Proceedings & Abstracts

2nd International Scientific Conference

Soil and Crop Management: Adaptation and Mitigation of Climate Change

26-28 September, 2013, Osijek, Croatia

CROSTRO – Croatian Soil Tillage Research Organization

Under the auspice

ISTRO – International Soil Tillage Research Organization

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Preface

Dear colleagues, ladies and gentlemen,

On behalf of the Organizing Committee of Croatian Soil Tillage Research Organization (CROSTRO), branch of the International Soil Tillage Research Organization (ISTRO), we are pleased to welcome you to the 2nd International Scientific Conference, which is taking place again in Osijek, Republic of Croatia, 26-28 September 2013.

At the dawn of mankind, first crop - growers figured out that plant is thriving stronger and yielding more if soil had been tilled. Since then, the agriculture, including soil and crop management, had the strongest influence at the environment, modeling and adopting soil for growing crop in a way no other human practices have been done.

As that influence inevitably grew, following mankind growth and civilization improvement, dynamics between people and its environment raised many questions and problems, together with attempts to overcome them. This 2nd CROSTRO conference, being created as well for scientific as for experts and practitioners, has goal to promote correct agricultural practices, the newest state - of - the - art informatical, bio - technical, environmental and engineering solutions, as well as alternative and inventional approaches in agricultural production, all in attempt to cope with ever - changing environment and ensuring sufficient food and energy resources on sustainable ways.

Bearing in mind all previously mentioned, our Conference, entitled "Soil and Crop Management: Adaptation and Mitigation of Climate Change", will present current scientific achievements through following topics, hoping that will create answers for future agriculture practices in everchanging World:

1. Soil tillage and crop management in function of environmental protection
2. Adaptation and mitigation of climate changes in crop production
3. Soil degradation (biotic and abiotic) in agriculture production
4. Good agronomy practice
5. Sustainable production systems for food and bioenergy

With kind regards, and hope that this 2nd CROSTRO International Conference will create viable solutions and science-based answers of agricultural problems of today, together with tighter connections among all who attend, both scientific and social, thus creating better tomorrow,

Prof. dr. sc. Danijel Jug

President of Croatian Soil Tillage
Research Organization
President of Organizing Committee

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Chairmen:

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Vladimír Smutný
Dušan Kovačević
Márta Birkás
Yosef Steinberger

Abstract paper

Impact of climate change on soil temperature in Croatia

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Abstract

The mean, maximal and minimal soil temperatures have been analyzed, at different depths 2, 5, 10, 20, 30, 50 and 100 cm, for selected meteorological stations in Croatia. The main goals were to study the impact of climate change on soil temperature by depth and identify vulnerable areas due to the high soil temperature.

At most stations mean annual soil temperatures have increased by approximately 1°C at all depths in the last three decades. The analysis of the linear trend and the Mann-Kendall test confirm the existence of a significant positive trend of mean annual soil temperature at the 0.05 significance level.

A significant increase in soil temperature is observed, at the depth of 2 cm in particular, at all meteorological stations in the period 1961–2010. In shallower soil layers, up to a depth of 10 cm, the positive trend is between 0.2 and 0.7°C/decade. In deeper layers, up to 100 cm, the trend is slightly less pronounced (0.3–0.6 °C/decade). Seasonal trends show the greatest contributor to the increase in mean annual soil temperature is their increase in the spring and summer. A more significant trend of temperature increase is in the upper layers because the surface layers are heated more quickly during the day and in the summer, and cooled more quickly during the night and in the winter.

In the period 1961-2010 for almost all stations in all seasons and depths there are positive trends of maximal soil temperature. Annual trends of maximal values at 2 cm of depth are 0.4–2.6 °C/decade and generally decrease with depth. However, there are not so many significant annual and seasonal trends of minimal soil temperature. In the continental part of the country, mainly positive significant summer trends are in deeper layer and some positive significant winter trends. In the upper layer, a couple of stations mark negative significant winter and autumn trends. In the coastal part of the country some positive significant spring and summer trends are through all depths. Thus, annual trends of minimal values at 2 cm of depth are -0.45–0.3°C/decade with variations of trend values with depth.

Analysis of consecutive days with daily maximal soil temperatures above 30°C shows the longest extremely warm periods in the wider Dubrovnik area. Soil temperatures above 45°C in the surface layer with duration above 10 days appeared only in Trsteno near Dubrovnik in the period 1961–1990. Since 2000 year such warm period has began to occur along the Adriatic coast and islands, and at the Đakovo area. Vulnerability of the high soil temperatures in agriculture is defined by warm period longer than 10 days which appeared in the six years out of the observed 30 years. Thus, the likelihood of the occurrence is above 20%. A soil temperature above 30°C for depth of 2 cm affected the entire Croatia according to available data of soil temperature.

Vulnerability is greater on the Adriatic coast and islands than in the Croatian inland at a depth of 5 cm and 10 cm. With increasing the critical soil temperature and the depth, the size of vulnerable areas decreases.

Key words: climate change, soil temperature, Croatia

Original scientific paper

Soil management to adaptation and mitigation of climate threats

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Abstract

The possible relations between main climate factors and soil state defects have received great attention in the recent years. These factors that are light, temperature, precipitation, and wind have positive and negative impacts on soils. We consider it our duty to assess the main consequences of moisture surplus and water shortage in soils. The third goal of this paper was presenting the combined effect of the climate induced and the tillage induced damages on soil condition. While crop production is one of the sectors adversely affected by climate damage, so steps to prevent and alleviate the deterioration of soils are also drawn up. Five of the important solutions are as follows: 1. Cover the surface to alleviate both the rain and the heat stress mainly in summer. 2. Create surface to be adaptable to water infiltration and water retention. 3. Prevent the pan compaction formation in soils and keep the soil in well-loosened state. 4. Prevent the situations may lead to clod (and dust, crust) formation and use crumb conserving tillage tools. 5. Manage the stubble residues rationally; residue cover is primary in surface preservation, secondly, the residues are basic source of soil organic matter, and also, food of the earthworms.

Key words: soil, climate, tillage, moisture surplus, water shortage

Introduction

Various climate extremes, for instance drought stress, water deficit or water-logging, hail storms etc. have been afflicted the soils of the Pannonian region in the last decade. One of the fundamental causes of climate damage is extreme shortage or abundance of precipitation, i.e. too dry or too wet soil. As Szalai and Lakatos (2013) noted, the tendencies in the precipitation sums, the number of precipitation events with threshold values, especially the more intense rain events shows tendencies having serious effects on the available water amount and the surface water balance. From the aspect of cropping the damage caused by the underlying factor is also affected by the site parameters, the actual soil fertility, nutrient supply and water regime (Várallyay, 2013). Research findings show that agricultural activities have contributed to climate change and that at the same time (Jolánkai et al., 2013). Soil is an environmental element labelled by a variable state and quality, renewed or degraded (Várallyay, 2011). This renewal capability of the soil can be maintained by continuous treatment carefully aligned to the prevailing circumstances. Therefore the primary task of tillage is to maintain favourable soil quality and fertility and to prevent climate sensitiveness. The state of soils – mainly has there been a compact layer in it limiting moisture transport from deeper layers to the root zone or its movement down to be stored in deeper layers – is another modifying factor in the degree of the climate stress. Moreover, the unreasonable insistence on applying habitual tillage practices has really increased vulnerability of soils (Várallyay, 2013). These phenomena may relate to both site and soil. As authors (Birkás et al., 2011a, Vach et al., 2013; Kalmár et al., 2013) has already stressed, to maintain good soil quality may reduce the effects of climatic extremes at reasonable cost. Although the climate situation is rather grave today, there is a wide variety of solutions for soil stress-alleviation and for climate stress mitigation.

Materials and methods

The problem referred to in this paper was studied in long-term trials those have been underway since 2002 in a field of the Experimental and Training Farm of the Szent István University, located in the micro-region of the town Hatvan (47°41'N, 19°36'E, 136 m a.s.l.). The research site is flat and the soil – Chernic Calcic Chernozem soil by WRB (2006) with a clay loam texture – is moderately sensitive to compaction (Csorba et al., 2011, 2012). Soil assessment was extended to the surrounding area of an approx. 10 km radius with similar type of soil. In this site the long-term annual precipitation is 580 mm. The various years' precipitation figures are as follows: average (2002, 2006), dry (2004: -101 mm, 2011: -283 mm, 2012: -286 mm) and rainy (2005: +125 mm, 2008: +152 mm, 2010 +371 mm). Years 2007 and 2009 were dry in the growing seasons. The continuous soil state studies were comprised the possible soil state variants, e.g. shallow and deep, good and bad soil tillage, pan free and pan presence in soil, clean and covered (0, 15, 25, 35, 55, 65 %) surface, cloddy and levelled surface etc. which gave chance to learn more about soils sensitivity to the climate stresses (Kalmár et al. 2011). Colleagues, from Croatia and from Czech Republic, have followed with attention these experiments (Spoljar et al., 2011; Birkás et al., 2010). The measurements were taken and evaluated in accordance with the applicable standards (Csorba et al., 2011); Soil Sampling Protocol, JRC, 2010).

This study is the summary of a series of articles and conference papers published in the last decade. The following subjects are discussed below: 1) Listing the impacts of climate factors on soils condition. 2) Evaluating the main consequences of moisture surplus and water shortage in soils. 3) Presenting the combined effect of the climate and the tillage induced damages. 4) Listing the prevention and the alleviation modes of soil deterioration.

Results and discussion

Listing the impacts of climate factors on soils condition

Table 1: Impacts of climate factors on soils condition

Climate factors	Positive impacts	Negative impacts
Light	Photosynthetic green and purple bacteria and algae	*Connected with heat*: strong photochemical UV radiation kills microbes
Temperature	*Moderated warm* beneficial both on soil and living creatures	*High*: over-warming, drying, killing beneficial living creatures, Soil shrinking and cracking
	Frost: killing pests and diseases in surface layer (?)	*Frost*: dust formation on the surface
Precipitation	*Soaking rain* and moderated amount; dew in summer	*Lack*: soil drying, over drying
		Extra: crumb deterioration, silting (later crusting), dust leaching, water erosion
		Freezing rain: causing airless condition
Raindrops	*Moderated*: alleviating crusts	*Strong*: crumb explosion, crumb collapse
Downpour	-	Leaching, out-washing, gullying, soil removing, water-logging
Hail storm	-	Crumb deterioration, settling
Hoar/rime	-	Cooling
Snow	*Beneficial cover*, water source, moderating frost effects	Soil settling, Iced crust on the surface
Wind	*Breeze*: temperature moderating	*Warm wind in summer*: soil desiccation
		Wind-storm: soil removing/depositing, erosion

Assessing climate factors – light, temperature, precipitation and precipitation forms (raindrops, downpour, hail-storm, hoar, rime, snow), and wind – impacts on soil condition, more negative and less positive impacts were found (Table 1). Temperature of soil may regulate – warming or cooling – a by ratio of the surface cover. A clean surface is found to be beneficial in early spring achieving a sufficient temperature for sowing. However, the bare surface may often disadvantageous during the later phases of the season. Amount and distribution of precipitation in the growing season are the key factors both in improvement and in deterioration of the soil state. The crumb formation, the silt- and crust-free state, the harmonic water infiltration and storage in soils are known to be favourable impacts of the optimal water supply. However, water surplus in soils caused by extra amount of rain or downpours deteriorate crumbs in soil surface, remove soil particles and contribute surface water-loggings. Unfortunately, most of the harmful precipitation phenomena are occurred incalculably. In this case the most important solution is to be decreasing of the soil damage. I our long-term soil state assessment stubble residues were found as the possible surface preserving matter. Residues are known to be usually more reflective than bare soil, reduce solar radiation, heat and rain stress and thus water and wind erosion (Shen et al., 2012). Hail-storm hit both the crops and the soils hard. The soils that had been silted by hails became severely crusty. The soils sensitiveness (high, moderate or low, Várallyay, 2011) is one of the key factors in the damaging of the soils. In soils that had been found to be sensitive and moderately sensitive, the unfavourable precipitation patterns aggravated the damage (Birkás et al., 2011a).

Evaluating the main consequences of moisture surplus and water shortage in soils

Problems are often caused the quantity of precipitation and also the extremes of its distribution, sometimes up to 150-160 mm rain may fall in a matter of 4-6 days. The soils are fully saturated by water and the existing crumbs in the surface layer are soaked, collapsed and silted. The rising of the groundwater table caused heavy damage by water-loggings. However, surface run-off and the stagnation of water on the surface depends on the soil mechanical composition and structure, on the soil original moisture content, the surface condition, the soil water permeability and conductivity and on the quantity and intensity of the precipitation The most exposed situation can be assessed in the degraded soil and bare surface variants (Birkás, 2011). As we found, the former dust ratio had significantly decreased in the tilled, and it had increased in the bottom layer from early season till the end season. At the same time the former compact layer had also been extended, probably been caused by the dust leaching from the tilled layer. The rain stress proved to be moderate on soils kept in good state in long-term, however the difference between minimum and maximum values were lasted. As Birkás et al. (2013) noted, the long term soil conservation and the effectual surface cover have really been mitigated the rain and water surplus damages. Both assessed factors, namely surface silting, silt-film formation, crusting, crumb reduction, dust leaching, compaction occurrence, and settling showed lowest degree of damage in the well-managed soils. The hailing destroys not only the field vegetation but the uncovered soils as well. Due to the hard hit of the hail, the depth of the loosened layer may decrease by 9-22 %, related to the soils condition. As Várallyay (2013) noted, the soils sensitiveness (high, moderate or low) is known one of the key factors in the soil settling. A moderated settling and less crumb deterioration and a relatively rapid regeneration were assessed on soils maintaining the organic matter continuously. This finding is similar to that observed Tóth et al. (2013) in their long-term filed trials. On the other hand, soils that had been cultivated unreasonably, found to be more sensitive to the climatic phenomena including hail-stones.

The further extreme is the drought that is the long-term precipitation deficiency. The drought is often occurred in soil when moisture level has gradually been reduced and the root system can not intake the bound water (Szász, 1997). Soil is severely shrinking, deeply cracking, and breaking plant roots. The negative consequences of the long-term dry period worsened by heat stress are the soil desiccation, the increasing water deficit, the crumb degradation, strong clod formation by the soil disturbance, and declining of the soil biological life. We found the compact pan layer occurred in soil close to the surface a drought-increasing factor. Tillage of compacted soil – regardless of its moisture content – takes an increased energy input and the increment is to be booked as a loss (Nikolic et al., 2002). From the aspect of crop production restricted water infiltration and storage as well as the blocking of the water transport from deeper soil layers towards the root zone, are some of the most unpleasant consequences of soil compaction (Birkás et al., 2011b).

