very sensitive and respond by their number and enzymatic activity to any changes in the habitat, hence they can be used, besides the total number of microorganisms, as a good indicator of the soil status. On average at the end of vegetation found their number is higher than at the beginning of vegetation. At the beginning of the vegetation at the inoculation with diazotrophs was determined *Azotobacte*r greater numbers than at the end of vegetation (Table 2) compared to other fertilizers, while in the end most of their vegetation determined the fertilization with celuflorom.

Fungi and *Actinomicetes* groups of microorganisms have a very powerful enzyme system and have the ability to break down a complex of carbon compounds. In both phases of physiological development of plants of their number was higher in all the fertilizer used organic fertilized, but it is the beginning of the vegetation their number was higher than at the end of vegetation.

In Table 3 and 4 are shown results of basic agro-chemical basic properties of pure and a joint crop and vegetation at the beginning of the end of vegetation, as well as values agro-chemical properties set before the start of experiments. The pH can be seen that the land within the limits of a neutral reaction, which is suitable for living microorganisms.

Table 3: Effect of fertilization on soil properties agro-chemical when growing plants in pure crops at the beginning of vegetation

Fertilizers	pH		Humus	Total N	C/N	Ca	P_2O_5	K_2O
	H_2O	KCl	%	%			mg kg^{-1}	
Initial state	7.58	6.26	1.21	0.18	4.5	5262	2.68	26.1
Mineral NPK	7.62	6.26	1.00	0.17	3.4	5962	3.37	25.42
Index Level	100.5	100.0	82.6	94.4	75.5	113.3	125.7	97.4
Celuflora	7.66	6.42	2.16	0.20	5.7	5831	6.94	27.52
Index Lavel	101.1	102.6	178.5	111.1	126.7	120.8	258.9	105.4
Manure	7.32	6.18	1.58	0.21	5.14	5516	3.92	30.37
Index Level	96.6	98.7	130.6	116.7	114.2	104.8	146.3	116.6
Microbiology	7.36	6.08	1.33	0.20	3.95	5572	4.03	22.2
Index Level	97.1	97.1	109.9	111.1	87.8	105.9	150.7	85.1

At the beginning of the set reflected the level of basic agro-chemical properties of soil - humus and total nitrogen, is very low, is located on the lower limit values. Also small amounts easily accessible forms of nitrogen (NH4, NO3-N), especially nitrogen contained in the soil solution and form that plants can adopt directly. However, their quantity is also very variable in relatively short intervals, and this information can be instantaneous.

Based on the results notes that the ratio of C/N rather narrow, which is about fast mineralization of nitrogen that is in compatibility with the obtained results of mineral forms of nitrogen. As quantity difficult motile soil phosphorus and potassium, observed that the levels of these nutrients in the soil varies. Since was established only 2.96-3.92 mg P_2O_5/100 g. At the beginning of experiment can be said that the land is poor and requires increased amounts of fertilizer, even 130-150% higher than that adopted by plant. What is concerning the quantities of potassium can they say that even high compared to the optimum. Application of organic fertilizers and the system of growing plants is significantly influenced the increase in value agro-chemical properties. The breeding of crop plants in a joint all parameters had higher values.

Table 4: Effect of fertilization on agro-chemical properties when growing plants in a joint crop at the end of vegetation

Fertilizers	pH		Humus	Total N	C/N	Ca	P_2O_5	K_2O
	H_2O	KCl	%	%			$mg.kg^{-1}$	
Initial state	7.7	6.38	1.16	0.19	3.59	5623	3.92	27.2
Mineral NPK	7.13	5.93	1.21	0.5	3.78	4005	7.08	24.6
Index Level	92.6	92.9	104.3	263.2	105.2	71.2	180.6	90.4
Celuflora	7.55	6.43	2.16	0.2	6.18	5337	8.38	25.6
Index Lavel	98.0	100.8	186.2	105.3	172.1	94.9	213.8	94.1
Manure	7.27	5.93	1.55	0.19	4.92	4896	7.86	28.3
Index Level	94.4	92.9	133.6	100.0	137.0	87.1	200.5	104.0
Microbiology	7.49	6.12	1.33	0.19	4.00	6351	6.38	27.6
Index Level	97.3	95.9	114.7	100.0	111.4	112.9	162.7	101.5

Conclusion

Based on the results it can be concluded that the application of organic fertilizers is very important to increase the basic biogenity parameters of soil microbial communities and thus affect the maintenance and creation of productive properties of soil. Aggregation of crops and fertilization with organic fertilizers increase the values of parameters land biogenity, and thus increase the production processes of soil properties. Fertilization with organic fertilizers and crop aggregation is significant from the aspect of increasing biodiversity and environmental protection.

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Can we increase available nutrients using bacteria?

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Abstract

The intensive land use, including the artificial N-fertilizers in agriculture causes the acidification of soils due to the harvest or leaching of cations. Soil microbes are of great importance in cycling nutrients such as carbon, nitrogen, phosphorus and sulphur. Beside their effects on the availability of nutrients the bacterial soil life prevents the uptake of several harmful ions. The most important limiting factor for microbial growth in soil is the abundance of available organic carbon sources. To increase microbial activity in a soil one must make the environment optimal, or at least more favourable, in terms of aeration, moisture and pH, and above all provide the organic substrates needed to fuel the population.

The main object of our study was to examine the impact of bio fertilizer Phylazonit MC® as the potential tool to reduce the risk of agricultural production.

Keywords: bio fertilizer, plant growth promoting bacteria, soil tillage

Introduction

The soil-root interactions basically determine the success of plant production. The soil life is one of the most important components of this interaction. It is known, that the soil born, plant growth promoting bacteria (PGPB), affect the physiological processes in the roots, and consequently in the shoots. The intensity of soil life depends on the physical condition of the soil. Although there is a competition between the bacteria and roots for the available nutrients, the sufficient level of soil life is advantageous for the plants. When the level of different nutrients seems to be enough in the soil, but the symptoms of mineral-deficiency appear. There are several similarities between the nutrient uptake mechanisms of bacteria and higher plants. The bacteria release organic compounds, forming complexes with sparingly soluble nutrients, as the iron and the phosphorous are. These complexes could be taken up by the roots too. The bacteria origin organic compounds also bind the heavy metals. There are observations, when much more less aluminum concentrations were detected in the plants when the activity of bacterial life was high in the nutrient solution. The photosynthetic activity is limited by the CO_2 when the light intensity is the highest and there is no shortage of water. Therefore attention should be paid to the possibility, how to provide the soil life on high level in order to be able to reduce the costs of plant production, to increase the yields, to minimize the use of chemicals and to protect the environment more effectively from the heavy metal pollution.

The lead concentration of most vegetation is relatively low despite evidence that it is probably five times higher than prior to industrialization (Shirahanta et al, 1980). Animal inputs of heavy metals to certain ecosystems can be significant. Large quantities as As, Cu, and Zn can come from domestic livestock manure. The heavy metals in manure are originated from the fodder crops. To provide a relatively clean environment for growing the crop plants has distinguished importance because of the food chain, with the humans at the end! Certain heavy metals, as Cu, Zn, Mn, Mo are essential for plants, while Fe can be essential and toxic, depending on its amounts and charge. The contradiction in the handling of heavy metals is, one part of these are essential, while one part is toxic, sometimes essential for the plants and toxic for the humans.

Materials and methods

Sugar beet *(Beta vulgaris L. sv. Sacharina cv. Bounty),* cucumber *(Cucumis sativus L. cv. Delicates),* wheat *(Triticum aestivum L. cvs. Mv Palotás)* and sunflower *(Helianthus annus L. cvs. Arena)* were used in the laboratory, and only the sugar beet in the field experiments. The seeds were germinated on moistened filter paper at 25°C in dark. The seedlings were then transferred to a continuously aerated nutrient solution of the following composition: 2.0 mM $Ca(NO_3)_2$, 0.7 mM K_2SO_4, 0.5 mM $MgSO_4$, 0.1 mM KH_2PO_4, 0.1 mM KCl, 1µM H_3BO_3, 1µM $MnSO_4$, 0.25 µM $CuSO_4$, 0.01 µM $(NH_4)_6Mo_7O_{24}$. Iron was added to the nutrient solution as Fe-EDTA at a concentration of 10^{-4}M. Phylazonit MC®, as an *Azotobacter sp.* and *Bacillus sp.* containing organic fertilizer, was added to the nutrient solution in the quantity of 1 ml dm^{-3}, and 10 l/ha in the field experiment. The nutrient solution was completed with aluminum, when the Al- stress was examined. The concentration of $Al_2(SO_4)$ was 10^{-4} M. The seedlings were grown under controlled environmental conditions (light/dark regime 10/14 h at 24/20°C, relative humidity of 65–70% and a photosynthetic photon flux of 300 µmol $m^{-2}s^{-1}$. The contents of elements were measured with ICP, the relative chlorophyll contents with of SPAD 502 (Minolta). The samples were dried at 85°C, for two days, the dry matters of shoots and roots were measured.

Results and discussion

Certain heavy metals, as Cu, Zn, Mn, Mo are essential for plants, while Fe can be essential and toxic, depending on its amounts and charge. The contradiction in the handling of heavy metals is, one part of these are essential, while one part is toxic, sometimes essential for the plants and toxic for the humans. Soils are the main substrate on which most plants are cultivated. In any soils where there is an abundance of organic matter, there will be organic matter - heavy metal interactions. The interaction between heavy metals and humid substrates has been characterized mainly as chelation, complexation, and adsorption.

The concentrations of heavy metals in soil water and stream water are lower than the concentration found in soils. Lead concentrations found in Vermont soil were 80-200 ppm while soil water and stream water samples from the same location were 1 to 5 ppm (Lindberg, 1987). Usually the growth is the most sensitive for heavy metals. The growth is a complex process, so the heavy metals can affect on several points of it.

Reduction of growth and productivity, changes in membrane structure, enzyme activity, metabolic processes, water, and ion uptake, the membrane permeability are the most studied fields. The reduction of root growth can be observed very often. This effect has wider consequence. The root surface gets smaller, the ion and water uptake are decreasing, the citokinin levels are low, and the ageing processes are accelerated. Inhibition of root extension growth can be the result of interference with cell division or with cell elongation. It is observed, that the main influence of lead is the inhibition of cell elongation (Garland and Wilkins, 1981). The elasticity of cell walls is not so much reduced by lead that under mechanical stress they may break (Lane and Martin, 1982).

In crop production aluminum toxicity is one of the major growth limiting factors in acid mineral soils. The toxic actions of aluminum are primarily root related. The root system becomes stubby as a result of inhibition of elongation of the main axis and lateral roots. The severity of inhibition of root growth is a suitable indicator of genotypic differences in aluminum toxicity (Kruger and Sucoff, 1989).

The use of Phylazonit MC® modified the toxicity of Al, supposedly by the increasing uptake of elements that are responsible for the defence mechanisms of the plants.

Table 1: Concentrations of examined elements in the second leaves of cucumber under Al-stress and treated by Phylazonit MC® (mg kg-1) n=4± s.e.

Treatments	Al	Fe	Mn	Zn
Control	24.20± 1.7	194.20± 8.5	61.30± 4.7	75.60± 5.8
Al	68.40± 3.8	139.10± 9.3	17.60± 1.8	52.10± 4.7
Al+Phy	23.90± 3.0	143.50± 10.1	51.90± 6.1	67.80± 4.9

In crop production aluminum toxicity is one of the major growth limiting factors in acid mineral soils. The toxic actions of aluminum are primary root related. The root system becomes stubby as a result of inhibition of elongation of the main axis and lateral roots. The aluminum toxicity often expressed simultaneously in two ways, namely induced deficiency of mineral nutrients, and inhibition in root elongation. Inhibition of root growth by aluminum should further increase the risk of phosphorus deficiency on acid mineral soils, where aluminum toxicity may inhibit the shoot growth by limiting supply of nutrients and water by poorer subsoil penetration or lower root hydraulic conductivity (Kruger and Sucoff, 1989).

The limited supply of cytokines from the roots may inhibit shoot growth of soybean grown either in acid soil or nutrient solutions with aluminum, has been obtained from the beneficial effect on growth by application of cytokines to the shoots of such plants (Pan et al., 1989). Inhibition of cell division in root apical meristems is a rapid response to aluminum treatment. Cell division may resume after some time but remains at lower level than in controls not exposed to aluminum. The root retardation can be an indirect effect. The aluminum can bind the DNA of the root cap cells causing a decrease in cell division.
The aluminum may bind to the other surface of the plasma membrane of root rhizodermal and cortical cells and thereby impair plasma membrane functions. Aluminum (Al^{3+}) has a 560 fold higher affinity than Ca^{2+} for certain phospholipids in membranes (Akeson et al., 1989). It seems to be proved, that the primary target of aluminum is the root cap which perceives the „aluminum signal", similarly to that of gravity or of mechanical impedance.
In some cases metals affect to water uptake. Zinc inhibition of water uptake might be due to binding of the metal to a water channel protein. It is proved, that the mercury binds to cystein in the water channel protein. The number of water-channel proteins decreases during the night and starts to increase again just before the beginning of the light period, which suggests a rapid turnover, and a tight connection with diurnal periodicity.

The Phylazonit MC® was more effective, when the treatment was started on the first day of experiments. In the case of Phylazonit MC® the specific leaf area was increased with 10%, with the respects to the fact, that the time of treatment was short it acceptable as good results. Additionally, the fresh weight of roots increased up to 20%. The uptake of nutrients increased, and the concentrations of Fe, Mn and Zn in the roots were higher than those in the control. The concentrations in the leaves also were increasing (date not shown).

The chlorophyll contents of the plants were higher when Phylazonit MC® was added to the nutrient solution. Phylazonit MC® had an increasing effect on the level of photosynthetic pigments (Figure 1.)

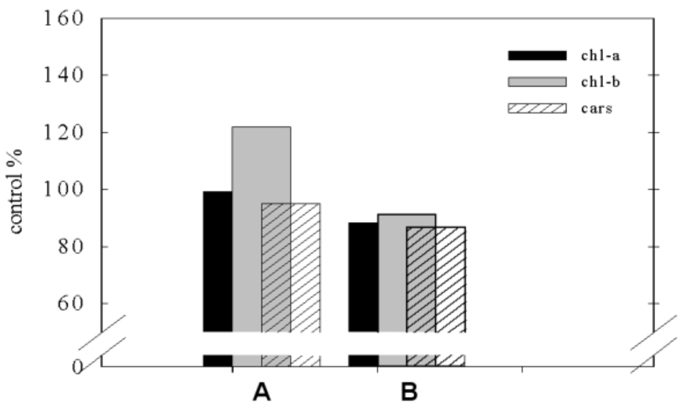

Figure 1: Alteration in the amount of photosynthetic pigments (chlorophyll$_a$= chl-a; chlorophyll$_b$= chl-b; carotenoids= cars) by the effect of Phylazonit MC® in the percentage of control. (Treated from the 1st (A) and from 4th (B) day of experiments.)

The accumulation of wheat and sunflower stems was more intensive. The dry matter loss from the original weight was 15-20% higher than those in the control. The amounts of available P and K nutrients were higher, while the amount of N remained around at the same level in the soil, near the stems (Table 2-3).

Table 2: The effect of Phylazonit MC ® treatment on mineralization of wheat and sunflower stems. The running time of experiment was 2 weeks. (Phy: Phylazonit MC®, before: before the experiment, end: end of the experiment) n=4± s.e.

Dry weight of sunflower and wheat stems (g)				
Time	Wheat	Wheat+phy	Sunflower	Sunflower+phy
Before	11.09± 1.2	10.98± 0.9	15.27± 1.7	15.13± 2.1
End	8.40± 0.9	7.11± 1.3	12.15± 0.8	10.00± 0.6
Lost of weight %	24.25	35.24	20.43	33.90

Table 3: The available N, P, K concentrations in the soils containing wheat and sunflower steems, and treated with Phylazonit MC®. The running time of experiment was 2 weeks. n=4± s.e.

Treatments	P_2O_5 mg kg^{-1}	K_2O mg kg^{-1}	N%
Wheat	228.80± 14.0	315.10± 23.0	0.16
Wheat+phy	249.90± 9.0	352.40± 19.0	0.17
Sunflower	278.80± 11.0	346.60± 15.0	0.15
Sunflower+phy	309.50± 21.0	403.80± 31.0	0.17

The uptake of inorganic ions by roots is an important process. Most of the mineral nutrients essential for life enter the biosphere and the food chains of the animal world through the roots of higher plants. Since roots acts a source of organic carbon, the population density of microorganisms, mainly bacteria, is considerable higher in the rhyzosphere than in the bulk soil. The relative increase in the number of microorganisms is expressed as an R/S ratio, R being numbers per gram of soil in the rizosphere and S in the bulk soil. The ratios vary greatly, between 5 and 50, depending for example on plant age, plant species, and nutritional status of plants. In general, all endogenous and exogenous factors which affect rhizodeposition and thus provision of organic carbon have a similar impact on population density on the rhyzoplane and in the rhizosphere. Well known, that in soil grown plants between 75% and more than 85% of the total organic carbon supply for microbial activity in the rhizosphere is represented by sloughed-off cells and tissues. Despite the high supply of organic carbon compounds the rhizosphere microorganisms can be nutrient limited, particularly of nitrogen. Therefore, in no legumes species, the number of rhizosphere bacteria increases with nitrogen fertilization (Liljeroth et al, 1990). Limitation of nitrogen is probably also a main reason for the drastic decrease in bacterial turnover rates at the rhizoplane. For growth and physiology of the roots and nutrient dynamics in the rhizosphere not only is the total number of rhizosphere microorganisms important but even more the types (species and strains) and their physiological characteristic, for example, producers of phytohormones, nitrogen-fixers, pathogens or antagonists. Within a given plant species the amount and form of nitrogen fertilizer supply also alter the rhizosphere micro flora. By increasing the nitrogen supply both the number and proportion of diastrophic bacteria decrease at the rhizoplane of various grasses, whereas the total number of bacteria increases. In wheat, depending on whether nitrogen is supplied as ammonium or nitrate, there is a considerable shift in the proportion of pathogens and antagonists in the rhizosphere (Sarniguet et al., 1992).

The root fresh weight and the sugar contents were higher in the field experiments, measured in June. The results are shown in Table 4.

Table 4: The yields in the field experiments (control: 20ha, treated by Phylazonit MC®: 20ha)

Treatments	yield t/ha	K mM kg^{-1}	Na mM kg^{-1}	N mM kg^{-1}
Control	62.80	34.75	25.90	23.27
Phy	77.20	31.02	20.27	19.37

The Phylazonit MC treatment equalized the effect of 80 kg ha^{-1} nitrogen fertilization in the field experiments. The contents of nitrogen, and other compounds in the sugar beet were smaller than in the non-treated plants, which is advantageous for industrial process.

Non- infecting (PGPB: plant growth promoting bacteria) rhizosphere bacteria might affect mineral nutrition of plants through their influence on: 1. growth, morphology and physiology of roots; 2, the physiology and development of plants; 3. the availability of nutrients; and nutrient uptake processes.

Conclusion

The soil life is one of the most important factors, promoting root growth, to protect the plants from heavy metal toxicity or sometimes to increase the chance of toxicity. Attempts to improve plant nutrition by inoculation with soil microorganisms fall mainly into two categories: (1) improving nutrient availability and (2) enhancing plant nutrient uptake. Less than 5% of the total soil phosphate content is available to plants. Early efforts to improve phosphorus availability to plants by means of soil microorganisms resulted in isolation and characterization of several phosphate-solubilizing bacteria.

On the other hand, there are observations which prove the beneficial role of soil born bacteria in the uptake of iron, zinc and other micronutrients. The bacteria release siderophores, and several organic matters, including acids, and these organic compounds, released by the bacteria, make the sparingly soluble micronutrient available to the plants. So the effects of soil born, plants growth promoting bacteria are: (1) increase the root development, the ion uptake capacity of enhanced root surface is higher, and (2) the organic compounds released by the bacteria make the micronutrients more available. It is also clear, that there is a thigh connection between the soil life and the root activity. The roots also release several organic matters, acids, as citric acid, malic acid, amino acids.

The application of Phylazonit MC® increased the yields in the laboratory and in the field experiments. The physiological basis is: an increased chlorophyll synthesis, a more intensive uptake of nutrients causes a more intensive growth of leaves. The larger leaf area produces more organic compounds. Due to the more active bacterial soil life the level of several organic compounds, as malic acid, citric acid, and syderophores is higher, that makes the solubility and availability of nutrients easier in the rizosphere (Lévai, 2005). The early treatment gave higher values in the chlorophyll contents.

On the basis of our results, we came to the conclusion, that the Phylazonit MC® is an alternative for replacing chemical fertilizer with a biologically active, environmentally protective agent, and at lower cost.

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[Session:]

[1. Conservation tillage – direct seeding – no-tillage]
[2. Soil tillage – new approach – technologies – perspectives]

[CHAIRMEN]

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The impact of reduced tillage on the morphological and physiological parameters of soybean

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Abstract
The scope of this research was to determine impact of different soil tillage on the morphological parameters (number of branch, pod weight and stem length) and physiological parameters (chlorophyll a, chlorophyll b, chlorophyll a+b and carotenoids) of soybean. The research for soybean has been conducted at the North-eastern Croatia chernozem soil type during the period of 2001/2002–2002/2003, with following continuous soil tillage treatments: CT – conventional soil tillage, based on mouldboard ploughing; DH – multiple pass diskharrowing; and NT – no-tillage. The influence of Year was significant for the production of chlorophyll b and carotenoids, while the soil treatment had significant effect on the concentration of chlorophyll (a + b) and chlorophyll b. The interaction Year x Tillage proved to be significant only for concentration chlorophyll b and carotenoids. Agroclimatic conditions significantly affected all the morphological characteristics of soybean, while the effect of tillage was not statistically significant.

Keywords: reduced tillage, chloroplastic pigments, morphological parameters of soybean, yield

Inroduction
Soybean is C3 plant which the maximum saturation of photosynthesis, light can reach at relatively low values. At the time of flowering and pod formation, LAI (leaf area index) and intensity lights are of paramount importance to yield (Vratarić and Sudarić, 2008). The photosynthetic potential and primary production of plants, directly affects the concentration of chlorophyll, which, according to numerous authors, influenced by numerous external and internal factors. The achievement of high yields higher, cultural plants, the extremely great importance photosynthetic potential and levels of photosynthetic activity (Vidović, 1998; Sabo et al., 2005; Jug et al., 2008). Also, many studies indicate the dependence of concentration chloroplast pigments on the growth and development of plants, and the concentration of pigments and photosynthesis intensity in close relation with the ontogenetic growth of cultural plants (Vukadinovic et al., 1987). The photosynthesis is determined by numerous internal and external factor, such as: plant's development conditions, degree of adaptability to environmental conditions, water and nutrient supply, temperature, quality and quantity of the light, CO_2 and O_2 concentration, etc. (Vukadinović et al., 1989). The most important for photosynthesis activity are light, nutrition, water supply and temperature. The interaction of each cultivar and agroecological factors are pointing out their huge inter-dependence, thus making needed investigations of each cultivar x soil tillage system interactions. Pod abortion caused by lack of photosynthetic supply late in the growing period is a major factor limiting soybean yield (Taylor et al., 1982). According to Jiang and Egli (1993) shade imposed from first

flower to early podfill reduced flower production and enhanced flower and pod abcission, resulting decreased pod number and yield. Soybean plants grown under reduced tillage often appear smaller than those grown under conventional tillage (Yusuf et al., 1999). Same authors reported that grain yield was similar for No tillage treatment and conventional tillage treatment. The aim of this study was examine the influence of agroclimatic conditions and soil tillage treatment on morphological and physiological characteristics of soybean.

Materials and methods

Field experiments were conducted at Kneževo site in Nothern Baranya region for soybean (*Glycine max* L.), cultivar Tisa, during 2001/2002–2002/2003 years (Jug, 2006). The main experimental set-up was a complete randomized block design in four replications, with three continuing soil tillage systems: CT – conventional tillage with ploughing up to the 30 cm as a primary tillage, followed by diskharrowing, sowing preparation and sowing with no-till driller John Deere 750A; DH – diskharrowing only up to the 15 cm and sowing as for CT and NT – No-tillage sowing without any primary tillage operation. The experimental site soil is classified as a calcareous chernozem on loess substrate (FAO, 1990). The soil analyses presented very favorable chemical properties (pH in H_2O = 8.1, pH in 1M KCl = 7.7; humus = 3.1%, $CaCO_3$ = 2.6%; AL-soluble P_2O_5 and K_2O = 13.5-14.7 and 25.2-27.3 mg $100g^{-1}$, respectively). The size of basic experimental plot was 900 m^2. The fertilization was uniform across treatments and years, and it consisted of $N:P_2O_5:K_2O$ = 40:130:130 kg ha^{-1}.

Climatic conditions studied years (Table 1), differed significantly according to rainfall during the growing period from emergence to early pod formation (April-July). Total precipitations during the growing season in 2002 had 91 mm less precipitation compared to 2004. Amount of precipitation in 2003 was 172 mm less than in 2004 and 81 mm lower compared to 2002. So, in the mutual comparison of all three years of investigation can be concluded that in 2002 was average, 2003 extremely dry, and 2004 extremely wet year.

Table 1: Total precipitation (mm) from April to July at Kneževo site during 2001/2002 and 2002/2003

	2002	2003
	Precipitation (mm)	
April	64	9
May	86	33
June	49	19
July	61	61
Growing season	260	179

Before sowing, soybean seed was inoculated with nitrate-fixing symbiotic bacteria Bradyrhizobium japonicum (trade-mark "Biofiksin-S") from the collections of the Department of Microbiology, Faculty of Agriculture in Zagreb. Plant sampling was done four times during the 2002 and 2003 soybean vegetation season in vegetative stages: V3 nodes, reproductive phase: R1 (beginning bloom), R2 (full bloom), and R3 (beginning pod). Phenological observations were made using the Fehr and Caviness (1977) growth stage key.

Chlorophylls pigments were determined on 0.1 g of the fresh material from the most developed leaf of the soybean stalk. The concentration of chlorophyll a, chlorophyll b, chlorophyll a+b and carotenoids were determined spectro-photometrically (at wave lengths 662, 644 and 440 nm) from an acetone extract using the methods of Holm and Wettstain and expressed in mg per g fresh weight (mg g^{-1}FW) (Arsenijević-Maksimović i Pajević, 2002). Morphological parameters include number of branch per plant in R2 stage, pod weight (g per plants) and stem length (cm) in R1 stage. The grain yield was sampled at harvest maturity. The grain yield was adjusted to 9% moisture.

The statistical analysis of single-year data has been made by Split-plot program with calculation of LSD values for P<0.05 significance levels, whereas split-split-plot analysis has been made over two year data, with Year as the main level, Soil Tillage System as sub-level, and Phenophase as sub-sub-level treatments. Achieved grain yields and morphological parameters were processed by split-plot ANOVA.

Results and discussion

By split-plot method it was determined that varying of chlorophyll a in 2002 (Table 2) was strongly influenced by Phenophase (F=13.423**). The average concentration of chlorophyll a in 2001/2002 was 1.570 mg g^{-1}FW. The highest chlorophyll a concentration was recorded in R1 stage, and the lowest in R3 stage.

Table 2: Chlorophyll a concentration (mg g^{-1} FW) for different soil tillage systems (B) for four phenophases (C) in years 2001/2002 and 2002/2003 (A)

	CT (B_1)	DH (B_2)	NT (B_3)	average C
		2001/2002 year (A_1)		
V_3 (C_1)	1.873	1.669	1.695	1.746 a
R_1 (C_2)	1.891	1.768	1.662	1.774 a
R_2 (C_3)	1.666	1.379	1.545	1.530 b
R_3 (C_4)	1.336	1.163	1.196	1.232 c
average B	1.692	1.495	1.524	1.570
		2002/2003 year (A_2)		
V_3 (C_1)	1.477	1.500	1.363	1.447 a
R_1 (C_2)	1.621	1.298	1.628	1.516 a
R_2 (C_3)	1.874	1.876	1.721	1.824 b
R_3 (C_4)	1.926	1.982	1.809	1.906 b
average C	1.724	1.664	1.630	1.673 c
average of experiment				1.622
average A_{1-2}	1.570	1.673		
average B_{1-3}	1.708	1.579	1.577	
average C_{1-4}	1.567	1.645	1.677	1.569

In 2002/2003 chlorophyll a concentration was under significant influence of the Phenophase (F=24.855**) and interactions Tillage x Phenophase (F=2.566*) whereas influence of Tillage was not significant. The average concentration of chlorophyll a in 2002/2003 was 1.672 mg g^{-1}FW. The highest chlorophyll a concentration was recorded in R3 stage (1.906 mg g^{-1}FW), and the lowest in V3 stage (1.447 mg g^{-1} FW). This can be explained by the fact that 2002/2003 was extremely dry year, and soybean plants had a smaller increase in the overhead mass, whereas the production of chlorophyll remained the same intensity. The lower mass of fresh matter in terms of lower soil moisture can be caused by increased concentration abscisic acid (ABA). Abscisic acid in unfavourable conditions inhibits growth, protein synthesis, regulates stomatal closure and transfer of ions (Jug, 2008). The average concentration of chlorophyll a for both years was 1.622 mg g^{-1} FW. There was a significant interaction Years x Phenophase, while other indicators had no significant effect on the concentration of chlorophyll a (Table 2).

The chlorophyll b concentration in 2001/2002 was significantly influenced by Phenophase and Tillage. The average concentration of chlorophyll b in 2001/2002 was 0.556 mg g^{-1} FW (Table 3). The highest concentration of chlorophyll b was found in CT (0.609 mg g^{-1} FW), while the minimum chlorophyll b measured in NT treatment (0.521 mg g^{-1} FW). The highest chlorophyll b concentration was recorded in R2 stage (0.640 mg g^{-1} FW), and the lowest in V3 stage (0.463 mg g^{-1} FW). In 2003 study year tillage had no significant influence on the concentration of chlorophyll b. The highest concentration of chlorophyll b was measured in the full bloom of soybean (0.508 mg g^{-1} FW) and lowest chlorophyll content was measured at the beginning pod (0.421 mg g^{-1} FW).

Table 3: Chlorophyll b concentration (mg g^{-1} FW) for different soil tillage systems (B) for four phenophases (C) in years 2001/2002 and 2002/2003 (A)

	CT (B_1)	DH (B_2)	NT (B_3)	average C
	2001/2002 year (A_1)			
V_3 (C_1)	0.512	0.468	0.410	0.463 a
R_1 (C_2)	0.603	0.531	0.553	0.562 ab
R_2 (C_3)	0.664	0.698	0.558	0.640 b
R_3 (C_4)	0.660	0.452	0.563	0.558 ab
average B	0.609 a	0.537 b	0.521 b	0.556
	2002/2003 year (A_2)			
V_3 (C_1)	0.455	0.457	0.424	0.445 a
R_1 (C_2)	0.443	0.426	0.457	0.442 a
R_2 (C_3)	0.531	0.511	0.482	0.508 b
R_3 (C_4)	0.429	0.430	0.402	0.421 a
average C	0.464	0.456	0.441	0.454
average of experiment				0.505
average A_{1-2}	0.556 a	0.454 b		
average B_{1-3}	0.537 a	0.497 b	0.481 b	
average C_{1-4}	0.454 a	0.502 a	0.574 b	0.489

The average concentration of chlorophyll b for both years was 0.505 mg g^{-1}FW. The chlorophyll b concentration was under significant influence of the Year (F=45.219**), Phenophase (F=5.734**), and Tillage (F=4.734*).

The highest concentration of chlorophyll b was measured on CT (0.537 mg g^{-1}FW) and in the full bloom of soybean (0.574 mg g^{-1}FW), and lowest on NT (0.481 mg g^{-1}FW) and in V3 stage (0.454 mg g^{-1} FW).

In 2001/2002 the concentration of chlorophyll a+b was under significant influence of Phenophase (F=6.069**) and Tillage (F=6.652*). The highest concentration of chlorophyll a+b was measured on CT (2.301 mg g^{-1} FW) and in R1 stage (0.606 mg g^{-1} FW), and lowest on DH (2.032 mg per g FW) and in R3 stage (1.790 mg g^{-1} FW). In 2002/2003 at concentration of chlorophyll (a+b) very significant influence showed Phenophase. The highest chlorophyll concentration (a+b) was recorded in R2 stage (2.332 mg g^{-1} FW), whereas the lowest chlorophyll concentration (a+b) was recorded in V3 stage (1.892 mg g^{-1} FW). The ANOVA for concentration chlorophyll (a+b), (Table 4) during both years showed significant impact of factor Tillage during experiment period (F=5.279*), and Phenophase (F=2.777*). Very significant influence was recorded for interaction Year x Phenophase (F=14.739**). The average concentration of chlorophyll a+b for both years was 2.126 mg g^{-1} FW. The highest concentration of chlorophyll a+b was measured on CT (2.245 mg g^{-1} FW) and in R2 stage (2.251 mg g^{-1} FW), and lowest on NT (2.059 mg g^{-1} FW) and in V3 stage (2.050 mg g^{-1} FW).

Table 4: Chlorophyll a+b concentration (mg g^{-1} FW) for different soil tillage systems (B) for four phenophases (C) in years 2001/2002 and 2002/2003 (A)

	CT (B_1)	DH (B_2)	NT (B_3)	average C
		2001/2002 year (A_1)		
V_3 (C_1)	2.385	2.137	2.105	2.209 a
R_1 (C_2)	2.494	2.299	2.214	2.336 a
R_2 (C_3)	2.329	2.076	2.102	2.170 a
R_3 (C_4)	1.996	1.615	1.759	1.790 b
average B	2.301 a	2.032 b	2.045 b	2.126
		2002/2003 year (A_2)		
V_3 (C_1)	1.932	1.956	1.788	1.890 a
R_1 (C_2)	2.064	1.724	2.084	1.958 a
R_2 (C_3)	2.405	2.387	2.203	2.332 b
R_3 (C_4)	2.356	2.412	2.212	2.326 b
average C	2.189	2.120	2.072	2.127
average of experiment				2.126
average A_{1-2}	2.126	2.127		
average B_{1-3}	2.245 a	2.076 b	2.059 b	
average C_{1-4}	2.050 a	2.147 ab	2.251 b	2.058 a

Average concentration of carotenoids in 2001/2002 was 0.542 mg g^{-1} FW (Table 5). Concentration of carotenoids was under significant influence of Phenophase (F=38.539**). The highest concentration of carotenoids was recorded in V3 stage (0.667 mg g^{-1} FW), and lowest on R3 stage (0.442 mg g^{-1} FW). In 2002/2003, concentration of carotenoids was under significant influence of Phenophase (F=15.616**). The lowest concentration of carotenoids was recorded in V3 stage (0.539 mg g^{-1} FW), and highest on R3 stage (0.703 mg g^{-1} FW)

Table 5: Carotenoids concentration (mg g^{-1} FW) for different soil tillage systems (B) for four phenophases (C) in years 2001/2002 and 2002/2003 (A)

	CT (B_1)	DH (B_2)	NT (B_3)	average C
		2001/2002 year (A_1)		
V_3 (C_1)	0.690	0.660	0.651	0.667 a
R_1 (C_2)	0.603	0.628	0.588	0.606 b
R_2 (C_3)	0.463	0.421	0.471	0.452 c
R_3 (C_4)	0.465	0.446	0.415	0.442 c
average B	0.555	0.539	0.531	0.542
		2002/2003 year (A_2)		
V_3 (C_1)	0.529	0.562	0.526	0.539 a
R_1 (C_2)	0.597	0.483	0.595	0.558 a
R_2 (C_3)	0.669	0.676	0.636	0.660 b
R_3 (C_4)	0.690	0.732	0.688	0.703 b
average C	0.621	0.613	0.611	0.615
average of experiment				0.578
average A_{1-2}	0.542 a	0.615 b		
average B_{1-3}	0.588	0.576	0.571	
average C_{1-4}	0.603	0.582	0.556	0.573

The average concentration of carotenoids for both years was 0.578 mg g^{-1} FW. The ANOVA showed that the carotenoids concentration was under significant impact of the Year (F=19.490*).