Table 2. The drought stress impact on soils condition (2011, 2012)

Phenomenon	Situation on heavy soils*		Situation on loamy soils**	
	Clean surface	Covered surface (55%)	Clean surface	Covered surface (55%)
Surface crusting (%)	45-65±5.0	5.5-8.5±1.0	15-25±5.0	2.5-4.5±1.0
Cracking (depth ≥ 10 cm, nr m^{-2})	3-7±2.0	0-2±1.0	2-3±1.0	0-1
Crumb reduction (%)	45-65±5.0	15-25±2.5	20-30±2.5	5-10±1.5
Water loss mm day^{-1} (dry summer)	4.5-5.8±0.4	1.6-2.2±0.2	4.2-6.2±0.2	1.4-1.9±0.2
Increasing penetration resistance (%)	68-88±10.0	26-38±8.0	52-68±9.2	21-32±5.4
Prone to clod formation	very strong	medium	strong	slight
Earthworms (0-20 cm) nr m^{-2}	0	5-7±5.0	2-5±2.0	10-20±5.0

*n= 310; clay content 55-75 %, and/or silt content: 25-40 %, Fluvisols, Gleysols; **n=345, clay content 35-50 %, Chernozem

The drought induced problems occurred both in the experimental fields, and in the region has really been offered new research challenges. A peculiar finding of the long-term soil condition assessment is worthy more attention. The negative influence of the water surplus in soils can really be proved in the increase of the soils' drought stress. Tracing soil state deterioration back to the rain stress has prolonged for the next two dry seasons. In Table 2 six types of soil state damage are selected and evaluated on the bases of the measurements. Considering the degree of phenomena, appreciable differences appeared between heavy and loamy soils, and the preserving effect of the clean and the covered surface. A bare surface through both water loss and crumb deterioration is greatly exposed to the crusting and cracking processes. The soil penetration resistance increase is also affected by great water loss which contributes similarly to the strong clod formation. According to Birkás et al. (2012), a sufficient ratio of the surface cover may veritably decrease the degree of the drought damage. Considering the possible extremes, we outline, that a larger – minimum 45 %, or more – cover ratio correspond to the soil conservation requirements in the dry summer period. The unprofessional soil tillage, as an aggravating factor of the drought stress is mainly unacknowledged in the tillage practice.

The combined effect of the climate and the tillage induced damages

Due to long-term soil state assessments, a close coherence was found between climate and the technology induced damages (Figure 1).

In wet periods traffics' loading, pan-compaction creating and extending, soil smearing and kneading, and crumb deterioration are found to be frequent types of the tillage induced damage. There are serious indirect consequences of these phenomena that are the water stagnation on the surface, and/or on the pan layer, dust leaching to the nearest compact layer and extending the former pan.

In the course of the summer period – from mid-July till end of August, or, sometimes till mid-September – typical tillage defects have really been increased the soils' exposure to the climatic threats. The most frequent tillage defects are as follows: 1) leaving bare soil surface after harvest, 2) creating large, cloddy, water wasting surface after deep and rough tillage interventions, 3) leaving cloddy state, full of cavities in the tilled layer, 4) forming dusty structure during clod breaking. 5) over-pressing the tilled soil layer during clod breaking operations. Surveying the coherence between tillage induced and climate induced damages both in wet and dry seasons two or three levels of the problems may indicate, that is unacceptable, tolerable from time to time, and tolerable rate (presented in a conference paper at Vukovar, in May, 2013, see Birkás et al., 2013).

Findings and recommendations for prevention and alleviation modes of soil deterioration

The extreme weather conditions afflicted the agricultural activity requires professional competence and specialists are to elaborate the concrete and adaptable mitigation techniques. While the number of the extreme climatic and water transport conditions show upward tendency, the key issues of the mitigation cover both soil quality improvement and conservation of the water and organic material content in soils and alleviation of the soils sensitivity to the climate extremes. The new findings summarised by our research staff are as follows:

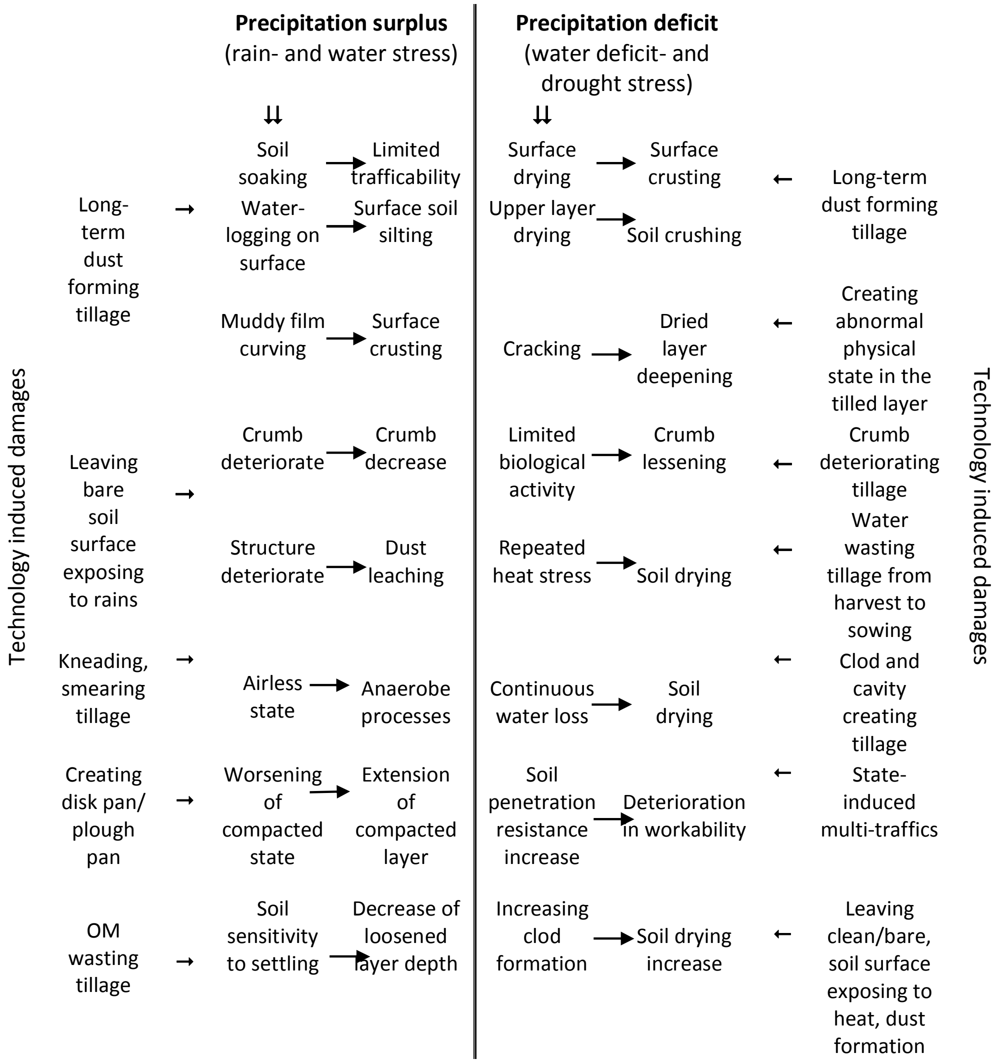

Figure 1. Influence of climate and faming induced damages on soil condition

(1) Identification of the different effects on soil of the water-logging caused by natural factors and stagnant water saturation caused by wrong tillage practices.

(2) Pulverising of soils' structure in the top layer by frosts in ploughed fields left them in cloddy state.

(3) Proving the silting of bare soil surface in the wake of repeated rain stress, in the case of >17.5 % surface dust and small crumb (<2.5 mm fraction) content.

(4) Demonstrating the leaching of dust (<0.25 mm fraction) formed by mechanical impacts and by natural processes in the surface and top layer, in the case of frequent heavy rains.

(5) Proving the aggravation of compaction as a consequence of the dust and clay colloids leaching in a rainy season.

(6) Observing the impact of the leaching of dust and mineral colloids magnifying consistency phenomena, e.g. swelling, then slow and later rapid desiccation, shrinking and capping.

(7) Identification of the decrease in the depth of the of loosened layer in chernozem, forest and gley soils depending on organic matter content, in rainy periods (in 90-120 days).

(8) In the case of bare soil surface, decrease (by 63.1 – 81.5 %) in the ratio of crumbs in the top soil layer between seedbed preparation and the development of complete coverage by vegetation.

(9) Demonstration of a certain special stratification of the soil after tillage carried out when the soil moisture content was not suitable for tillage (autumn of 2010, spring of 2011): relatively loosened layer 0-250 mm (after ploughing), 0-120 mm (after disking) with puddled, compacted tillage pan (50-300 mm) underneath, below which the soil is settled and wet.

(10) The unavailability of the moisture content of the deeper soil layers if wrong tillage has resulted in a thick (50-300 mm) compact layer over them; appearance of heavy drought damage (with at least 22.5 % – most often twice as heavy – yield loss).

(11) Demonstrated the limited rooting depth in soils degraded by tillage pan forming (spring and early summer in 2011); which improved only a little after abundant rains (July 2011). The few roots that actually penetrated the compact layer proved the gravity of the situation again.

(12) Different fraction sizes in the layer loosened by breaking up the tillage pan (at least 45 % >100 mm), a lot of cavities appeared between the clods which could not be remedied by one pass with a soil compacting tool. The moisture rising towards the surface from deeper layers condensed in the cavities and failed to reach the surface pressed by rollers; this is considered to have caused the uneven emergence of rape seedlings.

Considering the results achieved in Hungarian relation – on 2 million hectares –, we may conclude that there are number of mitigation techniques which can effectively be used in our arable fields in the future. The most important principles are listed below (Table 3). The prevention and remediation methods should be demonstrated and trained for land users; that can be a new major challenge for us who know more accurately the cause of the troubles, so the solutions, too.

Table 3. Mitigation tillage techniques in rainy and droughty seasons

Mitigation tillage techniques in rainy seasons	Mitigation tillage techniques in droughty seasons
• Creating and maintaining soil condition suitable for water surplus intake. • Prevention of surface silting: revising and neglecting the overrated practice e.g. sowing into dust. • Preventing clod formation as the preceding phase of the pulverisation: a) tilling the soil at workable state, b) neglecting tillage tools creating clods.	• Creating and maintaining a loosened state promoting water transport from the deeper layers to the root zone. • Creating water retaining surface in the critical periods. • Increasing water retention ability of soil by organic matter adding. • Prevention of clod and dust formation in the critical periods.
• Extension of the loosened state duration by OM recycling and using carbon conserving tillage. • Preventing soil compaction aggravation: as leaching dust disperses in a deeper layer in soil being a pan-free state (where is no pan, there is no dust filter).	• Extension of the loosened state duration by OM recycling and using carbon conserving tillage. • Re-loosening pan layers occurred in wet seasons.
• Prevention of swelling and shrinking: limiting surface silting and quick drying by surface cover (at least 50 %). • Prevention of crusting and crust thickening by increasing soil resistance (or decreasing soil sensitivity) with long-term OM recycling and surface covering.	• Avoiding surface crusting and cracking by adaptable surface preservation (covering by 50 %). • Avoiding dust formation in winter (as frost effect) by leaving smaller surface for wintering.
• Soil structure improvement by OM and carbon conserving, and crumb preventing tillage. • Assessing soil condition critically in and out of growing season	• Maintaining crumb forming ability by OM recycling, surface covering and crumb preventing tillage. • Assessing soil condition critically in and out of growing season.

We may outline again that an effective mitigation of the climate extremes can only be realised in a frame of the long-term national and regional program.

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Original scientific paper

A climate gradient approach toward understanding terrestrial ecosystem function

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Abstract

Recent global climate patterns demonstrate alterations in temporal and spatial rain distributions. Such alterations can potentially have very pronounced effects on water availability in Mediterranean and semi-arid regions due to characteristically high evaporation intensities. Understanding the consequences of altered water availability in Mediterranean and semi-arid regions for soil abiotic (e.g., organic matter) and biotic (e.g., soil microbial communities) components is essential, considering their crucial functions in soil fertility. The aim of the present study was to gain insight into feedback mechanisms that operate across boundaries of abiotic and biotic components, in order to expand our understanding of potential climate alterations on spatial and seasonal scales. Soil abiotic parameters (moisture, organic carbon, dissolved organic carbon, and total soluble nitrogen contents) as well as biotic parameters (microbial CO_2 evolution, biomass, qCO_2, and fungal community) were determined. Soil abiotic parameters, such as moisture, organic carbon, and dissolved organic carbon, demonstrated a great contribution to plants in semi-arid regions. The analyses of microbial activity data collected along spatial and temporal axes in different climatic regions can contribute to our ability to predict functional changes in ecosystems found under changing climatic conditions. Climate aridity level and the associated intensities of solar radiation and dry-wet cycle frequency enhance soil organic-matter liability.

Key words: Mediterranean ecosystems, climate gradient, aridity, microbial community, fungal community

Introduction

According to Houghton et al. (2001), changes in global climate associated with increased greenhouse gas emissions are expected to be among the main factors affecting temperature and hydrological cycles, resulting in more severe droughts and floods. Based on the above assumption, Ben-Gai et al. (1998), in their study on climate models for the Middle East, predict a rise in winter temperatures combined with changes in rainfall amounts and distribution. These changes may affect key soil processes, such as CO_2 evolution and net nitrogen (N) mineralization, thus affecting key ecosystem functions, such as carbon (C) storage, nutrient availability, soil biotic community and population processes, e.g., primary production, plant litter decomposition and biodiversity (Sternberg et al., 1999; Chapin et al., 2000; Sarah and Rodeh, 2004). CO_2 evolution from soils to the atmosphere depends mainly on climate and organic-matter availability and is limited by primary production and decomposing kinetics. Alvaro-Fuentes and Paustian (2011) have recently shown that soil organic-matter (SOM) turnover and decomposition processes are limited by moisture availability and temperature. According to Kurz-Besson et al. (2006), LeRoy and Marks (2006) and Liski et al. (2003), on regional scales, SOM is controlled by temperature, moisture, soil texture, plant lignin, and nitrogen inputs. According to Meentemeyer (1978), the relative importance of the above factors diverges across ecosystems.