The stem length of soybean had a significant impact as weather conditions (F=41.387**) during both years studied, while the effect of soil treatment missed. On average, for both year the stem length of soybean was 85.33 cm (Table 6).

Number of branch was under significant influence of Year (F=33.380**). The average number of branch per plant for both years was 2.10. The highest number of branch was recorded in 2002/2003.

Weight of pods on average for both years was 25.96 pods per plant and was under a significant influence of climatic conditions in these years. In dry year (2002/2003), weight of pods was for 12.32 g per plant increased compared to 2001/2002.

The average yield was 2.87 t ha^{-1} and was significantly influenced by climatic conditions in years of research, variations of soil treatment, and interaction of these two factors. The highest yield was achieved in 2002 and it was 3.58 t ha^{-1}, which is 1.42 higher compared to 2003 (Table 6). Reduced yield in 2002/2003 was consequence of unfavourable climatic conditions (Jug, 2006). The highest yield was recorded on CT (3.23 t ha^{-1}), while the lowest yield was detected on NT (2.37 t ha^{-1}).

Table 6: Analysis of variance and mean for morphological parametars and yield of soybean as affected by tillage from 2001/2002 to 2002/2003

Variable	Lenght of stem (cm) R1 –	Number of branch per plant R2	Pod weight (g per plant)	Yield of grain (t ha^{-1}) R8 –
Year				
2002	93.26	1.65	19.80	3.57
2003	77.39	2.54	32.11	2.16
Tillage				
CT	85.98	1.99	25.97	3.92
DH	87.89	1.94	26.91	3.00
NT	82.11	2.35	24.98	2.37
Average	85.33	2.10	25.96	2.87
Year	41.39**	33.38**	48.22**	400.11**
Tillage	ns	ns	ns	32.85**
YxT	ns	ns	ns	8.15**

ns: not significant; *Values significant at P<0.05 level probability; **Values significant art P<0.01 level probability

Conclusion

The influence of Year was significant for the production of chlorophyll b and carotenoids, while the soil treatment had a significant effect on the concentration of chlorophyll (a + b) and chlorophyll b. The interaction Year x Tillage proved to be significant only for concentration chlorophyll b and carotenoids. Effect of tillage was significant only in 2002 (the highest concentration of chlorophyll b and chlorophyll (a + b) was measured in the CT - 0601 mg chlorophyll b per g FW, 2.301 mg chlorophyll (a + b) per g FW) while in 2003 of testing this effect was missed. Agroclimatic conditions significantly affected all the morphological characteristics of soybean, while the effect of tillage was not statistically significant. The longest stems of soybean were measured in 2002 (93.26 cm), while the number of branches per plant and weight of pods per plant were higher in the dry year, 2003 (2.54 branches per plant, and 32.11 g per plant). The yield was significantly influenced by agroclimatic conditions in these years as well as significantly influenced by variants of tillage. The highest yields were obtained in 2002 (3.58 t ha^{-1}) and on CT treatment (3.23 t ha^{-1}).

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Numerical Approaches in Tillage and Soil Modelling

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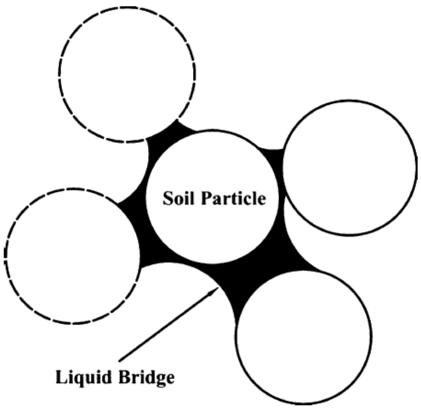
Abstract
The discrete element method (DEM) seems to be a promising approach for constructing a highfidelity model to describe the soil–implement interaction. Discrete Element Models were built in correspondence with the field tests. In this paper we will introduce the methods of DEM approach was used in developing a modell for the prediction of draught force on cultivator sweeps. The mechanical behavior of soil is very complex, and depends on factors including confining pressure, density, and drainage condition. Conventional approach to explore the mechanical behavior of soil mainly relies on the experimental tests in laboratory. The implementation of the DEM is carried out by a series of numerical tests on granular assemblies with varying confining pressures. The results demonstrate that such numerical simulations can produce correct responses of the soil behavior in general, including the critical state response, as compared to experimental observations. In the second half of this paper we demonstrated the influences of cultivator sweep geometry was researched by the DEM and compared the results of soil bin tests to validate the sweep shares. And as the result of the methodology we can validate the optimal β angle of the sweep in a 2D model.

Keywords: Soil, Cultivator, DEM, Modeling, Tillage, Soil Bin, Forces, Optimization

Introduction
The Discrete Element Method
DEM is a discontinuous numerical method based on molecular dynamics. It was developed and applied for analyzing rock mechanics by Cundall in 1971. The soil which is cut or separated by soil engaging components is much more discrete, therefore DEM is an ideal method to analyze large discontinuous deformations of soil. Cohesive soils are very common we come across in agricultural operations and constructions. The analysis of the dynamic mechanical behavior of cohesive soils subjected to external forces is very important in designing and optimizing the tillage tools. Cohesive soil contains water, and the presence of water can produce cohesion between soil particles, which makes the mechanical structure of these soils much more complex. In order to simulate and analyze the mechanical behavior of cohesive soil accurately, it is necessary to establish a DEM mechanical model of cohesive soil by considering the effects of water on the mechanical behavior of cohesive soil. We could simulate this cohesion in the PFC2D Discrete Element Program, because it allows particles to be bonded together at contacts.

Model description
The Parallel-Bond Model
The parallel-bond model describes the constitutive behavior of a finite-sized piece of cementatious material deposited between two balls. The two balls are treated as either spheres or cylinders. These bonds establish an elastic interaction between particles that acts in parallel with the slip or contact-bond models thus; the existence of a parallel bond does not preclude the possibility of slip. Parallel bonds can transmit both forces and moments

between particles, while contact bonds can only transmit forces acting at the contact point. Thus, parallel bonds may contribute to the resultant force and moment acting on the two bonded particles.



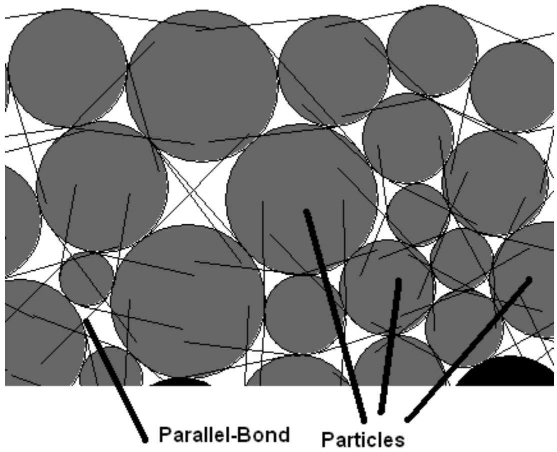


Figure 1: Liquid bridges between soil particles. Figure 2: The finite-sized piece of cementatious material

The DEM appears to be a pertinent complementary tool for the study of unsaturated soil mechanics. More precisely, discrete methods should convey a new insight into the discussion about the controversial concept of generalized effective stress by relating basic physical aspects to classical phenomenological views.

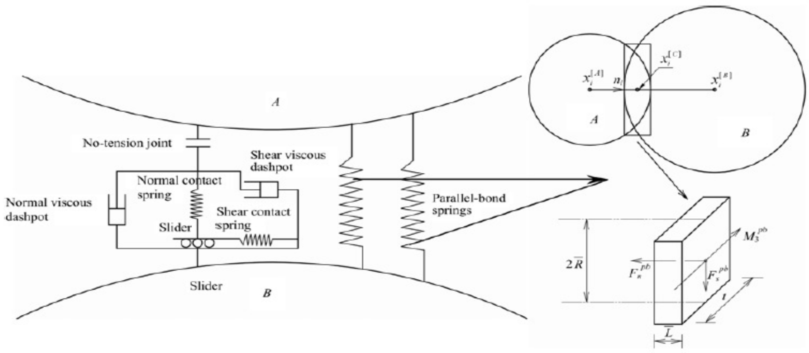


Figure 3: The nonlinear mechanical model of contact between soil particles.

A parallel bond can be envisioned as a set of elastic springs with constant normal and shear stiffnesses, uniformly distributed over either a circular or rectangular cross section lying on the contact plane and centered at the contact point. These springs act in parallel with the point-contact springs that are used to model particle stiffness at a point, and whose constitutive behavior. Relative motion at the contact (occurring after the parallel bond has been created) causes a force and a moment to develop within the bond material as a result of the parallel-bond stiffnesses. This force and moment act on the two bonded particles and can be related to maximum normal and shear stresses acting within the bond material at the bond periphery. If either of these maximum stresses exceeds its corresponding bond strength, the parallel bond breaks. A parallel bond is defined by the following five parameters: normal and shear stiffness kn and ks [stress/displacement]; normal and shear strength σc and τc [stress]; and bond radius R.

Material and methods

Choosing Material Properties for PFC Models

Although it is relatively easy to assign chosen properties to a PFC model, it is often difficult to choose such properties so that the behavior of the resulting synthetic material resembles that of an intended physical material. For codes such as PFC that synthesize macro-scale material behavior from the interactions of microscale components, the input properties of the microscopic constituents are usually not known. In this case, we must first determine the relevant behaviors of our intended physical material, and then choose the appropriate microproperties by means of a calibration process in which the responses of the synthetic material are compared directly with the relevant measured responses of the intended physical material. This comparison can be made at both laboratory scale (e.g., triaxial, biaxial and static-fatigue response) and field scale (e.g., evolution and extent of damage around various excavations), depending upon the intended application of the PFC model.

Biaxial Test

A series of shear tests were performed. The simulated mechanical behaviour of granular materials is compared with those observed from the laboratory tests. The soil sample is loaded initially by a vertical force only, applied by the dead weight of a loading plate and some additional weights on it, through the intermediary of a small steel plate on top of the sample. Because of this plate the sample is free to deform in vertical direction during the test. The actual consists of the lateral movement of the lower half of the box with respect to the upper half, at a constant (small) speed, with a horizontal force acting in the plane between the two halves. This force gradually increases, as the box moves, and is measured by a pressure ring or a strain gauge. The horizontal force reaches a maximum value after some time, and the force remains more or less constant afterwards, or it may slowly increase or decrease. It seems logical to assume that the maximum value of the horizontal force (Tf) is related to the vertical force N by a relation of the form

$$Tf = cA + N \tan \varphi,$$

where A is the area of the sample, c is the cohesion of the material, and φ its friction angle.

A point of Mohr's circle defines the normal stress and the shear stress on a certain plane. The stresses on all planes together form the circle. It appears that the ratio of shear stress to normal stress varies along the circle, i.e. this ratio is different for different planes. It is possible that for certain planes the failure criterion is satisfied. In this failure criterion has also been indicated, in the form of two straight lines, making an angle φ with the horizontal axis. Their intersections with the vertical axis are at distances c. In order to underline that failure of a soil is determined by the effective stresses as σ'. Thus it can be conjectured that failure will start to occur whenever Mohr's circle just touches the Coulomb envelope. This is called the Mohr-Coulomb failure criterion. If the stress circle is completely within the envelope no failure will occur, because on all planes the shear stress remains well below the critical value.

Biaxial-Test Environment

The biaxial-test procedure is described in terms of the following four sets of inputs listed in:

- During a typical biaxial test, all four walls are frictionless. The normal stiffnesses of the lateral walls are set equal to βx times the average particle normal stiffness of the specimen.

The normal stiffnesses of the top and bottom walls are set equal to βy times the average particle normal stiffness of the specimen.

- The biaxial test begins by applying confining and vertical stresses (σtx and σty, respectively) to the specimen by activating the servo-mechanism that controls the velocities of the four confining walls. The servo behavior is controlled by the wall-servo tolerance, such that the corresponding velocity will be zero when $|(\sigma - \sigma t\ )/\sigma\ t| \leq$ -. After the specified values of confining and vertical stress have been applied (within the given tolerance) to the specimen, the specimen dimensions at this stage are taken as the initial (reference) dimensions to be used in the computation of stresses and strains (see below) during the subsequent loading phase.

- The specimen is loaded by moving the platens towards one another at the velocity vp. If this velocity is applied in a single step, the large acceleration will produce inertial force within the specimen that may produce damage. In order to eliminate such inertial effects, the platen acceleration can be controlled by specifying appropriate values of Np and Sp. The platen velocity will be adjusted to reach a final value of vp in a sequence of Sp stages over a total of Np cycles.

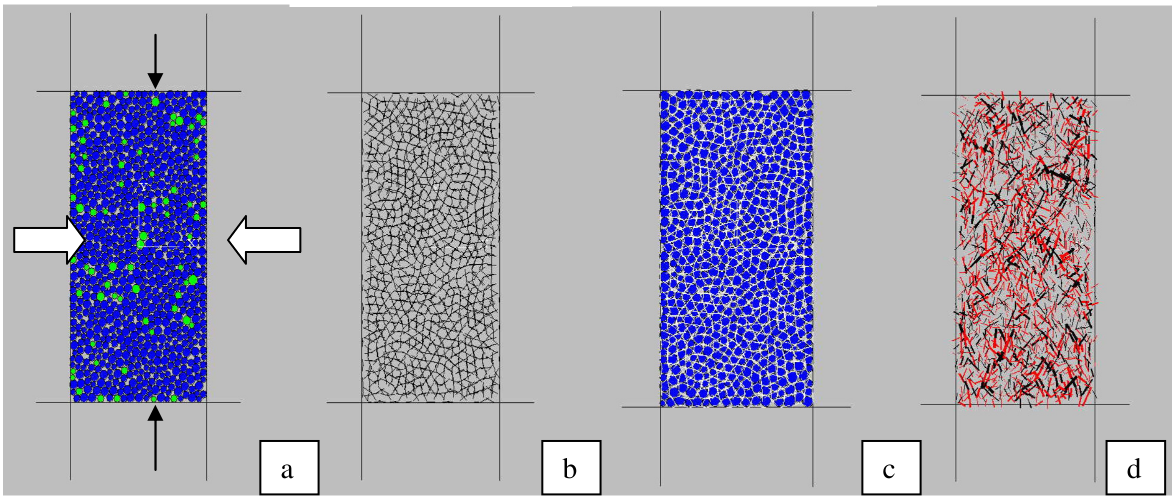


Figure 4: The specimen (a) vertical and confining stress, (b) contact structure, (c) the parallel bonds between particles, (d) the parallel bonds normal and shear forces, when acting the vertical forces under the biaxial test.

	SOIL
material designator	
specimen-genesis control param.	
et2_rlo (mm)	0,275
et2_radius_ratio ()	1,66
md_wEcfac ()	1,1
tm_req_isostr (MPa)	-1,0
tm_req_isostr_tol ()	0,5
flt_def ()	3
flt_remain ()	0,0
particle-based material param.	
md_dens ()	2630,0
md_Ec (GPa)	62,0
md_knoverks ()	2,5
md_fric ()	0,5
parallel-bond param.	
md_add_pbonds (boolean)	1
pb_radmult ()	1,0
pb_Ec (Pa)	1e6
pb_knoverks ()	1,0
pb_sn_mean (Pa)	1e3
pb_sn_sdev (Pa)	1e3
pb_ss_mean (Pa)	1e3
pb_ss_sdev (Pa)	1e3

Table 1: Specimen properties

***** Biaxial-test results follow. . .
md_run_name = sC1_mA_tA10
md_numballs = 843
Confinement: et2_wsxx_req = -1.00000000000e+005
===== Elastic Constants:
E (plane stress, meas-based) = 8.71373504175e+009
nu (plane stress, meas-based) = 3.81784724083e-001
===== Strengths:
peak strength (wall-based) = -8.26286568304e+005
peak strength (meas-based) = -5.84096792850e+005
crack-initiation factor, pk_ci_fac = 1.00000000000e-002
crack-initiation stress (wall-based) = -5.29886535498e+005
===== Damage at peak stress (wall-based):
pk_crk_num = 4.50000000000e+002
pk_crk_num_cnf = 0.00000000000e+000
pk_crk_num_csf = 0.00000000000e+000
pk_crk_num_pnf = 3.09000000000e+002
pk_crk_num_psf = 1.41000000000e+002

Table 2: Biaxial test results

- During the biaxial test, the deviatoric stress, $\sigma d = \sigma y - \sigma x$, is monitored, and the maximum value of $|\sigma d|$ is recorded. During a typical test on a bonded material, this value will increase to some maximum, and then decrease as the specimen fails, and the test is terminated when $|\sigma d| < \alpha\ (\sigma d)\ max$. If the test is performed on an unbonded material, the test is terminated when $-y < (-y)$lim.

-During the biaxial test, the specimen behavior is monitored using the *PFC* history mechanism to sample and store relevant quantities. The quantities that are monitored include: a) stresses and strains; b) energy quantities; and c) microcracks.

Description of the Synthetic Material

In this biaxial test, one parallel bonded fine-resolution specimen were generated. The specimen has a height of 63.4 mm and a width of 31.7 mm and have uniform particle size distributions bounded by *R*min and *R*max, with *R*max = 1.66 *R*min.

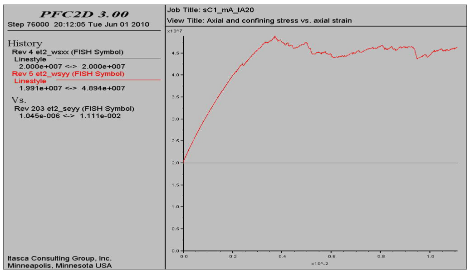


Figure 5. Axial and confining stress vs. axial strain.

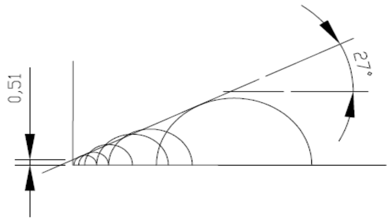


Figure 6. Mohr’s circles, define the cohesion and the internal friction angle.

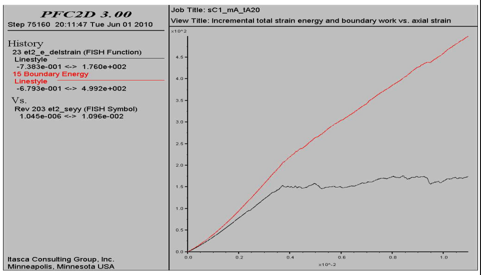


Figure 7: Incremental total strain energy and boundary work vs. axial strain.

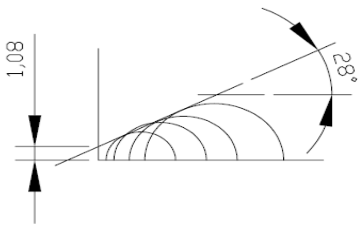


Figure 8: Mohr’s circles, define the cohesion and the internal friction angle.

A strength envelope (peak strength versus confining pressure) was obtained by subjecting both rectangular specimens to a set of biaxial tests at confining pressures of 0, 1, 5, 10, 20, 30, 70 MPa. For each confining pressure:

During the biaxial test, the wall normal stiffnesses are set and the platen velocity is adjusted to reach a final value of 0.05 m/s in a sequence of 10 stages over a total of 400 cycles. In this test, the top and bottom wall normal stiffnesses were set equal to 1.0 times the average particle normal stiffness. The lateral wall normal stiffnesses were chosen to minimize the amount of overlap between the particles and the wall.

Test Results

The biaxial-test result presented in Figures 6-9 The information was obtained from the functions In these figures:

SPECIMEN		Results of Biaxial Tests			
x: pack	y: Pc	sig_f	sig_ci	N_fn	N_fs
	($x10^4$Pa)	($x10^4$Pa)	($x10^4$Pa)	(piece)	(piece)
1	1	36,5	4,91	8	5
1	5	45,26	19,5	158	81
1	10	59,87	38,56	571	200
1	20	92,1	60,5	1053	277
1	30	117,2	65,1	1057	303
1	70	226,9	117,7	1172	321
avg.	*0,1*	*131,7*	*61,3*	*590*	*163*

Table 3: Biaxial Test Results

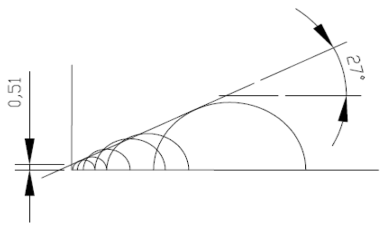


Figure 9: Mohr’s circles

6

(a) the Young's modulus is computed using the axial stress and strain at a point when one half of the peak strength had been obtained and is designated by *E*;

(b) the peak strength is the maximum value of axial stress existing at peak load and is designated by **sig-f**;

(c) the crack-initiation stress corresponds with the point during the test at which 2% of the total number of crack existing at peak load have been formed and is designated by **sig-ci**;
(d) the total number of normal- and shear-type cracks existing in the specimen at peak load are designated by **N fn** and **N fs**.

Simulation and analysis in cohesive soil by DEM
The dynamic behavior of cohesive soils during the loosening process by a cultivator sweep was simulated by using the above established DEM mechanical model of cohesive soil via PFC2D. The initialization of the interaction between the tool and cohesive soils is the complete model. The model is composed of different sizes of discrete particles. The parallel bonds produce cohesive forces between discrete particles, so parts of discrete particles are conglomerated and form particle aggregate clusters after the tillage process. The complete model is formed by bonding of elements in wide sizes. This structure of the model is similar to that of the actual cohesive soils.

The distance between the lines is equal to two times the parallel-bond radius _R and the two lines have lengths equal to the distance between the centers of the two bonded particles. Parallel bonds near the tool decrease significantly and even disappear with time going. The reason is that the parallel bonds break (if the parallel bonds break, they will disappear) with the rupture and separation of the soil particle aggregate clusters. The disturbance of cohesive soil increase and more soil bonded particle rupture and separation with the tool moving.

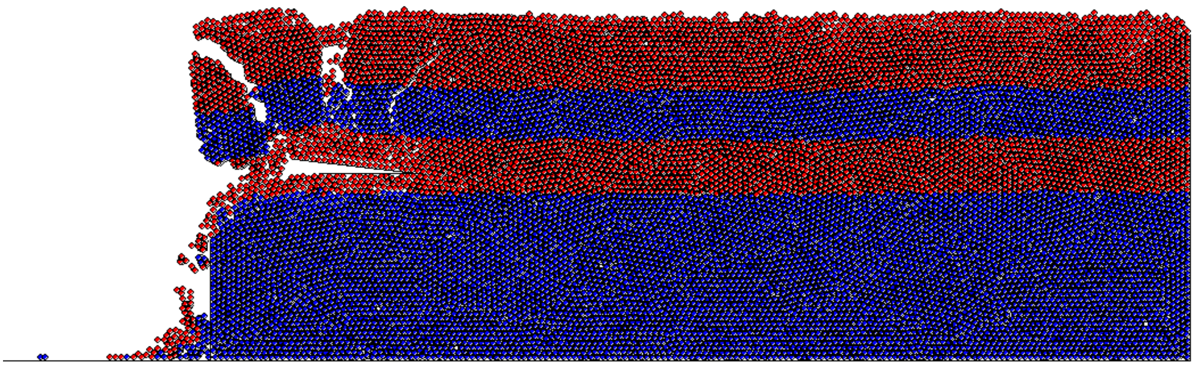


Figure 10: Loosening and clod generation

Results
The parallel-bond contact was used to describe the behavior of the cohesive soil (discontinuous) during soil-tool interface process. A series of models were analysed with various soil properties, speed and inclined angles using two dimensional models. The results showed the significant effect of the tool incline angles and working speed on cutting

forces in 20 cm depth. The parallel bonds produce cohesive forces between discrete particles, so parts of discrete particles are conglomerated and form particle aggregate clusters after the tillage process. The complete model is formed by bonding of elements in wide sizes. This structure of the model is similar to that of the actual cohesive soils.

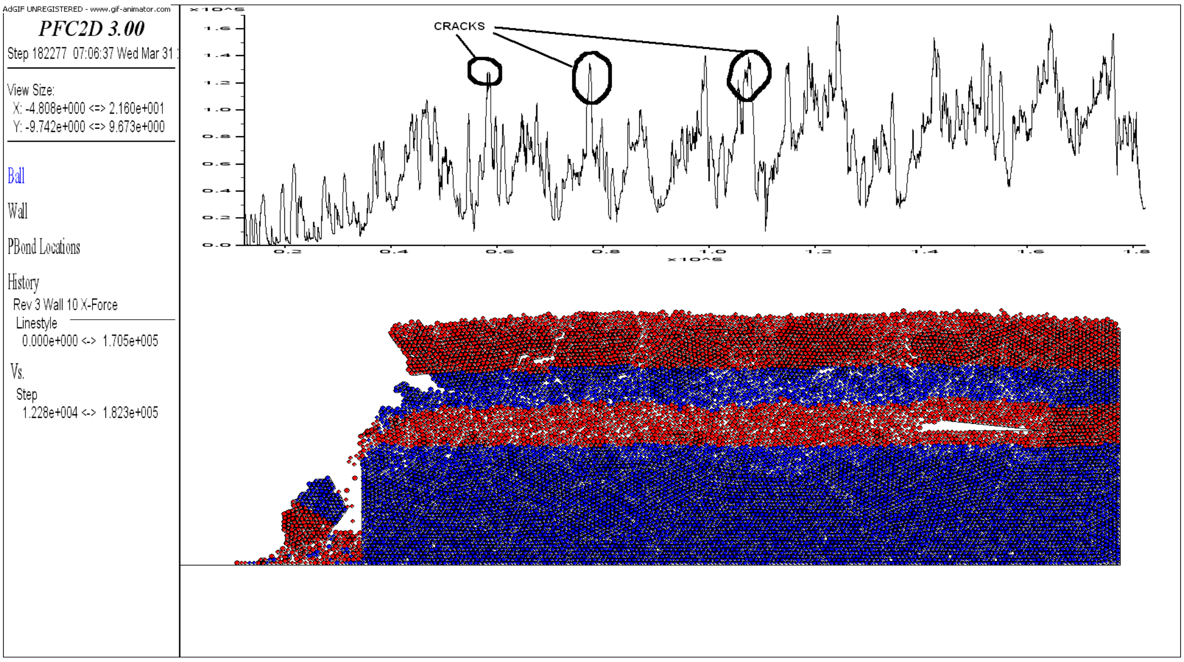


Figure 11: Draft force (N). Speed: 0.6 m/s. Result of a shear process, with the cracks marked.

During the simulated tillage process by a cultivator sweep, soil evolves from the extrusion between soil clumps, the humping ahead of the tillage tool, and the climb along the surface of the sweep, to the rupture and separation of cohesive soil cluster.

When the maximum normal stress exceeds the normal bond strength, or the maximum shear stress exceeds the shear bond strength, the parallel bonds between the contact particles within the particles rupture. In the tillage process, the resulted clusters break and divide into smaller clusters or discrete particles that seems a sin the real time research. That means, the clusters rupture and separate into more discrete particles with the tool tillage.

Conclusion

In this paper, granular material behaviour is investigated by the numerical approach with the aid of DEM. While the experimental approach works at a macroscopic level, the numerical method has the advantages of providing the mechanical behaviours of the granular assembly at both the macro- and micro- scales.

The two dimensional discrete element analyses carried out to simulate soil-tool interaction and the effect of soil properties and the tool inclined angle on predicted cutting forces was studied. The parallel-bond contact was used to describe the behavior of the cohesive soil (discontinuous) during soil-tool interface process. After the biaxial test methods with which we validated the micro propertys, a series of models were analysed with various soil properties, speed and inclined angles using in the two dimensional models. The results showed the significant effect of the tool incline angles and working speed on cutting forces in 20 cm depth.

Results calculated from the DEM model support the following conclusions:

- The mechanical behavior of cohesive soils during the tillage process by a sweep was simulated. It can be seen from the simulation, the parallel bonds in the model made the discrete particles bond into clusters initially, and then these clusters were broken into smaller clusters or discrete particles during the process.
- The DEM mechanical model of cohesive soil with parallel bonds between particles was established by considering the capillary and the dynamic viscous forces induced by the presence of water, along with the contact forces and the forces of friction between soil particles by the conventional DEM model.
- It is improtant to simulate the behavior of a synthetic material whose microproperties can be chosen to reproduce the relevant behaviors of a particular solid. The appropriate microproperties are determined by a calibration process in which the response of the synthetic material is compared directly with the measured response of the physical material.
- Using the calibrated material parameters, a tool (sweep) moving through the soil were modelled and the results compared to experimental results. Results show that during the initial stages of sweep displacement, DEM can accurately predict the tool forces.

It can be concluded that the discrete element method can be used for simulating the soil cutting processes in non-homogeneous soils and investigation of soil loosening and sweep performance. The model can be used in development procedures of soil loosening tools, reducing the number of soil bin and field test.

Acknowledgement

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Geostatistical model evaluation for soil tillage suitability on Osijek-Baranya County example

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Abstract
This paper presents a computer model to determine land suitability for soil tillage in eastern Croatian based on geostatistical analysis of soil data. As the basis and source of soil types data was used the Croatian soil suitability map in digital form from which used data of soil types and soil chemical analysis data from the interpretative database fertility control of Osijek-Baranja County, a total of 17 341 samples of soil. Presents the model evaluation arable land workability uses a 6 indicators benefits of which three were identified accurately (pH, humus and elevation), and the remaining three are based on Digital Soil Map of Croatian and pedosystemic units whose inherent properties are ranked relative to particular indicators of suitability for soil tillage. Computer simulation using the described models and kriging geostatistical method obtained results showed that 66% of agricultural land belongs to the class of limited suitability for soil tillage (P3), approximately 21% is moderate and very convenient (P2 and P1), and only ~13% belong to the temporary or permanently unsuitable for soil tillage.

Keywords: Geostatistical computer model, soil suitability, soil tillage, kriging

Introduction
The basic role of soil is a function of substrate plant nutrient from plants that satisfy needs for water and nutrients. For rooting and uptake mineral elements, including water and air, is desirable as larger volume of soil and soil tillage or preparation of soil for growing plants emerged as extremely important agro technical measures that strongly influence the growth, development and primary production. In practical farming, such as tillage, crop rotation and fertilization, not only to affect crop yields, but changing the quality of the soil through changes in individual indicators (water-air regime, the availability and dynamics of nutrients, accumulation or loss of organic matter and other.).

Evaluation of soil suitability for a particular purpose, and also for its tillage, must respect the functions, processes and relevant indicators of soil quality which can be defined as a measurable value on an appropriate methodology (Vukadinovic et al., 2009). In general, the attributes describe the critical properties of the soil, but in many cases can not be measured directly, so they joined the substitute property or pedotransfer functions as indirect, practical measures of attributes which is used in this model. The indicators may represent one attribute or set of attributes. It is generally accepted as indicators of benefits should be easily measurable, sensitive to variations in soil with relatively low analytical or measurement error (MacEwan and Carter, 1996).

Since the model calculates a simplified version of reality obtained without the need to carry out field experiments, often and successfully used in the assessment / evaluation of land. Mainly biophysical models are simplified systems of land use that allow prediction of their performance before their actual implementation (Rossiter 1996, 2003). It provides the behavior of land use in the physical, quantitative terms, such as crop yield, nutrient supply, and the effects on the environment, the risk of erosion, workability, etc. and the impact on land management. Classified according to the complexity of calculation (qualitative and quantitative), complex descriptive (empirical and mechanistic) and may be different levels in the organizational hierarchy.

Models for evaluation of soil are very widespread and may be based on land indexes, yield, price of land, soil fertility / quality or combined, for example, land prices and yields achieved and even the difference to other land use types (LUT = Land utilization Type), but always within the established order of importance of the model or hierarchy certain properties (LC = Land Characteristics) (FAO, 2000).

However, it is very difficult to create efficient and also reliable model estimates of soil suitability for tillage and this work is the first attempt in this direction that takes into account the soil-physical and climatic particularities of the eastern Croatian. Therefore, very few models to assess the benefits of soil treatment, and they are mainly based on only a few indicators. For example, within the interpretive base ISPAID (Iowa State University, 2006) are just two indicators for evaluating the benefits of soil tillage (Tilt and Power Rating Index), based on the content of clay, silt and sand, the participation of organic matter and soil drainage. In Croatia, Bogunović et al. (1998) gives a presentation of Croatian soil suitability based solely on the few and not sufficiently reliable data General Soil Map of Croatia.

Although GIS is powerful in many areas, many models for land suitability assessment now imperfect, they lack the appropriate tools for data input and management, and have poor presentation of soil properties and hence the low applicative value. Therefore, the focus of this work, not only presenting a conceptual point of view, or inventory of land resources, but the integration of GIS, the first of geostatistical methods and mathematical-computer model of land suitability assessment for the soil tillage in working-experimental validation of the model is subject to specific conditions in the eastern Croatian (Vukadinovic et al., 2008a and 2008b).

This paper describes a geostatistical computer model of soil suitability assessment of Osijek-Baranja County for soil tillage, and data were analyzed and visualized by GIS tools (ArcMap V9.3). For the modeling we have used data from Croatian soil suitability map (Bogunović et al., 1997) and the results of soil analysis from the interpretive database fertility control of our county (17,341 samples), which in addition to the exact chemical indicators of soil contains some estimates of physical properties, and information about soil landscape, crop rotation, organic fertilization, soil biogenity etc.

Methodology

GIS as a foundation and source of information relating to the soil physical properties was used Croatian soil suitability map. Work on it was started in 1962 in continuation to 1985, and despite the work to continue 1997 years still does not contain all the necessary data for assessing soil suitability for any purpose. Because of a very small number soil physical and chemical analysis, aggregation of basic pedosystemic units (digital form of maps) into larger polygons, as the basis for any kind of modeling is not sufficiently reliable, but can serve as a demonstration model able to estimate the benefits of our soils.

According to the basic programming document Croatian Basic Soil Map gives as idea of global inventory of research fund Croatian soil, and an indispensable condition for responsible management and soil protection. The map consists of:

a) Soil map in scale 1: 50.000,
b) Explanation of soil maps with soil map sheets,
c) Regional studies to review soil maps in scale 1:200.000 and
d) Monograph of Croatia soils with soil map in scale 1:500.000.

Since the model is always an approximation of reality, include only relevant aspects of land suitability assessment for soil tillage on the basis of available data Croatian soil suitability maps and chemical analysis of soil samples which were geolocated with the GPS:

1) General soil tillage workability (5 classes based on soil types, f1),
2) Soil tillage workability in the unfavorable state of humidity (3 class based on the type of soil wetting, f2),
3) Index of the required power (3D function that combines the bulk density of soil and organic matter content, f3, Graph 1),
4) Applicability of direct seeding (3 class based on the physical properties of soil, f4),
5) Automorphic (includes pH) or hydromorphic soil type (4 class, logical function, f5*)*
6) Slope (Six classes based on altitude).

The computer model uses tables of ranks for the five indicators of suitability (F1 to F5), and was built as an application in MS Excel, and allows easy application and for other agroecological areas, of course, with the change of ranks. Tables are shown the value and description of the ranks (more is better) and rules for their use:

Table 1: General soil workability (f1)

General workability	rank
1) soil suitable for tillage	15
2) soil moderately suitable for tillage	10
3) limited soil suitable for tillage	5
4) soil temporarily unsuitable for tillage	2
5) soil permanently unsuitable for tillage	0

Table 2: Workability in the unfavorable soil moisture (f2)

Workability in the unfavorable conditions of moisture	rank
1) tillage possible in a wide range of moisture levels	25
2) tillage possible in optimum range of moisture	10
3) tillage possible in the narrow limits of humidity	5

Table 3: The possibility of direct seeding (f4, No-tillage)

Applicability of direct seeding (No-tillage)	rang
1) Without restriction	10
2) After agro- and hydro technic measures of improvements	7
3) permanently restricted	4

Index of soil tillage power required depends on the bulk density of soil (6 classes, field evaluating texture group, converted to bulk density) and determined the exact content of humus with 3D function (Picture 1.):

$\underline{\text{Power Index} = -65.74+92.66\times tgr+10.54\times humus-32.14\times tgr^2-1.09\times tgr\times humus-1.08\times humus^2}$

Index of ways the wetting soil (F5) may be negative in hydromorphic soils, including soil pH (due to the leaching process and the creation of argiluvic layer), is determined by the logical expression:

IF (soil type = automorphic and pH-KCl > 5)
THEN rank = 20
ELSE rank = 0
ELSEIF (soil type = hydromorphic AND pH-KCL > 5)
THEN rank = -5
ELSE rank = -10
ENDIF

Ways of wetting (automorphic or hydromorphic soil type) was determined by *Škorić (1986)*.

Graph 1: Function index necessary power for soil tillage (f3)

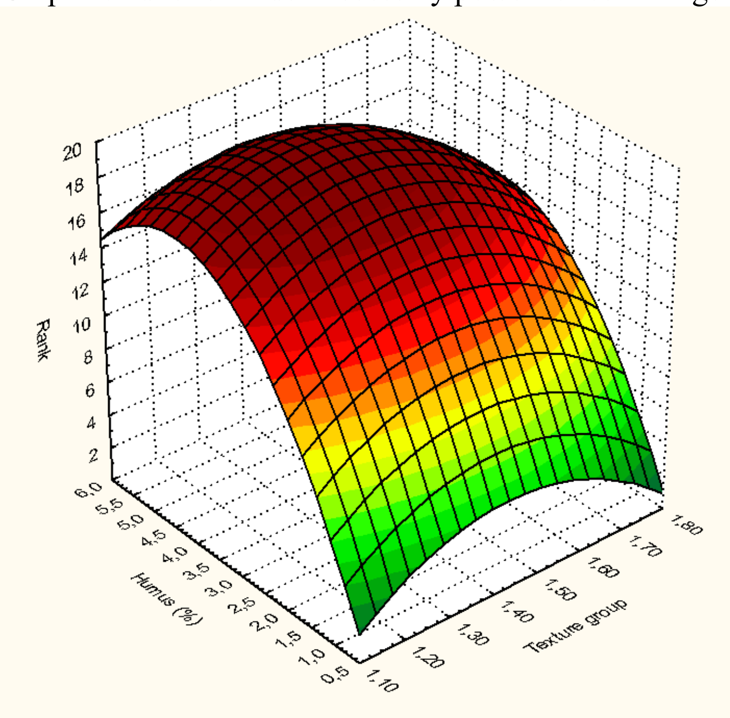


Table 4: Slope (f6, estimate based on altitude)

Slope (Latidude m)	rank
1) 0	10
2) 100	8
3) 150	6
4) 200	4
5) 250	2
6) 500	1

The described model suitability assessment for soil tillage is tested on the based of 17 341 samples of soil taken in the eastern Croatian in period 2003-2009. Since each sample is exactly geopositioning in WGS 1984 projection (lat, long, alt), with Croatian soil suitability maps in digital format are obtained by overlapping layers (layer intersect, GIS ArcMap tool V9.3) data on soil type on which the automatically ranked indicators of underlying soil type. Thus, the geographical position, altitude, humus and pH-KCl were determined to exact laboratory analysis; the texture class is given by "feeling method" on the field when taking soil samples, and the least reliable data on soil type taken with the ArcMap V9.3, given the low accuracy and unreliability of data Digital Soil Map of Croatian. Also, it was not possible to use physical data on soils, because the territory of the Osijek-Baranja County, Croatian digital soil map contains only 20 soil profiles with the needed information.

Rankings are fitted so that the sum of the greatest value of all indicators is 100 and the expression of soil suitability for processing is always in the range 0-100, or a percentage (relative suitability).

Results and discussions

After the modeling was first performed basic statistical analysis of the results (Table 5).

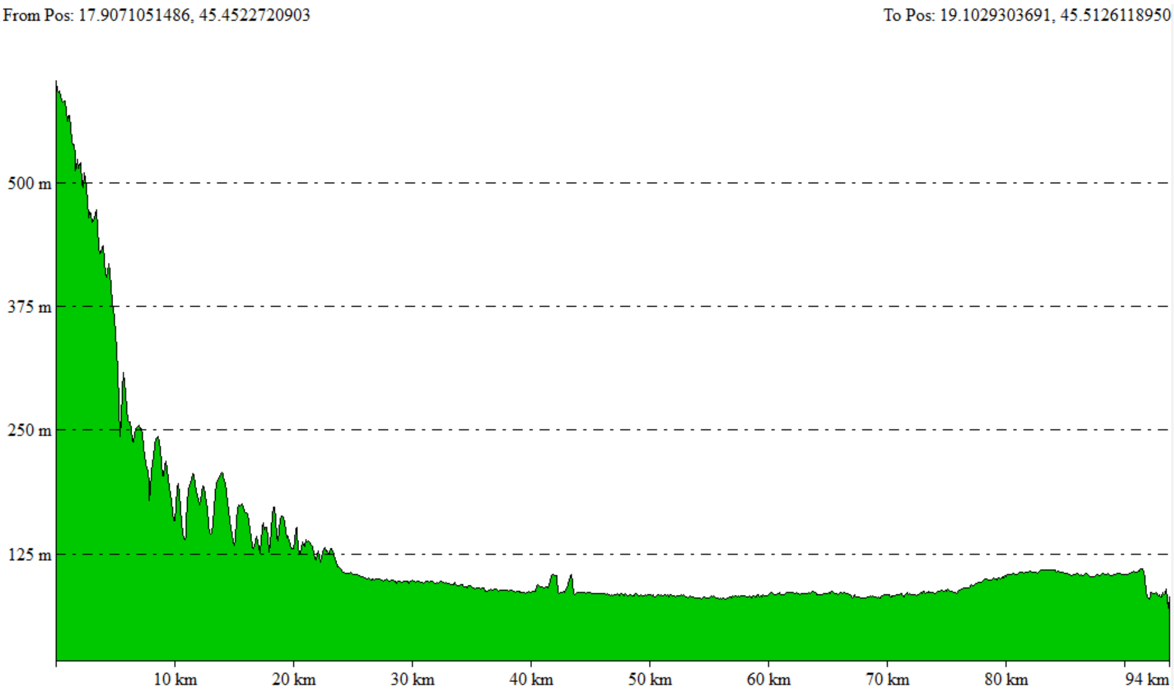
Table 5: Basic statistical indicators modeling of soil suitability for tillage

	Alt	Humus	ρ_v	Rel. suit.	f1	f2	f3	f4	f5	f6
Average	92.01	2.13	1.42	49.60	9.58	12.80	14.39	7.49	-4.03	9.60
Sd	19.39	0.75	0.09	16.49	3.51	8.44	2.71	1.12	7.93	0.96
Kv%	21.08	35.17	6.69	33.25	36.69	65.91	18.82	14.94	196.69	9.98
Max.	831.30	6.92	1.75	99.78	15.00	25.00	19.78	10.00	20.00	10.00
Min.	74.70	0.32	1.20	0.00	0.00	5.00	3.10	4.00	-10.00	2.00

Basic statistical data analysis and assessment of soil suitability for tillage shows that the average altitude is 92.01 m, which includes parts of Pozega-Slavonia County and the mountain Krndija and Papuk and with a few samples that did not significantly affect the average altitude. Figure 1 shows the height profile of Osijek-Baranja County in the west → east direction. Thus, the study included predominantly lowland eastern Croatian region which clearly shows the inclination indicator (F6) with the rank of 9.60 (of 10 maximum) with very little variation (CV% = 9.98). Of course, on sloped terrain, especially in higher positions should be ranked on the potential of erosion, which was planned after the completion of DEM maps (Digital Elevation Model) of our county.

The humus concentration in the studied soils was on average 2.13% with a high variability of CV% = 35.17% (a sample with very little, but a lot of humus, 0.32 to 6.92%). Soil bulk density (ρv) averaged 1.42 g/cm^3 (moderate) with little variability, such as the participation of a large number of soil types (30 of 64 contained in Soil Map of Croatia) probably indicates a poor field evaluation of texture, or low level of training of field teams for taking soil samples, which also estimated the additional properties of the terrain (slope, exposure, texture, biogenity, etc.). Of course, high reliability can be achieved only by pedological analysis and determining the bulk density of all samples within the chemical analysis of soil for fertility control of Osijek-Baranja County.

In comparison with all other indicators of soil suitability for tillage treatment, F5 has a negative value (the way of wetting the soil) with extremely high variability. This result is logical since the ranking was performed only in four classes where the automorphic soils provide a positive and a negative value hydromorphic rank, depending on the response of soil pH, or potential emergence and creating argiluvic layer. It was found that 37.98% of samples (6588) have a pH in KCl in less than 5.0, thus indicating that it is part of automorphic soil pH reaction. In these reducing conditions, comes regularly to eluviations clay in deeper layers, and forming a barrier impervious to water and high risk of compaction by the use of machinery, but also the formation of tillage pan (plow pan and disc pan).



Picture 1: Elevation profile of Osijek-Baranja County (W-E)

Average soil suitability for tillage of the eastern Croatian estimate is described by the model to 49.60% (equivalent to the FAO classification, S3, limited suitable) with a relatively high coefficient of variation (CV% = 33.25, Table 5). However, very few permanently unsuitable soils (0.7% and only Gleys vertic type), temporarily unfavorable has almost a third (29.7%), while the S3 is nearly half of the samples (45.2%), the S2 (moderately suitable) sixth (17.6%) and high quality soils (S1, very suitable) for the tillage is only 6.7%.

Geostatistical kriging analysis (Malvić, 2005) is limited to the Osijek-Baranja County (Figure 1) where it is most of the analyzed soil samples. The analysis showed a partially different distribution of the soil suitability for tillage (Table 6) than in the east Croatian (includes only 4 Counties on Eastern Croatian). In fact, less than 13% is unsuitable agricultural land (FAO class of suitability N1 and N2, temporarily and permanently unfavorable), while 2/3 were classified as Class S3 (limited suitable) which indicates the number of potential problems in processing. Only 20% (S1 and S2 soil tillage suitability) of soil is good and excellent soils for tillage.

Finally, it should be noted that in the paper describes an experimental version geostatistical computer model to estimate the soil suitability for tillage. Our intention is to develop a model incorporating more analytical data, especially indicators of physical and mechanical properties of soil and its validation for specific soil conditions especially in smaller production areas.

Table 6: Distribution of soil suitability for tillage of Osijek-Baranja County (ha)

The total area of Osijek-Baranja County	413.923,00 (100%)		
Area of agricultural and forest land	187.808,81 (45.4%)	N2	250,77 (0.08%)
		N1	38.038,46 (12.7%)
		S3	198.819,55 (66.3%)
		S2	58.989,19 (19.7%)
		S1	3.908,85 (1.30%)
Area of forest and grove			112.198,00 (27,1%)

Conclusion

In short it can be concluded, following a test on a large number of eastern Croatian land data, as shown by geostatistical computer model estimates the soil suitability for tillage:

1. Automated, fast and easy to use due to the implementation of GIS and automatic downloading of the necessary indicators of the benefits of digital soil maps with the ability:
   a. visualization the soil suitability for tillage,
   b. predicting benefits for the wider area using the gerostatistical method kriging and
   c. adequate planning tillage machinery due to the size requirements of land space and the necessary power.
2. Practical application of computer models, given the lack of reliability, "input" must be gradual and cautious, limited to areas where the model will be tested and then calibrated (fitted) to model parameters were adjusted so that the prediction is closest to reality, within acceptable errors / risks.

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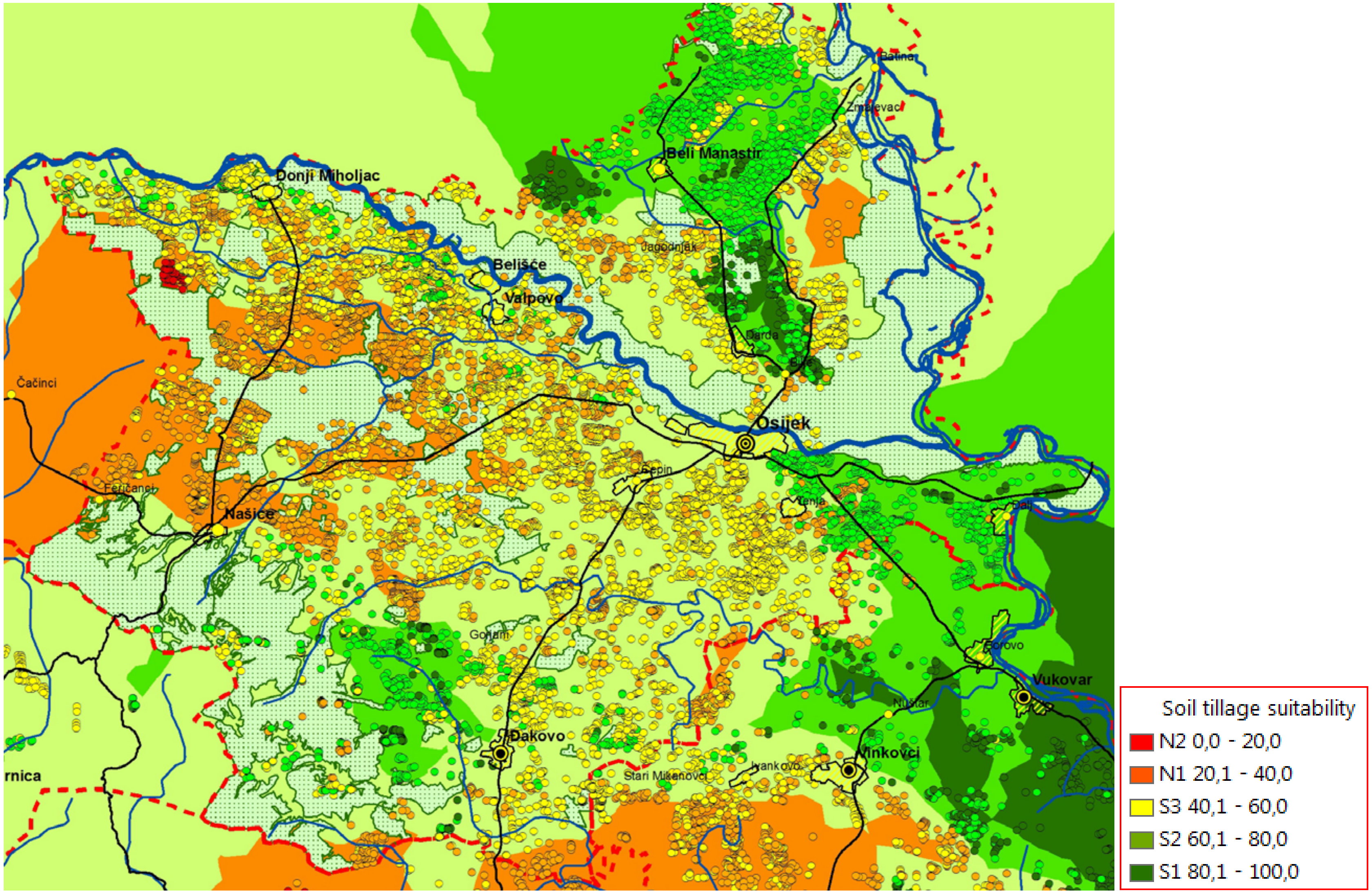

Picture 2: Kriging of soil suitability for tillage in Osijek-Baranja County

The yield and quality of bread wheat under different agronomic factors

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Abstract
Winter wheat is the most important crop in the Czech Republic. Regions with a less frequent occurrence of precipitation during the period of ripening are favourable for production of high quality bread wheat. However, a lack of water in earlier growth stages can be a limiting factor of yields. Different agronomic factors (forecrop, soil tillage, straw management) themselves or in action in interaction could influence the water management of crops in the course of growing season. The analysed data are coming from field trials which were established in South Moravia and years 2005 – 2008. Two field trials were established as model concept for farming with or without animal husbandry. The winter wheat was grown after four forecrops (winter wheat, safflower, silage maize and lucerne) and two methods of soil tillage (conventional and minimum tillage). The grain yield of wheat was affected by interaction of soil tillage and forecrop and year. Qualitative parameters for bread wheat were mainly influenced by year or in combination with the effect of forecrop, but the values of bulk density, falling number and Zeleny sedimentation test were in limits for bread wheat.

Keywords: soil tillage, crop rotation, bread wheat

Introduction
In the Czech Republic, there are about 1.6 million hectares of cereals and approximately half of this area is under winter wheat. The method of tillage represents one of the most important factors that could influence the water management of crops in the course of growing season. A numbers of field trials with various methods of tillage (Miština 1992, Procházková and Dovrtěl 2000) brought some new data about positive effects of minimum and zero tillage on the production of field crops. In each region, appropriate practices of conservative tillage may take reasonable use of cultivation to address soil and climatic constraints and use tillage for straw incorporation to avoid the adverse effect of crop residues on the growth of the following crop (Hakansson 1994). Yields of winter wheat may be influenced also by other intensification factors, e.g. by application of fertilizers (above all of nitrogen) and by protection against biotic factors (weeds, diseases and pests). The importance of crop rotation should also not be neglected because winter wheat belongs to crops that are very demanding as far as the forecrops are concerned. All aforementioned factors can be, to a certain extent, influenced by the grower. However, it also should not be forgotten that there are some factors that cannot be controlled in a direct way. They involve both the amount and the time distribution of rainfalls in the course of the growing season. In this context the problem of the occurrence of draught periods and their impacts on plant production is being more and more discussed, also under the climatic conditions of Central Europe. The data in this study demonstrate that in future properly selected growing technologies can play a more and more important role not only from the viewpoint of yields but also of the quality of grain.

Material and methods
The impacts of different agronomic factors were evaluated in the field trials established in Žabčice in the years 2005-2008. This locality (179 m above sea level, 49°01′ N, 16°37′ E) is

situated 25 km southwards from Brno (South Moravia region, Czech Republic). It is a warm and dry region with average annual temperature and precipitation of 9.2°C and 480 mm.

The soil is classified as gleic fluvisol which has developed on alluvial sediments of the Svratka River, the groundwater level fluctuates between 0.8 and 2.5 m. Under soil texture, it is heavy soil. The two field trials were established in this locality as a model concept for farming within/without animal husbandry. First trial is based on 5-year crop rotation with a high concentration of cereals (spring barley, safflower, winter wheat, winter wheat, maize) where all crop residues are incorporated into the soil. Second trial is a concept of farming within animal husbandry, there is crop rotation for the management system with animal husbandry, in which all straw is harvested (1. lucerne; 2. lucerne, 3. winter wheat, 4. silage maize, 5. winter wheat, 6. sugar beet; 7. spring barley). The effect of different forecrops for winter wheat (safflower, silage maize, lucerne and winter wheat) and two ways of different soil tillage was evaluated in both trials. The variant of conventional tillage (soil tillage I) consisted of stubble breaking after harvest and ploughing down to the depth of 0.20-0.24 m. The variant of minimum tillage (soil tillage II) included stubble breaking after harvest followed by a shallow loosening to the depth of 0.15 m. Fungicides against leaf and ear diseases of winter wheat, were applied twice, at the beginning of stalk shooting (BBCH 32, TANGO SUPER – 84 g epoxiconazole + 250 g fenpropimorph) at the dose of 1.0 l/ha and in the growth stage of heading (BBCH 55, FALCON 460 EC – 250 g spiroxamine + 167 g tebuconazole + 43 g triadimenol) at the dose of 0.6 l/ha. The winter wheat variety Sulamit was sown at the rate of 4 million of germinating seeds per hectare. The experimental dose of fertilizers was 120 kg N ha^{-1} (30 kg N prior to sowing as ammonium sulphate, 50 kg N in the spring for regeneration as calcium ammonium nitrate (CAN, 27.5%) and 40 kg N till the end of tillering as DAM 390. The plots of winter wheat were harvested and the grain yield was assessed. Qualitative parameters for bread wheat (protein content (%), bulk density (kg/hl), Zeleny sedimentation test (ml) and falling number (s) were analysed as well.

Results and discussion

Grain yield of winter wheat

The yield results from year 2005-2008 are in Fig. 1. The grain yield of winter wheat was affected by year and forecrop. The lowest yield was after fore-crop winter wheat (6.83 t/ha). Grain yield level of wheat grown after maize, safflower and lucerne was very similar. The difference between yield after wheat and the yield average after safflower, maize and lucerne as forecrops was 1.3 t/ha. In general, it is known, that safflower and lucerne are good forecrops. Similarly Stasinskis (2009) found, that the average of three years' results shows that the significantly highest yield of winter wheat was in crop rotation after winter rape, other good forecrop for winter wheat. Almost, the effect of soil tillage was not significant. The results showed, that the grain yield of wheat was affected by interaction of soil tillage and forecrop and year. In 2005, there are not any differences between soil tillage. In 2006, statistically significantly higher yield was in conventional tillage after winter wheat (difference was 1.65 t/ha) and grain maize (difference was 0.81 t/ha). The vegetation period of this year, especially in spring, was almost wet. The weather conditions probably caused, that minimum tillage variant had soil capillaries almost filled with water. Also the soil structure was destroyed, mainly after winter wheat and maize, which does not have positive effect on soil structure. A lack of air was essential factor for growth of roots. In 2007, minimum tillage variant had significantly higher grain yield after safflower (difference was 1.25 t/ha). In 2008, the higher yield was found out in variant with minimum tillage after lucerne (difference was 0.79 t/ha). These years were characterized with dry weather, when the soil water content was a limiting factor for many crops, especially spring crops with weak roots, e.g. spring barley. The results showed, that in these conditions, reduced soil tillage is a water saving technology.

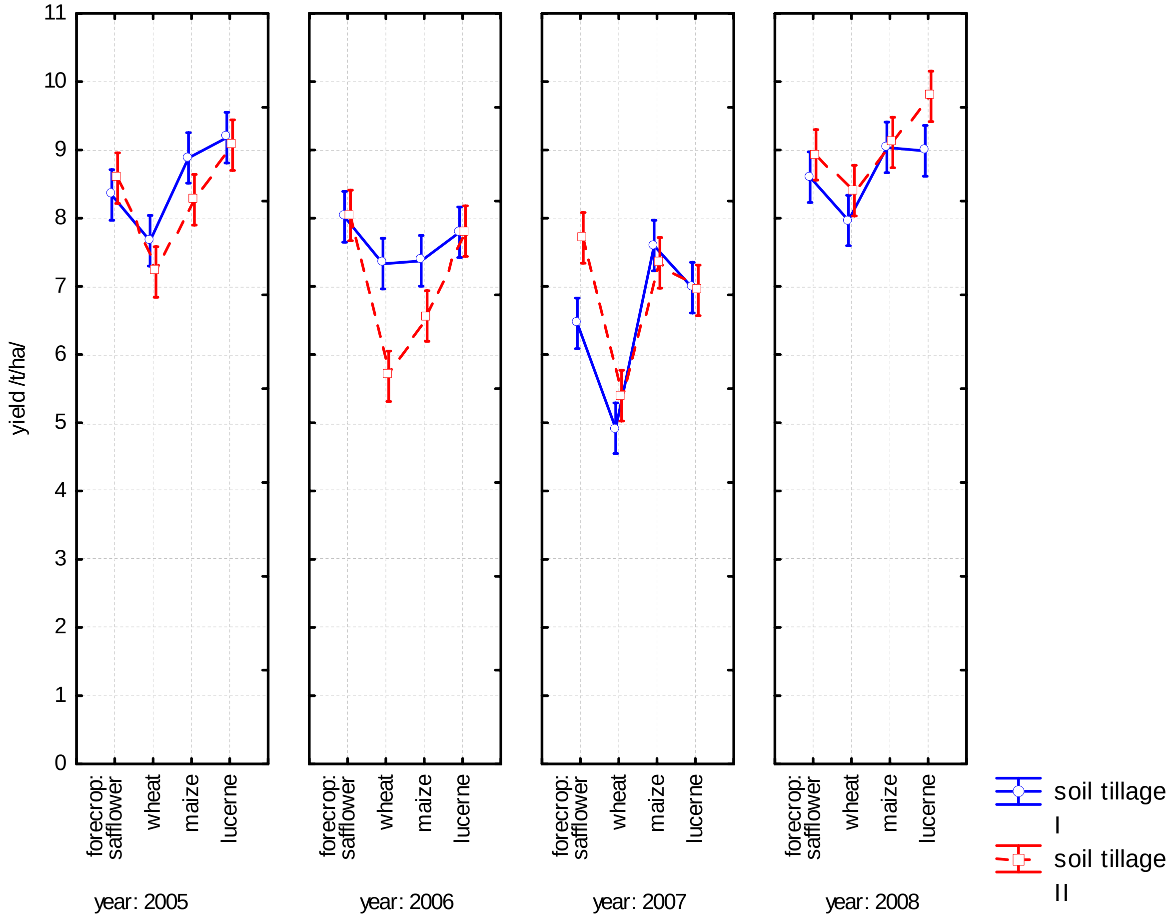

Figure 1: Grain yield of winter wheat under different forecrops and soil tillage methods (2005–2008)

Qualitative parameters for bread wheat

The protein content as a one of the important parameters of quality for bread wheat was mainly influenced by individual factors (year and forecrop). The lowest protein content was in 2005 (10.35%) in comparison with other years (2008 – 12.27%, 2007 – 13.00% and 2006 – 13.21%). In average, the highest protein content was in wheat grain after lucerne (12.85%), lower after grain maize (12.66%), after safflower (11.80%) and wheat (11.43%). These results of protein content (Fig. 2) are connected with sources of nitrogen which is coming from decomposition of organic matter (plant residues). For lucerne is typical higher content of nitrogen (because fixation of air nitrogen). Crop residues of grain maize are very slowly decomposed and nitrogen can be used for incorporation into plant tissue later, in time when it decides about grain quality. The difference between soil tillage was not significant, conventional tillage had mean value of protein content 12.27% and minimum tillage 12.10%. When winter wheat was grown after wheat, safflower and lucerne, lower protein content was found in minimum tillage variant, but not statistically significant.

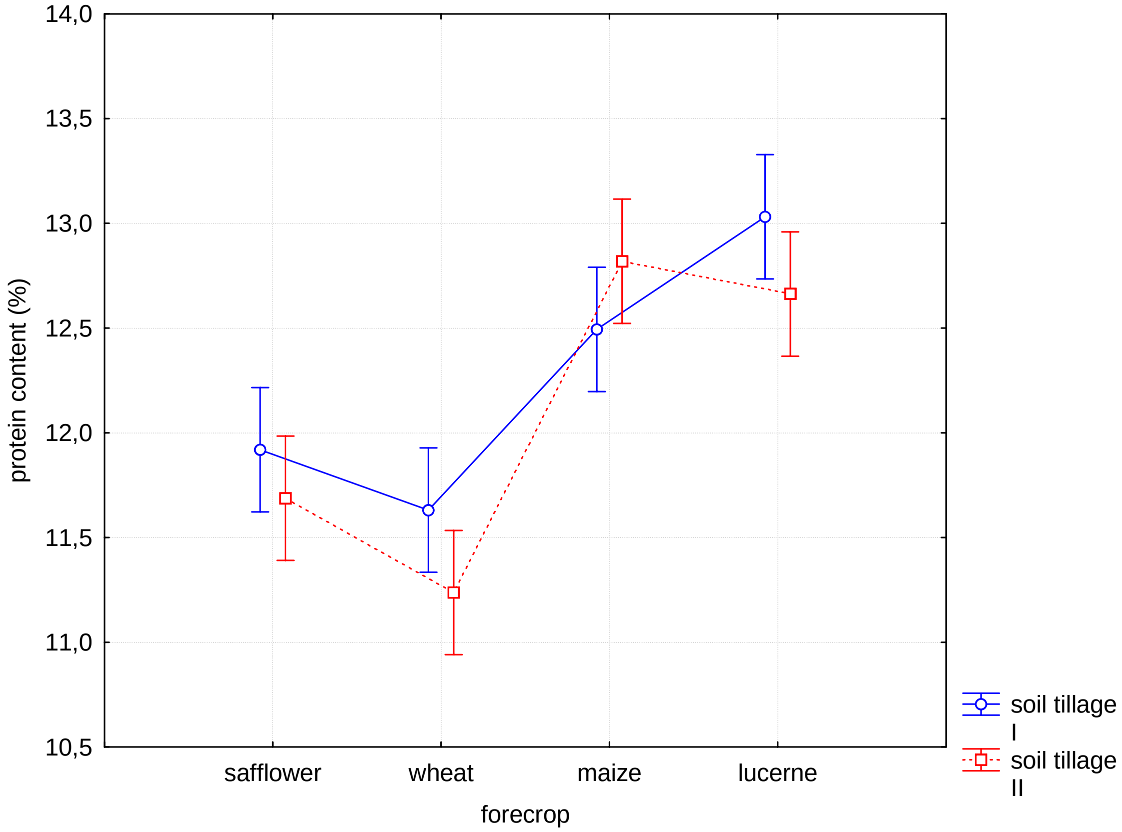

Figure 2: Protein content in grain of winter wheat (%)

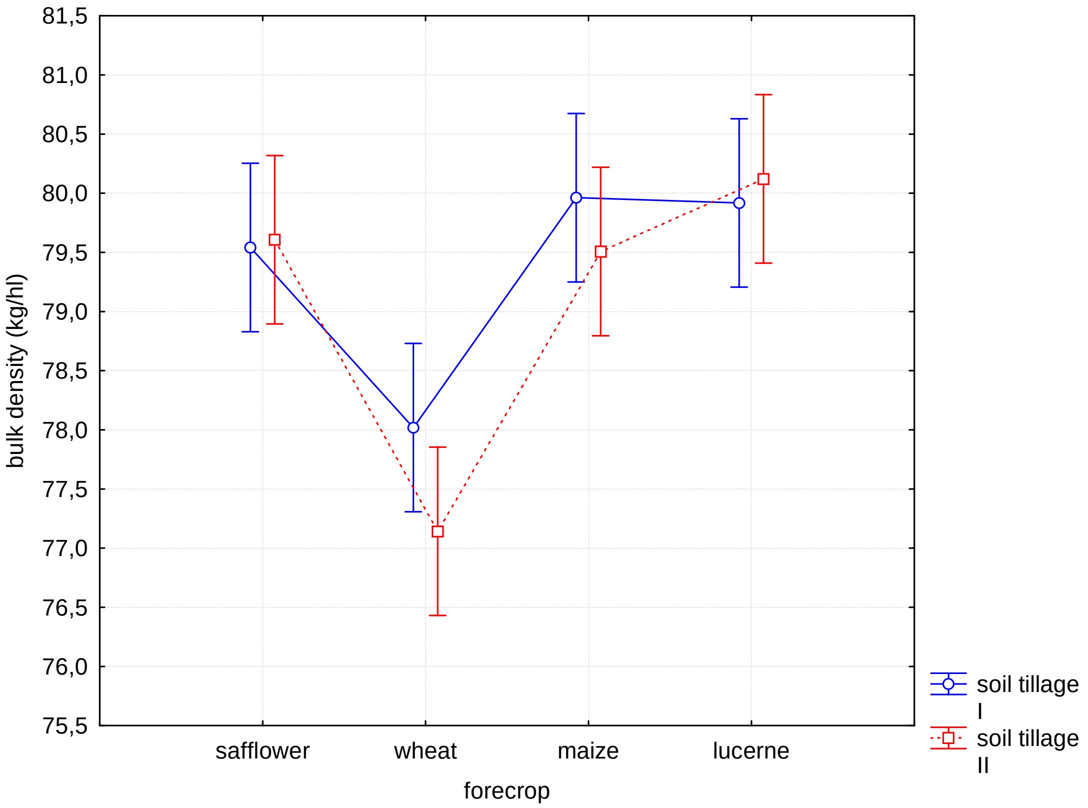

Figure 3: Bulk density of grain of winter wheat (kg/hl)

When conventional soil tillage was used, sedimentation index was very similar among different forecrops. Different results were from minimum tillage, where significantly lower values of sedimentation test were after maize. Also the results of Rusu et al. (2008) show non-significant differences between wheat quality parameters at chosen soil tillage method. All the variants have quality parameters in the standard limits.

Values of other qualitative parameters (bulk density, falling number and Zeleny sedimentation test; Fig. 3 – 4) were in limits for bread wheat. Mostly, the impact of year had the highest effect. But, there are some trends, which are interesting. For example, when winter wheat was grown after wheat and maize, lower bulk density was in variant with minimum tillage. Higher values of falling number were after lucerne as a forecrop.