Plant litter decomposition into SOM through biotically mediated nutrient cycling is known to be one of the most important factors sustaining ecosystem stability and productivity. It is also known that its turnover rate is determined by organic-matter transfer below-ground, the rates of SOM transformation and decomposition and that it is controlled by complex interactions between the biotic community and abiotic factors (e.g., temperature, rainfall, moisture availability) (Meentemeyer, 1978; Aerts, 1997; Swan and Palmer, 2004; Talmon et al., 2011). The interaction between the biotic and abiotic factors, along with litter-decomposition processes, on a temporal and spatial basis, was the subject of many studies conducted in different ecosystems (Whitford et al., 1986; Murphy et al., 1998; Whitford, 2002; Aneja et al., 2006). However, due to the complex nature of the interaction between temperature and moisture in regulating decomposition rates, in addition to the difficulty raised by soil physical and chemical soil composition, the challenge of modeling SOM turnover rates across climate – both geographically and seasonally – is basically unapproachable.

In order to be able to break this barrier – at any scale – using a natural climate-gradient platform sounds promising (Neff and Hooper, 2002; Oren and Steinberger, 2008). A continuous gradient that hosts a variety of climate gradients with large climatic variables within a relatively small area is located in the Eastern Mediterranean region, which is part of the GLOWA Jordan River project (Steinberger et al., 1990, 1999). At this transect, climatic subtypes range from humid (e.g., up to 1,300 mm mean annual rainfall) to extreme arid conditions (e.g., down to 20 mm annual rainfall), and support large plant diversity (Sternberg et al., 1999). In the present study, an attempt was made to evaluate the effects of the climate gradient (e.g., rainfall and temperature), on the one hand, and the seasonal pattern (e.g., mild, rainy winters and dry hot summers) controlled on a regional scale, on the other hand.

In the present study, the impact of climate (changes in precipitation) on a temporal basis (seasonality) and the four ecosystems along the gradient used as a spatial dimension (geographical basis) on microbial community activity, e.g., CO_2, biomass associated with soil organic matter (SOM) turnover, were studied. We hypothesized that: (1) a decrease in xeric environmental conditions will increase the microbial-community component's biomass and decrease microbial functional diversity; (2) the correlation between total rainfall and soil microbial-community activity, e.g., CO_2 evolution and biomass, will increase as we move from a humid-Mediterranean (HM) to a xeric-arid (A) ecosystem; and (3) SOM turnover dynamics will be strongly determined by the spatial, rather than the geographical, scale.

Methods

Study site

Four study sites, located along a 245-km stretch from the northern part of Israel toward the southern part, represent a climatic gradient. These sites represent different environmental and climatic conditions: humid-Mediterranean (HM), Mediterranean (M), semi-arid (SA), and arid (A) ecosystems.

The common basic climates for all four sites are characterized by rainy winters (October-April) and prolonged, dry summers (June-August). The plant-growing season commences soon after the first rains, between October and December (Fleischer and Sternberg, 2006). The sites are located at similar elevations, ranging between 470 and 620 m above sea level (a.s.l.), and are positioned on south-facing slopes. Each site overlies calcareous bedrock, giving pH values in the alkaline range (7.5-7.9). A significant decrease in yearly rainfall relative to the mean multiannual rainfall was obtained at each of the four sites.

The humid-Mediterranean (HM) site is located (N 33°0' E 35°14') in the northern Galilee Mountains, at an elevation of 500 m a.s.l., on montmorillonitic terra rossa. The average annual rainfall at this site is 780 mm and the mean annual temperature is 18.1°C. Vegetation varies from a dense-closed oak maquis cover to more open garrigues dominated by shrubs. Herbaceous vegetation, mainly composed of annuals, coexists with shrubs.

The Mediterranean (M) site is located 18 km southwest of Jerusalem (N 31°42' E 35°3') at 620 m a.s.l., on terra rossa. The average annual rainfall is 537 mm and the mean annual temperature is 17°C. Vegetation is dominated by shrubs and large numbers of herbaceous (mostly annual) plant species.

The semi-arid (SA) site is positioned between the southern Judean Mountains and the northern Negev (N 31°23' E 34°54') at 590 m a.s.l., on light brown rendzina. The average annual rainfall is 300 mm and the mean annual temperature is 18.4°C. Vegetation is dominated by dwarf shrubs associated with herbaceous (chiefly annual) plants.

The arid (A) site is situated on the Negev plateau (N 30°52' E 34°46') near Sde Boker, at an elevation of 470 m a.s.l., on desert lithosol. The average multi-annual rainfall is 90 mm, and the mean multi-annual temperature is 19.1°C. Vegetation at this site is dominated by small shrubs and sparsely growing desert annuals and geophytes (Fleischer and Sternberg, 2006).

Soil sampling

Soil from the upper 0-10 cm was randomly sampled in four replicates from the open spaces between the perennial plants. Soil samples were collected over three consecutive years on a seasonal basis. Each soil sample was placed in an individual plastic bag and transported to the laboratory, where the soil samples were sieved (< 2 mm) and kept at 4°C before chemical and biological analyses (within a four-month period).

Laboratory analysis

Soil moisture (SM) content was determined gravimetrically by drying soil samples for 24 h at 105°C.

Total organic-carbon (TOC) content was determined by oxidation with 1 N potassium dichromate in acidic medium, according to Rowell (1994).

TSN and DOC content was determined by a Skalar Analytical San Plus Analyzer (Breda, The Netherlands) in soil samples extracted with a 0.01 M $CaCl_2$ solution (Houba et al., 1987).

Soil microbial community

The soil microbial community was determined by the MicroResp™ method (Campbell et al., 2003), with which we assessed the microbial biomass (MB), and CO_2 evolution (MBR). In order to determine MB, a glucose solution was added to soil samples, while no substrates were added to samples in order to determine basal CO_2 evolution (Anderson and Domsch, 1978; Carpenter-Boggs et al., 2000; Berg and Steinberger, 2010).

The dye plates were read twice in a spectrophotometer at 590 nm: just before they were placed on the deep plates containing the soil samples (Time 0) and after discerning colorimetric changes in the indicator plate (Time 1). After Time 0, the plates were incubated in the dark at 27°C. The results per well were calculated in comparison to the 16^{th} well, which contained the same soil sample.

Isolation of microfungi

Microfungi were isolated using the soil dilution plate method (Davet and Rouxel, 2000). Three culture media with different carbon and nitrogen sources were used for cultivating microfungi: malt extract agar (MEA) with disaccharide maltose and organic nitrogen, Czapek's agar (CzA) with disaccharide sucrose and mineral nitrogen (both media of Conda Pronadisa Labs, Madrid, Spain), and carboxymethylcellulose agar (10 g polysaccharide carboxymethylcellulose, 1 g K_2HPO_4, 0.5 g KCl, 0.5 g $MgSO_47H_2O$, 0.01 g $Fe_2SO_47H_2O$, 0.5 g yeast extract, 15 g agar). Streptomycin (Sigma-Aldrich Inc., St. Louis, MO) was added to each medium (100 µg/ml) in order to suppress bacterial growth. One gram of pounded soil samples was initially diluted with 9 ml sterile water and the suspensions were agitated for 5 min. One milliliter of that dilution was transferred to a new tube containing 9 ml sterile water and the suspensions were agitated for 5 min. Two-hundred µl samples of the suspensions from the dilutions of soil were placed in 90-mm–diameter Petri dishes. After that, the agar medium (about 11 ml) at approximately 40ºC was added and mixed with the sample suspension. All plates were incubated at 27ºC (all plates) in darkness for 7-10 days.

Statistical analysis

All the data obtained in the present study were subjected to statistical analysis of variance (ANOVA) using the SAS model (Duncan's multiple range test and Pearson correlation coefficient [SAS Institute, Inc.], one-way ANOVA, and T test) for evaluating differences between separate means. Differences at the $p<0.05$ level were considered significant (Kandeler et al., 1999).

Results

Geographic variability of the soil ecosystem along the climate gradient

Soil-moisture contents were found to correspond to the spatial distribution of precipitation along the gradient: arid (A) < semi-arid (SA) < Mediterranean (M) < humid-Mediterranean (HM) (Fig. 1A). This can be attributed to the water-holding capacity (WHC) of these soils, which decreases from the HM to A, and which was found to decrease by 41% (Fig. 1B).

Soil total organic-carbon (TOC) pattern was found to follow soil moisture, producing nearly identical relations, where the mean values for the entire study period demonstrated significant differences along the climate gradient, i.e., HM > M > SA > A (Fig. 1C).

Soil dissolved organic content (DOC) followed the same trend, with values of 257, 230, 168, and 164 mg kg^{-1} soil, respectively ($P<0.0001$). Accordingly, a positive Pearson correlation ($P<0.0001$) was established between TOC and DOC for data joined from all sites. It is noteworthy that DOC was significantly greater during the dry period than during the rainy period at all sites ($P<0.0001$ for the Mediterranean sites and $P<0.05$ for the arid sites). A similar trend was generally observed for TOC, even if it was significant only for the semi-arid site ($P<0.05$).

Soil biotic properties (community-level MBR and MB) exhibited continuous decreases southward along the gradient, with some exceptions in the course between the humid and the typical-Mediterranean climate subtypes (Table 1). This trend is emphasized by positive and significant correlations between MB and SM along the geographic axis in all seasons, and between MBR and SM in spring and summer only. .Both MBR and MB correlated positively and significantly with both TOC and DOC in summer and autumn, while in winter and spring, the correlations with DOC were not significant. Contrary to the spatial trend obtained with MBR and MB levels increased steadily southward along the gradient, with the only exception being in the humid-to-typical-Mediterranean course in winter (Table 1).

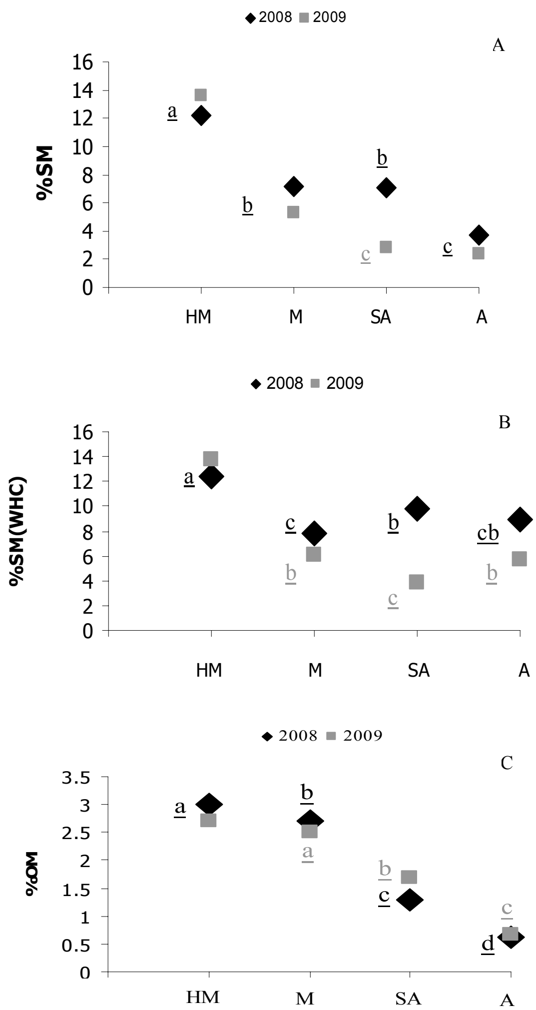

Figure 1. Changes in mean values of soil moisture (SM) (A), soil moisture based on water holding capacity (WHC) (B) and percent organic matter (OM) (C) during the study period at different locations along the climatic gradient. HM = humid-Mediterranean; M = Mediterranean;SA=semi-arid;A=arid.

Table 1. Soil parameters determined in the various study sites along a Mediterranean climate gradient in the various seasons. Variation among study sites is denoted by Duncan's multiple range test groupings (*n* = 2 years * 4 replicates = 8).

Winter	HM	M	SA	A
SM (%)	29.6 (±4.8)[a]	22.3 (±7.7)[b]	17.6 (±2.9)[c]	9.0 (±1.9)[d]
TOC (%)	1.84 (±0.26)[a]	1.56 (±0.12)[b]	0.81 (±0.24)[c]	0.31 (±0.13)[d]
DOC (mg kg^{-1})	231 (±220)[a]	186 (±142)[a]	126 (±101)[a]	116 (±75)[a]
MBR (µg CO_2 -C g^{-1} h^{-1})	0.130 (±0.058)[a]	0.122 (±0.074)[a]	0.104 (±0.062)[a]	0.098 (±0.062)[a]
MB (µg C g^{-1})	46.8 (±14.9)[ab]	71.5 (±48.7)[a]	22.3 (±10.6)[bc]	11.2 (±7.4)[c]
Spring	HM	M	SA	A
SM (%)	14.9 (±10.2)[a]	9.9 (±4.2)[b]	4.4 (±1.6)[c]	2.8 (±1.9)[d]
TOC (%)	1.75 (±0.11)[a]	1.53 (±0.29)[b]	0.95 (±0.28)[c]	0.42 (±0.10)[d]
DOC (mg kg^{-1})	158 (±92)[a]	142 (±42)[a]	160 (±164)[a]	126 (±156)[a]
MBR (µg CO_2 -C g^{-1} h^{-1})	0.154 (±0.055)[a]	0.150 (±0.050)[a]	0.137 (±0.036)[a]	0.074 (±0.031)[b]
MB (µg C g^{-1})	109.8 (±58.5)[a]	115.1 (±128.8)[a]	28.4 (±9.7)[b]	9.1 (±5.7)[b]
Summer	HM	M	SA	A
SM (%)	8.0 (±1.6)[a]	5.8 (±1.1)[b]	3.0 (±0.7)[c]	1.3 (±0.3)[d]
TOC (%)	1.92 (±0.21)[a]	1.65 (±0.19)[b]	0.62 (±0.21)[c]	0.43 (±0.10)[d]
DOC (mg kg^{-1})	227 (±150)[a]	232 (±96)[a]	146 (±70)[ab]	132 (±92)[b]
MBR (µg CO_2 -C g^{-1} h^{-1})	0.173 (±0.042)[ab]	0.193 (±0.060)[a]	0.126 (±0.083)[bc]	0.097 (±0.071)[c]
MB (µg C g^{-1})	75.2 (±32.9)[a]	59.4 (±29.8)[a]	19.4 (±12.6)[b]	11.8 (±8.8)[b]
Autumn	HM	M	SA	A
SM (%)	20.0 (±10.5)[a]	17.8 (±8.9)[a]	6.2 (±2.3)[b]	1.8 (±0.2)[b]
TOC (%)	1.64 (±0.13)[a]	1.40 (±0.27)[b]	0.83 (±0.34)[c]	0.33 (±0.12)[d]
DOC (mg kg^{-1})	320 (±192)[a]	230 (±114)[ab]	137 (±91)[b]	151 (±122)[b]
MBR (µg CO_2 -C g^{-1} h^{-1})	0.278 (±0.162)[a]	0.181 (±0.087)[ab]	0.221 (±0.046)[ab]	0.122 (±0.069)[b]
MB (µg C g^{-1})	124.5 (±69.1)[a]	60.6 (±38.0)[b]	42.1 (±13.4)[bc]	16.1 (±8.9)[c]

Notes: Abbreviations of study sites: HM – humid-Mediterranean; M – typical Mediterranean; SA – semi-arid; and A – arid. Abbreviations of soil parameters: SM- soil moisture; TOC – total organic carbon; DOC – dissolved organic carbon; MBR – microbial basal respiration; MB – microbial biomass. All soil parameters are expressed on a soil dry-weight basis.