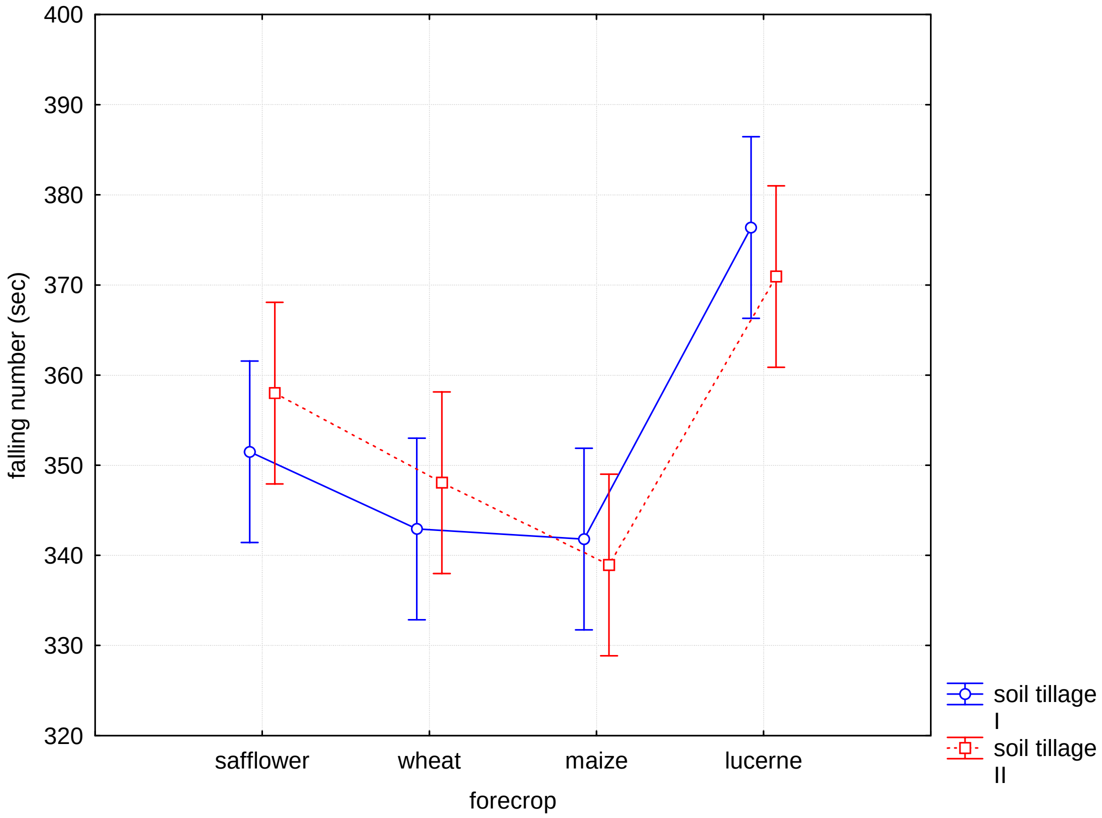

Figure 4: Falling number of winter wheat (sec)

Conclusion

Crop rotation and soil tillage are agronomic factors, which can influence yield and quality of bread wheat. They work often in interaction and results are depending on weather during vegetation. The results obtained from study are useful in modification of crop management practices. Both soil tillage systems (conventional and reduced) are acceptable for winter wheat, but other agronomic measures could correspond with chosen tillage. Appropriate fertilization, especially with nitrogen, included dose, type of fertilizer and time of application, are essential points which often decide about bread quality of winter wheat.

Acknowledgement

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The influence of soil tillage system at germination of buckwheat, millet and sudan grass sown as post-harvest summer crops

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Abstract
Research on the influence of the soil tillage systems (CT - moldboard ploughing, MD – multi discharrowing, SD - single discharrowing) on emergence of buckwheat (*Fagopyrum esculentum L.),* millet (*Panicum miliaceum L.*) and sudan grass (*Sorghum sudanense L.*) crops was done on eutric brown soil at site Široko Polje (Croatia) after winter barley (*Hordeum vulgare L.)* had been harvested in July 2009. The formation of soil surface crust after planting on treatments CT and MD significantly reduced the emergence of all three crops. The soil crust at the CT treatment showed the thickest (2.3 cm) and hardest to break (used crust breaking pressure was 1.9 MPa), the MD's crust was significantly thinner (0.9 cm) and easier to break (1.1 MPa), whereas, due to the large soil surface coverage by harvest residues (>80%), the crust was not even formed at SD treatment.

Keywords: buckwheat, millet, sudan grass, soil tillage, soil crust

Introduction
Growing the post-harvest summer crops is, beside the attempt to grow another crop during the season (Bayhan et al., 2006), one of the methods to maintain soil coverage during substantial time when arable land is bare, waiting for following crop, usually during the time of year with expressed weather extremes (drought, torrential precipitation, storm events).

This can produce soil surface crust, which can contribute substantially to soil degradation, impacting mostly soil physical properties (Bilbo and Wanjura, 1982; Dao, 1993; Unger, 1984). This process can be detrimental especially for early crop development stages, such as germination and emergence (Daba, 1999; Misra, 1995), even can inhibit seedling emergence and crop development (Rathore et al., 1983; Rapp et al., 2000).

Soil surface crusting formation is still in the focus point of researchers who are investigatin soil degradation on crust susceptible soils (Fox et al., 2004; Gallardo-Carrera et al., 2007), regardless of soil forming factors across a wide range of agricultural soils around the world (Usón and Poch, 2000; Robinson and Philips, 2001).

The crust formation on a tilled soil is a complex phenomenon moderated mostly by factors involving soil properties, rainfall characteristics, water flow conditions and agricultural practices (Sivaprasad and Sundara Sarma, 1987; Freebairn et al., 1991; Baumhart et al., 2004). Surface crust development reduces the infiltration rates (Moore and Singer 1990) and soil roughness, leading to an increase in runoff and to the speeding up of the erosive process.

Finding the most appropriate soil tillage system with low risk for soil surface crust for buckwheat, millet and sudan grass, was one of aims of this research.

Material and methods

The experiment with different soil tillage systems has been established on 6 July 2009 at Family Agricultural Enterprise "Matricaria", near town Široko Polje, Croatia. The soil type on which experiment field has been set up was the eutric brown soil, with favorable crop production properties. The summer crops used in the experiment were next: 1) buckwheat (*Fagopyrum esculentum*), cultivar "Darja", obtained from seed producer Sjemenarna Zagreb, with the seeding norm of 80 kg ha^{-1} and aimed crop density of 130-150 plants per square meter; 2) millet (*Panicum miliaceum*), cultivar "Kornberg", obtained from seed producer RWA, with the seeding norm of 15 kg ha^{-1} and aimed crop density of 180-200 plants per square meter, and; 3) the sudan grass (*Sorghum vulgare var. sudanese*), cultivar "Susu", obtained from seed producer Sjemenarna Zagreb, with the seeding norm of 30 kg ha^{-1} and aimed crop density of 100-120 plants per square meter. The preceding crop for all three crops was the winter barley, sown on October 2008, after preparing soil by conventional tillage, based on autumn moldboard ploughing before fine seedbed preparation by diskharrowing and seedbed cultivator.

The experiment was set up in each of three crops as the completely randomized block design with three levels of the soil tillage in four repetitions, with each basic tillage plot 6 m x 15 m, and treatments as follows:

- CT) conventional soil tillage, executed by moldboard ploughing up to 25-30 cm depth, followed with two light diskharrow passages at 10-15 cm and with seedbed preparation cultivator, with the finest seedbed preparation and no previous crop residues at the soil surface;
- MD) one passage with heavy diskharrow up to 15-20 cm, followed with two passages of light diskharrow and seedbed preparation cultivator, with around 30% of soil surface covered by previous crop's straw; and
- SD) single passage by heavy diskharrow up to 15-20 cm, followed by seedbed preparation cultivator, with coarse seedbed preparation and over 50% of soil surface covered by previous crop's residues.

The cereal seeder made by "OLT-Osijek" has been used for all three crops, with seeding depths for buckwheat and sudan grass of 3-5 cm, and 2-3 cm for millet.

The single precipitation event occurred after seeding, within the same day, with approximately 15 mm of rain, fallen within the 30 minutes time period.

The final crop density has been determined by counting number of plants in ¼ m^2 frame, randomly thrown four times at each basic plot, on 22 July 2009, two weeks after seeding date.

At the same date, the soil crust thickness and soil resilience readings has been done. The soil crust thickness has been measured by digging up crust clods from 5 positions on each basic plot, and measuring thickness by the ruler. The soil surface crust breaking pressure point has been determined on 10 positions on each basic plot, by applying pressure on the soil crust until the breaking moment, by "Eikelkamp" recording penetrometer, with the cone of 30° angle and 1 cm cone base.

The statistical analysis of variance (ANOVA) of CRBD was performed by SAS statistic package (V 9.1, SAS Institute, Cary, NC, USA, 1999) for each crop and tillage means. The Fisher protected LSD means comparisons were performed for P=0.05 significance levels.

Results and discussion

According to present weather patterns in Northeastern Croatia, during the summer months the short but intensive rains are usual, as a result of penetrations of low pressure systems on Europe continental mass from the Atlantic Ocean. Usually, the July's rain is welcome for vegetation of spring crops sown at the beginning, such as maize, soybean or sunflower, which is at that stage at the beginning of generative stages of development. But, for post-harvest summer crops, such as buckwheat, millet or sudan grass, with rather small seed (diameter between 2-4 mm) and low seed reserves, the crust forming as a result of intensive rain can present serious problem, as it is shown in the Table 1. For all three crops, the CT treatment, with the finest seedbed preparation, thus the highest susceptibility for crusting, had the lowest emergence rate, ranging from only 50% for sudan grass to 75% of buckwheat and millet, when compared to respective planned crop stands. Similar findings for small grain crops were presented by Sivaprasad and Sundara Sarma (1987) and Misra (1995), where authors pointed out low emergence rate in relation with crust thickness and seeding depth. Rathore et al. (1983) emphasized the time of crust forming in relation with the emergence, where faster emerging crops had better emergence rate if crust formation occurred after germination stage was already completed. Reduced crop density on CT was statistically lower than on both other two treatments, MD and SD. The MD treatment's surface had been less impacted by the same precipitation, due to more coarse soil surface, somewhat covered by previous crop residues, which prevented formation of thick crust. The counted crop densities were comparable with lower ranges of aimed crop stands for buckwheat and millet, and around 30% lower for sudan grass. Very coarse soil surface at SD treatment, covered with previous crop harvest residues, which somewhat presented problems for seeder, which couldn't leave seed uniformly at planned depth all the time, showed unsuitable for crust formation. No crust obstacle lead toward good emergence and aimed crop density for all three crops.

Table 1: The crop's density (plants per m^2) for buckwheat, millet and sudan grass on three soil tillage treatments (CT-moldboard ploughing; MD-multi-diskharrowing; SD-single diskharrowing), Široko Polje site, summer 2009

Soil Tillage	Buckwheat	Millet	Sudan Grass	Tillage Mean
CT	110 a†	146 a	59 a	105 A
MD	136 b	172 b	77 b	128 B
SD	151 b	197 b	96 b	148 C
Crop Mean	132	172	77	

†the means labeled with the same letter within the same crop and soil tillage mean are not significantly different according to Fisher protected LSD test for significance level P<0.05.

The crust formed on all three crops showed the highest thickness for CT, in average 2.3 cm thick (Table 2), which was significantly thicker than crust formed on MD and SD soil tillage treatments. Crusts formed on MD and SD treatments were very thin, and without significant differences. The highest values were recorded for sudan grass, which is probably the consequence of somewhat deeper seeding depth, in combination with less dense crop population than under buckwheat and millet, thus giving more material for crusting above seed. Similar relations among soil tillage systems and soil surface crust forming reported Unger (1984) for silty clay loam soil, where moldboard ploughing has been affected the most by rain event, leading toward the reduction of sorghum crop stand.

Table 2: Soil surface crust thickness (cm) for buckwheat, millet and sudan grass on three soil tillage treatments (CT-moldboard ploughing; MD-multi-diskharrowing; SD-single diskharrowing), Široko Polje site, summer 2009

Soil Tillage	Buckwheat	Millet	Sudan Grass	Tillage Mean
CT	1.8 b†	2.1 b	3.1 c	2.3 B
MD	0.8 a	0.5 a	1.5 b	0.9 A
SD	0.1 a	0.1 a	0.5 a	0.2 A
Crop Mean	0.8	1.0	1.7	

†the means labeled with the same letter within the same crop and soil tillage mean are not significantly different according to Fisher protected LSD test for significance level P<0.05.

The highest pressure needed to break crust was recorded at CT treatment (Table 3), with average of 1.9 MPa, ranging from 1.1 MPa under buckwheat, to 2.8 MPa under sudan grass. The crust breaking pressure was lower for MD (significantly on millet and sudan grass), with average of 1.1 MPa. The SD treatment, being with the tiniest crust, and with the most organic residues from previous crop, showed the lowest crust breaking pressures, in all cases significantly lower than values for MD treatments.

Table 3: Soil surface crust breaking pressure (MPa) for buckwheat, millet and sudan grass on three soil tillage treatments (CT-moldboard ploughing; MD-multi-diskharrowing; SD-single diskharrowing), Široko Polje site, summer 2009

Soil Tillage	Buckwheat	Millet	Sudan Grass	Tillage Mean
CT	1.1 b	1.8 c	2.8 c	1.9 C
MD	0.8 b	1.0 b	1.5 b	1.1 B
SD	0.1 a	0.1 a	0.2 a	0.1 A
Crop Mean	0.7	1.0	1.7	

†the means labeled with the same letter within the same crop and soil tillage mean are not significantly different according to Fisher protected LSD test for significance level P<0.05.

Conclusion

The results of this experiment are showing that in given agro-conditions the soil tillage for post-harvest summer crops such as buckwheat, millet and sudan grass, based on single diskharrowing, has the lowest chance for soil surface crust formation, which, if formed, has the highest chance of breaking.

The multiple diskharrowing, in spite that prepared soil for seeding better than single diskharrowing, is more susceptible toward soil surface crust forming, which can lead toward reduced crop density.

The moldboard ploughing, in spite of the most tilled soil, can present very high risk of soil surface crust formation, which can be significantly thick and requires very high pressure to break, thus leading toward significant and substantial crop density reduction, and it should not be used in given agro-environmental conditions.

Acknowledgement

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Primary production at seed rice

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Abstract
One of the challenges crop protection specialists are trying to contribute is the development of the quality of rice seed (*Oryza sativa* L.). These techniques rely on examining the concentration on organic biomolecules (proteins, carbohydrates-total and soluble sugars and organic acids). Eleven pure lines of rice seed (0015, 0025, 0030, 0035, 0042, 0048, 0061, 0063, 0072, 0074 and 0084) were examined in order to show the valuable nutritional factors. Oxidative stability was confirmed by measuring the activity of oxidoreductase - catalase which has the highest effect in the samples 0015 and 0030.

Keywords: rice, organic biomolecules, oxidative stability.

Introduction

Rice is one of the most sufficient and affordable food for more than half of the world. International Rice Research Institute (IRRI) through its gene bank protects over 80000 varieties of wild rice from all over the world (Usher, 1995).

The examination of pure, certified varieties of rise seed contributes in bettering the productivity of crops as well as their quality. Seed quality is the summation of all attributes that contribute to seed performance. Seeds of high quality (like the samples used in this experiment) are true to variety and have high percentages of vigour and germination. Certified seed is high in genetic purity, high in germination and vigour and of good quality (free from disease and from damaged or immature seeds).The examination of pure, certified varieties of rise seed contributes in bettering the productivity of crops as well as their quality. Seed quality is the summation of all attributes that contribute to seed performance. Seeds of high quality (like the samples used in this experiment) are true to variety and have high percentages of vigour and germination. Certified seed is high in genetic purity, high in germination and vigour and of good quality (free from disease and from damaged or immature seeds).

One of the main factors that allow efficient primary production is the activity of antioxidative molecules including antioxidants such as catalase. The experiment includes calculation of the activity of catalase in order to present the oxidative stability of rice seed.

Activation of catalase which functions as a cellular sink for H_2O_2 and indispensable for stress defence in plants (Willekens et al., 1997) is mainly activated during accumulation of hydrogen peroxide in macrophage-mediated destruction of pathogens and activation of stress responses (Sundaresan et al., 1995; Sohal and Weindruch, 1996). The experiment includes calculation of the activity of catalase in order to present the oxidative stability of rice seed (*Oryza sativa L.*). Organic acids, mainly produced by decomposition of organic matter (Tsutsuki, 1984) have positive (nutrient acquisition and metal detoxification)

(Jones, 1998) or negative effects (enhance soil fertility and sustainability and reduces plant growth) on some crop plants including rice (Cannell and Lynch, 1984). Some organic acids, including acetic acid, strongly inhibit the uptake of P, K, Si, Mn, Mg and Ca (Rao and Mikkelson, 1977) and reduce root respiration (Tanaka and Navasero, 1967).

Material and methods

The rice seed material came from the experimental station of the Agricultural Institute, Skopje, R. Macedonia. Certified lines of seed (0015, 0025, 0030, 0035, 0042, 0048, 0061, 0063, 0072, 0074 and 0084) were developed in OPO Kocani, R. Macedonia, on a parcel of $10m^2$, during continuous manual sowing in autumn.

The concentration of total nitrogen was calculated using the method of Kjeldahl (1883) and the percent concentration of organic acids was measured by using a titrimetric method. To determine the content of total and soluble sugars the extract was measured (485nm) according to the spectrophotometric method of Dubois et al. (1956). The measurement of the catalase activity (calculated by mg converted H_2O_2 by present oxidative enzyme) was presented using the method of Bah and Oparin.

Results and discussion

The enzymatic activity as well as the accumulation of pigments in plant cells is one of the most precise indicators of the physiological condition of organisms. We investigated the activity of oxidoreductase (catalase) as an enzyme which has the fastest and the most effective impact in development during ecological stress conditions although its translocation and effects on plant metabolism is hard to follow. It is well known that the first defensive mechanism of plants is an oxidative reaction which temporary increases the extracellular activity of oxidative enzymes (catalase and peroxidase) (Wojtaszek, 1997) as well as intoxication that leads to explosive oxidative stress. By measuring its activity the investigation can conclude the photosynthetic stability of plants (Zelitich, 1992; Shikanai et al., 1998). Matsumura et al. (2002) confirmed that the expression of wheat catalase in transgenic rice plants shows tolerance for chilling injury.

Table 1: Enzymatic activity of catalase (mg H_2O_2 converted by catalase) in certified pure varieties of rice seed (*Oryza sativa L.*)

Sample No	Enzymatic activity of catalase (mg H_2O_2 converted by catalase)
0015	0.850
0025	0.340
0030	0.765
0035	0.255
0042	0.084
0048	0.084
0061	0.043
0063	0.170
0072	0.084
0074	0.084
0084	0.255

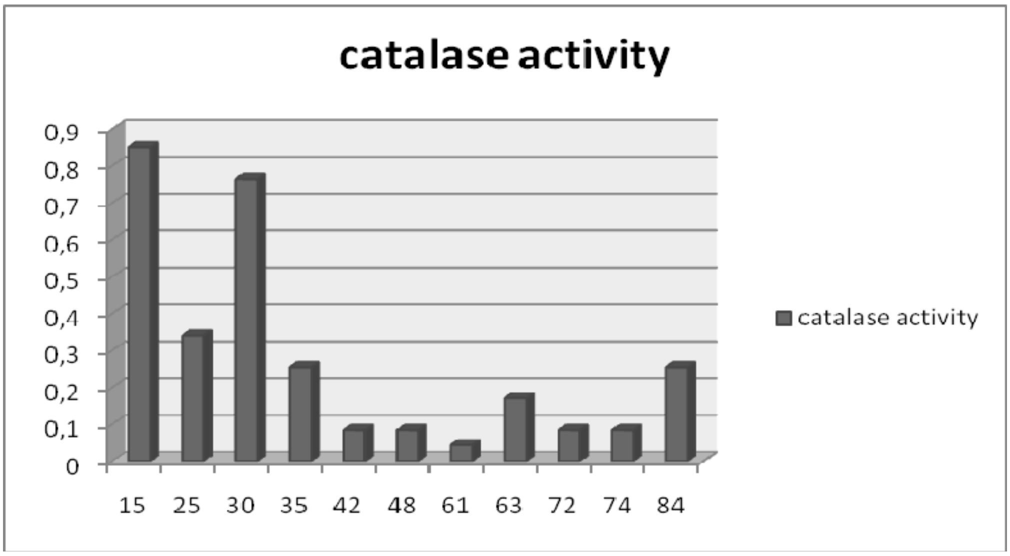

Figure 1: Enzymatic activity of catalase (mg H_2O_2 converted by catalase) in certified pure varieties of rice seed (*Oryza sativa L.*)

Organic acids have the greatest influence in defining the taste characteristics of plants. They are mostly bond as organic bases or minerals. In fermented material (dried on 60^{o}C) organic acids are present as Ca-salts of oxalic, malic or citric acid. The highest concentration of organic acids has the sample 0048 which confirms the qualitative stability of these rice seeds.

Table 2: Concentration of organic acids (%) in certified pure varieties of rice seed (*Oryza sativa L.*)

Sample No	Acetic acid (%)	Malic acid (%)	Lactic acid (%)	Citric acid (%)	Tartaric acid (%)
0035	0.320	0.358	0.480	0.342	0.400
0063	0.214	0.239	0.321	0.228	0.267
0074	0.191	0.213	0.286	0.204	0.239
0030	0.190	0.212	0.285	0.203	0.238
0072	0.268	0.300	0.402	0.286	0.335
0042	0.161	0.180	0.242	0.172	0.202
0048	0.394	0.440	0.591	0.421	0.493
0061	0.296	0.330	0.444	0.316	0.370
0025	0.199	0.222	0.298	0.212	0.249
0015	0.259	0.289	0.389	0.276	0.324
0084	0.228	0.263	0.386	0.200	0.313

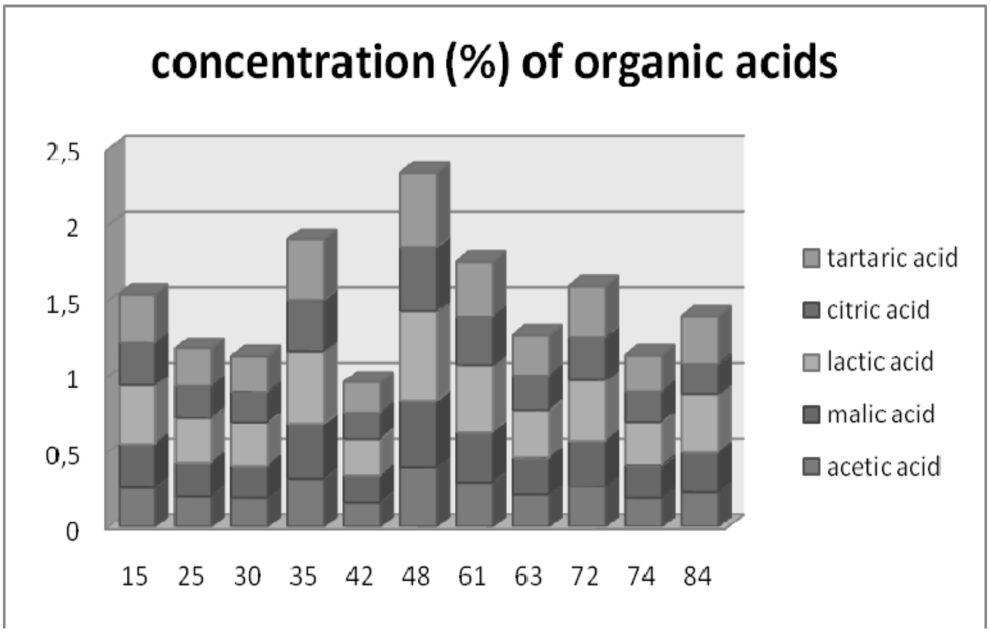

Figure 2: Concentration of organic acids (%) in certified pure varieties of rice seed (*Oryza sativa L.*)

There is a correlation between desiccation tolerance and soluble sugars in rice seed. The results suggest that desiccation tolerance might be associated with the increase in seed viability and the changes in sugar level. We measured the concentration of total and soluble sugars in order to perform the viability of rice seed (*Oryza sativa L.*) as well as the quality of these pure varieties. The results showed that that seeds with lowest concentration of total sugars have the highest concentration of soluble sugars due to the extracellular utilization of carbohydrates (samples 0015, 0042 and 0074). Our investigation is supported by the findings of Amino and Tazawa (1988), who also confirmed that the hydrolysis may be a result of the activation of cell wall associated acid-invertase.

Table 3: Concentration of total and soluble sugars (%) in certified pure varieties of rice seed (*Oryza sativa L.*)

Sample No	Total sugars (%)	Soluble sugars (%)
0015	50.822	17.759
0025	58.931	8.794
0030	60.016	7.309
0035	62.358	11.021
0042	58.131	15.875
0048	60.301	7.880
0061	63.728	8.451
0063	61.044	6.624
0072	64.299	9.079
0074	56.419	12.222
0084	59.674	9.308

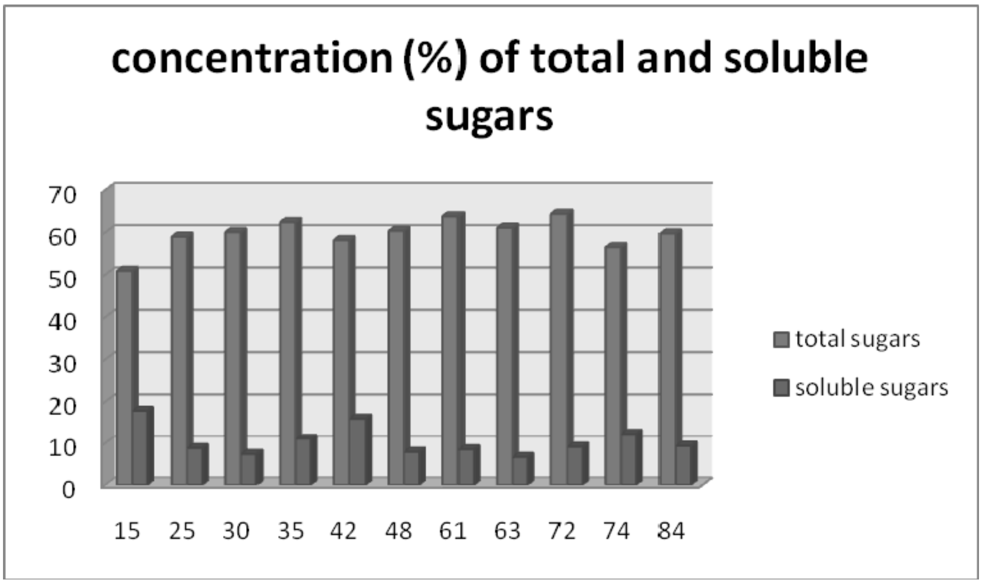

Figure 3: Concentration of total and soluble sugars (%) in certified pure varieties of rice seed (*Oryza sativa L.*)

During the investigation period we managed to measure the concentration (%) of total nitrogen revealing to the essential function of the element as well as the concentration of total mineral matter. At the end of plant feeding N is found mainly as nitrate form (in roots, stem and leaves) (Muhammad and Kumazawa, 1974). During plant development most of the nitrogen from the nitrate source is transported from the roots to the shoot in nitrate and amino acid forms. Uptake of N is intensive in early development of plants which is the main reason for the high concentration of this element in rice seeds examined (~1.0%). The nitrogen incorporation is greatest in amino acids of root and decreased towards stem and leaves.

Table 4: Concentration of total nitrogen, mineral matter and sand (%) in certified pure varieties of rice seed (*Oryza sativa L.*)

Sample No	Total nitrogen (%)	Mineral matter (%)	Sand (%)
0015	1.10	1.74	4.42
0025	1.34	1.72	3.32
0030	1.09	1.73	3.87
0035	1.27	1.72	3.32
0042	1.11	1.75	2.71
0048	1.11	1.03	2.22
0061	1.13	1.71	2.76
0063	1.41	0.87	2.71
0072	0.95	1.71	2.76
0074	1.35	1.70	2.21
0084	0.82	1.02	2.45

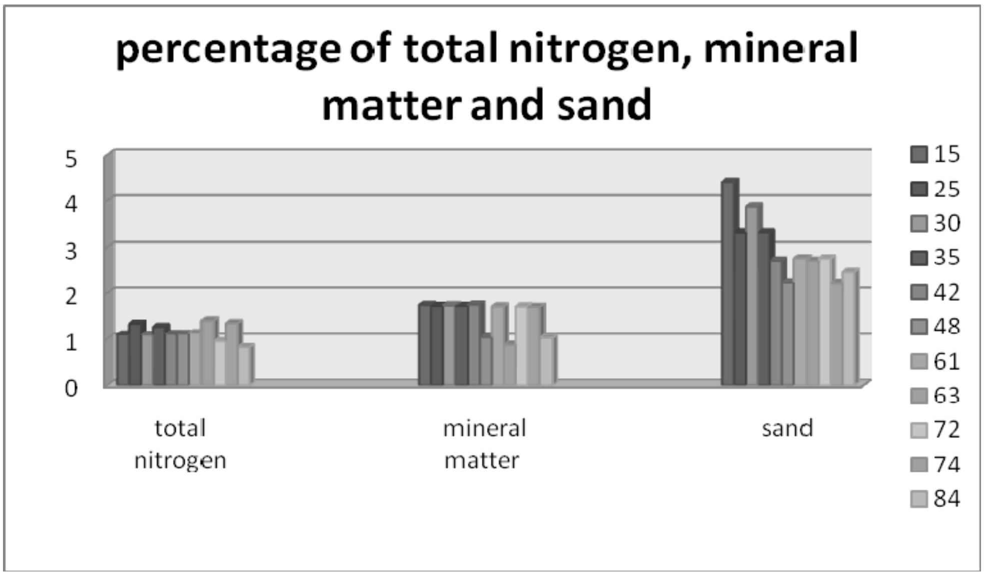

Figure 4: Concentration of total nitrogen, mineral matter and sand (%) in certified pure varieties of rice seed (*Oryza sativa L.*)

Conclusion

- The enzymatic activity of catalase with the highest values for the samples 0015 and 0030 means that those seeds are more tolerant to the ecological stress conditions (chilling, mechanical injury, intoxication) and have the highest photosynthetic stability.

- By measuring the concentration of organic acids (acetic, malic, lactic, citric and tartaric) we concluded that rice seed variety 0048 has the highest concentration which confirms the qualitative stability of the material.

- Due to the activity of invertase (utilization of carbohydrates) seeds with lowest concentration of total sugars (samples 0015, 0042 and 0074) have highest concentration of soluble carbohydrates.

- Examined seeds have very high concentration of nitrogen (~1.0%) because of its accumulation during the formation of seed structure.

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[Poster Session:]

[CHAIRMEN]

Ivica Kisić

Tamás Kornél

Effect of reduction of drought stress using supplementary irrigation of dry farming chickpea (*Cicer arietinum L.)* varieties

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Abstract
An experiment was carried out in 2007 to investigate the effects of different irrigation regimes, and chickpea cultivars on chickpea production in the Agricultural Research Station, college of Agriculture, Islamic Azad University, Kermanshah Branch .The experiment was split-plot in a randomized complete block design with three replications. Supplementary irrigation at three levels: control treatment (without irrigation),one time irrigation at 50%- flowering stage and one time at pod- filling stage, was allocated to main plots and the varieties (Arman, Hashem and ILC-482) was allotted to sub plots. A significant difference was observed between irrigation treatments in terms of plant height, number of axillary branches, distance to the first pod from soil surface, number of grain per plant, number of pod per plant, grain yield, biological yield, harvest index and100-grain weight; such a difference was observed between test varieties in terms of all trials rather than 100-grain weight. The grain yield mean was significantly higher for Arman than that of Hashem and for Hashem was significantly higher than that of ILC-482. Of course, there was no significant difference between Hashem and ILC-482 in terms of grain yield. The highest values of the number of grain per plant relate to Arman and of pod per plant pertained to Arman and Hashem, respectively. High rate of grain yield in irrigation treatment at pod- filling stage was associated with yield components, especially with the number of pod per plant and 100- grain weight. The grain yield was positively correlated with number of pod per plant ($r = 0.654^{**}$), number of grain per plant ($r = 0.902^{**}$) and 100 grain weight ($r = 0.707^{**}$). This research showed that grain formation and pod- filling stages is the most sensitive one to water-deficit, and under water limitation conditions, we can considerably increase grain yield at this stage by irrigation, especially for Arman.

Keywords: Chickpea, Supplementary irrigation, Drought stress, Grain yield, Yield components.

Introduction
Having cultured area of 755,000 ha, chickpea possesses a vast part of cereal- farming area in our country (FAO, 2004). Application of appropriate methods of irrigation, supplementary irrigation, and water collection is among strategies reducing the risk of crop production within arid and semi- arid areas, hence providing relatively permanent yield in these areas. In fact, supplementary irrigation is applicable for those crops that are capable of producing economic products naturally using rainfall water, therefore, irrigation results in their permanence and yield improvement. In other words, supplementary irrigation is aimed at supplying minimum amount of plants water requirement, not maximum of it; and compared to full- irrigation during plants growth period, its efficiency has been reported about 60% to 70% in some countries (Perrier and Salkini, 1987).Optimal supplementary irrigation is done in dry- farming regions based on3 flowing basic aspects: 1- Water is utilized only to improve crop yield , which has been planted through dry- farming (and has a normal yield without irrigation). 2- Under conditions in which rainfall is the most important supply to provide moisture, supplementary irrigation is done when rainfall does

not provide moisture necessary for yield improvement and permanence. 3- Amount and time of supplementary irrigation are planned in such a manner that we can attain optimum yield with the least amount of water available during sensitive stages of crop growth (Oweis, 1997). In Yadav et al. (1994) experiment, cohesion of supplementary irrigation at the stage prior to flowering and pod – filling increased the yield to 600 kg ha^{-1} although it did not have any significant effects on the weight of 100 grains, number of grain per pod, number of pod per plant, biological yield, and harvest index. Also, Romteke et al (1998), Summerfield and Roberts (1986), Singh et al. (1991), and Silim and Saxena (1993) have emphasized on negative effects of moisture defect on chickpea grain yield and yield components. Dahiya et al. (1993) determined nutritional requirement of 2 chickpea varieties in semi- irrigated conditions and specified that their highest yields were attained by using 27 kg ha^{-1} nitrogen and 69 kg ha^{-1} phosphorus and by 2 times irrigation at branching stage and onset of pod formation stage, obtaining the maximum consumption of water with one time irrigation. Krentoz (1987) obtained four different yields of 4 varieties of wheat Neorum under the effects of supplementary irrigation and reported that, to make the most use of consumed water, the water consumed amount and plant developmental stages are important to supplementary irrigation. Nelson (2001) and Nagarajan et al. (1999) reported, respectively, relating to chickpea and wheat, the significant effect of moisture stress on the grain yield and biomass at final growth stages. According to Silim et al. report (1993), high percentage of green sheath, especially in critical period of grain- filling reduces evaporation from soil surface, resulting in the improvement of soil moisture status and an increase in the amount of water available for plants, superiority of yield under irrigation conditions at sheath formation stage to irrigation regimes at flowering or branching stages is attributed to high velocity and duration of grain- filling period, which results in producing more coarse grains. Dahiya et al. (1993) argued two times of irrigation at branching and the onset of pod formation stages entailed the highest yield. Drought stress is among important challenges to producing chickpea in western part of Iran and in Kermanshah province. Objectives of this research are as follows:

- To study the effect of drought stress;
- To take advantage of supplementary irrigation;
- To select adapted varieties in order to increase this crop production; and
- To present management strategies.

Materials and methods

Present research was done in farming year of 2006-2007 on the Agricultural Research Station, College of Agriculture, Islamic Azad University, Kermanshah Branch, Iran (47°20 ′ E, 34°20 ′ N). Its elevation is about 1362 m from sea level and with annual mean precipitation of 435 mm. This region according to Koupen's classification, has a cold, semi- arid climate (Table 1). The soil texture of test site is clay- silt, having PH 7.5. The land of test site was cultured with wheat in the year prior to the experiment. To prepare it, the land was plowed with a chisel plough .on the basis of soil test, 40 kg ha^{-1} urea fertilizer and 80 kg ha^{-1} ammonium phosphate fertilizer, were spread on the field in late of winter.