Soil fungal biomass (FB) increased along the gradient with increasing climate moisture availability, excluding the semi-arid site. At the semi-arid site, FB values reached the highest value of 112 mg C*g^{-1} soil in the HM and 104 mg C*g^{-1} soil in the arid soil, while significantly ($p<0.05$) lower values (by 25%) were obtained at the two remaining sites. Fungal CO_2 evolution was significantly higher ($P<0.05$) in the semi-arid and arid soils (0.54 and 0.35 mg CO_2 C g $soil^{-1}$*h^{-1}, respectively) on the geographical gradient compared to the Mediterranean and humid-Mediterranean soils (0.26 mg CO_2 C g $soil^{-1}$*h^{-1}).

The ratio between the CFU of fungi and the number of species at each site along the gradient was found to be relatively higher at the HM and arid sites compared to the other two sites (M and SA).

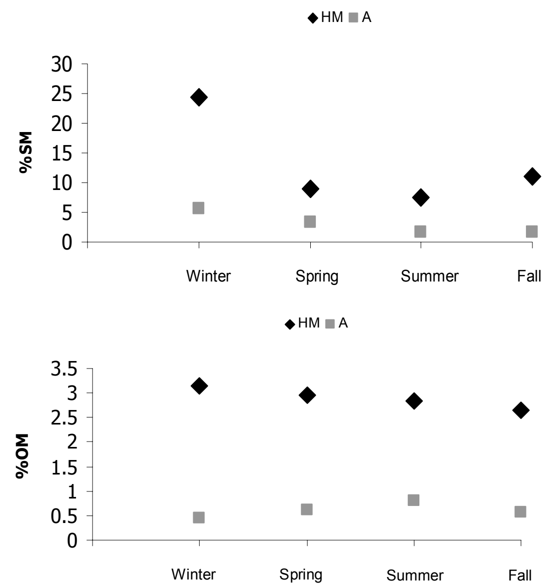

Figure 2. Changes in mean values of soil moisture (SM) (A and percent organic matter (OM) (B) during the study period at HM and A sites along the seasons. (HM = humid-Mediterranean; A = arid)

Seasonal variability of the soil ecosystem

The seasonal changes in soil moisture at the two extremes sites, the humid Mediterranean and the arid site, demonstrated sharp and significant ($p<0.05$) differences in the winter season (Figure 2) as a result of differences in total rainfall. The decrease in moisture along the seasons was strongly related to moisture availability and site location. The amounts of OM were similar along the seasons for each site, showing six-fold higher values for the HM than the A site (Figure 2).

Regarding soil biotic activity, both MBR and MB generally decreased on a seasonal scale, with increasing SM at all sites (although significant only for MBR in the typical-Mediterranean site). In contradistinction, MBR and MB were positively and significantly correlated with organic carbon at all study sites.

The CFU fungi at the HM decreased sharply with the decrease in SM along the seasons (Figure 3), where the changes at the A site demonstrated a significantly different trend. A sharp 4-fold increase toward the spring season compared to the winter season and again a relatively significant increase in the autumn relative to the summer, triggered by dewfall, are known as important moisture sources in A systems (Figure 3). No significant differences were found in the number of fungal species between the sites.

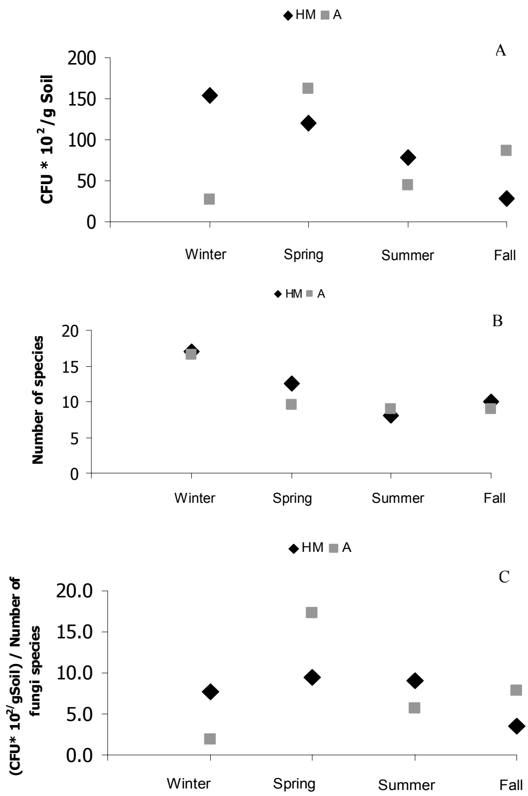

Figure 3. Changes in mean values of soil fungi colony forming units (CFU)(A), number of species (B) and the ratio between them (C) during the study period at HM and A sites along the seasons. (HM = humid-Mediterranean; A = arid)

Discussion

The relationships between abiotic and biotic soil ecosystem properties obtained in the current study are in good agreement with accepted ecological perceptions. The observation that moisture and organic matter availability account for a significant proportion of the substrate for microbial activity, is well-known (Jandl and Sollins, 1997; Bengtson and Bengtsson, 2007; Jones et al., 2008; Ghani et al., 2010). The significant positive correlations between microbial CO_2 evolution and dissolved organic matter along the geographic axis of the engaged climatic gradient are analogous to results obtained by the direct measurement of soil CO_2 efflux in the field, obtained at the same study sites by Talmon et al. (2011). They reported that the variation in soil organic-carbon content along this climatic gradient accounted for 77% of the variation in annual soil respiration. While no dissolved organic carbon was measured in that field study, total organic carbon and dissolved organic carbon were found to be correlated along the geographic climate transect. Raich and Schlesinger (1992) obtained similar results: in reviewing soil respiration data from a wide range of vegetation biomes, they reported positive correlations between annual net primary productivity and annual soil respiration rates.

On the seasonal axis, only the typical-Mediterranean site exhibited a significant positive correlation between microbial CO_2 evolution and total organic carbon, similar to results obtained by Korschens et al. (1998). However, at all the other sites, the microbial CO_2 evolution-organic carbon was persistent, and complemented a similar correlation every season along the geographical axis. This spatio-temporal correspondence emphasizes the fundamental role of soil organic C availability in regulating soil metabolic activity.

Based on the present study, we can emphasize that climatic gradients with different environmental components, such as altitude, topography, temperature, and precipitation, provide a useful framework for studying the effects of climate change, as discussed by Diaz and Cabido (1997) and Dunne et al. (2003). In the gradient studied in the present study, with four different natural environments, a diverse microbial-community level was found. In the arid ecosystem, the low levels of organic matter might be the reason for relatively high utilization of organic matter without any inconsistency in its composition. At the humid-Mediterranean site, the frequency of high amounts of organic matter that may be easily decomposed is relatively high and can maintain a relatively high microbial community compared to the other locations along the transect.

The present study elucidated the complex interplay between microbial-community litter decomposition and climatic features. However, further studies should be conducted in order to understand the partial contribution of organic-matter composition and the interaction between precipitation, volatilization, litter quality, and microbial community function.

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Original scientific paper

Agricultural compaction of some soil types in eastern Croatia

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Abstract

Frequent use of heavy equipment (mechanisation) lead to soil degradation processes of physical-mechanical properties of soils in agricultural production. Soil compaction, as one of the main causes of soil degradation, reduces pore volume in the soil, which directly influence on water-air relations. A very common problem is the impossibility of infiltration of rainwater and its retention on the surface in a shorter or longer period. In such conditions, plants suffer from lack of oxygen (hypoxic or anoxic stress) which resulted of reduction conditions and may lead to decreasing of pH reaction and availability of plant nutrients. In addition, when the bulk density reaches a critical value, e.g., 1.6 Mg m^{-3} for loam and clay loam, significantly increases resistance to root penetration in soil depth. Research was conducted at 40 locations on three soil types with the aim of recording the current situation and the intensity of soil compaction damage in agricultural area of eastern Croatia (Slavonia and Baranja region) and to determine the soil properties that are in a strong correlation related to the compaction. According to the values of packing density, researched soils can be classified as medium (PD = 1.35 to 1.57 Mg m^{-3}) to very compacted (PD = 1.77 to 1.99 Mg m^{-3}).

Key words: soil degradation, soil compaction, bulk density, packing density

Introduction

Modern trends in agricultural production in the last few years more and more imposing use of heavy duty mechanization (mass and power). In addition to the reached of positive financial effect (high yields and profit) in modern agricultural production may occur and some negative effect (Chamen et al., 2000) through the physical and mechanical degradation of soil properties. Soil compaction, according Pagliai et al. (2003), is one of the main causes of degradation of the physical properties of soils. Changes resulting from these processes (Horn, 2000; Czyż, 2004) very unfavourable affect the growth and development of plants in the early growing season, and as such, are becoming an increasing agroecological problem. Due to the large number of passes by heavy mechanization and soil tillage in wet condition, soil pore volume becomes reduces which directly impair on water-air relations. In arable and subarable horizons due to the impossibility of rainwater infiltration comes to waterlogging. In these conditions occurs reduction processes and usually lead to decreasing of pH reaction and availability of plant nutrients. Furthermore, increases resistance of root penetration in soil depth, reducing the yield but also the quality of the crops. According Miloš (2007) on compacted soils average yields can be decreased by 15-20%, but in the same time the fuel consumption can increase by 20-30%.

These changes can be followed in continuity by readings of bulk density and total porosity (Håkansson and Lipiec, 2000) or packing density (van der Akker, 2002). According to Lebert et al. (2007) only five parameters can be used to assess soil compaction in subarable horizons, and one of them is packing density (PD). Based on these values, the soil can be classified into five classes: from 1 (very light structure) to 5 (very heavy structure).

Researches were conducted with the aim: a) recording the current situation and the intensity of soil compaction damages in agricultural area of eastern Croatia; b) identification of soil properties that are in a strong correlation related to the compaction.

Material and methods

Research of compaction of agricultural soils in intensive agricultural production were conducted on 40 locations in eastern Croatia (Slavonija and Baranja region). From the opened profiles at the locations describes the morphological properties and samples from genetic horizons for soil types identification were collected. For the assessment of soil compaction of arable and subarable horizon, samples were collected in disturbed condition (80 samples) and undisturbed conditions in the cylinders of 100 cm^3 in five repetitions at each depth (total 400 samples). According to the Croatian soil classification (Škorić, 1986) was determined are three soil types: Chernozem (10 locations), Luvisol (15 locations) and Pseudogley the other 15 locations. In samples were analysed: soil texture according to HRN ISO 11277:2004, humus content with modified bichromate method, particle density by Albert-Bogs method, bulk density with cylinders of 100 cm^3 volume. Total porosity and packing density of particles were determined by calculation. The results were statistically analysed in Statistica 10.

Results and discussion

On the intensity of agricultural soil compaction directly affects the content of clay and organic matter. The research covered three soil types: chernozem pseudogley and luvic soil. In samples of arable and subarable horizons in addition to texture and humus content and the soil density (bulk and solid phase), overall porosity and packing density.

Humus content

Data from the Table 1 show low humosity agricultural soils. The average humus content in the arable horizons varies between 2.06% of the Pseudogley soils and 2.18% of the Chernozem. The humosity decreasing with the depth (Table 2). So average value of subarable horizons varies betwen 1.17% in Pseudogley to 1.57% in Chernozems. In the upper horizons of chernozems humus content are in highly significant correlation with packing density (r = 0.874**) and significant correlation with bulk density (r = 0.695*). In Figure 1-4 are shown the influence of humus content on compaction parameters.

Texture and clay content

Analysis of the clay content in the arable horizons (Table 1) shows considerable variability among soil types, but also within the same type. In Chernosems is in the range from 21.05 to 42.64%, and according to the particle size distribution: silty clay (50%), silty clay loam (40%) and silty clay (10%). In pseudogley soils dominated silty loam texture (80% of samples) over silty clay loam (20%). Content of clay particles varies in a range from 15.94 to 31.89%. In Luvisols the clay content vary from 17.13 to 28.64%, and prevailing (53%) silty clay loam over the silty loam (47%). Clay content vary from 15.94 do 31.89%. In luvisol soil clay content ranging from 17.13 to 28.64%, but unlike pseudogley prevalent (53%) silty clay loams over silty loam (47%).

In subarable horizons of chernozem clay content is lower and vary in the range from 20.23 to 44.29%. Prevailing silty loam (60%) (Table 2). This lower clay content in deeper horizons of chernozems is logical. In fact, the forming processes of chernozem are related to semiarid climate in which there is not enough rainfall (Škorić, 1986) for more intensive leaching process of colloidal fraction from surface horizons.

On the other hand, the results in Table 2 show different intensities of eluviation in pseudogley and luvisol soil types. In subarable horizons of pseudogley, clay content are significantly increased in relation to upper layers. The average content was 26.44%, but with a lower coefficient of variation (CV = 18%) than in the upper horizons, where it amounted to 23.47%. Intensive eluviation confirmed the fact of increasing the silty clay loam content to 47%, and silty clay content decreased to 53% compared to the arable horizon. In subarable luvisol soil horizons (Table 2), the clay content in the range from 17.53 to 33.40%. This means an increase of silty clay loam at 80%, and a lower of silty clay content for 27%.

Table 1. Soils physical properties in arable horizon

Soil type		Clay %	Organic matter %	Bulk density Mg m^{-3}	Packing density Mg m^{-3}	Overall porosity %
CHERNOZEM	n	10	10	10	10	10
	x	29.29	2.18	1.42	1.69	41.98
	Sd	7.85	0.40	0.08	0.13	4.01
	Cv	26.78	18.26	5.60	7.93	9.54
	min	21.05	1.70	1.29	1.51	37.08
	max	42.64	2.83	1.52	1.89	48.40
PSEUDOGLEY	n	15	15	15	15	15
	x	21.35	2.06	1.43	1.62	42.15
	Sd	5.01	0.39	0.11	0.14	4.02
	Cv	23.47	18.83	7.78	8.95	9.53
	min	15.94	1.60	1.20	1.35	35.60
	max	31.89	2.89	1.61	1.90	52.00
LUVISOL	n	15	15	15	15	15
	x	24.74	2.08	1.42	1.65	42.23
	Sd	3.25	0.44	0.07	0.09	3.40
	Cv	13.16	21.26	5.08	5.29	8.06
	min	17.13	1.36	1.29	1.44	33.62
	max	28.64	3.10	1.56	1.77	48.40

Note: n - number of analysed samples (locations), x - arithmetic mean value, max -maximal value, min - minimal value, Sd - standard deviation, Cv – variation coefficient (%).

Soil bulk density

To estimate the intensity of compaction of agricultural land one of the most important indicators is the soil bulk density. Higher values indicate increased density, mostly due to low humus content, increased content of clay or tiny pores. The result is greater resistance of plant roots penetration to soil. Critical values are 1.6 Mg m^{-3} for loam and clay loam, 1.4 Mg m^{-3} for clay soils, and for silty clay loams 1.7 Mg m^{-3} (Jones, 1983, quote: Hazelton and Murphy, 2007).

Result in Table 1. According Hart (quote: Hazelton and Murphy, 2007) show low to medium values of bulk density in the upper horizons (1.20 to 1.61 Mg m^{-3}). Highly significant correlation (r = 0.665**) between bulk density and clay content with only the upper horizons of pseudogley soil type. In subarable horizons of pseudogley clay content and bulk density are in significant correlation relationship (r = 0.567*), as in luvisol soils (r = 0.596*).

Table 2. Soils physical properties in subarable horizon

Soil type		Clay %	Humus %	Bulk density Mg m^{-3}	Packing density Mg m^{-3}	Overall porosity %
CHERNOZEM	n	10	10	10	10	10
	x	28.87	1.57	1.38	1.64	45.19
	Sd	7.87	0.35	0.06	0.10	2.50
	Cv	27.27	22.31	4.61	6.38	5.53
	min	20.23	1.17	1.3	1.48	41.96
	max	44.29	2.42	1.48	1.82	49.02
PSEUDOGLEY	n	15	15	15	15	15
	x	26.44	1.17	1.52	1.76	40.49
	Sd	4.76	0.27	0.09	0.12	3.83
	Cv	18.00	22.76	5.79	6.69	9.45
	min	21.25	0.74	1.37	1.57	34.12
	max	37.72	1.59	1.68	1.99	47.91
LUVISOL	n	15	15	15	15	15
	x	27.82	1.42	1.55	1.80	38.93
	Sd	4.03	0.32	0.09	0.12	3.41
	Cv	14.49	22.78	5.90	6.49	8.76
	min	17.53	0.73	1.39	1.55	33.33
	max	33.40	1.97	1.72	1.99	45.49

Note: n - number of analysed samples (locations), x - arithmetic mean value, max - maximal value, min - minimal value, Sd - standard deviation, Cv – variation coefficient (%).

Effect of humus and clay content on bulk density in subarable pseudogley horizon is shown in Figure 3. Maximum values of bulk density in subarable horizons pseudogley and luvisol soils (Table 2) reaches a critical value after which is very difficult due to penetration of plant roots.

Packing density

According Kämpf et al. (1999) increasing the packing density values significantly influence on mechanical resistance of the soil root penetration. Very heavy compacted soils have very low infiltration, poor aeration and resistance of roots penetration. Reduced growth of plant roots in depth, according to Croucher (2005), occurs with the bulk density of 1.2 Mg m^3. However, the problem is not easy to notice with high content of clay which cracking, because the root grows through the cracks occurred, even if the bulk density increases. As in soils with a high clay content effects of compaction occur at lower values of bulk density, for evaluation of clay component influence on soil compaction need to be used packing density, which is calculated according to the formula: PD = ρ_v + (0,009 × clay %).

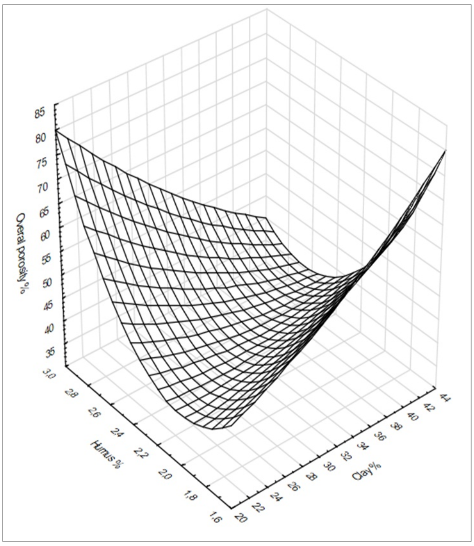

Figure 1. Impact of the clay content and humus to the overall porosity in arable horizons of the Chernozems

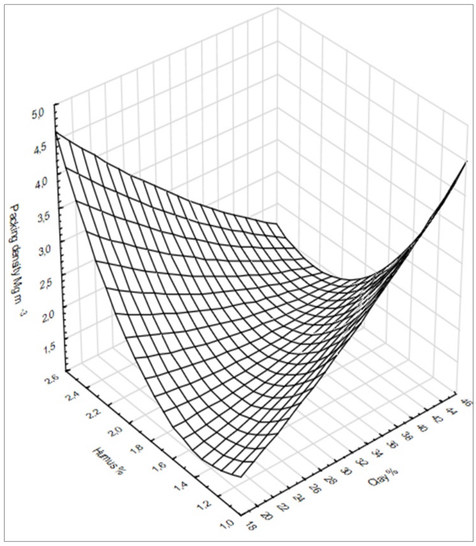

Figure 2. Impact of the clay content and humus to the packing density in subarable horizons of the Chernozem

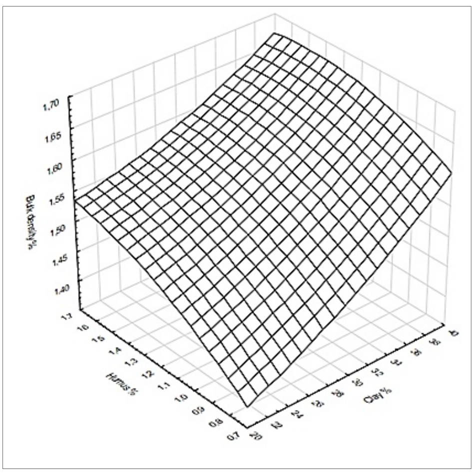

Figure 3. Impact of the clay content and humus to the bulk density in subarable horizons of the Pseudogley soils

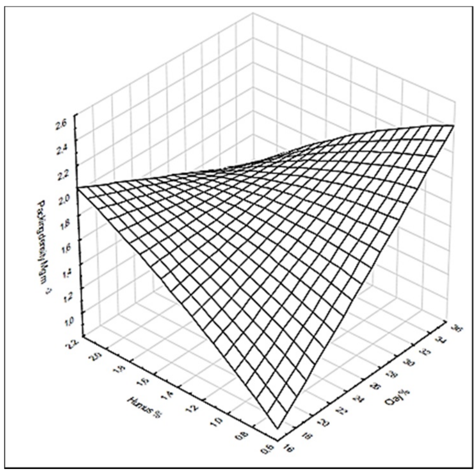

Figure 4. Impact of the clay content and humus to the packing density in subarable horizons of the Luvisols

Values of packing density are in very strong connections with bulk density and clay content (Table 1 and 2). Minimal values in arable and subarable horizons (1,35-1,57 Mg m^{-3}) indicate the mean density packaging, and maximal values (1,77-1,99 Mg m^{-3}) are indicator of the high compaction. Figure 2 shows the dependence of the packing density to the clay content in chernozem subarable horizons (r = 0,788**), and on the Figure 4 are shown same dependence (relationship) in luvisols (r = 0,777**).

Overall porosity

The process of soils compaction primarily reflects on decrease in the volume of large pores and then on small pores. Therefore, the calculation of the total porosity are an indirect indicator of the compaction of agricultural land, because any increase in clay content, bulk density or density packaging reduces the amount of pores in soils. Figure 1 shows the impact of the clay and humus content on the total amount of pores in the upper horizons of chernozems. Between clay content and porosity is significant negative correlation (r = -0.702*), and between the humus and porosity very significant negative correlation (r = -0.808**).

Conclusions

Based on the results of the research presented in this paper can be concluded that the agricultural land in eastern part of Croatia (Slavonia and Baranja region) present different degrees of degradation of soil physical properties. Soil are, according to the values of density packaging, within the limits from medium to severe compaction in the upper (0-25 cm) and subarable (25-50 cm) horizons. There was a strong and very strong correlation of soil compaction with the clay content, humus content and soil bulk densities. Porosity is in a very strong negative correlation with soil compaction.

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Review paper

Review of research and practice of production and tillage systems in Podravje region (Slovenia)

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Abstract

In the scope of production and tillage systems for Eastern part of Slovenia (Podravje region) we analyzed results of 4 research projects and two case studies: company Perutnina Ptuj ploughing and non ploughing tillage and farm Majerič used just conservation tillage in integrated production system in field crop and vegetable rotation. In case of comparison of grain maize yield between conventional tillage incl. sowing and direct sowing into cover crops the yields were not different in the case of use *Trifolium incarnartum*, but in the case of *Lollium multiflorum* was lower on sandy soils. On the slope field with clay soils comparisons between conventional tillage and sowing in cover crops resulted up to 3.5 t ha^{-1} of eroded soils. In two soil types between conventional and conservation tillage incl. ripping were not significant differences in crop rotation yields (maize, winter wheat and oilseed rape), but the yields decreased in direct sowing treatment. No significant differences were among content of humus, but CO_2 emissions differed just after tillage. The highest Ecological Foot Print was calculated in case of conventional tillage, and the lowest in case of conservation tillage and depending mainly on use of fuel. After 3 years trials no impacts were on the content of humus in the soil regards different tillage systems, but number and mass of living organisms and ecological foot print of crop and vegetable production differed significantly among production systems (conventional, integrated, organic and biodynamic). However, after 7-years crop rotation in different production systems show promising results about soil characteristics and yields. For those further research of tillage systems needs to be focused more interdisciplinary, especially on sustainable i.e. organic production systems.

Key words: production system, tillage system, organic matter, foot print, yield,

Introduction

Food, feed and energy production, their low prices and safety, rational use of energy, low environmental impacts on the soil characteristics and biodiversity are the main contradictions depending on production and tillage systems, mainly influenced by climate and type of soils. Innovative solutions with lot of 'Pro et Contra' arguments

(Gomiero et al., 2011; Williams and Hedlunt, 2013) are only partly acceptable for producers because of lack of interest, machinery, profit, not clear long term effects on the soil, biodiversity and yields. Also public opinion is very often opposed to alternative tillage systems. Apparently good solutions like sowing clover into interrow space of maize and direct sowing of maize in the second year in Switzerland (Amon et al., personal communication Swiss federal agric. institute) have never been accepted in practice. In whole scale accepted USA practice of conservation tillage after soil erosion crisis of conventional produced maize in monoculture brings the new problems in weed resistance, increased pest damage and the negative effects on soil profile. Solutions like pest and Roundup resistant GMO plants are under debate in context of long term effects on environment and even food safety.

The problems in a long term acceptable production and tillage systems with strong influences to storage and supply of water, soil fertility, soil compaction, weed suppressing, yielding, use of energy, environmental impacts, etc. However, organic agriculture relies on a number of farming practices based on ecological cycles and aims at minimizing the environmental impact of the food industry, preserving the long term sustainability of soil and reducing to a minimum the use of non renewable resource (Gomiero et al., 2011). Even conventional researchers like Karlen et al. (2013) conclude that good nutrient management and crop rotation reflect in yield and soil fertility differences between no-tillage and more intensive tillage. Based on 9-year maize-soybean rotation average grain prices and yields was twice more profitable as continuous maize. The fact is that many factors like crop rotation and complete nutrition to meet requirements to help soil/plant system to resist harmful external stress has interdisciplinary co-effect on soil compaction (Hamza and Anderson, 2005). In this contexts conservation agriculture systems appear to be interesting options to achieve more sustainable and intensive crop production under different agro ecological environments because they use efficiently available resources and maintain soil fertility. However, this mostly results from the permanent presence of organic mulch on the soil surface and the incorporation of cover crops in the rotations. Such modifications require a significant reorganization of the production process at farm level, and when facing technical or socioeconomic constraints, most farmers usually applying only partially the three main principles (soil tillage reduction, soil protection by organic residues and diversification in crop rotation) of conservation agriculture. Investigating the consequences of such partial implementation of conservation agriculture principles on its actual efficiency and assessing the most efficient participatory approaches needed and adapt conservation agriculture principles to local conditions and farming systems (Da Silva et al., 2013).

Due to previously mentioned statements and findings, the aim of this contribution is research evaluation of production and tillage systems (done by University of Maribor) in Eastern part of Slovenia during past 15 years with focus to user area with critical assessment of the topic.

Methods

We have analysed situation in the Podravje region (Slovenia) and reviewed 4 national research projects:

a) Bavec F. et al. (1996-1998): L4-7408. Technological - environmental comparison of conventional and more environmental friendly maize production systems;
b) Bavec M. et al. (2008 – 2010): J4-9532 Quality of food depending on agricultural production system;
c) Stajnko D. et al. (2010-2012): V4-1042 Research of alternative soil tillage systems on better soil fertility, increasing of humus and decreasing of CO_2 emission;
d) Bavec F. et al. (2012-2014): V4-1137 Alternative crops in different production and crop rotation systems as a basic parameter for adaptation to climatic circumstances for food and feed supply.

Projects were provided by University of Maribor, Faculty of Agriculture and Life Sciences and also the newest research papers were analyzed. The aims of review are suggestions for further development of tillage and production systems.