This experiment was carried out in the form of split plot with complete, randomized block design with three replications. The major factor of experiment included control treatment(without irrigation), one- time irrigation at 50%- flowering stage and one- time irrigation at pod- filling stage; and minor factor of experiment included varieties Hashem, Arman and ILC-482. Each plot was 4 m long, including 4 planting rows 25 cm apart. Planting was done on 5 of April. Before planting, the seeds were sterilized with fungicide Mankuzeb in the amount of 1.5 per 1000. To plant seeds, some grooves of 5 cm depth were made with Fuka and seeds were used 2 times the amount of seeds needed for planting. Target density was achieved by thinning plants after locating seeds. To do supplementary irrigation at 50%- flowering stage and pod- filling stage, a sample of soil was taken from 0-60 cm depth and sent to a lab in order to determine the soil weight moisture. Then the samples were oven- dried at 104^{o}C (24h), and moisture in soil was specified. Water needed for each treatment to reach the capacity of field was calculated based on which the irrigation was performed .Total waster needed for each treatment was measured with a counter. With the field soil sampling and lab measurements, it was known that the limits of field capacity were 16.7% of and 17.8% of weight at 50%- flowering and pod- filling stages, respectively, and nominal specific mass of soil was 1.32gr.cm^{-3}.To estimate moisture coefficient (FC) and nominal specific mass(BD), such parameters as soil texture and content of soil organic matter were employed, then the amount of net irrigating water at the stages of 50%- flowering and pod- filling were estimated at134.64 and 146.30, respectively, by using equation of moisture fraction.

$In = (FC-M) \times B \times D$

where BD, is nominal specific mass gr cm^{-3}; D, is the depth of root extending (60 cm); M, is pre- irrigation weight moisture; and In, is the depth of net irrigation water fraction .Ten plants from each plot were used to specify yield components and plant morphological traits. Grain yield was calculated after eliminating two side rows of each plot and 0.5 m from both ends of its central rows. Parameters of rainfall rate and diurnal temperatures were obtained from Meteorology General Office of Kermanshah province. Statistical analysis was performed by MSTATC and SPSS software.

Results and discussion:

Number of axillary branches per plants

The number of axillary branches per chickpea plant was significantly affected by irrigation factor. Among various irrigation levels, maximum number of axillary branches per plant pertained to the treatment with on- time irrigation at pod- filling stage, which was 58.1% higher than the number of axillary branches under without irrigation conditions. Although there was no statistically significant difference between the treatment without irrigation and the treatment with on- time irrigation at 50% flowering stage, the treatment with on- time irrigation at 50% flowering stage and the treatment without irrigation were, respectively, placed after the treatment with on- time irrigation at pod- filling stage in terms of a decrease in number of axillary branches. Palled et al. (1985) reported that number of axillary branches per plant increases due to irrigation. Auld et al. (1980) reported that number of branches per unit area decreases as moisture available at terminative stage reduces. The effect of variety on number of axillary branches per chickpea plant was significant so that Arman had the highest number followed by ILC-482 and Hashem. Reciprocal effects of irrigation and variety were not statistically significant for the number of axillary branches per chickpea plant. Indicating that tested varieties gave the same responses to irrigation treatments.

Number of pod per plant

Number of pod per chickpea plant was highly significantly influenced by irrigation factor. Compared to treatment without irrigation, the treatments with only one- time irrigation at 50%- flowering and pod – filling stages had 149.9% and 117.9% increases, respectively in the number of pod per chickpea plant (Table 2). Number of pod per chickpea plant was highly significantly affected by variety factor. Number of pod per plant was significantly higher for Arman and Hashem than that of variety ILC-482.There was no significant difference between Arman and Hashem in this regard. Results of experiment show that sufficient water available at flowering and pod formation stages increases the number of pod per plant. The existence of significant difference between tested varieties regarding the number of pod per plant indicates the effect of genetic structure on this trait. For chickpea and Mungbean, Singh et al. (1994) and Pannu and Singh (1993), respectively, reported that, among yield components, the number of pod per plant is more sensitive to drought stress.

Number of grain per plant

Effects of irrigation and variety on the number of grain per plant were highly significant. So that the highest number of grain per plant pertained to the treatment with on-time irrigation at pod – filling stage followed by treatment with one- time irrigation at 50%-flowering stage and treatment without irrigation. The treatment with one- time irrigation at pod- filling stage had a 188% increase in number of grain per chickpea plant in comparison with the treatment without irrigation. There was no significant difference between ILC-482 and Hashem in terms of the number of grain per plant .The highest number of which pertained to Arman.

100 grains weight

The weight of 100 grains of chickpea was highly significantly affected by irrigation. Among different irrigation levels, maximum weight of 100 grins pertained to treatment with one-time irrigation at pod-filling stage and minimum of it pertained to the treatment without irrigation. The significant effect of irrigation on grain weight during varied stages of plant growth, especially at grain-filling stage, has been reported for common been by Singh in 1995. During a research Tuba Bicer et al. (2004) reported that chickpea 100 grain weight was affected by irrigation. It appears that moisture defect at the time of pod formation and grain- filling can decrease the rate of photosynthetic products transmission, resulting in grain wrecking. Given that, in this research, supplementary irrigation has been done at the time of pod formation and grain-filling, moisture defect has been resolved firstly, therefore, period of grain - filling has lengthened, as a result more photosynthetic products accumulated in grains. So, supplementary irrigation at this stage has resulted in a 137% increase in the weight of 100 grains compared to conditions without irrigation. Silim et al. report (1993) is in agreement with findings of this experiment.

Plant height

The effects of irrigation and variety on plants height are significant at level of 1%. The treatment with only on- time irrigation at pod- filling stage had the highest and the treatment without irrigation had the lowest height of plants. Arman had the highest plant height, and there was no statistically significant difference between Hashem and ILC-482. Hawtin and Singh (1984) suggested that variation in plants height depends on variety, latitude, date of planting, and slope. In fact, water defect at germinative and generative stages decreased plants height. Results of this experiment regarding with results was reported by Gupta et al. (1995).

Distance to the first pod from soil surface

The effects of irrigation and variety on distance to the first pod from soil surface were sharply significant. The highest and lowest distances to the first pod from soil surface pertained to the treatment with one- time irrigation at pod-filling stage and the treatment without irrigation respectively, among different irrigation levels. The highest value of the distance to the first pod from soil surface and the lowest one pertained to Arman and ILC-482, respectively.

Biological yield

Irrigation has a highly significant effect on biological yield. The treatment with one-time irrigation at pod- filling stage had the highest biological yield and the treatment without irrigation had the lowest one. Sharp reduction of shoots weight and of production of photosynthetic products caused by water limitation has been reported by Singh et al (1987) and Xia (1997). The effect of variety on biological yield is significant (Table 1). Among tested varieties, Hashem had the highest biological yield followed by Arman and ILC-482. Reciprocal effects of irrigation and variety are significant. Based on reciprocal effects of experimental factors, the highest biological yield pertained to the treatment of Arman (one-time irrigation at pod-filling stage) and the lowest biological yield pertained to the treatment of ILC-482(without irrigation).

Harvest index

Harvest index was highly significantly affected by irrigation factor. The maximum and minimum harvest indexes pertained to the treatment with one- time irrigation at pod-filling stage and to the treatment without irrigation, respectively. There was no statistically significant difference between treatment with one- time irrigation at pod- filling stage and treatment with one- time irrigation at 50%- flowering stage. Chickpea harvest index was completely significantly affected by variety factor (Table 1). The highest and lowest values of harvest index pertained to Arman and Hashem, respectively (Table 2). Harvest index of Hashem was lower than those of two other varieties, which is attributed to late- maturity and lack of timely formation of flowers, pods, and grains of aforesaid variety. Having done an experiment on 25 chickpea genotypes under dry-farming and irrigation conditions in Syria, Singh and Saxena (1991) concluded that grain size, grain yield, biological yield, and harvest index are improved through irrigation, which is in agreement with result of present experiment.

Grain yield

Irrigation effect on chickpea grain yield was significant statistically so that, compared to the treatment without irrigation, the treatment with one- time irrigation at pod- filling stage had the highest grain yield (1194.2 kg ha^{-1}), having a 216.7% increase in yield of chickpea grains. Saxena (1980) reported that using supplementary irrigation in order to resolve stress at critical stages of plant growth had on important effect on grain yield increase. Also many researches have emphasized on the effect of water defect an reduction of yield in the plant growth period, especially at the stages of grain formation and grain-filling (Desclauxs and Roumet, 1996; Meckel et al., 1984; Shaw and Laing, 1996; Specht et al., 1989; Vieira et al., 1991; Xia, 1997).The effect of variety on chickpea grain yield per unit area was completely significant (Table 1).Variety Arman had the highest chickpea grain yield (1194.6 kg ha^{-1}),which was significantly different from means of grain yield of Hashem (788.5 kg ha^{-1}) and ILC-482 (667.2 kg ha^{-1}). It was found that using supplementary irrigation to free the crops from soil moisture stress at critical growth and development stages increases chickpea grain yield (Soltani et al., 2001).It appears that water defect at chickpea generative stages prevents yield potential attainment through flowers and pods shedding (Nayyar et al,2006).Iyadao et al.(1994). Rummteke et al. (1998) and Ney et al. (1994) have reported an increase in grain yield due to supplementary irrigation for chickpea and green pea, respectively.

Correlation between grain yield and yield attributes

There was highly significant positive correlations of grain yield with number of pods per plant(r =0.654**), number of axillary branches (r =0.837**), plant height (r =0.715**), number of grain per plant (r =0.902**), 100 grain weight (r =0.707**), distance to the first pod from soil surface (r =0.837**), harvest index (r =0.594**) and biological yield (r =0.776**) (Table 3). These results indicated that a high yielding genotype should have taller plants with higher number of axillary branches, which resulted production of higher number of pods per plant and grain yield. These results are consistent with the results of many workers in chickpea (Sharma et al., 1990; Filippetti, 1990; Mani and Bahl, 1990; Singh and Saxena, 1991; Silim and Saxena, 1993; Chavan et al., 1994; Kumar et al., 2003; Jeena et al., 2005; Obaidullah et al., 2006).

Conclusion

Results of this research showed that average of grain yield was 1194.2 kg ha^{-1} for treatment with one- time irrigation at pod-filling stage, showing a 216.7% increase in comparison with control treatment without irrigation with yield of 551.1 kg ha^{-1}. Varieties Arman and Hashem, and variety Arman the highest values regarding the number of grain per plant and number of pod per plant, respectively. Among yield components, the number of pod per plant and 100 grains weight had the most effect on increasing the grain yield. Given the increase in regional temperature in late of season usually associated with rainfall stoppage, it appears that using supplementary irrigation at pod- filling stage strengthens the plants in terms of tolerance, transition and escape from dryness of late growth period, and increases velocity of grain-filling and, ultimately, causes an increase and improvement in stabilizing chickpea yield in unit area, especially for variety Arman.

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Assessment of conservation tillage effect on Luvisol, loam soil, consequently on cereal production in the Central Bohemia

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Abstract
In fourteen-year field experiment on *Luvisol,* loam soil winter wheat, spring barley and pea (later white mustard) are grown in short crop rotation. The stands of these crops are established by classic, conventional technology, by reduced tillage with chopped straw incorporation and by direct drilling into no-tilled soil with no mulch or covered with mulch from chopped straw of previous crop. Grain yield trends of winter wheat were compared with trends of soil fertility indicators. Until 10-year duration of the experiment no significant yield differences among soil tillage treatment used were found. Approximately from the year 2005 grain production significant increase in conservation soil tillage variants was recorded in comparison with conventional check variant varying about average values. The change was conditioned by soil fertility increase in conservation tillage treatments. It was confirmed by trends of soil fertility indicators that they copied the trends of grain yields in the particular tillage treatments. The best production level was found in the minimum tillage treatment with chopped straw incorporated.

Keywords: conservation tillage, soil fertility, soil microbial activity, crop production

Introduction
Sustainable development of farming systems is one of the significant criteria of their evaluation. Sustainable agricultural systems are based on their stability and capability to utilize climatic, ecologic, technologic, economic and other changes for their own development, eventually to be resistant against them without damages and losses. After decennaries of the experience with conservation soil management both in Europe and in America and in other continents, it is possible to declare responsibly that these systems represent the important benefit for sustainable development of agricultural production, thereby they raise the hope for possibility of food sufficiency for the growing wide range of the world human population at the same time.

Seeing that conservation soil tillage technologies have been under research from the various points of view and have used in farming practice as well relatively for a long time, there are known the basic traits of their short-term and long-term effects. These effects can varied depending on the site conditions and on their mutual interactions therefore ongoing research can give continuously the new information.

Naturally, conservation soil tillage methods for crop stand establishment influence above all on the soil, especially its physical (Rasool et al., 2008; Filho et al., 2002; Seybold and Herrick, 2001 etc.), chemical (Matowo et al., 1999; Vogeler et al., 2009 etc.) and biological (Young and Ritz, 2000; Balota et al., 2004; Kostopoulou and Zotos, 2005) properties. Positive effects of conservation technologies improve the properties above mentioned thereby increase soil fertility.

Higher soil fertility as a set of properties ensuring the optimal conditions for growth and development of plants must have, of course under favourable meteorological conditions, stimulation effects on the crop production. Assessment of the influence of the soil microorganisms on production of the selected crops under different methods of conservation soil tillage during 14-year duration of the field experiment in Prague-Ruzyně is the aim of this contribution.

Materials and methods

The experiment has been running from 1995 in a temperate semiarid climate, 338 m above sea level, with an annual mean air temperature of 8.2°C, and mean annual precipitation of 477 mm. The field site has a soil of clay-loam texture (Orthic Luvisol, FAO Taxonomy), with a bulk density of 1.57 - 1.65 (CT-NT) g/cm^3, pH(KCl) 7.7, electrical conductivity 12.5 mS/m, organic carbon 1.86 - 2.09%, total N 0.164%, Mehlich 3 P 155 - 207 (NT-CT) mg/kg, K 285 - 413 (NT-CT) mg/kg. The experiment was established as a rotation of three crops (winter wheat, spring barley, and pea/white mustard from 2005). A split-plot method, with four replications, was used and four treatments (tillage methods) were set-up: 1) Conventional tillage (CT), i.e. mouldboard ploughing to a depth of 0.20 m, usual seed bed preparation and sowing; 2) No tillage (NT), i.e. sowing with special drill machine into no-tilled soil; 3) No tillage + mulch (NTM), i.e. direct drilling into no tilled soil covered with forecrop (pea/mustard) post harvest residues and chopped straw; 4) Minimum tillage (MTS), i.e. shallow disking (about 10 cm deep) and chopped straw with post harvest residues of fore-crop incorporating. All crop stands (including CT) were sown with a John Deere 750A drill machine. Three levels (low, medium, high) of nitrogen fertilization were used for all crops; 50, 100, and 150 kg N per ha for winter wheat. The P and K fertilizer doses were determined and applied according to P, K content in the soil. Standard herbicides were used, depending on the intensity of weed infestation. Grain yields were determined on a 24 m^2 test area, at harvest. Representative soil samples were taken from plots after winter wheat growing at the beginning of October from the selected treatments from topsoil in the depths of 0-0.1 m and 0.1-0.3 m and from subsoil from the horizon 0.3-0.5 m. The soil samples were sifted through a 2 mm sieve. Analyses were done in six replications. In the figures there are presented the average values of urease and arylsulphatase activity and Cox content in the soil, in the tables C/N total values and humus content in three layers of topsoil.

Results and discussion

In the Figure 1 there are shown the yield trends in the particular treatments of soil tillage in the given interval from the year 2002 to 2009. The start of soil biology analysis in this experiment from the year 2002 is the reason of this selection. Until the year 2006 it is evident, that grain yield in all treatments varied depending on individual year conditions. In the monitored interval very dry year 2003 is interested when all conservation variants had higher yields than the conventional one although the differences were statistically insignificant. Furthermore, it is evident that in the monitored period the highest grain yields were mostly achieved in the treatment of minimum tillage (MTS). From the year 2005, i.e. after 10 years from the beginning of this trial, it is possible to record up to now permanent production increase of winter wheat in conservation tillage treatments (except NTM in 2009), crossing the limit 8 t/ha and achievement 10 t/ha in NT treatment, while in CT treatment grain yields have been varied between 6 – 8 t/ha. It corresponds with findings of some authors (Arshad et al., 1990; Kladivko, 2001 and others) who declared that after implementation of conservation technologies, their impacts develop till after certain time interval when stabilizing processes of soil environment, connecting with tillage method change, take place. This interval length depends on range of factors, especially on the basic soil fertility and on site conditions

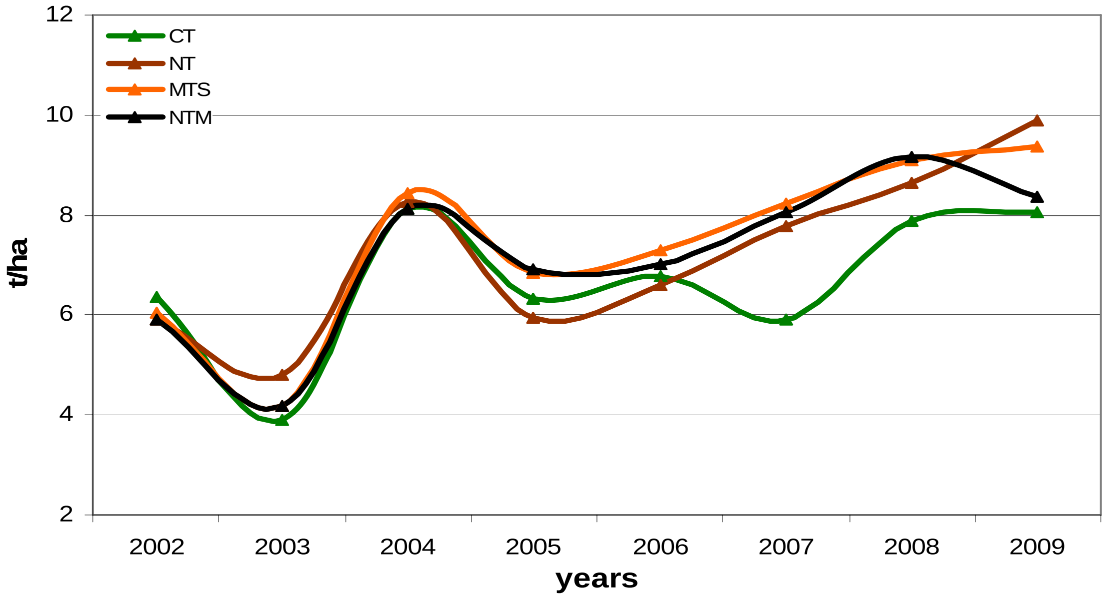

Figure 1: Time line of yields of winter wheat under different soil tillage

The difference in biological activity between tillage variants with less and higher grain production of winter wheat was the significant object of the study of soil fertility. As an indicator of soil fertility, the activity of some soil enzyme is utilized. Urease that participates in hydrolysis of urea is one of the most often used. In the Figure 2 it is shown that trends of urease activity copied the yield curves in the particular tillage treatments but there are higher differences among treatments. The highest urease activity was predominantly found in the MTS treatment. From the year 2005, the levels of activity are differentiated similarly as yield curves and their running in the time mutually corresponds.

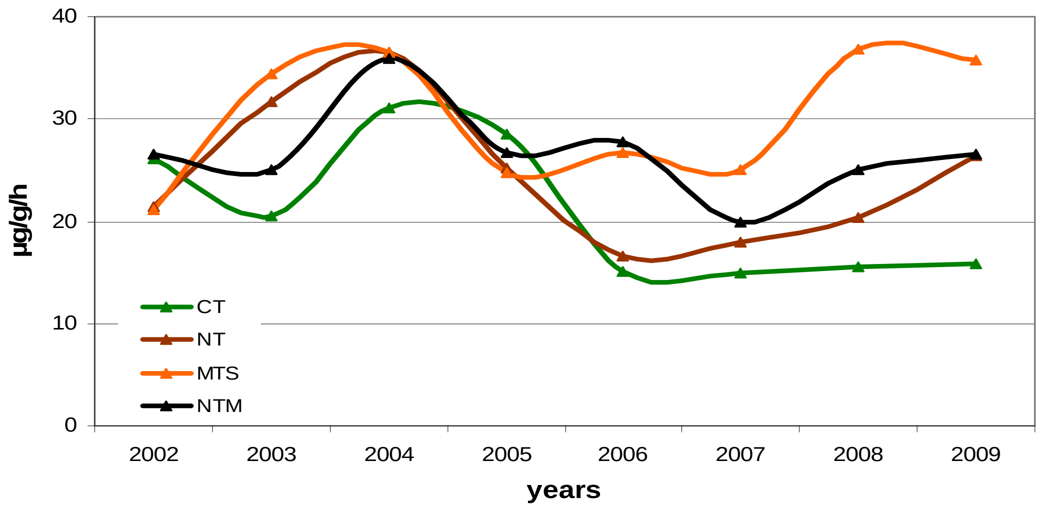

Figure 2: Urease activity in upper layer of topsoil (0-0.1 m) tilled by different methods during the given time period

In the Figure 3, trend of arylsulphatase activity is shown. This enzyme participates in cellulose decomposition processes and therefore its activity is underlain with higher content of organic matter in soil.

It is evident from the figure, because the trend curve in CT is largely running below the level of all three conservation treatments.

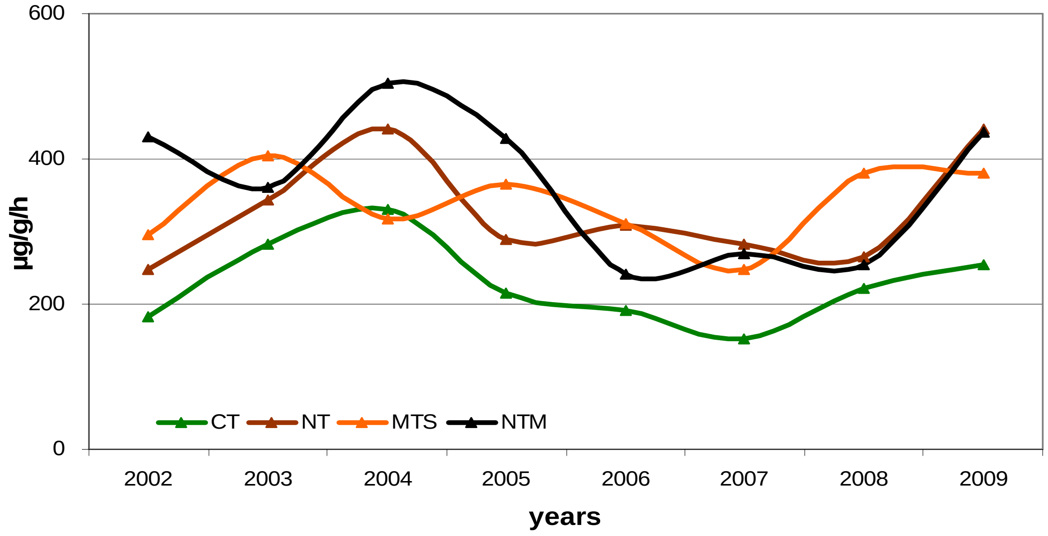

Figure 3: Arylsulphatase activity in upper layer of topsoil (0-0,1m) tilled by different methods during the given time period

Higher C sequestration in the soil is a result of the intensive utilization of organic matter in technologies of soil management in the conservation systems. In the Figure 4, there is shown the trend of Cox content in the particular treatments and from the year 2006 the separation of values from CT variant and other conservation treatments is apparent. In this figure it is possible to notice of remarkable year differences. In dry years (2003, 2005) the differences among variants are higher than in the years with normal amount of precipitations.

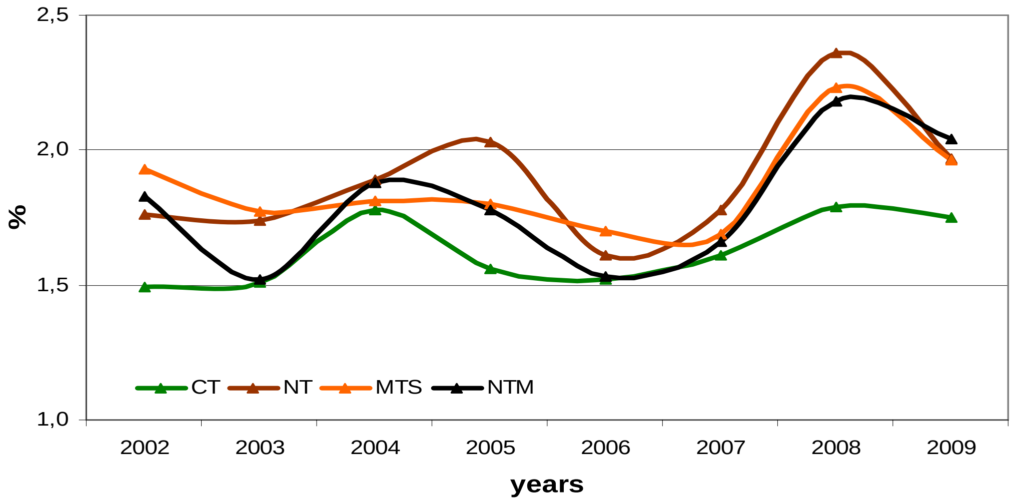

Figure 4: Oxidizable carbon in upper layer of topsoil (0-0.1m) tilled by different methods during the given time period

Differences of Cox content among the tillage treatments are also confirmed in the Table 1 where the values of N total content are included that show the similar differences as well.

Table 1: The total content of nitrogen (N) and carbon (C) in the depth of soil 0-0.1 m

Treatment	N total (%)	C total (%)
1. CT	0.166 ± 0.012	1.922 ± 0.102
2. NT	0.182 ± 0.014	2.125 ± 0.140
3. MTS	0.180 ± 0.012	2.013 ± 0.121
4. NTM	0.175 ± 0.013	1.928 ± 0.201

Carbon and nitrogen are the essential components of humus in the soil and more intensive sequestration C and N in the soil is an assumption of higher humus content formation in soil, thus contributes to higher soil fertility with use of its favourable impact on the soil properties. The values in the Table 2 that are the averages of last 8 years present the differences of humus content in the soil among the individual treatments. There exist statistically significant differences between the conventional variant and no till variants, especially with mulch in upper and middle sampling horizons of topsoil profile. These findings correspond closely with above mentioned results of C/N content analysis.

Table 2: The influence of soil tillage method on the humus content in topsoil (the average of last 8 years)

Soil depth (m)	Humus content (%)				LSD 0,05
	CT	NT	MTS	NTM	
0 – 0.1	2.79	3.47	3.31	3.82 +	0.726
0.1 – 0.2	2.70	3.37 +	3.10	3.44 +	0.612
0.2 – 0.3	2.60	3.10	2.64	3.04	0.598

The results presented confirmed namely favourable influence of conservation technologies of soil tillage on biological soil activity in long-term horizon. For instance Chaudhary et al. (2003) also refer on increase of microbial metabolic activity with all its beneficial effects which can be significant during continuous use of conservation tillage practice for a longer period. More intensive activity of soil microorganisms and higher enzymatic activity in soil processes result in higher C/N content in the soil and in their transformation in high-molecular substances increasing soil fertility (Franzluebbers et al., 1994). It is shown in yield level of the concrete soil tillage methods when after certain time interval from the beginning of conservation technology use, there comes the permanent, statistically significant increase of crop production in comparison to classic, conventional tillage method. If exists the possibility of mutual comparison among the tillage treatments, then it is evident that these yield changes outlasted even different conditions in the individual years. The time of soil environment stabilization after change of soil tillage method and processes leading to higher soil fertility can be different-length depending on site conditions, especially on he basic soil fertility. Some authors mention that significant difference of soil fertility, finally of crop production can occur after more than 20 years (Kladivko, 2001).

Conclusion

After change of soil tillage method from conventional to conservation one usually it is impossible to expect an immediate impact on crop production. At first, it is necessary to improve soil fertility. Depending on local conditions it can be of different duration. In 14-year field experiment under the given site conditions, till now permanent significant increase of wheat grain production was recorded in the conservation treatments comparing with check variant after 10 years from the trial beginning. The essential influence of higher soil fertility on the production increase has been indicated by soil fertility indicators (soil enzyme activities, C/N sequestration, increase of humus content). Among conservation tillage method used the highest grain production was found in minimum tillage treatment with chopped straw incorporated.

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The role of non-chemical plant protection in conservation methods of winter wheat growing

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Abstract

In four-year field experiment (2006-2009) at Prague-Ruzyně site the use of different forms of biofungicide application in combination with different technologies of soil tillage for crop stand establishment were studied. Besides conventional soil cultivation, reduced tillage with chopped straw incorporated and direct drilling into no tilled soil covered with mulch were used. The preparations were applied as follows: Supresivit (*Trichoderma harzianum*), Polyversum (*Pythium oligandrum*) and Trianum P (other strain of *Trichoderma harzianum*). Effect of these preparations, homogenized both with seed (seed treatment before sowing as a dressing) and used as a mixture with mineral fertilizer ANL, on grain production and health state of winter wheat were evaluated. The results obtained showed favourable influence of biofungicides used not only on crop production but especially on health conditions of winter wheat in conservation tillage treatments, where the possibility of infection occurrence is higher comparing with classic technology.

Key words: conservation soil tillage, winter wheat, plant protection, biofungicides, fungi pathogens

Introduction

In the contemporary conditions of market economy, effective field crop cultivation demands utilization of adequate methods of crop management that guarantee not only profitable but also high quality crop production. In agricultural practice there have been used biofungicides for some time that are able to suppress phytopathogenic fungi and parasitical soil microorganisms by natural way, which means by effect of antagonistic relationships thereby influence positively health conditions of crop stands.

Furthermore they improve nutrient utilization thereby ensure higher efficiency of mineral fertilizers applied into the soil. The effective use of biofungicides in practice is desirable especially in crop stands where minimization of soil tillage is being applied because, just at these fields covered with mulch or shallowly loosened with straw incorporated, higher possibility of pathogen fungi infection is supposed (Weber et al., 2001).

Failure to observe the rules of correct crop rotation that is caused by cultivation of only economically attractive crops, top selling at home and foreign markets, is being more and more frequent reason of undesirable development of soil pathogens. One of the possibilities causing dissemination of pathogenic fungi can be also incorrectly used conservation and minimization technologies of crop growing, especially when positive effect of direct drilling into mulch of cover crops or cover crop biomass incorporation into the soil are utilized insufficiently.

Materials and methods

At the experimental site in Prague-Ruzyne there were assessed yield results of biofungicide application and health state of winter wheat, variety Ebi (years 2006-2008) and Cubus (2009), under different technologies of crop stand establishment. The stands of winter wheat were established by 3 different methods of soil tillage (a, b, c), that were subsequently assessed.

Methods of soil management:

a) classic (conventional) soil tillage, preparation and sowing
b) sowing into no-tilled soil covered with mulch from chopped straw and post harvest residues of pre-crop
c) sowing into shallowly tilled soil with chopped straw of pre-crop incorporated

As regards biopreparates, we used biofungicide Supresivit, based on fungus *Trichoderma harzianum* containing the viable conidia of antagonistic fungus, creating mycelium inhibiting pathogenic fungi development. Polyversum, as the second preparates, is based on the antagonistic fungus *Pythium oligandrum.* The third biofungicide is termed Trianum P. It is based on the similar substance as Supresivit but the difference consists in another strain of the fungus.

Experimental treatments:

1. Check treatment, fertilization by ammonium nitrate with limestone (ANL)
2. Fungi fertilizer (ANL mixed with 10 g of Polyversum per 1 kg of fertilizer)
3. Fungi fertilizer (ANL mixed with 5 g of Supresivit per 1 kg of fertilizer)
4. Fungi fertilizer (ANL mixed with 5 g of Trianum P per 1 kg of fertilizer)
5. Seed dressing with 10 g of Polyversum per 1 kg of seed, fertilization by ANL
6. Seed dressing with 5 g of Supresivit per 1 kg of seed, fertilization by ANL
7. Seed dressing with 5 g of Trianum P per 1 kg of seed, fertilization by ANL

For winter wheat there was used two different methods of biofungicide application, it means that the effects of selected biofungicides were observed both as a mixture with mineral fertilizer ANL (fungi fertilizer) and as a mixture with seed (seed dressing) prepared before sowing.

Nitrogen fertilization was applied in the total dose 100 kg per ha. The first dose 40 kg per ha was used in early spring as a regeneration dose, the second one 30 kg per ha was applied in the shooting stage as a production dose and the last one 30 kg per ha was used as the late fertilization. Fungi ANL fertilizer (tr.No. 2-4) was applied only in the regeneration and production doses.

Beside grain yields and yield parameters, biofungicide effects in combination with different method of soil tillage on pathogen fungi occurrence of *Fusarium* genus in soil and *Septoria, Drechslera, Alternaria* on the plant surface were assessed as well.

Results and discussion

Overall results of grain yield of winter wheat, obtained in the period 2006-2009, are presented in the Table 1. The highest grain yields (8.37 t ha^{-1}) and at the same time high yield increments comparing with the check variant (+0 57 $t.ha^{-1}$, i.e. +7.1%) were recorded on plots with direct drilling into no tilled soil and treated with biofungicides Trianum P in the mixture with ANL fertilizer – treatment No.4. Slightly less average yields were reached in the variants with Trianum P in seed dressing form (treatm. No.7; 8.23-8.36 $t.ha^{-1}$) and also after use of biofungicide Supresivit in the both forms of application (treatm. No.3 and 6). For example, the use of Supresivit in the joint application with ANL fertilizer increased grain yield by 5.6-6.0% depending on soil tillage method for wheat stand establishment. Increments of grain yields after use of biofungicide Polyversum varied, in the average of assessed years, from 3.0 to 5.2% comparing with yields from fertilized variants but untreated with biopreparations. The effect of biofungicides applied varied, in the average of assessed years, from 5.8 to 6.1 %. Regardless of the method of crop stand establishment, it is evident that the effects of preparation Trianum P and Supresivit transcended markedly the impact of biofungicide Polyversum, both in the form of seed dressing or fertilizer fungi.

Table 1: The grain yields of winter wheat from evaluated variants (average 2006 - 2009)

Treatment		Winter wheat						
		A		B		C		Average
		($t\ ha^{-1}$)	(%)	($t\ ha^{-1}$)	(%)	($t\ ha^{-1}$)	(%)	($t\ ha^{-1}$)
1.	Check treatment	7.69	100.0	7.80	100.0	7.70	100.0	7.73
2.	Fertilizer + Polyversum	7.95	103.4	8.04	103.0	7.95	103.1	7.98
3.	Fertilizer + Supresivit	8.15	106.0	8.32	105.9	8.19	105.6	8.22
4.	Fertilizer + Trianum P	8.23	107.0	8.37	107.1	8.22	106.8	8.27
5.	Seed + Polyversum	8.09	105.2	8.23	103.3	8.13	103.9	8.15
6.	Seed + Supresivit	8.14	105.8	8.34	104.8	8.23	105.2	8.24
7.	Seed + Trianum P	8.26	107.4	8.36	107.0	8.23	107.2	8.28
Grain yield average:		8.07	x	8.21	x	8.09	x	8.12
The effect of biopreparates:		x	105.8	x	106.1	x	106.0	x
The effect of stand establishment:		100%		101.7 %		100.2 %		x

Notes: Methods of stand establishment of winter wheat:
A - conventional tillage
B - no tillage - direct sowing into untilled soil, covered with mulch
C - minimum tillage- sowing into shallow tilled soil with chopped of pre-crop straw incorporated

In the average of assessed years and regardless of biofungicide impact, there were obtained higher winter wheat yields (Table 1) at the plots tilled with conservation technologies than in variants under conventional soil tillage. Considering the comparative base 100% grain yields reached in conventional treatment, then production from the conservation variants in the average of 4 years achieves the values 101.7% under no tillage and 100.2% under minimum tillage. In the first two years of the monitored period, higher grain yields of wheat were obtained in the conventional treatments. But in the year 2008 and namely in 2009, after 6-year period of conservation tillage method application when the conditions in the soil stabilized, there were recorded higher yields of wheat by about 4% in conservation variants than in conventional ones.