Results and discussion

Ploughing vs. direct sowings into cover crops

In autumn sowing - biennial (rye, Italian ryegrass) and spring sowing - annual cover crops (phachelia, white mustard) decreased soil erosion for 90% during growth period of maize. On the other hand uncovered soils after ploughing decreased runoff surface water from 30 to 50%. Thus, covered field surface and the method of treatment or pre-sowing preparation are found as very important factors influencing the reduction of soil erosion. But opposite to the expectations, also in rye sowing comes to extremely high soil erosion immediately after sowing, when the pre-sowing preparation is very fine. In contrast, the unstructured soils or open soils boost erosion especially in slope land. Yield of silage maize is not reduced after dead cover crops, but it is reduced after rye. There has been delay of maize development in early growth stages, especially in case of incarnatum. The main reasons are low temperatures of soil under cover crops and in case of rye the content of N_{min} in the soil after different tillage systems. Mineralization processes were slower after rye compared to white mustard, N was used by competition for decomposition of plant rests and maize yields were reduced eventhough rye plants accumulated about 60 kg N ha^{-1}. Dead cover crops accumulated about 90 kg N ha^{-1} in the autumn, which was available for the plants in the spring.

After 439.6 mm of rainfall in the period from October to April in case of loam to clay soils at slope field up to 27%, the sum of eroded soils are follows: a) in the treatment of ploughed open furrow from 2900 to 3450 kg of dry eroded soil ha^{-1}, b) on untreated field 1550 to 2800 kg of dry eroded soil ha^{-1} and c) on the plots sown with rye from 174 to 200 kg of dry eroded soil ha^{-1} were found. In the case of plowed fields before sowing was 83.2 kg NO_3-ha^{-1} and after rye 42.7 kg NO_3-ha^{-1} on the slope part of fields, but under hill slopes 112.9 kg and 78.3 kg NO_3-ha^{-1}, respectively. Emergence of maize plants delay 7 days in rye comparing with ploughed field, but the final number of plants were similar among all treatments (81500, 82200 and 81000 plants ha^{-1}). Ploughed plots, untreated plots and rye treatments did not statistically differ in green mass yield (81.6, 83.7 and 81.0 t ha^{-1}) and grain yield (7.6, 7.6 and 7.3 t ha^{-1}), respectively.

In case of undersown clover into the maize plants in the heavy soils at University center the soil erosion was reduced, but due to the intensive growth of weeds (especially *Convolvulus* sp.) the system of undersown clover gave statistically lower yields and system was completely unsuccessful.

Production systems

The project was carried out on University centre of the Faculty of Agriculture and Life Sciences in Pivola in Maribor where in field experiment were produced different field and vegetable crops in two rotations (1- usual in the region, 2 – alternative) in four production systems: conventional, integrated, organic and biodynamic and in the control plots. Yields were significantly different between production systems in wheat and spelt with higher yields in conventional and, b integrated out for cabbage, beetroot and cucurbits has been a noticeable trend of higher yields in alternative systems. In experimental plots earthworms were determined in rotation 1 in October 2009 and 2010 using the 'hot' mustard extraction. Earthworm populations and their biomass were significantly higher and similar levels of biodynamic and organic plots compared to conventional and integrated in all studied crops where the highest value were found on plots with oil pumpkins. The next section focuses on the environmental footprint, using the included fixing life cycle assessment (LCA - Life-Cycle Assessment), which is still under development for use in agriculture. For the purposes of the research for the calculation was used the Sustainable Process Index ® (SPI) – a tool created by the Technical University of Graz (TU Graz). SPI's methodology was adapted for use in agriculture (Turinek et al., 2010). Three-year (wheat and spelt) and one year (other crops) data from long term trials and the field results reflected the real situation data and production systems were analyzed. Ecological footprint of wheat and spelt of organic and BD was 6-8 fold lower compared to conventional and production systems, but ecological efficiency of organic and biodynamic was 5-6 fold higher compared integrated to conventional production systems. The majority of ecological footprint is in conventional and integrated due to the use of pesticides and mineral nitrogen using a lot of energy in their production. But in the case of biodynamic and organic the majority was due to use of mechanization. The basic issue was how to make more sustainable production systems, which are largely used today and how they can be improved in order to increase sustainable food production for future generations. However, we found that improvements are needed in the mechanization in all investigated systems and also better yield of organic system. We have projected the magnitude of the change if any current arable land intended for wheat and spelt switching to organic and biodynamic. The yield (taking into account the relatively low yields in the ecosystem in our study) would be reduced by almost a third and partial footprint and footprint by almost two thirds. As consequence, the environmental performance of production increased threefold. For potentially lower yields in the future solutions and improvements will be needed in production techniques (tillage, fertilization, etc.), land use change (food production, altered rotation, the question of energy crops and sealing the best agricultural land), as amended subsistence policy. The changes are necessary as fossil fuels on which today is almost exclusively based industrial agriculture subsidy, and are expected by the end of this century as well spent. We concluded that uncertainty about oil reserves, rising energy prices and the threat of harmful climate change effects has intensified the search for alternative farming systems that reduce negative environmental impact. Thus, organic and biodynamic farming systems present viable alternatives for reducing the impact of agriculture on environmental degradation and climate change. Nevertheless, possibilities for improvement exists in the area of machinery use in all systems studied and yield improvement in the organic farming system (Bavec et al, 2012). In the next step we studied the sensory quality of white cabbage and red beets in 2008 and 2009. A total of 167 consumers evaluated the four properties (color, smell, taste and willingness to buy) using a nine-point hedonic scale. The results show significant differences between the two PS vegetables; better evaluated was cabbage from integrated control treatment versus conventional model (biodynamic and organic samples were in between), biodynamic and control samples of red beet were evaluated better than the conventional and integrated samples (organic samples were between). In two consecutive years (2008 and 2009) have been measured major macro and micro nutrients in fresh samples of cabbage and beetroot. We have also analyzed different sugars, organic acids, total phenolic compounds and antioxidant activity in samples of beetroot and cabbage in 2009, using established methods. Statistically significant differences between production systems in red beets were found for the content of malic acid, total phenolic content and total antioxidant activity. Characteristically malic acid was present in samples from the control plots, which are followed by samples from biodynamic plots. Conventional, integrated and organic samples contained significantly less malic acid than samples from control. Excretion of malic acid through roots activates the bacteria living in the area around the roots and stimulates their interaction with plants. Plants of "friendly" bacteria also establishing resistance to a wide range of foliar diseases through the activation of plant defense systems. Furthermore, they have samples from a biodynamic and control plots significantly higher content of total phenolic compounds than samples from conventional plots. Even with antioxidant activity samples from biodynamic and control plots had higher values than samples from conventional plots. There is also a significant positive linear correlation between the total phenolic content and antioxidant activity (r^2 = 0.6187), which coincides with the results of studies in other vegetables. Finalizing work on the quality of beetroot, we researched, is presented the importance of the measured ingredients for human health, as well as the resilience and health of the plants and we put them in perspective for the future. In the growing seasons 2008-2010 we had a similar experiment at additional sites in the area Goricko Natural Park, but with less studied crops (wheat, cabbage, beetroot and oil pumpkins) and three production systems (conventional, integrated and organic) and a control treatment. Sensory quality of cabbage and beetroot were tested for processed products (sauerkraut and beetroot juice). Based on the results of this experiment the broader impact of different production systems were studied, namely, agronomic, environmental and economic efficiency of production systems, the impact on crop quality parameters and a framework of indicators which included agronomic, environmental, economic and social indicators were established. In 2010, we also conducted an epidemiological study in which the two test groups of people ate differently, ranging from 63 students 31 got organic and 32 conventional food diets for three consecutive days. The results have confirmed the hypothesis of the effect of diet on the presence of pesticides in human body fluids – students eating organic had less organophosphorous compounds in the urine.

Comparison of ploughing, conservation tillage and direct sowing

In three year field experiment with three treatments, the ploughing and conservation tillage incl. ripping did not result in significantly different yields, but direct sowing reduced the yield of rotated crops (corn-wheat-rapeseed). The values of humus in both locations in all three treatments increased, but between treatments were not shown statistically significant differences. In experiments the organic matter transported to the fields was estimated and share of accumulated carbon was 10-15% higher, which is less than was found in the literature without removal of crop residues, which increased organic matter in the soil for 21 and 7%. The most important results are direct measurement of CO_2 emissions from the soil by plants using LC PRO + ECHO. The highest CO_2 emissions of 13.94 µmol $m^{-2}s^{-1}$ were measured immediately after treatment of the soil with a plow during the first 24 hours. Followed by treatment with loosening where we measured the maximum value of 11.54 µmol $m^{-2}s^{-1}$ CO_2 also immediately after treatment. In the next days emissions were equal to the emissions in the raw soil and reach values 3.54 to 6.32 µmol $m^{-2}s^{-1}$ CO_2), partly due to dehydration of the surface layer of soil and unexplained causes. These findings are partly consistent with literature where the highest recorded emission was almost 15 days after disc harrows without tillage. The dynamics of CO_2 emissions in the Slovenian agro-ecological conditions are mostly affected by fluctuations in temperature, which match with the reporting of Bruce et al. (1999). Lack of rainfall was correlated with reduced emissions only in extreme summer droughts. In contrast to some other experiences we have in the winter mostly positive measure CO_2 emissions, but do not exceed 0.29 µmol If the ground was frozen for several days in a row, has been measured negative CO_2 flux $m^{-2}s^{-1}$ with a maximum of 0.12 µmol. Different systems had significantly different fuel (plowing + pre-sowing preparation of 23 l ha^{-1}, loosening 13.60 l ha^{-1}, direct sowing of 21 l ha^{-1}), but the savings in fuel and working time can be quickly lost due to the increased application of herbicides. We found that for the production of rapeseed and ecological footprints left by the plow treatment (4.25 ha), followed by ripping (3.75 ha) and direct sowing of 1.95 ha. Even in the cultivation of maize direct sowing resulted in foot print of 1.85 ha, while the largest footprint re-calculated in the conventional treatment (4.15 ha). The most objective assessment (expressed in ha/t crop) showed that the production of one t of oilseed rape left the biggest footprint (9.2 ha/t of grain) left the conventional cultivation of oilseed rape, the smallest (2.86 ha/t) conservation tillage of maize. Ecological footprint of production of one t of above-ground biomass fraction is significantly greater in the conventional production of rapeseed (4.14 ha t^{-1} of grain), followed by production of winter wheat and maize with absolute minimal footprint (2.86 ha t^{-1}) in conservation tillage (Stajnko et al., 2010-2012).

Crop rotation in different production systems

The study of rotation in different production systems incorporating alternative crops shows significant differences among yields in conventional, integrated and organic treatments. Till now we can conclude that chemical composition of dwarf French bean (*Phaseolus vulgaris* L.) cv. Top Crop was compared among five production systems: conventional, integrated, organic, and biodynamic production systems and the control. Determination of sugars and organic acids was performed with a HPLC system, and identification of individual phenolic compounds using HPLC-MS. The chemical composition of the beans was unaffected by the production systems; however, levels of individual compounds contents were changed. The pods from integrated production contained the lowest levels of glucose and sucrose and the highest levels of catechin, procyanidin dimmers and a vanillic acid derivative. The control treatment, organic and biodynamic production systems, positively affected the levels of sugar content and caused a lower content of catechin and *trans-p*-coumaroylaldaric acids. Beans from the conventional production system contained the lowest levels of fructose, glucose, ascorbic acid, and many phenolics from various groups (Jakopič et al., 2013).

Situation in practice

In flat Eastern part of Slovenia in Podravje and Prekmurje region production system was changing from conventional to integrated (about 25%) and organic (7%), where tillage system is still based on ploughing and separate pre-harvest treatments. But, 30-40 years ago, the systems like direct sowing and similar concepts of 'conservation' tillage were not accepted by professionals. Because of the costs, the company Perutnina Ptuj, started with no-ploughing tillage for winter cereals, and even with spring glyphosate treatments before sowing (it was not allowed in integrated system). Two framers started with direct sowing (one in maize, one in sugar beet). For now is only one who represents success of direct sowing with special activities (crop rotation, deep ripping, care for organic matter, weeding) in the scope of soil conservation.

If we compare upper results (3.1-3.5) with recent literature we can agree that reduced tillage systems have been proposed to prevent soil erosion while the present increase of no-till is motivated mostly because of the decrease of production and mechanization costs. However, the efficiency of the numerous no-plough tillage systems on erosion control is not systematic. The soil must be sufficiently covered by crop residues and the infiltration rate has to remain high enough (Roger-Estrade, 2011). Conservation tillage is a system of management that leaves at least 30% of the soil surface covered by residue between crop harvests and planting, which increases bulk density in the absence of cultivation and may lead to decreases in soil aeration, increases soil organic carbon (SOC) at or near the surface of the soil profile and increases soil microbial biomass and diversity (Page et al., 2013). The soil biological activity depends on the organic matter supply. In addition to providing nutrients and habitat to organisms living in the soil, organic matter also binds soil particles into aggregates and improves the water holding capacity of soil. Most soils contain 2 to 10% organic matter. However, even in small amounts, organic matter is very important. Tillage is one of the major practices that reduce the organic matter level in the soil. Each time the soil is tilled, it is aerated. Soil enzymes act as biological catalysts of specific reactions that depend on a variety of factors, such as the presence or absence of inhibitors, tillage and fertilization, and can be considered as early indicators of biological changes (Mohammadi et al., 2011). But, the presence of plant diseases and weeds may also increase, where crop disease and weed growth, a lack of plant available nutrients, and/or adverse soil structure limit plant development, lower yields may also be observed (Page et al., 2013). According to Scopel et al. (2013) conservation agriculture has been promoted as a way to reduce production costs, soil erosion and soil fertility degradation. However, these effects are mostly result of the permanent presence of organic mulch on the soil surface and the incorporation of cover crops in the rotations. Such modifications require a significant reorganization of the production process at farm level, and when facing technical or socioeconomic constraints, most farmers usually decide for applying only partially the three main principles (Da Silva et al., 2013) of conservation agriculture. Investigating more fully the consequences of such partial implementation of conservation agriculture principles on its actual efficiency and assessing the most efficient participatory approaches needed to adapt conservation agriculture principles to local conditions and farming systems are top priorities for future research (Scopel et al., 2013).

As we found by analyzing foot prints, we agreed that adoption of recommended management practices is crucial to reverse the environmental footprint of agriculture and its impact on climate change. Regarding croplands, these practices can include reduced tillage systems, crop residue management, improved management of nutrients and pests, cover cropping, agro forestry, and utilization of precision agriculture technologies. Judicious implementation of related policies would be crucial for promoting the required links between agricultural production and environmental sustainability (Stavi and Rattan, 2013). There is a trend world-wide to grow crops in short rotation or in monoculture, particularly in conventional agriculture. Numerous factors have been hypothesized as contributing to yield decline, including biotic factors such as plant pathogens, deleterious rhyzosphere microorganisms, mycorrhizas acting as pathogens, and allelophaty or autotoxicity of the crop, as well as abiotic factors such as land management practices and nutrient availability. Despite long-term knowledge of the yield-decline phenomenon, there are few tools to reverting longer crop rotations or break crops. Alternative cropping and management practices such as double-cropping or inter-cropping, tillage and organic amendments may improve the negative effects seen when crops are grown in short rotation (Bennett et al., 2012). Karlen et al. (2013) conclude that with good nutrient management, crop rotation and yield; soil fertility differences between no-tillage and more intensive tillage systems can be minimized and that no-till production can be profitable on glacial till derived soils. Žugec et al. (2006) concluded that under hypogley soil and certain environmental conditions it is possible to apply reduced soil tillage and moderate N fertilization in maize and soybean as previous crop. Jug et al. (2011) found that tillage systems had significant effects on the yields and plant characteristics of wheat and soybean depending on year. Alternative tillage systems compared with conventional tillage gave similar or slightly better 1000 grains weight represents as an even - handed replacement for conventional soil tillage with alternate ploughing for previous crop or with autumn disc harrowing + chiselling.

Organic farming is conserving and utilizing soil, supports ecosystem services, and is more sustainable method of food production than conventional farming. However, conventional farms had significantly greater yield than organic farms, and there was no apparent trade-off between increasing yield and the level of supporting ecosystem services. The organic farms in this study appear to have been intensively managed, with a straight substitution of organic inputs for chemicals but little other efforts to enhance soil fertility. For example, the organic farms applied large quantities of manure compared to conventional farms but conducted mechanical weeding (harrowing), whereas conventional farms applied herbicides (Williams and Hedlund, 2013). Organic agriculture relies on a number of farming practices based on ecological cycles, and aims at minimizing the environmental impact of the food industry, preserving the long term sustainability of soil and reducing to a minimum the use of non renewable resources. Furthermore, organically managed soils have a much higher water holding capacity than conventionally managed soils, resulting in much larger yields compared to conventional farming, under conditions of water scarcity. Because of its higher ability to store carbon in the soil, organic agriculture could represent a means to improve CO_2 abatement if adopted on a large scale. Furthermore, the impact on biodiversity is highlighted: organic farming systems generally influence larger floral and faunal biodiversity than conventional systems. Gomiero et al. (2011) outline energy use in different agricultural systems: organic agriculture has higher energy efficiency of (input/output) but, on average, exhibits lower yields and hence reduced productivity (Gomiero et al., 2011).

Conclusions

Based on the review of analyzed projects and the newest literature we can conclude that sustainable production and tillage systems needs to be interdisciplinary researched and involved into the practice. There is no general rule for tillage systems because of soil texture and their physical conditions associated with climate differences. We suggest that optimal tillage and production systems need to be evaluated based on many impacts like energy use, energy costs, foot prints, environmental pollution, food safety, etc. and not just according to amount of yield for every region, soil type and farm.

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Original scientific paper

Oil rape harvesting by special adapter

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Abstract

Examination of the universal combine equipped with the new adapter for oil rape harvesting was conducted in 2012 yield.

Combine of new design, with 202 kW of engine power, was equipped with modern solution of adapter for oil rape harvesting, which is added – upgraded on to the existing wheat header. Examination of combine with adapter for oil rape harvesting was conducted with the goal to get the results of working quality and productivity which will serve as the mark index of applicability and payoffs of equipping combine with this kind of adapter.

Key words: oil rape, combine, losses, quality, output

Introduction

Based on a literature sources (Malinović et al., 2003, Turan et al., 2007), average losses for combine in oil rape harvesting are 4% to 25%. Besides that, mentioned literature sources point out that the level of harvesting losses is significant feature for a beginning and a deadline of the harvest and also applying of new sorts with reduced content of eurica acids and glucosinolates, which have the features of even maturing and there are no grain wasting in harvesting (collecting).

Examinations of losses and working quality in soy harvest were intensively conducted in the beginning of ‘80-es, when the oil rape also, as the cultivated plant, penetrated in to these areas.

That the harvest should begin when the grain moisture is optimal under 15%, and to end it before the harvest of winter barley and wheat. Influence on the maturing of oil rape has a line of factors: sort features, fore crop, fertilizing, climate conditions and such (Marinković 2006, Malinović, 2002). The fact that after the technological maturity, and which begins 10 to 14 days before the full maturity, there are no increment of dry matter and oil in grains, sends to application possibilities of certain procedures for accelerated moisture diminishing.

Modern combines which in their basic construction have more specific power apropos to generations before, with significant construction improvements of separators that accomplish working speeds in oil rape harvesting to 2 m/s, respectively about 7 km/h. Therewith the losses percentage has to be maintained in acceptable limits. (Turan, 2007).

Material and methods

Combine

For examining the combine with oil rape adapter a combine with tangential threshing system was used, which technical features are in Table 1.

Combine's header desk is a modern wheat variant solution. Separation and attaching to header elevator is easy. The commands for regulation of horizontal and vertical winch position are placed on a joystick, by which the commanding of position control is easily performed.

Table 1. Technical-technological combine features

Parameters	Combine type
	Tangential - LCS
Engine power (kW/HP)	202/275
Oil rape adapter Type	Laverda Biso Integral CX 100
Working width (m)	6.6
Characteristic of combine	
Drum	1
Width (m)	1.67
Diameter (mm)	600
Effective surface of threshing + separation (m^2)	5.58 + 9.06
Hopper volume (l)	8.800

Device for oil rape harvesting

A mean of adaptation for oil rape harvesting is a better adaptation of existing headers to oil rape harvesting. It enables an adaptation to working conditions and successful cutting of the path and the undone part of the crops (Figure 1). Its purpose is universal, adapted to all worlds' header builders with engagement width from 4.8 to 7.6 m.

Figure 1. Oil rape adapter

Crop

Oil rape harvesting is conducted yield, (Table 2).

Table 2. Basic crop data

Parameters	Marks
A. Crop	Oil rape
1. Accomplished yield (t/ha) - Biological - Collected	 4.800 4.637
2. Grain and straw moisture (%)	9.5 / 58.60
3. Assembly (plants/m^2)	34
4. Crop state	clear/upright
5. Grain: straw relation	1:3.46
6. Mass of 1000 grains (g)	3.48

Combine working regime

The combine worked in standard regime of adaptation for oil rape harvesting (Table 3).

Table 3. Combine working regime

Parameters	Value
1. Drum revolution (min^{-1})	750
2. Threshing concave extroversion	16-17
3. Fan revolution (min^{-1})	1.100
4. Sow adjustment: upper, lower (mm)	12/3/0
5. Working speed (km/h)	4.0
6. Mass flow (kg/s)	14.77
7. Grain flow (kg/s)	3.31

Working method

A test issue covered quality and exploitation parameters of combine work. Among quality parameters, the most important ones were established losses.
Thresher losses are recorded by use of the cloth for collecting a threshed mass, while header losses presented grains and husks, which were collected beneath the cloth. The data collected in the laboratory were processed by standard mass measuring apparatus, while the data were processed by standard statistical methods and presented in tables together with research results.

Among the exploitation parameters on the field, working speed was recorded, engagement width and production time structure. Based on these parameters, working exploitation parameters of combine with adapter for oil rape harvesting were calculated.

The examination of universal combine equipped with the adapter for oil rape harvesting was conducted yield on daily temperature of 34^{o}C and relative air humidity of 40%.

New conception combine, engine power of 202 kW, was equipped with modern solution adapter for oil rape harvesting, which was upgraded on to the existing old variant wheat header. The examinations of the combine with an adapter for oil rape harvesting was conducted to get the results of working quality and productivity, which will serve as the mark index of applicability and payoffs of equipping combine with this kind of adapter.

Results and discussion

Qualitative parameters of combine work

Header losses

Analyzing the loss examination results in conditions of biological yield of 4.8 t/ha oil rape, the header losses were low. Header losses in a form of free grain are insignificant and on the level of 2.17% with 4 km/h to 3.53% with the speed of 6 km/h. Grain losses in husk is not significant (Table 4). Total header losses were around 2.17% with the speed of 4 km/h and 3.53% with 6 km/h of biological yield. Lying crops and relatively high plant humidity explains this level of losses.

Table 4. Header losses

Working speed (km/h)	Mass flow (kg/s)	Grain flow (kg/s)	Header losses					
			Free Grain		Grain in husk		Total	
			kg/ha	%	kg/ha	%	kg/ha	%
4	14.77	3.31	104.24	2.17	0	0	104.24	2.17
5	18.46	4.14	137.15	2.86	0	0	137.15	2.86
6	22.15	4.96	169.34	3.53	0	0	169.34	3.53

Thresher losses

Thresher losses in a given examination conditions for oil rape have a tolerated value. Free grain losses were 0.53% respectively 2.77% depending on combine's working speed (Table 5). We can notice a significant increment of losses in the form of free grain by the function of working speed (from 0.53 to 2.77%).

Table 5. Thresher losses

Working speed (km/h)	Mass flow (kg/s)	Grain flow (kg/s)	Header losses					
			Free Grain		Grain in husk		Total	
			kg/ha	%	kg/ha	%	kg/ha	%
4	14,77	3,31	25,66	0,53	0	0	25,66	0,53
5	18,46	4,14	41,91	0.87	0	0	41,91	0,87
6	22,15	4,96	133,04	2,77	0	0	133,04	2,77

Total losses

Combine total losses represent a sum of header losses and the losses on the thresher. In this case they were from 2.71 to 6.3% with the working speeds of 4 to 6 km/h, which was expected for this crop and increased humidity and plant mass conditions like this (Table 6).

Table 6. Total combine losses

Working speed (km/h)	Mass flow (kg/s)	Grain flow (kg/s)	Header losses					
			Free Grain		Grain in husk		Total	
			kg/ha	%	kg/ha	%	kg/ha	%
4	14.77	3.31	129.91	2.71	0	0	129.91	2.71
5	18.46	4.14	179.05	3.73	0	0	179.05	3.73
6	22.15	4.96	302.39	6.30	0	0	302.39	6.30

Exploitation parameters of combine work

The combine is equipped with wheat header of engagement width 6.6 m. Engagement width accomplished was a working width of 6.2 m, respectively 0.94 of engagement width. Respectively engagement width was 28 rows of an inter row distance of 0.25 m. Working speed, which is one of the basic output factors, was 4 km/h.

Transport organization and reception capacities didn’t interfere the working of combine, so that weren’t any organizational stoppages during the working of combine. A display of basic exploitation parameters of combine working is given in Table 8.

Table 8. Harvester exploitation indexes

Parameters	Value
1. Working width (m)	6.6
2. Working speed (km/h)	4
3. Used time quotient (-)	0.9
4. Collected proceeds (t/ha)	4.63
5. Acreage output (ha/h)	2.23
6. Mass output (t/h)	10.72
7. Acreage productivity of the driver (min/ha)	26.9
8. Mass productivity of the driver (min/t)	5.6

Conclusions

Exploitation examinations of universal combine harvester were conducted in dry crop grains (9.5%). The crop was lying with increased plant mass humidity, which resulted in harder working conditions and increased losses on combine thresher (2.77 %), with the working speed of 6 km/h.

Based on losses that were realized by combines of older technological constructions that are used even today in Vojvodinian conditions, it wouldn't be surprising that the thresher losses, the header also, had even higher values.

In the given examination conditions the combine accomplished acreage output of 2.23 ha/h, respectively mass output or grain flow of 4.63 t/h.

An impression is imposed that there is a reason of applying the adapters for oil rape harvesting with two side scythes.

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Original scientific paper

Soil tillage systems in maize as a key factor in soil protection against erosion in the Czech Republic

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Abstract

Grain and silage maize are crops, where acreage increased in last years. Successful soil management system is based on improving soil properties. In lowlands, especially in dry areas, water saving soil tillage technologies can be enough efficient against a lack of suitable water for maize plants during vegetation. On the other hand, the systems, which are preserving soil erosion, could be used on slope areas. According to Czech legislatiton connected with protection of soil against erosion, different types of conservation tillage methods are applied by farmers. The results have shown that conventional and also minimum soil tillage can be suitable for maize growing, especially in lowlands. For areas endangered by water erosion, different modifications of conservation tillage are used. Suitable soil tillage management has to create good conditions for germination, emergence a development of maize stands. Conditions for high yield productivity could be in relation with improvement of soil fertility and protection soil against erosion.

Key words: soil tillage, grain ans silage maize, water erosion, crop residues

Introduction

Maize (*Zea mays*) is warm-requiring crop growing in the Czech Republic for silage maize (180 000 ha) and for grain (120 000 ha). Growing area for silage maize is in last years increased, when biomass is requested by biogas stations (total number 487, and from it 317 are agricultural; 1.7.2013). With increasing growing area of maize, some agronomic aspects are coming:

In general - maize:

- is a wide row crop, with slow growth at the beginning of vegetation period, sensitive to soil erosion,
- according to Czech legislation, there are valid rules for growing of maize in soil erosion areas,

- possibility to grow some years repeatedly in sequence, but with some risks; especially higher occurrence of pests – corn borer (*Ostrinia nubilalis*) and western corn rootworm (*Diabrotica virgifera virgifera)*.

Grain maize
- grown in warmer conditions, harvested in late autumn (October, November),
- high amount of crop residues, which is a source for diseases (*Fusarium sp*., etc.),
- almost only spring crops are possible to grow after.

Silage maize – as fodder for animals
- with a closed cycle based on usage of farmyard manure,
- suitable fore-crop for winter wheat.

Silage maize – as a source of energy for biogas production – new phenomenon

System is based on production and usage of digestate, by-product of anaerobic digestion. Makádi et al. (2012) note that quality of a digestate is determined by the digestion process used and the composition of ingestates therefore the agricultural use and efficacy of the nascent materials could be different. Nevertheless, some common rules can be found in the course of the digestion process which allows us to evaluate the results of a digestion process.

All above mentioned aspects in combination with soil characteristics, properties and current soil state, could be used as important information for modification of appropriate suitable soil tillage. Successful soil management system is based on improving soil properties. In lowlands, especially in dry areas, water saving soil tillage technologies can be enough efficient against a lack of suitable water for maize plants during vegetation. On the other hand, the systems, which are preserving soil erosion, could be used on slopes. Haberle and Mikyskova (2006) write, that yields of crops, in a long term view, are the result of interaction of farmer's skill and technical equipment with either conservative environmental conditions of sites (altitude, soil, climate). The yield and quality is affected by occurence of biotic and abiotic stresses in a year governed by weather course.