At the plots under direct drilling into no tilled soil covered with mulch from chopped straw and post harvest residues of forecrop (B), stronger occurrence of pathogenic fungi on leaves and also on roots, especially of *Fusarium* genus, was according to our assumption recorded (see Table 2). After application of assessed biofungicides, namely in the mixture with fertilizer ANL, the significant reduction of fungi pathogens of *Fusarium* genus, particularly *Fusarium graminearum* was found, when in comparison to the untreated variants 15% decrease of microfungi, isolated from the soil, was recorded (in the Table 2). The largest impact of biofungicides on reduction of the pathogenic fungi occurrence on roots, leaves, stems and spikes of winter wheat was found at the plots where the method of minimum tillage with chopped straw incorporated was used (C). In these variants, the quantity of the pathogens of *Fusarium* genus was suppressed by about 15–19%.

On the basis of the detailed foliar analysis of the wheat plants, quantity infestation of leaf area by specific fungi pathogens was evaluated, namely fungi *Drechslera tritici-repentis,* *Septoria tritici* and *Alternaria triticina* were observed. From 4-year results presented in the table it is evident that the lowest infestation by fungi pathogens was recorded in the variant with conventional soil tillage (A) comparing with conservation tillage treatments (B, C). But in the conventional variant, at plots treated by Supresivit and Trianum P, the occurrence of pathogenic fungi of *Septoria* genus on the leaves was lower by about 23% (Table 2) in comparison with untreated check variant. Regardless of different method of winter wheat stand establishment, it was proved that biofungicide use avoided higher infestation of winter wheat plants by pathogenic fungi and thereby it contributed to better health state of wheat stands.

Table 2: The influence of selected biofungicide application on the health state of winter wheat (average of years 2006-2009)

Treatment	A				B				C			
	a	b	c	d	a	b	c	d	a	b	c	d
1. Check treatment	22	13	27	25	30	18	30	32	28	17	31	32
2. fertilizer + Polyversum	20	12	25	23	28	16	28	29	27	17	29	30
3. fertilizer + Supresivit	19	*10*	26	22	27	16	27	27	25	14	28	28
4. fertilizer + Trianum P	18	11	24	21	27	15	27	27	24	14	28	26
5. seed + Polyversum	21	11	25	25	28	17	29	29	26	16	30	30
6. seed + Supresivit	18	*10*	24	24	26	14	28	28	27	15	27	27
7. seed + Trianum P	18	*10*	23	22	26	15	26	29	25	14	27	28
Averages	19	11	25	23	27	16	27	29	26	15	29	29

a – leaf area infected by *Drechslera tritici-repentis* (%)
b - leaf area infected by *Septoria tritici* (%)
c - leaf area infected by *Alternaria triticina* (%)
d - *Fusarium graminearum* (number of CFU in 1 g of soil)

Conclusions

On the basis of presented 4-year results from the field trials under conventional and conservation soil tillage technologies it is possible to summarize that use of the selected biofungicides taking effect on the principle of the antagonistic relations with pathogens and applied in the form of seed dressing or fungi fertilizer had a positive effect on grain yield of winter wheat. Yield increase after biofungicide applications varied from 3.0% to 7.4%. The highest yield effect was reached by use of Trianum P preparation. From the results it is also evident that the 4-year average yield differences among the different methods of wheat stand establishment were minimal (+1.7%; resp. +0.2%), i.e. insignificant. But in the last two years, the trend of yield increase at the plots under conservation tillage technologies comparing with conventional tillage method was identified.

Regardless of soil tillage technology used, it is possible to explain the yield increase in the treated variants as a proven suppression of soil-born pathogens, especially microscopic fungi, attacking plant roots.

In comparison to untreated variants, it was found by about 10-19% decrease of microfungi number in soil. The reduction of pathogenic fungi occurrence of genera *Fusarium, Drechslera, Septoria, Alternaria, Pseudocercosporella* etc., having their infection potential in soil in the form of conidia and mycelium, is being very important from practical point of view. Especially fungi of the *Fusarium* genus, surviving on the crop residues in the soil, is very strongly suppressed by antagonistic fungi and then its negative effect is significantly reduced. The wheat stands, treated with biofungicides are healthier and they give higher and more quality production.

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Environmental aspect of nitrogen availability under subsoiling and mole drainage

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Abstract
The problem of compactness of heavy soils could be surpassed by mole drainage and subsoiling. The aim of this study was to investigate effects of mole drainage and subsoiling (treatment) on available nitrogen content in the soil profile, as well as, its uptake by maize and sunflower, on calcareous clay chernozem soil, in rainfed cropping during 2009.

The total N output by plants, leaching and evaporation in control (without mole drainage and subsoiling) was higher by 15% in sunflower and by 43%, in maize. Moreover, N deprivation by leaching and evaporation during the growing season of sunflower was 338.13 kg N ha^{-1} in control and 287.37 kg N ha^{-1} in the treatment, while it was 475.03 kg N ha^{-1} in maize in control and 268.63 kg N ha^{-1} in treatment.

The observed situation affected the plant growth during the growing season – biomass of both, sunflower and maize was higher, but the dry weight was lower in control. The N uptake by crops during the growing season was better in the treatment, resulting in the grain yield increase of 10% in maize and of 9% in sunflower.

Keywords: mole drainage and subsoiling, maize, sunflower, nitrogen regime, yield

Introduction
Heavy soils demand adequate tillage practice, which provide natural fertility potentials and restrain degrading processes in soil (Molnar et al, 1979). The preservation of soil bio-system, regulation of water and air regime, moisture conservation, as well as rational energy utilization and production level of heavy soils must be provided by tillage machinery (Raičević et al, 1997).

The effective tillage practice gives opportunity to correct negative physical and water features, increasing soil fertility and crops yield. The different tillage systems also influence the N conservation (Reeves and Touchton, 1986), N loosing via leaching and denitrification (Meisinger et al., 1985) and N uptake by plants.

The aim of this study was to investigate the effects of mole drainage and subsoiling on growth and yield of sunflower and maize, as well as soil nitrogen alterations, under rainfed conditions on a calcareous clay chernozem type of soil.

Material and methods
The trial was set up at the Krnješevci experimental field of the Maize Research Institute, on a calcareous clay chernozem type of soil, under rainfed conditions during 2009. Irrespective to absence of micro-depressions, the waterproofed localities existed on

experimental plot. One half of the plot (5 ha) was sowed with maize, and the other half (5 ha) with sunflower. Each half of the plot was divided in two subplots: treatment (where mole drainage and subsoiling were applied) and control (where mole drainage and subsoiling were not applied). All other cultivation practices were identical for each subplot. The previous crop was barley.

Mole drainage was performed with the drainage plough DP-4, resulting in drainage canals on the depth of 60-80 cm, 5 m apart. Subsoiling was performed with the vibratory subsoiler VR 5/7, consisting of 5 working organs 60 cm apart, operating 50 cm deep.

Sunflower (Albatre) was sowed on April 9th, and maize (ZP-360 Ultra) on April 28th. Sowing density was 56,000 plants ha-1 for sunflower and 58,300 plants ha-1 for maize. The 150 kg ha-1 of Ammonium nitrate and 134.8 kg ha-1 of Urea were applied before sowing.

The plants and soil were sampled for analysis on June 11th (Phase I), on June 16th (Phase II) and on August 24th (Phase III). Additionally, soil was sampled on May 11th and November 2nd in order to determine N content at the beginning and at the end of vegetation. Fresh matter, dry matter (after drying at 60°C) and total nitrogen content (by modified method of Allen (1931)) were determined from plant material. The soil was sampled from four layers of effective rhizosphere zone: 0-30 cm, 30-60 cm, 60-90 cm and from 60-90 cm layers. Average samples were used to determine the ammonium (NH_4) and nitrate (NO_3) from 1 M NaCl + 0.1 M $CaCl_2$ extracts by the method of Scharpf and Wehrmann (1975). Their sum was expressed as the mineral N. Sunflower was harvested on August 27th and maize on September 23rd.

The differences between observed data of each parameter were expressed by standard deviation (SD). Analysis of variance (ANOVA) and LSD test were performed on the soil N and moisture content data, depending on the investigated factors.

Total precipitation during the growing season (April–October) was 306.7 mm, with the maximum of 124.6 mm (recorded in June), while the average temperature was 20.9°C.

Results and discussion

The fresh matter of the root, the stalk and the leaves of sunflower was lower in treatment than in control in all three phases (Table 1). The average values per plant were 9.47 g (root), 137.59 g (stalk) and 27.83 g (leaves). Meanwhile, head weight was higher in treatment by 2.22 g in phase I, by 13.48 g in phase II and by 7.90 g in phase III – the average head weight was 10% higher in treatment. The obtained results are in opposition with results of Lowery and Schuler (1991) and Abu-Hamdeh (2003) – they indicate poorer plant growth on compacted soils. In maize root and shoot (stalk + leaves), the fresh matter content was lower in treatment in phases I and III: by 24.28 g (root) and by 84.64 g (stalk and leaves) in phase I, and by 4.80 g (root) and by 46.39 g (stalk and leaves) in phase III (Table 2). Contrary, fresh matter of maize root and shoot was higher in treatment in phase II by 56.50 g and by 42.47 g, respectively, as well as kernel fresh matter by 8.25 g, in comparison to control.

The applied treatment generally induced increase of dry matter during complete vegetative cycle of sunflower (up to 0.62% (head, phase II)), compared to control (Table 1). The exception is present only during phases II and III, where vegetative parts (root, stalk and leaves) had lower dry matter present in treatment. Considering maize dry matter, it could be assumed, that its lower content in treatment in phase I in root and shoot, had generally increasing trend (Table 2), what was particularly underlined in root from phase II (to 0.12% higher DM content in treatment) and kernel in phase III (0.88% higher DM content), compared to control. Increase of DM to blooming phase and particularly during kernel ripening could be to some degree connected to better soil aeration and water regime (Machado et al, 2002; Abu-Hamdeh, 2003).

Table 1: The fresh matter (FM), dry matter (DM), N content, grain yield and harvest index in sunflower, influenced by mole drainage and subsoiling (± SE values)

	Control			Treatment		
	FM (g)	DM (%)	N cont. (%)	FM (g)	DM (%)	N cont. (%)
			Phase I			
Root	89.20±56.3	15.64±4.8	1.25	70.48±23.5	14.54±4.1	0.93
Stalk	493.24±103.6	13.55±3.4	1.45	480.84±101.8	12.04±2.0	1.26
Leaves	440.76±150.8	12.91±2.8	3.49	371.08±123.6	11.47±3.1	3.14
Head	22.46±5.2	17.13±3.5	3.32	24.68±8.0	15.40±2.6	3.20
			Phase II			
Root	170.33±40.6	14.15±6.6	0.73	163.90±9.8	14.07±0.7	0.58
Stalk	843.77±46.3	14.42±6.8	0.89	462.63±42.3	20.38±7.0	0.62
Leaves	294.00±29.1	15.90±5.6	3.37	272.30±38.1	16.71±4.8	2.77
Head	289.87±31.8	14.62±4.7	2.24	335.03±19.0	17.01±4.2	2.72
			Phase III			
Root	26.70±3.0	47.57±0.8	0.46	23.45±0.8	68.75±1.6	0.34
Stalk	128.10±5.8	82.78±7.9	0.89	108.85±5.4	92.01±3.8	0.84
Leaves						
Head	89.85±8.0	88.95±7.6	2.19	97.75±8.1	96.63±4.5	2.23
Yield (t ha^{-1})	2.75			3.01		
Harv. index	0.58±0.4			0.74±0.5		

Higher N content was determined in vegetative parts of sunflower in all three examined phases in control (up to 0.60% in leaves, phase II, Table 1), while in generative part (head), it was lower only in phase III (by 0.48%). So as, at the end of the vegetative period harvest index and grain yield were lower in control by 22% and 9%, respectively. It was interesting to emphasize that N content of maize vegetative parts (root and shoot) was higher in treatment in phase I (0.30% and 0.22%, respectively), and expressed decreasing trend in the same maize parts, while it was increased in generative part (kernel), up to 0.45%, compared to control (Table 2). As consequence of noted situation, harvest index and grain yield were higher in treatment, by 7% and 10%, respectively. The results of Lowery and Schuler (1991) indicate that reducing of the soil compaction have positive influence on N uptake and higher grain yield.

Table 2: The fresh matter (FM), dry matter (DM), N content, grain yield and harvest index in maize, influenced by mole drainage and subsoiling (± SE values)

	Control			Treatment		
	FM (g)	DM (%)	N cont. (%)	FM (g)	DM (%)	N cont. (%)
Phase I						
Root	79.28±22.5	19.22±4.5	1.21	55.00±22.0	19.60±3.0	1.51
Stalk+Leaves	371.22±36.7	13.17±5.3	2.32	286.58±35.1	13.94±7.2	2.54
Phase II						
Root	114.67±38.8	18.31±0.9	0.82	171.17±45.6	17.35±0.9	0.98
Stalk+Leaves	604.93±107.7	24.68±2.8	1.50	647.40±104.3	25.57±7.8	1.20
Phase III						
Root	160.35±8.0	30.84±5.0	0.80	155.55±8.8	37.25±2.8	0.72
Stalk+Leaves	507.85±1.1	34.52±3.8	0.85	461.46±65.5	34.39±14.0	0.67
Kernel	290.75±3.5	63.73±6.4	1.43	299.00±14.6	62.71±17.0	1.88
Yield (t ha^{-1})	6.38			7.08		
Harv. index	0.41±0.4			0.44±0.3		

Soil available N content had decreasing trend during vegetation, as was expected, in all experimental subplots (Table 3). Significant decrease of N content, from sowing period, could be observed after phase I under maize and after phase III under sunflower, irrespectively to relative high N loss from sowing to phase I, which is connected to proximity of fertilizer application (Li et al, 2009).

Subsoiling and mole drainage did not affect N content significantly. The higher N output by plants, leaching and evaporation was observed in control in both crops (338.13 kg ha^{-1} under sunflower and 479.03 kg ha^{-1} under maize), during vegetative period, which is about 15% and 43% higher, compared to treatment (Table 3).

Table 3: The changes of available N content in soil, influenced by mole drainage and subsoiling

	Sunflower			Maize		
	N content (kg ha^{-1})					
	C	T	$\overline{X}$	C	T	$\overline{X}$
Sowing	496.49	522.01	509.25	661.93	571.62	616.78
Phase I	326.20	306.94	316.57	552.98	420.92	486.95
Phase II	251.11	281.16	266.13	334.34	417.70	376.02
Phase III	185.59	261.22	223.40	281.83	313.16	297.49
Harvesting	158.36	234.63	196.49	186.90	302.99	244.95
$\overline{X}$	283.55	321.19	302.37	403.59	405.28	404.44
LSD 5%	Treatment	Phase	Interact.	Treatment	Phase	Interact.
	160.23	283.24	238.73	110.72	190.10	288.91

When N quantity consumed by plants (Tables 1 and 2) is taken into consideration too, it could be pointed out that total N deprivation by leaching and evaporation was higher in control, by 118.08 kg ha^{-1} under sunflower and by 221.04 kg ha^{-1} under maize, that is in accordance with results of Reeves and Touchton (1986). The N deprivation in treatment was only 105.99 kg ha^{-1} under sunflower. Under maize, N content increased by 11.68 kg ha^{-1}, what could be explained by minor deprivation and additional decomposition of soil organic substance (Broader et al., 1984; Calderon and Jackson, 2002).

Conclusion

According to our data, mole drainage and subsoiling, applied on calcareous clay chernozem type of soil under rain fed conditions, during 2009 increased accumulation of dry matter and nitrogen in sunflower and maize, irrespective to lower fresh matter content. The observed situation, together with higher grain yield of both crops, obtained in treatment could be explained by better N utilization from soil and its lesser deprivation during vegetation.

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The impact of different soil tillage on weed infestation in cereals and winter oilseed rape

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Abstract

Soil tillage is one of the important factors which influence weeds. Actual weed infestation was assessed on farm level in crop stand of spring barley, winter wheat and oilseed rape during three years. Minimum tillage increased occurrence of *Equisetum arvense*, *Avena fatua*, *Galium aparine*, *Poa annua* and *Veronica polita* in cereal crop stands, *Apera spica-venti* and *Fallopia convolvulus* in winter crops. In most cases these are species which are difficult to control and which are capable of producing seeds or fruit very quickly. In conclusion it can be said that the areas cultivated using the minimum tillage method show those species in particular which produce seeds and fruit very quickly. Furthermore, these are species which are relatively resistant to chemical control. The occurrence of perennial species of weeds is apparently affected more by the quality and purposefulness of instances of chemical control, which can overlap with the impact of the technology of soil tillage. In addition, it is necessary to realize that the method of soil tillage affects the weed species as merely one of many factors, and also the fact that these act as a multifunctional factor in conjunction with many other factors, which can overlap the impact technology of soil tillage.

Keywords: weeds, cereals, oilseed rape

Introduction

Technology of soil tillage changes conditions for growth and reproduction of weeds. It caused changes in actual weed infestation, qualitatively and quantitatively. According to results of Mikulka (1999), weed spectrum diversity decreased with minimum tillage, but total number of specimens is increased. Gill and Arshad (1995) and Pykhtin et al. (1995) found out, that diversity of perennial weeds is increased with reduced tillage.

Reaction of chosen weeds to different soil tillage was studied in field trials in Higham (Great Britain). Population of *Bromus sterilis* was ten times higher on minimum tillage, but lower decrease was on variants with ploughing as well. Occurrence of *Papaver rhoeas* was stable. *Galium aparine* was spread on minimum tillage variants, except variants where *Bromus sterilis* had frequent occurrence (McCloskey et al., 1998).

Material and methods

Weed infestation was evaluated in stands of spring barley, winter wheat and winter oilseed rape in years 2000-2002. Observed fields were located in two farms (Olomouc Holice and Bohunovice) close to the town Olomouc (Moravia, Czech Republic). Long-term average annual precipitation is 517 mm and long-term average temperature is 8.6°C. The area of observed fields was changed in years, 422 ha in 2000, 688 ha in 2001 and 551 in 2002.

Conventional tillage (CT) is used on farm in Holice, where soil was ploughed to the depth of 0.15–0.25 depending on crop. Minimum tillage (MT) was technology applied in all grown crops on farm Bohunovice form year 1995 regularly. The principle of this technology is that the soil is loosened to the depth of 0.08 m, without ploughing. On both farm appropriate herbicide application is used.

Kühn's methodology (Kühn, 1982) was used for evaluation of weed spectrum. Fytocoenological relevés were recorded in July and August. Each assessed unit had 12 m^2 and represents approx. 2.6 ha.

Results (frequency of weed species occurrence) were evaluated using multidimensional analysis of ecological data. The choice of optimal ordination method depended on lengths of gradient, which was found out detrended correspondence analysis. Canonical correspondence analysis was used for following analysis. Data were analysed using software Canoco 4.0. (Ter Braak, 1998).

Results and discussion

Table 1 shows results of weed species numbers in phytocoenological reléves in two different variants of soil tillage during three years. Occurrence of the most frequent weed species during three years of observation in spring barley stand are in Graph 1, results in winter wheat stand are in Graph 2 and in winter oilseed rape are in Graph 3.

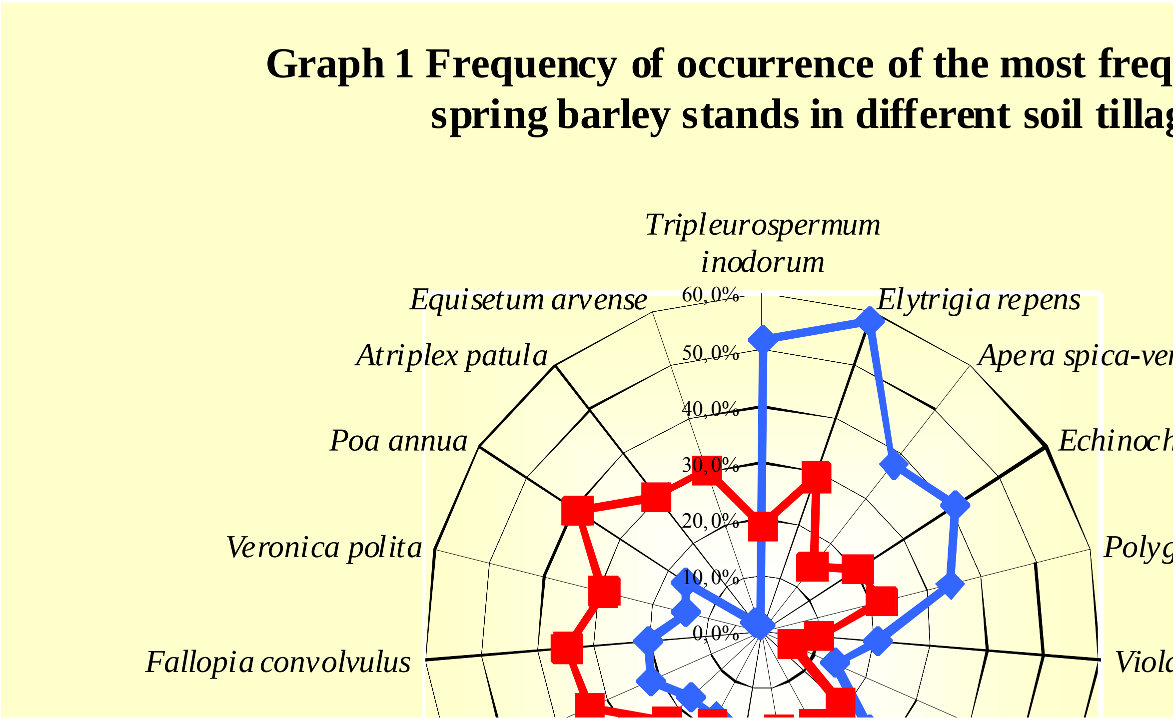
Table1: Number of weed species in different crops and soil tillage (2000-2002)

Years	Crop and soil tillage					
	Spring barley		Winter wheat		Winter oilseed rape	
	Conventional tillage	Minimum tillage	Conventional tillage	Minimum tillage	Conventional tillage	Minimum tillage
2000	5.7	8.2	6.1	3.7	9.0	8.1
2001	8.9	5.5	3.6	6.2	8.2	8.7
2002	5.8	5.4	6.7	4.6	6.9	9.0
Mean	6.8	6.4	5.5	4.8	8.0	8.6

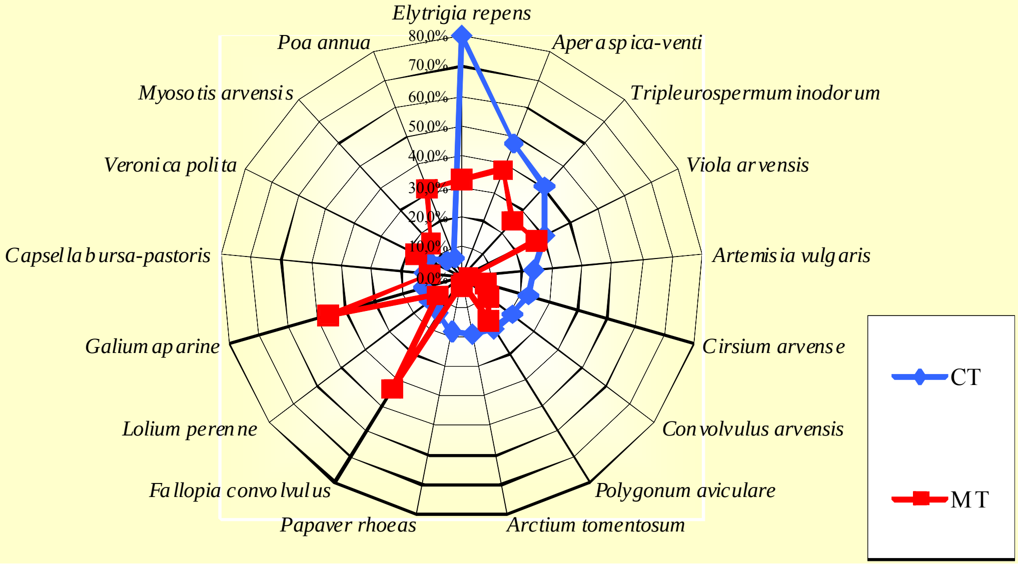
During three years 92 weed species were found in spring barley stand. In variant with conventional tillage (CT) 79 weed species were observed, in minimum tillage (MT) 65. In winter wheat, 91 weed species were found, 78 in CT and 64 in MT. In winter oilseed rape 98 weed species were found, in CT 75 and 66 in MT.

Based on DCA analyses (detrended canonical analyses) CCA analyses (Correspondence canonical analyses) was for evaluation of results in spring barley chosen, because the length of gradient was 5.194. Results of CCA analyses were significant on the significance level $\alpha = 0.002$, for all canonical axis. Based on this analysis, ordinatory diagram was created (Pic. 1), which is a graphic interpretation of the impact of different soil tillage technologies on chosen weed species. Minimum tillage (MT) is more suitable technology for weeds (red coloured): *Atriplex patula*, *Avena fatua*, *Convolvulus arvensis*, *Equisetum arvense*, *Galium aparine*, *Chenopodium album*, *Lapsana communis*, *Poa annua*, *Polygonum aviculare*, *Solanum nigrum*, *Veronica polita*. Weeds species with higher occurrence or cover (or both) in CT were: *Apera spica-venti*, *Echinochloa crus-galli*, *Elytrigia repens*, *Matricaria maritima* and *Plantago major*. Other weed species (green coloured) were more influenced with other factors which are not recorded in analysis.

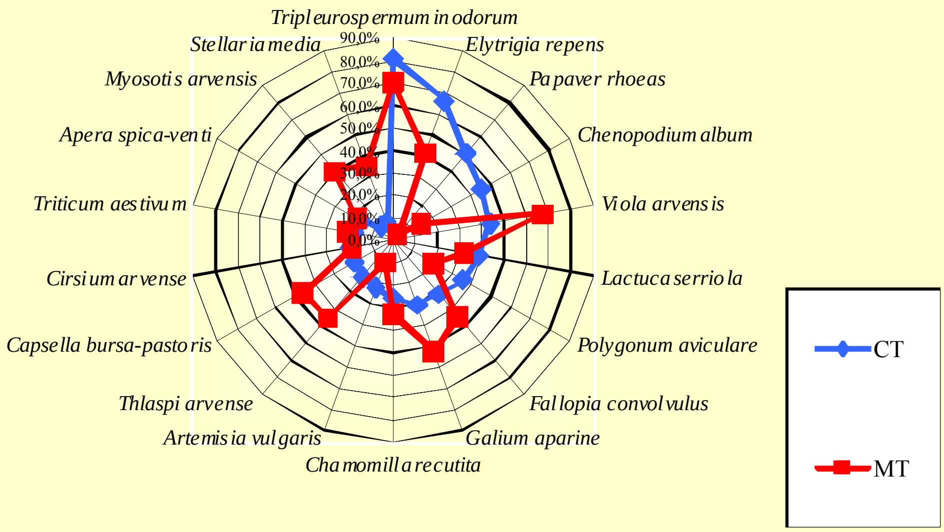
Based on DCA analyses or results in winter wheat stand CCA analysis was used for results of winter wheat when length of gradient was 4.938. Results of CCA analyses were significant on the significance level α = 0.002, for all canonical axis. Based on this analysis, ordinatory diagram was created (Pic. 2), which is a graphic interpretation of the impact of different soil tillage technologies on chosen weed species. Minimum tillage increased occurrence or cover of: *Apera spica-venti*, *Avena fatua*, *Equisetum arvense*, *Fallopia convolvulus*, *Galium aparine*, *Lapsana communis*, *Poa annua* a *Veronica polita* (marked as a red coloured). Species, which were more frequent or had higher cover in conventional tillage are marked within blue colour: *Arctium tomentosum*, *Artemisia vulgaris*, *Cirsium arvense*, *Elytrigia repens*, *Medicago sativa*, *Papaver rhoeas*). Species marked green were more affected with factors which were not recorded in analysis.



Graph 2 Frequency of occurence of the most frequent species in winter wheat stands in different soil tillage methods

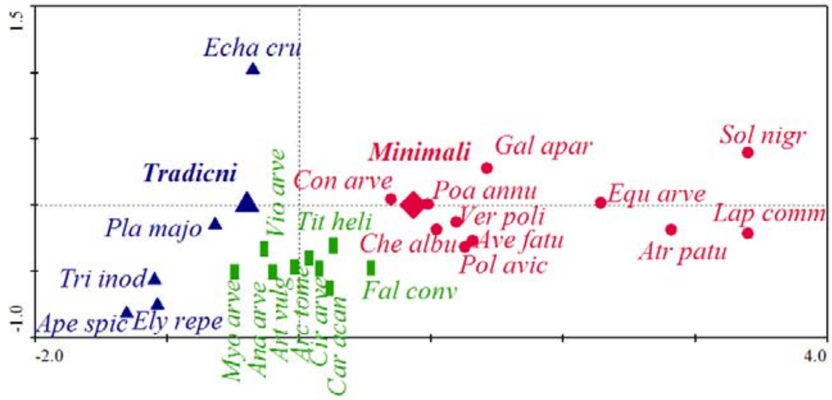


Graph 3 Frequency of occurrence of the most frequent weed species in winter oilseed rape stands in different soil tillage methods



Results of weed infestation in winter oilseed rape were analysed using CCA analysis. The length of gradient was 3.851. Results of CCA analyses were significant on the significance level α = 0.002, for all canonical axis. Based on this analysis, ordinatory diagram was created (Pic. 3), which is a graphic interpretation of the impact of different soil tillage technologies on chosen weed species. Minimum tillage increased occurrence or cover of (marked as red coloured): *Apera spica-venti*, *Atriplex patula*, *Cirsium arvense*, *Equisetum arvense*, *Fallopia convolvulus*, *Chamomilla recutita*, *Lactuca serriola* a *Myosotis arvensis.* Variant with conventional tillage had higher occurrence of (blue colour): *Elytrigia repens*, *Chenopodium album*, *Lolium perenne* and *Papaver rhoeas.* Species marked green were more affected with factors which were not recorded in analysis.

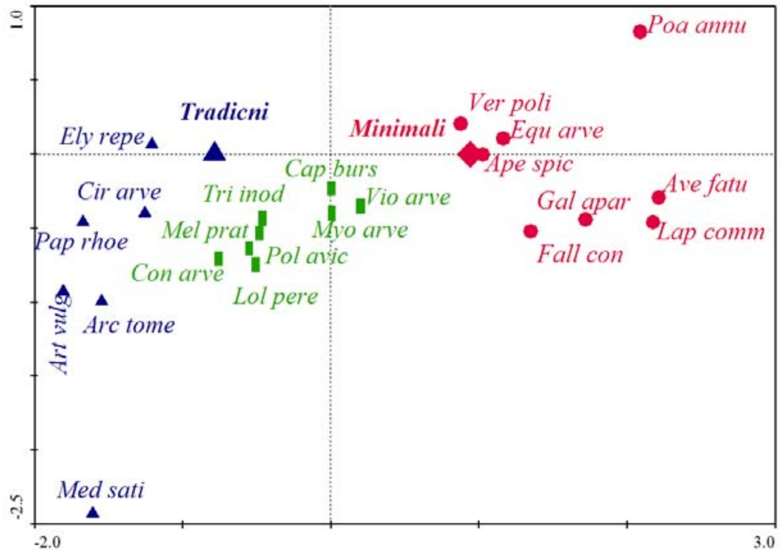
Picure 1: Ordinatory diagram recording the effect of different soil tillage on chosen weed species in spring barley stands



Legend to ordinatory diagram (Pic. 1): Soil tillage technologies: ▲Tradicni – conventional (CT), locality Olomouc–Holice; ◆*Minimali* – minimum tillage (MT), locality Bohunovice.

Abbreviations of chosen species: Ana arve (*Anagallis arvensis*), *Ape spic* (*Apera spica-venti*), *Arc tome* (*Arctium tomentosum*), *Art vulg* (*Artemisia vulgaris*), *Atr patu* (*Atriplex patula*), *Ave fatu* (*Avena fatua*), *Car acan* (*Cardus acanthoides*), *Cir arve* (*Cirsium arvense*), *Con arve* (*Convolvulus arvensis*), *Echa cru* (*Echinochloa crus-galli*), *Ely repe* (*Elytrigia repens*), *Equ arve* (*Equisetum arvense*), *Fal conv* (*Fallopia convolvulus*), *Gal apar* (*Galium aparine*), *Che albu* (*Chenopodium album*), *Lap comm* (*Lapsana communis*), *Myo arve* (*Myosotis arvensis*), *Pla majo* (*Plantago major*), *Poa annu* (*Poa annua*), *Pol avic* (*Polygonum aviculare*), *Sol nigr* (*Solanum nigrum*), *Tit heli* (*Tithymalus helioscopia*), *Tri inod* (*Tripleurospermum inodorum*), *Ver poli* (*Veronica polita*) a *Vio arve* (*Viola arvensis*).

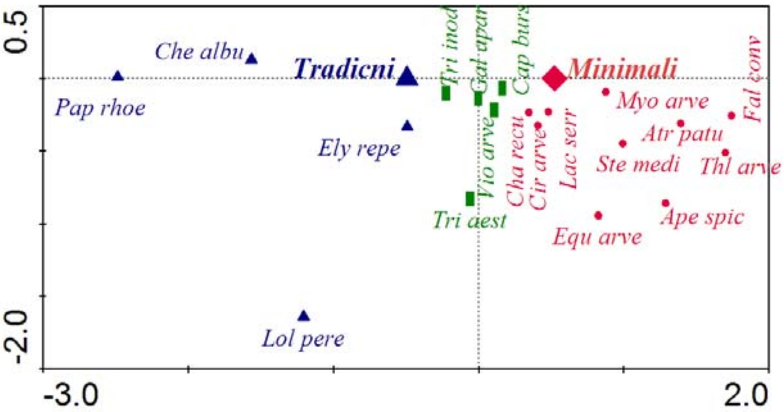
Picture 2: Ordinatory diagram recording the effect of different soil tillage on chosen weed species in winter wheat stands



Legend to ordinatory diagram (Pic. 2): Soil tillage technologies: ▲Tradicni – conventional (CT), locality Olomouc–Holice; ◆*Minimali* – minimum tillage (MT), locality Bohunovice.

Abbreviations of chosen species: Ape spic (Apera spica-venti), Arc tome (Arctium tomentosum), Art vulg (Artemisia vulgaris), Ave fatu (Avena fatua), Cap burs (Capsella bursa-pastoris), Cir arve (Cirsium arvense), Con arve (Convolvulus arvensis), Ely repe (Elytrigia repens), Equ arve (Equisetum arvense), Fal conv (Fallopia convolvulus), Gal apar (Galium aparine), Lap comm (Lapsana communis), Lol pere (Lolium perenne), Med sati (Medicago sativa), Mel prat (Melandrium pratense), Myo arve (Myosotis arvensis), Pap rhoe (Papaver rhoeas), Pol avic (Polygonum aviculare), Ste medi (Stellaria media), Tri inod (Tripleurospermum inodorum), Ver poli (Veronica polita), Vio arve (Viola arvensis).

Picture 3: Ordinatory diagram recording the effect of different soil tillage on chosen weed species in winter oilseed rape stands



Legend to ordinatory diagram (Pic. 3): Soil tillage technologies: ▲Tradicni – conventional (CT), locality Olomouc–Holice; ◆*Minimali* – minimum tillage (MT), locality Bohunovice.

Abbreviations of chosen species: Ape spic (Apera spica-venti), Atr patu (Atriplex patula), Cap burs (Capsella bursa-pastoris), Cir arve (Cirsium arvense), Equ arve (Equisetum arvense), Ely repe (Elytrigia repens), Fal conv (Fallopia convolvulus), Gal apar (Galium aparine), Cha recu (Chamomilla recutita), Che albu (Chenopodium album), Lac serr (Lactuca serriola), Lol pere (Lolium perenne), Mat mari (Matricaria maritima), Myo arve (Myosotis arvensis), Pap rhoe (Papaver rhoeas), Ste medi (Stellaria media), Tri inod (Tripleurospermum inodorum), Thl arve (Thlaspi arvense), Tri aest (Triticum aestivum), Vio arve (Viola arvensis).

Different soil tillage method in the field conditions can change some soil properties which can play important role in changes of weed spectrum. In general, conditions which are created with minimum tillage are suitable for *Equisetum arvense*. In cereal stands, minimum tillage increases occurrence of *Avena fatua*, *Galium aparine*, *Poa annua* and *Veronica polita*. We can expect an increase of *Apera spica-venti* and *Fallopia convolvulus* in winter cereals. The occurrence of worse chemical controlled weeds, with high level of reproduction, is more often in minimum tillage method.

Higher occurrence and cover was found out in spring barley by *Avena fatua*. It is related to findings of Dvorak (1988), who mentioned, that occurrence of this weeds increased in the fields where the soil is tilled to the depth of 0.1 m. Skuterud et al. (1996) found, that minimum tillage increases the infestation with monocotyledonous weeds. In our observations there were species *Avena fatua* and *Poa annua*. In *Galium aparine* higher occurrence connected with MT found also McCloskey et al. (1998) and Mikulka (1999). It could be caused with the fact that seeds are lying in shallow layer where from they can easily to germinate. On the other hand, *Elytrigia repens* had higher occurrence and cover in conventional tillage (Stach, 1992). But Mayor and Maillard (1995), Truchina (1997) and Mikulka (1999) found increase of this weed connected with minimum tillage.

Differences among our results and others from literature could be in different chemical weed management. Mostly of the research works are coming from field conditions where the same chemical management is used in all variants. In our case, in MT target chemical control against *Elytrigia repens* was applied. In CT this measure was not applied. *Apera spica-venti* in winter wheat stands increased occurrence in MT. These results are related to findings of Bujak and Pawlowski (1997) and Mikulka (1999). *Lactuca serriola* is now more and more important weed in winter oilseed rape. This weed is spreading by wind from non arable land: peak of its maturing is in time of seedbed preparation for oilseed rape. Minimum tillage creates good conditions for increasing occurrence of *Equisetum arvense*, but also for *Cirsium arvense*. By *Cirsium arvense* higher weed infestation found also Mikulka (1999), Legere et al. (1990), Gill and Arshad (1995). The results in our work are similar results of above mentioned authors.

Conclusion

The change of soil tillage method can caused development or spreading of some weed species in the field conditions. In some cases, the occurrence of some weed species decreased with reduction of tillage, when minimum tillage technology is used. In the field conditions, in minimum tillage variant, the development of *Equisetum arvense* was found in general, and *Avena fatua*, *Galium aparine*, *Poa annua* and *Veronica polita* were more frequent in cereals, and *Apera spica-venti* and *Fallopia convolvulus* were in crops with winter character. In minimum tillage, weed species. Weed species which very soon produce seeds are more frequent in minimum tillage variant. Also the occurrence of worse relatively chemical controlled weeds, with high level of reproduction, is more often in minimum tillage method. In some cases, the quality and target of application can be more important than soil tillage. Soil tillage is only one from many factors which can affect weed infestation and also works in interaction with many other impacts.

Acknowledgement

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Evaluation of soil tillage impacts on soil physical condition in different production sites in Hungary

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Abstract
The aim of the study is to evaluate soil tillage effects on soil physical condition in different production sites of Hungary. A multifactorial long-term tillage experiment was carried out on the Látókép Experimental Station of the Centre of Agricultural and Applied Economy Sciences, Debrecen University located in the eastern part of the Great Hungarian Plain (calcareous chernozem soil). Field experiments were carried out on meadow soil, on meadow chernozem soil, on chernozem meadow soil and on brown forest soil. The penetrometer resistance of the soil was measured on the investigate sites on the stubble-field following the harvesting of wheat and rape. Soil compaction caused by improper tillage was detectable in almost every sites involved in the analysis. As a result of tillage carried out on wet soil and in the same depth repeatedly (in multiple years) as well as the lack of deep tillage (deep loosening) 1-2 compacted layers have been formed in the analysed soil profiles. Soil compaction which developed at the investigated sites on the one hand the result of tillage on the other hand it is the result of trampling. It is hard to distinguish these two reasons of degradation, they often emerge together. By applying conventional tillage methods the intensity of factors causing soil degradation exceeded the speed of soil regeneration. Land users must support the regeneration of soil conditions – one of our most important natural resources – by choosing a tillage systems conforming to the soil conditions and reducing factors causing soil degradation.

Keywords: long-term tillage experiment, field experiment, tillage systems, penetration resistance, soil compaction

Introduction
In spite of the available new methods, the proportion of conventional tillage methods is high in Hungary, however degradation and compaction of soil structure is a concomitant effect of conventional tillage caused by frequent and intensive soil disturbance. Both natural factors and human activities can cause degradation of the soil's physical condition and soil compaction, but mechanization and non-proper tillage methods are the primary reasons for these In the past decades, the heavy and high-power machinery used in agriculture significantly contributed to the formation of thicker and more compacted soil layers starting from the surface of the soil (Beke et al., 2005; Földesi, 2006; Ujj et al., 2005).

To a certain extent soil filters the negative environmental effects but in many cases the rate of amelioration is behind the rate of degradation protection (Várlallyay, 1996; Birkás, 2004). In the interest of plant cultivation efficiency and environmental protection we have to strive to protect our soils with proper use thus increase its fertility and avoid yield-hindering factors.

The following soil characteristics are suitable for determining the compactness of the soil: the bulk density, total porosity, pore size distribution, penetration resistance, hydraulic conductivity and air permeability of the soil. Soil penetration resistance measured with penetrometer is one of the most frequently used methods for the examination of compactness of the soil, the location and extension of compacted layers and the spatial and temporal changes of the physical condition of soil. The extent of soil penetration resistance is greatly affected by the actual moisture content of the soil, therefore it is necessary to measure both soil parameters at the same time, high penetration resistance can be measured under both compacted and strongly dried out soil conditions. Similarly to other physical conditions of the soil, the penetration resistance also has a great spatial and temporal variability; therefore it is needed to perform a large number of measurements during the sampling of smaller areas as well.

Material and methods

This study was conducted at the Látókép Experimental Station of the Centre of Agricultural Sciences, Debrecen University located in the north-eastern part of the Great Hungarian Plain (Hajdúság loess plato, 47°30' N, 21°36' E, 121 m elevation). The investigations were part of a multi-factorial (irrigation, tillage, fertilization, plant density) long-term field experiment. The experiment is arranged split-split-plot, on the main plots there are three tillage and two irrigation varieties without replication. Maize hybrids are planted onto the primary sub-plots with a plant number of 50-70 thousand, while the fertilization treatments take place randomized on the secondary sub-plots in four replications. The investigated tillage treatments were winter ploughing to a depth of 27 cm, spring ploughing to a depth of 22 cm and disk tillage to a depth of 12 cm. The soil of the experimental site was a lowland pseudomyceliar chernozem (Mollisol-Calciustoll or Vermustoll, silt loam; USDA taxonomy), which is one of the major soil types of the region.

Field experiments was carried out on meadow soil at Gyomaendrőd (Site 2), at Kisújszállás (Site 3) and at Kunszentmárton (Site 8), and Karcag (Site 4) on meadow chernozem soil at Túrkeve (Site 5), on chernozem meadow soil at Nádudvar (Site 6), on brown forest soil at Tard (Site 7). We carried out the penetrometer measurements on the investigate sites on the stubble-field following the harvesting of wheat and rape with high replication (Table 1). The penetrometer measures the pressing- and shearing strength of the soil. During the penetration of the probe cone the registered soil resistance values allow the determination of the layers with different strength within the soil profile.

The aim of the study is to evaluate of tillage impact on soil physical condition in different production sites of Hungary.

Table 1: Characteristics of the soil profile at the experimental sites

Name	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7	Site 8
pH-KCl	5.6	6.39	6.65	7.01	6.88	7.19	4.51	7.09
Plasticity limit according to Arany (A_k)	42	67	56	52	55	43	40	50
$CaCO_3$ m m^{-1}	<0.1	<0.1	1.1	2.2	1.3	0.4	<0.1	<0.1
Humus %	2.72	2.73	3.81	2.45	2.46	3.03	2.7	2.62
P_2O_5 mg kg^{-1}	133	113	95	202	151	307	89	73
K_2O mg kg^{-1}	240	279	346	534	271	398	252	385

Results and discussion

During the examinations carried out by the penetrometer, significant difference has been found between tillage treatments in a depth of 5-45 cm (Figure 1). The soil penetration resistance in the depth of 5-25 cm was significantly lower in winter and spring ploughing treatment, than in disk tillage treatment. In a depth of 25-40 cm lower penetration resistance were measured in disk tillage treatment.

In all three treatments, penetration resistance was growing along with depth. The highest penetration resistance (Te_{max}) was measured in the compacted layer (tillage-pan layer) that evolved owing to the several years of tillage of the same depth. The compactness of the plough-pan layer shown the following order: disk tillage 7 MPa > winter ploughing 5 MPa = spring ploughing 5 MPa. The soil penetration resistance value (7 MPa) in the disk-pan layer measured at 70% moisture content of the soil's field capacity indicates a harmful compactness of the soil. The depth location of the compacted soil layer was equal to the depth of the primarily tillage. The thickness of plough-pan layer reached 20 cm in disk tillage treatment and 8-10 cm in ploughed treatments. Under a depth of 50-55 cm the compacting powers from the surface of the soil did not have an impact, the difference between the soil penetration resistance values of the treatments is caused by the spatial inhomogenity of the soil's physical characteristics.

Soil compaction caused by improper tillage was detectable in almost every sites involved in the analysis. As a result of tillage carried out on wet soil and in the same depth repeatedly (in multiple years) as well as the lack of deep tillage (deep loosening) 1-2 compacted layers have been formed in the analysed soil profiles (Figure 2-3).

Soil compaction which developed at the investigated sites on the one hand the result of tillage on the other hand it is the result of trampling. It is hard to distinguish these two reasons of degradation, they often emerge together. (Site 1; Site 3; Site 4; Site 6; Site 7; Site 8). Despite the difference in the depth of primarily tillage at Site 1, the almost identical penetration resistance profile measured beneath 35 cm proves that the soil compacting powers of the tools are limited to the 5-10 cm layer. In the lower layer, the compaction forces of the machinery's wheels are of primary importance. Compaction caused by trampling is caused by machinery traffic in the soil subsurface.

Plough-pan compaction is indicated in the soil profile by the layers of highest soil resistance depending on the depth of ploughing (Site 1; Site 3; Site 6; Site 8). Disk-pan compaction – as a result of shallow tillage – is formed close to the surface, the depth of 5-15 cm depending on the depth of tillage (Site 1; Site 2; Site 4; Site 5; Site 7).

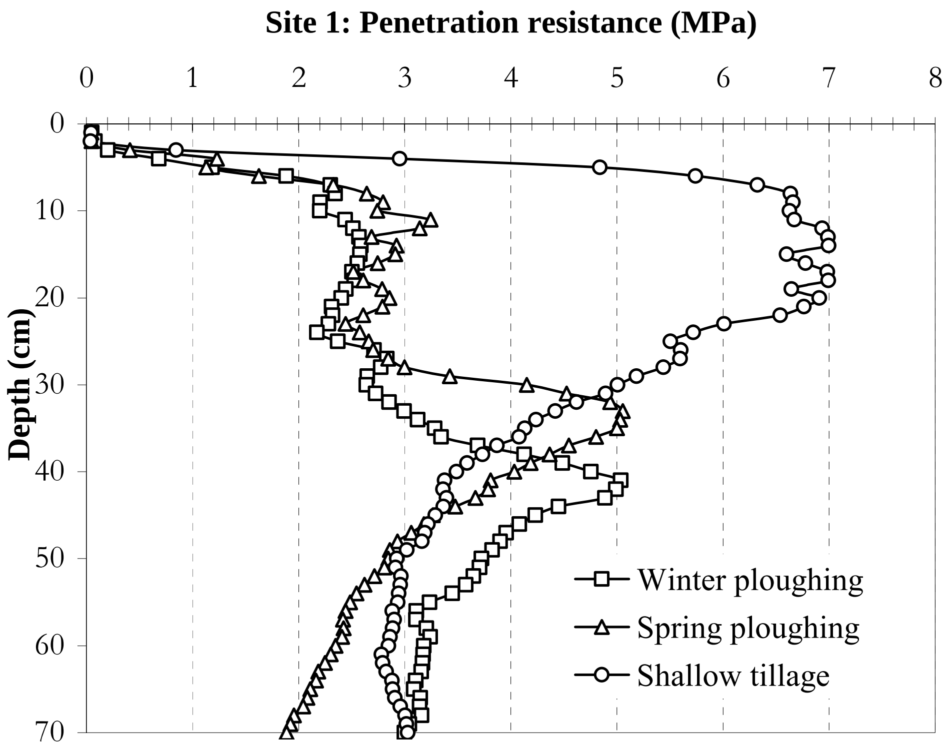

Figure 1: The effects of tillage systems on physical condition of chernozem soil as shown in penetrometer readings (Debrecen-Látókép, 2005)

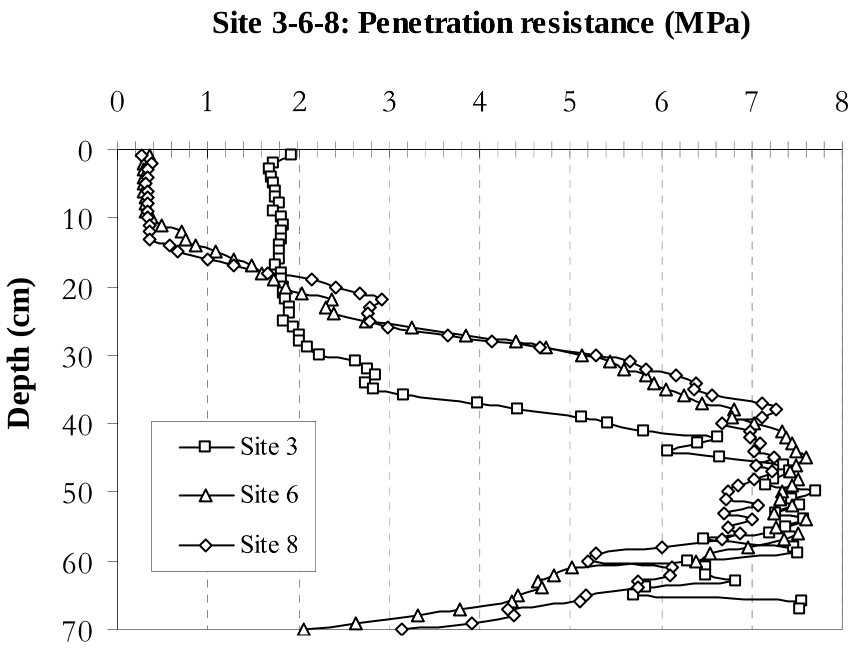

Figure 2: The effects of conventional tillage systems on physical condition of soils (Hungary, 2009)

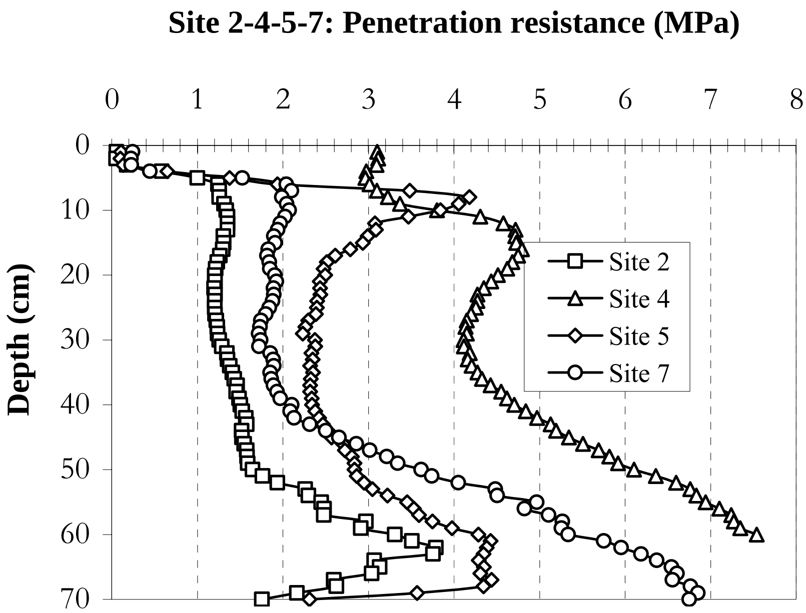

Figure 3: The effects of shallow tillage systems on physical condition of soils (Hungary, 2009)

Conclusion

In the past decades increasing environmental stresses have affected soils. From one hand the harmful effects of the environment damage the soil and from the other hand the damaged soil itself also has a negative impact on the other elements of the environment. Long-term conventional tillage management without deep tillage causes compaction on the investigated soil types. Land users must support the regeneration of soil conditions by choosing a tillage systems conforming to the soil conditions and reducing factors causing soil degradation. Formation of compacted soil layers can be prevented by keeping the optimal cultivation moisture, by decreasing the number of passes and by changing the depth of tillage.

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Influence of different soil tillage treatments on soil compaction and nodulation of soybean root

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Abstract

Stationary research of reduced soil tillage for soybean had been conducted on Northern Baranja chernozem soil type. Research had been conducted during two years (2003/2004 – 2004/2005), as completely randomized block design in four repetitions, with following soil tillage treatments: CT - Conventional tillage based on ploughing; DH - Diskharrowing; CwNs - Ploughing for winter wheat (odd years), in alternation with No-till for soybean as a proceeding crop (even years); and NT - No-tillage. Soil tillage resistance measurements for soybean crop were highest for DH (2.39 MPa) treatment. The anthropogenic compaction was recorded at 10-15 cm and 25-30 cm depths, but soil compaction values were not limiting for normal soybean crops development. Reduced tillage systems had positive trend on nitrogen-fixing bacteria nodulation, since the highest values of number and mass of nodules per plant were recorded. In two-year average period higher yields was recorded for treatments with lower reduction of soil tillage intensity, with following CwNs>CT>DH>NT order. This research was run during two average/wet years, so the research needs continuation.

Keywords: Reduced soil tillage, soil compaction, *Bradyrhizobium japonicum,* nodulation, soybean

Introduction

The primary soil tillage for different crops in Croatia is generally based on mouldboard ploughing which is the most expensive for crops production. The reduction of soil tillage particularly raised the question of efficiency of fertilizers, especially nitrogen, in interaction with the tillage systems and other yield improvement techniques, such as inoculation of soybean seed with symbiotic bacteria, for enhancement of nitrogen fixation. The soybean-Bradyrhizobium symbiosis can fix about 300 kg N ha^{-1} under good conditions. The factors which control the amount of N fixed include available soil N, genetic determinants of compatibility in both symbiotic partners and lack of other yield-limiting factors (Keyser and Li, 1992). Conventional tillage has adverse effects on the soil, including soil erosion, soil nitrate leaching, and subsoil compaction; as a consequence, the quality of the soil may deteriorate and the crop yield maybe low. Therefore, no-tillage has been proposed as a means of avoiding these negative impacts of conventional tillage. However and may induce changes in the conditions of the topsoil (lower soil temperature, higher soil moisture contents, and higher soil bulk density and, accordingly, greater soil strength). These soil traits limit root growth and the shoot development of crops. It is crucial to improve our knowledge of the response of root growth to the soil environment for the successful implementation of reduced and no-tillage systems. However, only few studies have been carried out on root morphology and the spatial distribution of roots as influenced by tillage intensity; the results are contradictory (Qin, 2003). According many authors, little compaction is good because it promotes good contact between the seed and soil, but compacted soils may reduce root growth. Soil compaction in the surface layer can increase runoff, increasing soil and water losses. The only reason the ploughed soil was slightly better (in comparison to reduced soil tillage systems), because the plough pan occurred relatively deeper in the soil, thus the root zone was also deeper. Severe damage is to be expected in a year of extreme weather conditions on soils where the formed disk pan or/and plough pan (Birkás et al. 2009). Since soybean is capable of using atmospheric nitrogen through the symbiotic relationships with symbiotic bacteria (*Rhizobium and Bradyrhizobium sp.*), the lack of nitrogen from fertilizers is usually not the problem to high and stabile yields (Hardy and Havelka, 1975; Stanhill, 1990; Temple et all, 1994; Evans and Barber, 1997).

The main objective of this research was to establish differences in soil tillage penetration resistance and nodulation of soybean root among different soil tillage systems at the chernozem of the northern Baranya. This investigation should contribute toward better understanding of each soil tillage system on anthropogenic soil compaction and nodulation of soybean root.

Materials and methods

Field experiment of influence of reduced soil tillage on anthropogenic soil compaction and soybean root nodulation was conducted on calcic chernozem at the north-eastern Croatia (Kneževo site; N:45°82′, E:18°64′) in two-year period (2003/2004-2004/2005).

The field experiment

Experiment for soybean (*Glycine max* L.), cultivar Tisa, was conducted in two-year crop rotation with winter wheat (*Triticum aestivum L.*) which basic experimental plot was 900 m^2. The main experimental set-up was a complete randomized block design in four replications, with four continuing soil tillage systems:

- CT – conventional tillage with ploughing up to the 30 cm as a primary tillage, followed by diskharrowing, sowing preparation and sowing with no-till driller John Deere 750A at the planned rate of 55 germinating seeds m^{-2}, with inter-row distance of 33 cm, by closing every odd seeding dispenser on the no-till driller;
- CwNs – conventional tillage with ploughing for winter wheat (odd years) as for CT, in alternation with No-till for soybean as a preceding crop (even years);
- DH – diskharrowing only up to the 15 cm and sowing as for CT;
- NT – No-tillage sowing without any primary tillage operation.

Before seeding the soybean seed (maturity group 0-1) was inoculated with nitrate-fixing symbiotic bacteria *Bradyrhizobium japonicum* (trade-mark name "Biofixin-S", D344). A seed was sown at 3-4 cm depth in optimal date.

The site's soil type was determined as a calcic chernozem on loess substrate, with silty clay loam texture, total porosity 45.5%, bulk density 1.30 kg dm^{-3}, and air capacity 7.33%. The soil analyses presented very favorable chemical properties, as folows: AL-soluble P_2O_5 – 18.7 mg 100 g^{-1}; AL-soluble K_2O – 28.4 mg 100 g^{-1}; pH (H_2O) – 8.1; pH (KCl) - 7,5; Humus – 2.6%; $CaCO_3$ – 2.1%. This soil type was classified as soil which belongs to first category of soil suitability for reduced soil tillage (Butorac et al. 1986.). The fertilization was uniform for all soil tillage treatments and investigation years, as follows: $N:P_2O_5:K_2O$ = 40:130:130 kg ha^{-1}. The crop protection was uniform for all tillage systems in both year according to demand of field and crop status and by local farm manager recommendations. In both experimental years, before sowing, NT treatment was treated with glyphosate (6 l ha^{-1}). The yield from each experimental plot was weighed at precision scale (± 1 kg 10^{-t}).

Collected data were statistically processed by ANOVA, according to the experimental design, and means were compared by the protected least significant differences for P<0.05 significance level of performed F-tests.

Plant material - sampling

The samples of soybean (fresh plant material) in both years was collected in R2 phenological stages (full bloom) (Fehr and Caviness, 1977), from area of 1 m^2 in four repetition per tillage plot and dried on 105^{o}C, for calculating of dry above ground mass and related roots. For calculation of influence of reduced soil tillage on nitrogen-fixing bacteria nodulation (*Bradyrhizobium japonicum*) was collected roots from 10 plants in four repetitions per plot. From these samples is determined number of nodule per plant, dry weight of nodule per plant, dry weight of root per plant, dry weight of plant.

Penetrometer resistant

Measurement of soil tillage penetrometer resistance was performed by electronic cone penetrometer (*Eijkelkamp Penetrologger*) on each 1 cm to the total depth of 40 cm, 10 times in four repetitions per plot. Used was cone with base of 1.0 cm^2 and angle of 60^o and speed penetration was 2 cm s^{-1}. Penetrometer resistance expressed in Mpa. Measurement was performed in R2 phenophase in same time with sampling of plant material. In the same time was sampling, drying and weighting of soil samples for current soil moisture. Soil samples were collected from four depths; 0-10, 10-20, 20-30 and 30-40 cm from 10 point per plot.

Weather characteristics

Weather characteristics in both experimental years were mainly specific in comparison with long-term means. For example, precipitation in the period April-September was by 17% and 7.4% higher for 2004 and 2005, respectively (Table 1), with very variable distribution of precipitation. Air temperatures in each experimental year were in long term means range.

Table 1: Total precipitation (mm) and temperature (ºC) in winter (October to March) and during the growing season (April to September) at the Kneževo site in 2003/2004 and 2004/2005

Year	2004	2005	1965- 2005	2004	2005	1965-2005
Month	Precipitation (mm)			Temperature (^{o}C)		
Winter season	332	384	266	4.3	3.8	4.5
April	119	54	49	12.0	11.5	11.1
May	77	55	58	14.9	17.0	16.5
June	114	88	88	19.5	20.4	19.7
July	41	168	68	21.9	21.4	21.2
August	52	155	54	21.6	19.7	20.9
September	43	82	55	15.9	17.5	16.4
Growing season	446	405	372	17.6	17.9	17.6

Results and discussion

Soil tillage compaction

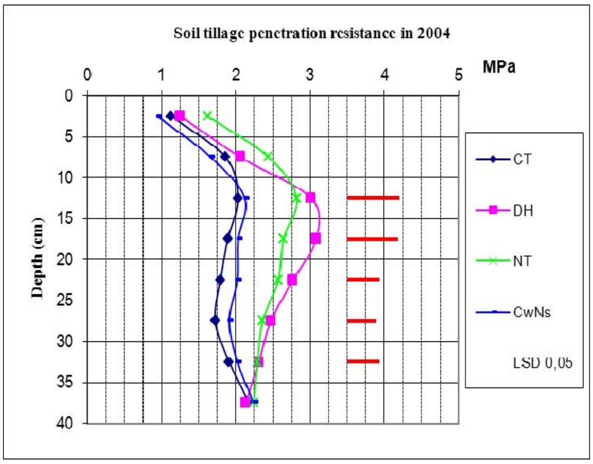
In both years of investigation in comparison of all tillage systems, greatest penetration resistant was recorded on DH and NT tillage treatment. This means that greatest penetration resistant was on tillage treatments with greater reduction of soil tillage.

Table 2: Influence of soil tillage treatments on soil compaction (MPa) in 2004 and 2005

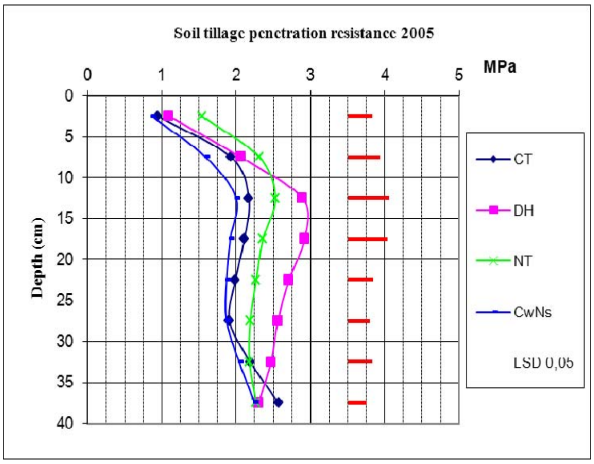
Depth (cm-D)	2004					2005				
	CT	DH	CwNs	NT	Average (D)	CT	DH	CwNs	NT	Average (D)
0-5	1.13	1.25	0.94	1.62	1.24	0.94a	1.09ab	0.86a	1.54c	1.11
5-10	1.86	2.06	1.66	2.44	2.01	1.93abc	2.06bc	1.59a	2.31c	1.97
10-15	2.03a†	3.01c	2.12ab	2.82bc	2.50	2.17a	2.89b	2.00a	2.53b	2.40
15-20	1.89a	3.08c	2.03ab	2.64bc	2.41	2.11a	2.92b	1.92a	2.36a	2.33
20-25	1.79a	2.77b	2.02a	2.57b	2.29	1.99ab	2.71c	1.87a	2.27b	2.21
25-30	1.72a	2.47c	1.91ab	2.36c	2.12	1.91abc	2.56e	1.87ab	2.19cd	2.13
30-35	1.91abc	2.31cd	2.02abcd	2.29cd	2.13	2.19ab	2.47bc	2.04a	2.18ab	2.22
35-40	2.18	2.13	2.24	2.24	2.20	2.57b	2.30a	2.25a	2.27a	2.35
Average (T)	1.81a	2.39b	1.87a	2.34b	2.10	1.98b	2.37d	1.80ab	2.21c	2.09

† Means in same column labelled with the same lowercase letter(s) are not significantly different at P<99% level

As is expected, according experience, greatest values of penetration resistant was recorded on 10-15 cm depth (depth of disking) and on 25-30 cm (depth of ploughing). But, this penetration resistant was not restricted to normal and usually rooting of soybean.



Graph 1: Penetration resistance in 2004



Graph 2: Penetration resistance in 2005

According Busscher and Sojka (1987), Angebag and Maree (1988), Žugec et al. (1996), recorded values was under critical level of tillage penetration resistant for normal rooting of soybean. Low values of penetrometer resistance on top layer (0-5, 5-10 cm) are very important for early and quality germination, emergency and rooting.

Tendency in appearance of plough pan and disc pan especially arise in very wet conditions in period of tillage, because of greater compaction/pressure and smoothing of bottom of the furrow (Jug, 2006). It was observed that water logging was more frequent on CT than on DH plots, partially due to induced plough pan (Stipešević et al., 2007), and partially because surface runoff from DH to deeper tilled CT furrows.

Nodulation of soybean root

Table 3 shown values of number and dry weight of nodule per plant which was used for evaluation of influence of different soil tillage treatment on capability for nodulation of symbiotic bacteria. Same table present dry mass of roots, dry mass of above ground mass and yields of soybean.

Number of nodules per plant which was developing on the soybean root in 2004 did not show any statistic significant difference between soil tillage treatments, which means that did not affected on nodulation capability of symbiotic nitrogen-fixating bacteria.

Highest number of nodules per plant was on CT treatment (20.6), and lowest on DH (11.2). In 2005 was recorded slightly higher number of nodules per plant on all tillage treatments, because of very favourable weather conditions. Among all of tillage treatments was found statistically significant differences. According Redžepović et al. (1990a; 1990b; 1991), on inoculation capability and forming of nodules on the roots highest influences have mechanical and chemical properties of soil: pH, moisture, salinity, amount of nitrogen in soil, amount and interactions of heavy metals, etc. According Tate (1995) symbiotic relationship and good nodulation of legumes plant and symbiotic nitrogen bacteria are possible in conditions of low soil moisture. But, density population has tending down toward stress of low amount of soil water. A little higher number of nodules was on NT treatment accordance to DH and CwNs tillage treatments, with presumption of higher amount of water on NT treatment. In average of both investigation years (2004, 2005) was determine statistically significant differences ($P<99\%$) among tillage treatments, but have to be mentioned that values of number of nodules per plant was higher in 2004 in comparison with 2005.

Second indicator of nodulation capability of symbiotic nitrogen fixating bacteria is dry mass of nodules per plant. Highest dry mass of nodules in 2004 was on NT treatment but without any significant differences among other tillage treatments. In 2005 were recorded little higher values of nodules dry mass and again NT has highest values but now with significant differences among other tillage treatments. Two-year average was shown significant differences in nodules dry mass among other tillage treatments. According this results NT is more favourable for nodulation of symbiotic fixating bacteria in comparison with CT and DH treatments. As long as soil loosening is effective and enough, present no limits for root nodes development (Birkas et al., 2002).

In both year of investigation highest dry mass of soybean roots was recorded on DH and lowest on NT treatment. Determined differences of soybean roots dry mass between tillage treatments was significant at $P<99\%$. Same tendency and significations between tillage treatments was determine in two-year average. The achieved results in this research were in accordance with usual soybean grain yields production level in given area, with necessary comment that the surplus of rain and water in soil during year 2004 probably affected rooting and later root uptake functions, thus resulting with somewhat higher yields for the CT, where autumn mouldboard ploughing, usually necessary for winter water accumulation in given climate, characterized with dry summers (Stipešević et al., 2009).

Highest value of dry above ground mass of soybean (Table 3) in two-year average was determined on CT treatment (15.65 g) and lowest on DH treatment (6.18 g). Statistical significant differences were determined only in two-year average but not separately in investigation years (2004, 2005).

Table 3: Number of nodule per plant, dry weight of nodule per plant, dry weight of root per plant, dry weight of plant and yields of soybean in 2004 and 2005 year and years mean

Parameter (per plant)	Year	Soil tillage treatments				LSD	LSD	F-
		CT	DH	CwNs	NT	P=5%	P=1%	test
Number of nodule	2004	20.6	11.2	15.8	17.4	8.65	12.43	n.s.
	2005	24.0	12.7	18.8	20.1	5.31	7.63	**
	Average	22.3	11.9	17.3	19.7	4.72	6.46	**
Dry weight of nodule (g)	2004	0.197	0.198	0.210	0.246	0.042	0.061	n.s.
	2005	0.201	0.211	0.238	0.243	0.018	0.025	**
	Average	0.199	0.204	0.224	0.244	0.021	0.029	**
Dry weight of rooth (g)	2004	2.624	3.483	2.775	2.568	0.493	0.709	**
	2005	2.868	3.523	2.900	2.640	0.268	0.385	**
	Average	2.746	3.503	2.838	2.604	0.261	0.357	**
Dry weight of plant (g)	2004	17.895	9.828	10.506	12.106	6.889	9.898	n.s.
	2005	13.399	9.821	16.448	11.080	5.427	7.798	n.s.
	Average	15.647	9.825	13.477	11.593	4.073	5.579	*
Yield (t ha^{-1})	2004	4.602	4.510	4.290	3.378	0.268	0.385	**
	2005	3.597	3.590	4.003	2.975	0.394	0.566	**
	Average	4.100	4.050	4.146	3.176	0.221	0.303	**

In 2004, average yields of soybean were 3.87 t ha^{-1}. According of potential of agroecological area of experiment was high. On CT treatment was recorded highest yield (4.602 ha^{-1}) and on NT treatment lowest (3.378 ha^{-1}) which according CT was significant lower at P<99%.

In comparison with 2004 in 2005 year were recorded lower yields with same tendency of amount of soybean yields among tillage treatments. Two-year average of soybean yields shown statistical significant differences among tillage treatments (P<99%). Amount of soybean yields was decrease with increase of reduction of soil tillage. Similar results of soybean yield at CT DH and NT soil tillage systems were also observed by Jug et al. (2005) in years 2002 (wet) and 2003 (drought).

Conclusion

Based on this research of the soil tillage resistant and nodulation of soybean under different reduced soil tillage systems, at the chernozem of the northern Baranya, following conclusions can be presented:

- Due to investigated tillage systems especially continuous diskharrowing and ploughing tillage depths, the anthropogenic compaction was recorded at 10-15 cm and 25-30 cm depths, but soil compaction values were not limiting for normal soybean crops development.
- Number of nodules at CT and NT systems, in average both experimental years, was very similar, but dry weight of nodules was lower at CT and higher and identical on CwNs and NT systems.

- Best values for dry weight of roots were recorded on DH tillage system mainly because of occurrence disc pan, but in the same time dry weight of plant was greater at CT and lower at DH tillage systems.
- In two-year average period higher yields was recorded for treatments with lower reduction of soil tillage intensity, with following CwNs>CT>DH>NT order.

The further research is required for better adoption of reduced soil tillage especially no-till system in soybean production.

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poljoprivredni fakultet osijek

Crop Production Department

General Plant Production

Project: Investigation of reduced soil tillage for winter wheat and soybean
Project coordinator: prof. dr. sc. Ivan Žugec
Project is granted by Ministry of Science, Education and Sports

Subject: Short information relating to the experiment

The experiment is carried out as stationarry with winter wheat and soybean in crop rotation (the both crops every year), during 2006/7-2010/11 year, at Šljivoševci, "Rosa d.o.o.", Slavonia an Baranya County, Croatia.

In the experiment there are included: eight tillage treatments, as main factor (A), and three level of nitrogen fertilization, as sub-factor (B), as follows:

1. Tillage variants (main factor A)

A-1. Standard, conventional tillage based on autumn ploughing (25-30cm for w. wheat and 30-35 cm for soybean), diskharrowing, seedbed preparation and sowing, for w. wheat and soybean every year,
A-2. Diskharrowing every year for the both crops, the other operations as for A-1,
A-3. Diskharrowing and soil loosenning up to 35 cm (only ploughhing layer, as chiselling) every year for the both crops, the other operations as for A-1,
A-4. Diskharrowing for w.wheat and conventional tillage for soybean, the others as for A-1,
A-5. Conventional tillage for w.wheat and diskharrowing for soybean, the others as for A-1 (these two variants (4 and 5) are in alternation),
A-6. No-till for w.wheat and conventional tillage for soybean,
A-7. Conventional tillage for w.wheat and NO-till for soybean (after wheat harvestig and before soybean sowing, herbicide based on gliphosate is applied (these two variants, 6. and 7. are in alternation),
A-8. No-till for the both crops, continuously. Herbicide after w. wheat as for variant 7.

2. Fertilization by nitrogen in three levels (sub-faktor B):

Winter wheat: **N-1.** level - 120 kg N/ha,
N-2. level - 150 kg N/ha,
N-3. level - 180 kg N/ha,

Soybean: **N-1.** level - 30 kg N/ha,
N-2. level - 70 kg N/ha,
N-3. level - 110 kg N/ha,

Phosphorus and potassium were applied uniformly for all plots, for w. wheat and soybean, as follows: 150 kg P_2O_5, 90 kg K_2O (MAP-12-52-0; 60% KCl, 46% UREA, 27% KAN).

Tillage variants in details:

a) **Tillage variants for w.wheat (factor A):**

Variant of soil tillage (A)	Autumn and spring
A-1. Standard, convencional tillage – in contunuity for the both crops	ploughing 25-30 cm, diskharrowing, sowing J. Deere 750A, herbicide in spring, two N top-dressigs
A-2. Diskharrowing in continuity for the both crops	Diskharrowing, the others as for A-1
A-3. Diskharrowing and soil loosenning (30-35) in continuity for the both crops	Diskharrowing, the others as for A-1
A-4. Diskharrowing for w.wheat (convencional tillage for soybean)	Diskharrowing, the others as for A-1
A-5. Conventional tillage for w.wheat (diskharrowing for soybean)	As for A-1
A-6. No-tillage for w.wheat (convencional for soybean)	No-tillage, sowing and the others as for A-1
A-7. Convencional tillage for w.wheat (No-till for soybean)	As for A-1
A-8. No-tillage for the both crops	No-tillage, sowing and the others as for A-1

b) **Tillage variants for soybean after w.wheat (factor A):**

Tillage variants (A)	Summer	Autumn	Spring
A-1. Standard, convencional tillage – in contunuity for the both crops	Stubble field shallow diskharrowing	Ploughing, 30-35 cm	Levelling, seedbed preparation, sowing J. Deere 750A, herbicides – preemergence and during vegetation if necessary
A-2. Diskharrowing in continuity for the both crops	-As for A-1	Diskharrowing	-As for A-1
A-3. . Diskharrowing and soil loosenning in continuity for the both crops	-As for A-1	Diskharrowing and soil loosenning, 30-35 cm	-As for A-1
A-4. Convencional tillage for soybean (diskharrowing for w.wheat)	-As for A-1	As for A-1	-As for A-1
A-5. Diskharrowing for soybean (conventional tillage for w.wheat)	-As for A-1	Diskharrowing	-As for A-1
A-6. Convencional tillage for soybean (no-till for w.wheat)	-As for A-1	-As for A-1	-As for A-1
A-7. No-till for soybean (convencional for w.wheat)	No-till, herbicide based on gliphosate)	No-till	No-till, presowing herbicide based on gliphosate, sowing J.Deere 750 , the others as for A-1
A-8. No-tillage for the both crops	No-till, herbicide based on gliphosate	No-till	No-till, presowing herbicide based on gliphosate, sowing J. Deere 750 , the others as for A-1

3. **Plot size for the main factor A (soil tillage):**
   - brutto – 19.5m × 30m = 585m^2
   - netto – 18m × 30m = 540m^2

   Plot size for the sub-factor B (N fertilization):
   - brutto 6×30m=180m^2 (5.5×30m=165m^2 netto)
   - Total for every crop cca **4 ha,** for both crops cca **8 ha.**

The experiment is carried out as two-factorial according to split-plot design, in four replications, with randomized blocks design (Scheme 1). The replications are separated with 20 m pathways in order to prevent soil pressing by mechanization.

4. Crop varieties: w. wheat -Srpanjka; soybean-Podravka 95 (maturity group I-II).

5. Soil analyses before starting the trial (September 2006)

	pH-KCl	pH-H_2O	AL-P_2O_5	AL-K_2O	humus%	Hy
W. wheat	4.36	5.55	7.6	27.1	1.84	4.8
Soybean	4.45	5.54	12.2	27.1	2.08	4.6

6. Plantig date: w. wheat 10 October 2010, soybean 30 April 2010.

Scheme (lay-out) of the experiment (1).

	20 m																							
	P1			P2			P3			P8			P4			P6			P5			P7		
I rep.	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
	20 m																							
	P8			P1			P2			P3			P5			P7			P4			P6		
II rep.	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1
	48	47	46	45	44	43	42	41	40	39	38	37	36	35	34	33	32	31	30	29	28	27	26	25
	20 m																							
	P3			P8			P1			P2			P6			P4			P7			P5		
III rep.	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2
	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72
	20 m																							
	P2			P3			P8			P1			P7			P5			P6			P4		
IV rep.	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
	96	95	94	93	92	91	90	89	88	87	86	85	84	83	82	81	80	79	78	77	76	75	74	73
	36 m																							
	S1			S2			S3			S8			S4			S6			S5			S7		
I rep.	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
	20 m																							
	S8			S1			S2			S3			S5			S7			S6			S4		
II rep.	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1
	48	47	46	45	44	43	42	41	40	39	38	37	36	35	34	33	32	31	30	29	28	27	26	25
	20 m																							
	S3			S8			S1			S2			S6			S4			S7			S5		
III rep.	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2
	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72
	20 m																							
	S2			S3			S8			S1			S7			S5			S4			S6		
IV rep.	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
	96	95	94	93	92	91	90	89	88	87	86	85	84	83	82	81	80	79	78	77	76	75	74	73
	20 m																							

Legend: P=w. wheat   S=soybean

1=Standard, conventional tillage, both crops

2=Disking, both crops

3=Disking and soil looseninng (chiselling), both crops

4=Conventional (Soybean), disking(W. wheat)

5=Conventional (W. wheat), disking (Soybean)

6=Conventional (Soybean), no-tillage (W. wheat)

7=Conventional (W. wheat), no-tillage (Soybean)

8=No-tillage, both crops

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Crop Production Department

General Plant Production

Project: Summer crops for food and bio-fuel

Project coordinator: prof. dr. sc. Bojan Stipešević

Project is granted by Ministry of agriculture, fishery and rural develpment of Republic of Croatia

The experiment with different soil tillage systems for four summer growing crops has been established on 26. July 2010, at Family Agricultural Enterprise "Matricaria", near town Široko Polje, Croatia.

The soil type on which experiment field has been set up is the eutric brown soil, with favorable crop production properties.

The summer crops used in the experiment are:

M) millet (*Panicum miliaceum*),

B) buckwheat (*Fagopyrum esculentum*),

S) sudan grass (*Sorghum vulgare var. sudanese*), and

C) maize (*Zea mais*).

The preceding crop for all three crops was the oilseed rape (*Brassica napus*), sown after preparing soil by conventional tillage, based on autumn moldboard ploughing before fine seedbed preparation by diskharrowing and seedbed cultivator.

For each crops, the following soil tillages were used:

FP) Fine preparation: two passages with heavy diskharrow up to 15-20 cm, followed with four passages of light diskharrow and seedbed preparation cultivator;

MP) Medium preparation: one passage with heavy diskharrow up to 15-20 cm, followed with two passages of light diskharrow and seedbed preparation cultivator;

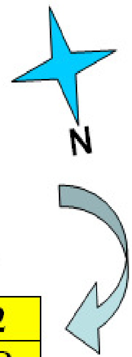
RP) Rough preparation: single passage by heavy diskharrow up to 15-20 cm, followed by seedbed preparation cultivator.

The cereal seeder made by “OLT-Osijek” has been used for all three crops, with seeding depths for buckwheat, sudan grass and maize of 3-5 cm, and 2-3 cm for millet.

Six different side-dressing treatments in four repetitions has been applied twice for each crop:

- **CT**) control: no side-dressing
- **AN**) 150 kg/ha of granular fertilizer KAN (27% N), in two side-dressings
- **P1**) 8 l/ha of foliar fertilizer „Profert Mara“ – liquid NPK and other macro and micro nutrients
- **P2)** 16 l/ha of foliar fertilizer „Profert Mara“
- **UR**) 50 kg/ha of Urea (47% N), applied as foliar fertilizer (5% concentration)
- **MT**) 3 kg/ha of foliar fertilizer „Morton“ – soluble NPK and other macro and micro nutrients

C			
S			
B			
M			
	RP	MP	FP



P1	AN	CT	MT	UR	P2
P2	P1	AN	CT	MT	UR
UR	P2	P1	AN	CT	MT
MT	UR	P2	P1	AN	CT

ĐAKOVO TOWN

Đakovo is a town in the region of Slavonia, Croatia, 37 km to the southwest of Osijek and 34 km southeast of Našice; elevation 111 m. It has a population of 20,912, with a total of 30,092 in the municipality (census 2001). Đakovo is the center of the fertile and rich Đakovo region. Chief occupations include farming, livestock breeding, leather and wool processing; horse selection center; major industries are wood processing (furniture), textiles, chemicals and food processing, building material, printing and tourism. Đakovo is located at the intersection of the main road (M17.01, E73) Osijek–Đakovo, the regional road Našice–Đakovo and the railroad Ploče–Sarajevo–Vrpolje–Osijek–Budapest.

Đakovo - The town history

There are numerous archaeological sites in the town and its surroundings. They are a symbol of this town's rich history. Excavations in 1997 confirmed that there were people living in the town's wider area as early as 5,500 BC in the Neolithic period. This area continued to be populated through the long and turbulent history and still continues today.

Đakovo is for the first time mentioned in written documents in 1239, in the deed of donation form the Croatian duke Koloman to the Bosnian bishop Ponsi, by which bishops become the masters of Đakovo and the Đakovo area. That is the beginning of the history of the Đakovo Bishopric. Nowadays, Đakovo is still a bishop's town - headquarters of the Đakovačko-srijemska Bishopric. In different periods in its history, the town itself is mentioned under similar names: DYACO, DIACO, DYACOW...

In 1536 the Turks occupied Đakovo and ruled it for almost 150 years - the town then got the name JAKOVA. That was a dark period in the town's history. Almost all Catholic churches were torn down and mosques were built. The best-known is the Ibrahim-pašina Mosque which was turned into a Catholic church after the Turks left. In 1690 the bishop returned to the town and the construction of town begun.

When the Turks left, the construction of a new, more modest cathedral and a bishop's palace started in Đakovo. This was the second of three cathedrals which have so far been built in Đakovo. Its construction was ordered by bishops Patačić and Bakić.

Today's St. Peter's Cathedral-Basilica is built in a combination of the neo-Gothic and the Romanesque style. Bishop Strossmayer started its construction in 1866, when he was 52-years-old and in his 16th year of bishop's service. Construction lasted for full 16 years (until 1882), of which the external construction works lasted for 4 years and the internal decoration of the Cathedral for 12 years. 7,000,000 brick-bats, baked in Đakovo, were used for the construction of the Cathedral. The stone was delivered from Istra, Hungary, Austria, Italy and France. The Cathedral's planning engineers were architects from Vienna, Karlo Rősner and Frederic Schmidt. The internal decoration was entrusted to German painters who lived in Rome, father and son Alexander-Maximilian and Ludwig Seitz. The Cathedral has 7 altars, and is decorated by 43 fresco paintings, 31 sculptures and 32 works of relief, as well as organs with 73 registers, three couplers and 5,486 reeds.

The Đakovo Bishopric and its bishops left numerous evidence of their activity in the town. In 1706 bishop Patačić ordered the renewal of the Horse Farm.

In 1773 Đakovo becomes the centre of the united Bosansko-đakovačka and Srijemska Bishopric, which includes all north-eastern parts of Croatia.
Bishop Antun Mandić opened today's oldest academic institution in Slavonija and Baranja, the Theological seminary. He also undertook large economic interventions on the landed estate, especially in the cultivation of vineyards. His name is preserved in far-famed 'mandićevački' vineyards.

When Josip Juraj Strossmayer was appointed bishop in 1849, the town's development was on a new rise. The Bishop's landed estate became the model of an exemplary economy, and with its considerable income enabled the great bishop to undertake patronage acts till then unseen in Croatia (Croatian Academy of Arts and Sciences, HAZU), and give a new outlook to the new Cathedral in Đakovo and also to numerous church and economic edifices.

Although the year 1506 is considered to be the year of its foundation, the history of the Horse Farm in Đakovo started with the foundation of the Bishopric and the deed of donation of ten Arab horses and one stallion. According to the bishop Bakić, horse breeding on the landed estate has existed since 1374. Breeding continues even today at the State Horse Farm of Lippizaner, which is one of the oldest in Europe, and there is also a large number of private horse breeders. For many years, the Horse Farm was a part of the agro-industrial plant PIK-Đakovo, and today it is the State Horse Farm of Lippizaner, in charge of raising and selection.

Đakovo has always been a town of artisans. In 1813 the association of craftsmen GUILD was founded. The industrial development started with the construction of mills and brickyards, and numerous craftsmen, of various lines of work, with their offer of products contributed to Đakovo becoming, particularly in connection to fairs, a well-known trading centre in whole of Slavonija. Today, Đakovo is a town with over 30,000 inhabitants.

THE NATIONAL LIPIZZAN STUD FARM ĐAKOVO

- The oldest Stud Farm in Europe
- The number of horses is about 180 to 200
- Within Stud Farm functions a horseman club and a humanitarian therapy riding association
- Tasks - horsebreeding and horse selection
  - work and dressage of horses for sport competitions

JUBILEES

- 500 years of the stud farm existance (1506 – 2006)
- 200 years of the breeding of lipizzaners (1806 – 2006)

THE STUD FARM HAS TWO LOCATIONS

1. **Stallion station**
2. **Ivandvor**

1. **Stallion station** – is located in the center of the town Đakovo. That is the place where 3 years old stallions go to train and drill.

2. **Ivandvor** - centered 6 km away from Đakovo

- the mother herd of mares is placed here, together with their offspring that are being bred and fed at this place until they are 3 years old

- the facilities have completely kept their original shape until today (in 1912 the bishop Ivan Krapac built stables for horses and apartment for the workers of the Stud Farm)

THE HISTORY OF NATIONAL STUD FARM ĐAKOVO

English Queen Elizabeth II. in visit to Đakovo in 1972

The Stud Farm in Đakovo was founded by Bosnian – Srijem bishops, on their estates in Đakovo which they were given by Croatian – Hungarian King Koloman. That deed of gift was certified in 1244 by King Bela IV.

- **1374** – the wedding of the Bosnian Banus Tvrtko with Bulgarian Princess Dorothea / Banus Tvrtko gave bishop Peter 10 arabian mares and 1 stallion

- **1506** – the year of founding the Stud Farm. The name Stud Farm is mentioned for the first time / bishop Mijo Keserić had the Stud Farm of 90 horses

- **1806** – Lipizzan horses were moved from the Stud Farm Lipizza to the Stud Farm Đakovo because of the war danger of Napoleon

- **1854** – bishop Josip Juraj Strossmayer brought from Lipizza in Slovenia 7 lipizzan mares and 1 stallion

- **1972** – the visit of English Queen Elizabeth II, Prince Philip and Princess Anne to the Stud Farm Đakovo

ABOUT LIPIZZANER HORSES

COLOR
80% of the lipizzan horses are black when they are born. After the 8th year they mostly become completely white. Their life time is 20 – 30 years.

STUDTABLE CONTAINS
- personal number from the studbook
- name of horse
- race
- the date of birth

WAYS OF SIGNIFYING (branding)
There are different ways of breeding of Lipizzan horses in Croatia and they depend on the breeding in which each horse was born. Lipizzan horses that were born on the Đakovo Studfarm since 11 January 1997 get the following brands:
- letter H on the left back represeting Croatia (Hrvatska),
- below letter H the number of the horse, according to the number in the studbook,
- letter Đ on the left thigh is representing National Lipizzan Stud Farm Đakovo

STALLION LINES AND MARE FAMILIES
On the stud farm Đakovo there are 7 stallion lines:
- Pluto
- Conversano
- Favory
- Maestoso
- Neapolitano
- Siglavy
- Tulipan

(and 11 original mare families).

FEEDING OF THE HORSES:
- three meals a day at the same time in the same amount
- food – oat and hay, drink - water
- they like apples, carrots, pears, watermelons and sugar

HORSE DRIVING SPORT

Croatia is the first country in the world by the number of lipizzaners. In the past, lipizzaners used to be a workforce, but with the introduction of the better technology the number of lipizzaners dropped, not only in Slavonia and Croatia, but in the world, too. During the years, lipizzaner became a part of traditional culture, folklore and the recognizing of the Slavonian plains.

ABOUT HORSE DRIVING SPORT:

- very important element of the horseman sport
- gives purpose to the existance of the lipizzaner race
- good looking horses and with quality genetics
- riding carriages with 1, 2 or 4 horses

LIPIZZANER CHARACTERISTICS:

- good temper
- great obediance
- ability for dressage
- extraordinary walks and safety
- horse for driving carriages and recreative riding

RIDING HALL

The purpose of the object:

- work and horse dressage
- sport competitions during the whole year
- the riding school
- the therapy riding
- the auction sale of the horses
- exhibitions and fairs during the whole year
- improving work of the Horseman Club
- providing quality services to the horsebreeding associations
- quality touristic offer and promotion of the continental tourism in Croatia and the world

CHARACTERISTICS:

- multi content complex with the size of cca 4200 sqm
  - souvenir shop,
  - restaurant
  - horse equipment shop
  - riding field - parkur
  - grandstands for 1000 viewers
  - stalls, solarium and bathrooms for horses
  - places for professional congresses and meetings

The project is 20 million kunas worth, and it is being financed by the government of the Republic of Croatia.

TVORNICA ŠEĆERA
OSIJEK

KANDIT PREMIJER, D.O.O.

Karbokalk je karbonatacijski (saturacijski) proizvod koji se u obliku finih kristalića izdvaja u procesu prerade šećerne repe. Posebnom obradom pretvara se u suhi praškasti proizvod i služi kao odlično sredstvo za kalcizaciju kiselih tala, te poboljšanje fizikalnih svojstava tla (lakša obrada, smanjenje pokorice). Zbog velike površine kristala, djelovanje je brzo. U najfinijim kristalima karbokalk nastaje pri kemijskom pročišćavanju soka šećerne repe, a izdvaja se na specijalnim filter-presama.

Zakiseljavanje poljoprivrednih tala Hrvatske veliki je problem. Preko 50% poljoprivrednih površina je kiselo, a povećan pad pH ponajviše je prisutan na tlima na kojima se prakticira intenzivna poljoprivreda. Niska pH vrijednost dovodi do niza negativnih pojava u tlu (slabija bioraspoloživost hraniva, narušavanje strukture tla, pad mikrobiološke aktivnosti tla, itd.) uz pad prinosa i kvalitete proizvoda. Zato se kao obvezna mjera popravke kiselih tala preporuča kalcizacija, ali uz detaljnu kemijsku analizu tla i uvažavanje ostalih mjera popravke (humizacija, fosfatizacija, primjena mikroelemenata i dr.) drugim riječima pravilnom gnojidbom.

Na području Osječko-baranjske županije provodi se sustavna kontrola plodnosti tla. U 5 godina istraživanja, pokazalo se da je oko 55% površina Osječko-baranjske županije kiselo, jer se pH kreće između 4,5 i 5,5. Korištenjem kriginga procijenjena je potrebna količina saturacijskog mulja (karbokalka) za kalcizaciju pri različitoj zasićenosti KIK-a bazama.Rezultati pokazuju da uz 95% zasićenja KIK-a bazama, na tlima čiji je pHKCl ≤ 5,5, prosječno treba 3,28 t/ha Ca ili ukupno 830 t/ha saturacijskog mulja.

Budući da tvornica šećera Kandit Premijer d.o.o. Osijek **godišnje** producira **oko 35.000 tona karbokalka** ,koji prosječno sadrži 70% kalcijevog karbonata, 5,3% organske tvari i drugih biogenih elemenata u manjoj količini, te uz podizanje pH ima i gnojidbeni učinak. Količina tog materijala, potrebna za kalcizaciju kiselih tala Osječko-baranjske županije odgovara približno **25-godišnjem radu šećerane .**

Ovaj materijal (karbokalk) je do nedavno tretiran kao otpad, čije je zbrinjavanje predstavljalo problem, pa je tvornica šećera Kandit Premijer osigurala površinu predviđenu za njegovo deponiranje u blizini Osijeka (Nemetin).
Uvođenje sustava kontrole plodnosti omogućilo je uvid u potrebe kalcizacije, a saturacijski mulj predstavlja dobar materijal za korištenje u te svrhe. Pravilne preporuke za kalcizaciju riješavaju, s jedne strane problem zbrinjavanja saturacijskog mulja, a s druge podižu plodnost tla.

Način upotrebe karbokalka:

-skladištenje karbokalka moguće je na polju ili na pripremljenom skladištu na otvorenom

-raspodjela se može povoljno vršiti rotacionim razbacivačima širokog zahvata ili s razbacivačima stajskog gnojiva

-karbokalk se treba po strništu raspodijeliti i zaorati

Preporuka za gnojidbu:	pH TLA	KARBOKALK
TEŽI TIPOVI TLA	4,0	8-10 t/ha
	4,5	5-6
	5,0	4-5
LAKŠI TIPOVI TLA	4,0	6-8 t/ha
	4,5	4-5
	5,0	3-4
	5,5	3

Kemijska analiza karbokalka tvornice šećera Kandit Premijer Osijek, obrađena u Sirovinskom laboratoriju tvornice: Karbokalk iz procesa proizvodnje šećera iz šeć. repe

Sadržaj	Na suhu tvar Karbokalka	U Karbokalku (kg/t)
Suha tvar (%)	68,71	
Sadržaj vlage (%)	31,29	
Ostatak nakon žarenja na 600^{0}C (%)	15,49	
$CaCO_3$ (%)	71,47	491,1
CaO (%)	40,04	275,1
C (%)	3,07	21,1
Humus %	5,29	36,4
N (%)	0,59	4,05
P_2O_5 (%)	0,035	0,24
K_2O (%)	0,180	1,24
MgO	3,017	20,73
Na_2O	0,078	0,54
Cu (mg/kg)	31,50	0,0216
Zn (mg/kg)	56,40	0,0388
Mn (mg/kg)	136,50	0,0938

KARBOKALK JE DOŠAO S ORANICA I TAMO GA TREBA VRATITI !

ĐAKOVO WINERY

More than 2000 years lots of people have enjoyed in wines in Đakovo. Lots of historical important people have visited our winery. Beginning the first century Roma's caesar Proba has enjoyed in our wines and in the third century ours bishops enjoyed too. Story about wines and his tradition comes since then.

The best confessions of excellent and stable quality of wines are continued and hight position conformation in word's fair. Our first presentation was been in Zagreb, Croatia in 1864.

We exhibitioned our wines in Paris 1864 and Wien 1873. Every year we are participate in Zagreb, Ljubljana, Đakovo, Orahovica and Trnava shows.

Today our basement and wine-cellar are equipped with the trendiest equipment for grape's processing and protection wines. On market you can find very large range for our wines: grasevina wine (tipe of woody wine), riesling, chardonnay, sauvignon, red pinot, traminac, table wine, small rose. All that sort of wine have his own continental character. They are freshest, delightfulness and drinking wine with safe aroma and bouquet of grape which stay long time in your palate for all truly fan of wine.

Wine growing field is situated east of slope Slavonia mountains. Krndija on the north and Dilj on the south.

Now we have 380 ha grape plantation and 250 ha of new plantation. They have gotten up before 3 years. We have production capacity of 4.600.000 L of wine and more than 100 employees. Qualification of the personnel in our company is on the high level.

KOSTELAC
INCANTO
FRUIT WINES & LIQUERS

About Us

The craft „FRUCTUS“ has been specialized for production of fruit wines and liquers. The basic determinants of business are high quality products, superior design, production based exclusively on natural raw-materials, as also professional relationship to buyers.

All products from our production program are made strictly of the first class fruit.

We do not use any additives (artificial aromas, colors, sweeteners, conservatives and similar) in production process, so all our products are entirely natural.

Brand INCANTO

Brand INCANTO (*lat. to charm, to fascinate)* is the name of the exclusive collection of fruit wines and liqueurs.

The connection of high-quality, and luxurious and superiorly designed packaging, make this collection truly attractive as a gastronomic product, but also as a unique gift.

Numerous awards for quality, design and innovation from various world trade fairs and competitions are the proof that INCANTO is a true combination of supreme results from the mentioned areas.

PHYLAZONIT®

BACTERIA-BASED FERTILIZER

History

Phylazonit—a product that was invented in the 70's, yet haven't received enough attention until the past few years. Hungarian laboratory "Phylaxia-Pharma" observed that intense chemical usage of the "modern" agriculture significantly decreased the population size of micro-organisms in the soil. They picked the three most important bacteria and by a fermentation process a "cocktail" called Phylazonit was created. 30 years of experiments proved that working the liquid into the soil recovers the environment vital for the plants. Using Phylazonit evidently results in **larger yield** and **healthier plants**, even with significantly **reduced chemical usage** (hence with **lower cost**). However, without a trading background, the laboratory couldn't merchandise the product well enough. In 2006 Agrova-Bio Ltd. and their two factory partners bought the exclusive licenses. After the buy-out, Phylazonit became a popular substitution of chemical fertilizers in Hungary.

Product components

Azotobachter croococcum: responsible for delivering 100-120 kg N per acre from air-bubbles in the soil to the plant roots.
Pseudomonas putida: provides 20-50 kg N-P-K per acre for the plant by disassembling roots and stems in the soil.
Bacillus megatherium: uncovers 30-40 kg bound P and K per acre from the soil for the plant.

Some facts

- Using Phylazonit results in larger yield, lower costs.
- Chemical use (fertilizers, pesticides) can be extremely reduced by using Phylazonit.
- Germination of the seed happens 2-4 days earlier and the process is more powerful.
- The root of the plant becomes larger and goes deeper, which:
  - makes the plant more resistant to drought and winter,
  - allows the plant to collect nutrient and water from a larger area,
  - makes the stems stronger and more resistant to wind.
- Phylazonit maintains the soil pH.
- Healthy soil life achieved by Phylazonit produces CO_2 that can be processed by the leaves of the plant even during the day.
- Bacteria in Phylazonit provide natural growth-stimulating hormones for the roots.
- The chance of virus infections and fungus diseases (like fusarium) is much lower because of the growing population of "good" bacteria in the soil.
- Usage of Phylazonit improves the soil-structure—water, air and thermal management of the soil becomes better.
- Without healthy soil-life, plants can't pick up important elements like chromium or selenium, lack of which results in human cancer and diabetes.

Usage

Phylazonit can be used for any plants at various steps of the agricultural technology throughout the whole year. It can be sprayed together with seeding or disking by traditional field spray or by a special tool supplied by Phylazonit.

Contact information

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PMT d.o.o. (PMT d.o.o. is an abbreviation for Poljoopskrba Međunarodna Trgovina d.o.o.), is a company that is based on more then 50 years of tradition of Poljoopskrba-Zagreb. The basic aim of PMT d.o.o. is to provide the quality of sale expressed through complete foreign trade services, the quality of products in the bid programme and the competitiveness in the market.

The aim of the PMT d.o.o. is to supply the agricultural production and food industry in Croatia as well as the sale of the goods resulting this branch of industry, but one of the main line of business will be and will remain the agricultural machines. The versatile foreign trade operations present in PMT d.o.o. on the existing programmes of agricultural technique are seen in the agency and agent agreements, exclusive sale, complete servicing support and supply of original spare parts during the whole period of exploatation.

PMT d.o.o. is distributor of Valtra tractors, Bauer GmBH equipment and Gebo GmBH sugarbeet cleaning machines. The quality of products in our programme besides the fulfillment of European and Croatian standards, reflects above all in your particular conditions, and is directed to the needs of the Croatian farmers.

In recent years PMT d.o.o. has also started with sugar beet seed and fruit seedlings business and with a distribution of the SESVanderHave sugar seed PMT has become one of the market leaders in sugar seed business in Croatia.

At the moment we have on Croatian market 9 varieties of sugar beet which are passed testing in The Institute for Seed and Seedlings and varieties are on Croatian National list of varieties. This year in recognition process we have 5 varieties of sugar beet, from which 5 in first year, 1 in second, and 2 in third year.

Last year we've started with serial seed business (corn, oil rape and wheat seed) and we have registered few varieties in The Institute for Seed and Seedling. As well known distributer of sugar beet seed in Croatia we assume that we are in very good position for increasing seed business.

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Eijkelkamp Agrisearch Equipment

Eijkelkamp Agrisearch Equipment BV, the full daughter of Eijkelkamp Earth Sampling Group B.V., is an international organisation that supplies all types of equipment in the area of environmental and agricultural research. The range of products that Eijkelkamp has to offer can best be described as equipment used for researching soil, water, sludge & slurry and earth monitoring. And this all is for the benefit of agricultural, hydrologic and environment-related studies.

Quality and Service

Quality and service are of paramount importance at Eijkelkamp Agrisearch Equipment. One is always striving for the right combinatory touch of supplying high-grade products and providing outstanding service.

Distributor's network

Thoroughly selected and well-trained representatives and retailers, in a number of countries dispersed all over the world, uphold the interests of Eijkelkamp Agrisearch Equipment.

Eijkelkamp Training & Consultancy

Eijkelkamp Agrisearch Equipment also has a modern Education and Training Centre. It offers a range of courses, training sessions and workshops in the area of environmental and soil research.

Our product range consists of the following groups of products:

SOIL
- Soil drilling and sampling
- Soil- and sediment samplers
- In-situ soil physical research
- Soil physical research in the laboratory
- General field equipment

WATER
- Hydrological research
- (Ground-)water sampling
- (Ground-)water analysis

SLUDGE & SLURRY
- Samplers for (layered) liquids
- Check-kit Chemviro
- Automatic sludge & slurry sampling

EARTH MONITORING
- Meteorological instruments
- Dataloggers, sensors and measuring stations
- e-SENSE®
- Plant physiological research
- Solar radiation measurements

e-SENSE®: measuring & monitoring that crosses boundaries

Measuring and control devices are increasingly needing to be used at a (greater) distance. Adjusting settings, reading data followed by taking appropriate action, if necessary, from a location of your own choice are possibilities that are now very much part of the standard package of requirements.

With the use of e-SENSE, taking measurements of data via intelligent sensors such as the e+ sensors the Diver® by Schlumberger Water Services has become more than just measuring. Intelligent sensors measure data in the field and store these internally. The e-SENSE field modem or the monitoring well modem makes it possible to transmit your data or alarms to a database which is located on your own computer.

e-SENSE direct

e-SENSE direct is a 'plug and play' arrangement and is simple to install, to operate and to maintain.
e-SENSE direct allows monitoring and communication with sensors to be carried out from your own computer. The entire installation is available to view and all setting adjustments can be made by you, enabling to achieve optimal performance as far as response speed, data traffic costs and battery use are concerned. The data can be imported into Logger Data Manager (LDM) e+ software which takes care of storing the data in a database. This also provides you with the means to process your data and produce graphic records and reports. Data can also be exported to your own database.

e+® Sensors

The e-SENSE® modem is user-ready for connecting to e+ sensors: e+ WATER L, the e+ SOIL MCT sensor (moisture, conductivity and temperature), the e+ RAIN sensor, the e+ OVERFLOW, further e+ sensors are developed.
All the members of the Diver® family (ground water dataloggers) can also be used in the e-SENSE telemetry system: e.g. Micro/Mini and CeraDiver, CTD-Diver and BaroDiver.
The sensors can be connected in any combination at all to the e-SENSE modem.

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