The aim of the work was to compare the effect of different soil tillage on yield of maize and to assess impacts on soil environment. In South Moravian region three soil tillage systems were compared (conventional, minimum and no-tillage). From the soil parameters, bulk density, soil moisture, porosity, minimum air capacity and water infiltration into soil were evaluated. In second part, approaches in soil tillage with the antierosion effect in conditions of the Czech Republic are decribed and explained valid legislation in this topic.

Materials and methods

The effect of different soil tillage for grain maize was assessed in two field trials established in different soil-climatic conditions in South Moravian region. Both localities are in maize-production region. Locality Visnove is characterized with brown loamy soil, in comparison with clay-loamy fluvisol, which is in Zabcice. Average annual temperature is similar in both localities (8.9°C), annual sum of precipitations differed (480 mm in Zabcice and 557 in Visnove). Different variants of soil tillage were used: CT – conventional tillage - ploughing to the depth of 0.22 m; MT – minimum tillage included soil loosening (disking) to the depth of 0.15 m and NT – no tillage (direct drilling without any tillage). In Zabcice, grain maize was grown after winter wheat and two variants of soil tillage were used (CT and MT). In Visnove, there is grain maize monoculture, all three variants were assessed (CT, MT and NT). The grain yield was evaluated in both trials, in Visnove physical soil properties (bulk density, soil porosity, soil moisture, minimum air capacity and water infiltration into soil) were assessed as well. Kopecky's physical cylinders were taken from soil depth (0–0.10 m; 0.10–0.20 m; 0.20–0.30 m) in five replications, each year in June (2005 – 2010). A double ring infiltrometers with diameter of 0.28 m and 0.54 m in soil depth of 0.1 m were used for soil infiltrability measurement.

Results and discussion

Soil tillage and the effect on yield and soil properties

The yield results in Zabcice (2008-2012) are shown in Figure 1. Within the five-year average, higher yield was by CT than MT (difference is 0.41 t ha^{-1}). It was found out, that higher yield was found out in four years from five (2011 is exception, when the yield on variant with MT was 0.17 t ha^{-1} higher than CT). Differences are almost non-significant. Only in 2010, statistically significantly higher yield was on CT (differed 1.27 t ha^{-1}). It could be caused by a lack of air content in the soil linked with very wet soil (high amount of precipitations during vegetation). Air content could be limiting factor for development of roots and reduce mineralization of organic matter (lower accessibility for maize).

Similarly, in Visnove, within the ten-years average (2002 – 2012, except 2009 when spring barley was grown), the highest yield was on CT (10.79 t ha^{-1}), following with MT (10.62 t ha^{-1}) and the lowest on NT variant (9.84 t ha^{-1}). Differences in yields between CT and MT were very low, differences among all variants statistically non-significant. Higher amount of crop residues on soil surface negatively affects maize stand establishment and often with higher weed infestation. The yield decrease of grain maize in no-tillage variant is mentioned by many other authors (Maurya, 1988; Borin and Sartori, 1995). No differences among various soil tillage systems found out Kosutic et al. (2005).

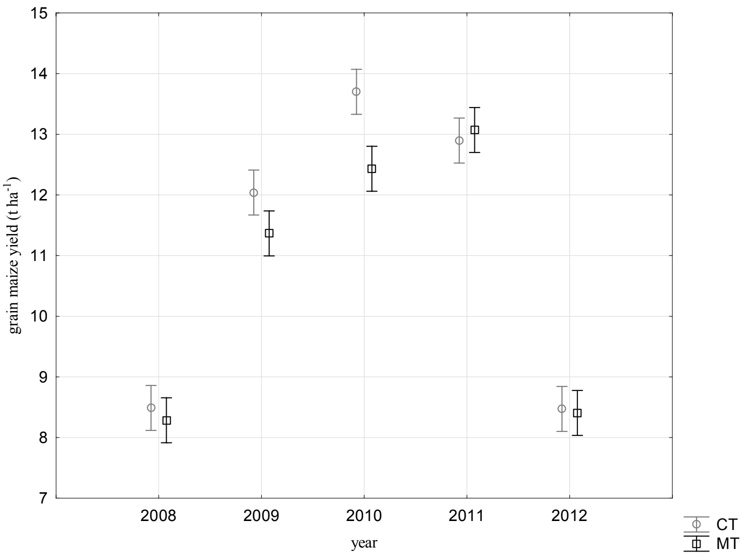

Figure1. Grain maize yield (t ha^{-1}, Zabcice 2008-2012)

Table 1 includes the results from impact of soil tillage on soil properties. Values of bulk density increased with lower intensity of soil tillage and with soil depth. Values around 1.50 g cm^{-3} were found out in variant MT and NT (except surface layer).

The highest values of soil porosity were in CT (50.24% in average of 0-0.30 m), the lowest in NT (44.18%). Smaller differences in soil porosity were between layers 0.10 – 0.20 m and 0.10 – 0.20 m in all variants of soil tillage. Minimum air capacity decreased with intensity of soil tillage, in MT and CT. The values in deeper layers were lower than 10%. Soil moisture was the highest in NT, where surface and the deepest layers had the highest values. CT and MT variants had the driest layer close to the surface.

Table 1. Physical soil properties (Visnove, 2005 – 2010)

Soil layer	Bulk density (g cm^{-3})			Soil porosity (%)			Minimum air capacity (%)			Soil moisture (%)		
Soil tillage	CT	MT	NT	CT	MT	NT	CT	MT	NT	CT	MT	NT
0 - 0.10 m	1.19	1.22	1.36	54.92	53.64	48.37	20.01	17.25	11.97	17.41	21.99	27.37
0.10-0.20m	1.35	1.53	1.52	48.71	41.68	42.07	12.39	7.94	8.44	25.10	25.66	23.70
0.20-0.30m	1.39	1.49	1.52	47.09	43.35	42.15	10.87	10.13	9.10	25.12	25.67	27.23
Average 0 - 0.30 m	1.31	1.41	1.47	50.24	46.22	44.18	14.42	11.77	9.84	22.54	24.44	26.10

Soil tillage and water infiltration rate

The results from location Visnove shown, that the highest infiltration rate in first minutes was for conventional variant (CT) and the lowest for no tillage variant (NT). But this order was changing through time intervals (1, 10, 30 and 60 min) and the infiltration rate of NT was increasing to the level of CT variant. This corresponds to the review of Strudley et al. (2008), which describes the tendency of NT to increase macropore connectivity and deeper movement of water. Lipiec et al. (2006) noted that the differences in initial infiltration and reduction of infiltration rate with time among tillage treatments imply higher capability of conventional tillage pore system to increase amount of water infiltrating before filling macro-pores and reaching steady state. Kroulík et al. (2007) compared the differences between tillage practices at same locality in 2006. The results were similar – the highest infiltration rate was observed for CT and lowest for minimu tillage (MT) variant. Coloured water infiltration was used as well, and it showed a water saturation of CT in the top layer, while the variants with reduced tillage (MT, NT) were saturated deeper.

The above mentioned results have shown that conventional and also minimum soil tillage can be suitable for maize growing. These soil tillage systems, in differrent modifications, are based on inverting (ploughing) or loosening soil (chiseling or disking) and used in areas without problems with soil erosion. No-tillage system is extreme variant which is not appropriate to standard crop management practice for maize in Czech conditions.

Soil tillage systems in areas threatened by soil erosion

In the Czech Republic there is more than 50% of agricultural land exposed to water erosion (Janeček et al., 2002). It is a very urgent problem at present and mainly for the future. The problem must be solved now when there is still something to protect. Detailed data about area with water erosion risk in Czech Republic are in Table 2.

Table 2. Structure of areas treatened by water erosion

Category of water erosion risk	Soil loss (t/ha/year)	% of arable land	Area (ha)
Very small danger	< 1.0	47.12	1 935 393
Small danger	1.1 – 2.0	16.90	694 090
Medium danger	2.0 – 4.0	17.19	706 021
Great danger	4.1 – 8.0	11.33	465 315
Very great danger	8.1 – 10.0	2.28	93 851
Extreme danger	> 10.1	5.18	212 798
Total	-	100.00	4 107 468

Degradation results in limitation or loss of both the productive and non-productive functions of the soil. A significant risk associated with soil in the Czech Republic consists in the accelerated erosion of agricultural land that is conditioned anthropogenically. The erosion itself is a natural process and predisposition of soil to erosion depends on natural factors (climatic conditions, soil conditions, morphology of the area, vegetation conditions), which, however, may be secondarily influenced by anthropogenic factors. Therefore, human activity can be the start-up factor of the accelerated erosion also on plots that are not otherwise threatened by erosion.

The Conception of the Agricultural Policy after the EU Accession for the Period 2004–2013 and the Strategic Framework for Sustainable Development in the Czech Republic mentioned the risk of water and wind erosion and other ways of soil degradation (such as compacting) among the significant problems. Subsidies to agriculture also support sustainable management of agricultural land. The payment of direct support for farmers under the *Council Regulation (EC) 73/2009* and of other selected subsidies is made dependent on fulfilment of the *Statutory Management Requirements (SMR) and Good Agricultural and Environmental Conditions (GAEC)*, while GAEC1 and GAEC 2 concern soil erosion. Emphasis is put on the protection of soil against erosion on sloping land, the soil protection against water erosion and on the effort to reduce the negative impact of the consequences of erosion (e.g. damage to roads and real estate). The GAEC and SMR standards are parts of the cross compliance system. The extension of GAEC 2, focusing on restrictions on the cultivation of wide-row crops on soils threatened with moderate erosion, is effective from 1st July 2011.

The Czech Republic pointed out, in particular, how the specific implementation of GAEC 1 and 2 is contributing to reduce soil loss, increase water retention and reduce the risk of extreme events such as floods: USLE equation (universal soil loss equation; Wischmeier and Smith, 1978), used for soil erosion allows quantifying the positive effects through 6 the Vegetation Protection Factor (Cp) identification. Soil use and type, erosion risk features, land sloping and annual precipitation patterns contribute to identify soil erosion risk maps which, if simplified and made available to farmers, can facilitate prevention activities, with reference to specific agricultural parcels concerned.

Combination of above mentioned data was used for definition of seriously and slightly endangered areas by erosion.

In *seriously endangered areas*, wide-row crops (maize, sugar beet, potatoes, sunflower, bean, soybean and sorghum) are not allowed to grow. Crop stands of cereals and oilseed rape must be established by conservation tillage technology, when crop residues cover on soil surface is at least 30% till emergence of crop.

In slightly *endangered areas,* growing of wide-row crops is allowed, but using conservation tillage. Limit for minimal crop residue cover is changing with developing of crop stand: 20% is requested during sowing, 10% till June, 30 and visual provability of usage of conservation tillage system after July, 1.

According to Czech legislatiton connected with protection of soil against erosion, different types of conservation tillage methods are applied by farmers. Conservation tillage technologies where ploughing is replaced by tillers and shallow soil loosening are increasingly used as soil treatment. It is typical for shallow soil tillage that all plant residues are left on the soil surface, or in the treated (tilled) upper soil layer. The plant residues can play a very important role by the next plant cultivation. Leaving crop residue on the soil surface year around, before and after planting provides soil surface protection at critical times to protect the soil against wind and water erosion. Reducing tillage operations improves soil surface properties, including improved soil aggregation accounting for increased infiltration and percolation; less compaction due to less usage of field implements; and more biological activity due to an increase in organic matter. Adding soil surface cover increases water infiltration, reducing soil drying and maintains more moisture for crop utilization. In the experimental section the aim of the research was described which is possible to summarize briefly as follows – evaluation of soil physical properties on the work quality of tillers, evaluation of sweep tillers and disc tillers work quality by stubble ploughing. Especially conservation tillage systems with their modification are increasingly being introduced under the economic pressure on the fields of the Czech Republic (Mašek et al., 2012).

Examples of conservation soil tillage methods:

- direct sowing (no-tillage) into postharvest crop residues,
- use of cover crops (intercrops) – sowing of winter rye or phacelia in autumn, direct sowing in spring (sometimes necessary to apply total herbicide),
- sowing of spring barley in spring, application of total herbicide, direct sowing of maize in spring.

Rules, which are based only on parameter of covering of soil surface by crop residues, are discussed and there is also space fore some modifications. Every soil tillage method has own advantage, but also disadvantage. It is important to choose soil management suitable to soil-climate conditions of some locations. Between farmers and research community there are a lot of negative remaks and recommendation, that these system evaluation of crop residues is very one-sided. In general, more complex system of evaluation is appreciate – with more broad view on the effect of soil tillage on soil properties parameters (content of soil organic matter, soil compaction, bulk density etc.). In soil tillage improvements, there are ideas about loosening soil profile in differed intensity in horizontal direction. Strip tillage is one the example of it.

Apart from above mentioned approches in soil tillage, new crop management practices are tested with potential effect against erosion. In maize, systems based on narrower rows and crop stand structure (distribution of plants in space) is evaluated in different locations of the Czech Republic. Practically, standard wide row (0.75 m) is compared with “narrow-row” in width 0.375 m between rows. Third system is called “twin rows”. In a twin-row configuration, maize is planted in paired rows, usually 0.2 m apart, on 0.75 m centers. The idea behind this system is to gain a more uniform spacing of plants, similar to narrow-row corn. The theory is reducing the amount of inter-row competition above and below ground allows the corn plant to maximize yield.

This approach is coming in USA, and the results showed, that maize grows, more and more of the sun light is captured by the leaves. The more nutrients that are captured, the more large healthy ears will be formed. That is why increasing the spacing between plants is the best way to encourage root development. Large healthy roots maximize nutrient retrieval and moisture absorption. All these results are concluding in higher yield level of biomass in comparison with standard wide-row systems. Also, twin-row’s larger stalks and increased root mass result in a plant that is stronger and better prepared to withstand high winds and storm damage.

Conclusions

The results have shown that conventional and also minimum soil tillage can be suitable for maize growing, especially in lowlands. For areas endangered by water erosion, according to Czech legislation, different modifications of conservation tillage are used. Suitable soil tillage management has to create good conditions for germination, emergence and development of maize stands. Conditions for high yield productivity could be in relation with improvement of soil fertility and protection soil against erosion.

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Review paper

Tillage systems in winter wheat production as a challenge to mitigate global climate changes

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Abstract

The effects of a year on winter wheat cannot be avoided. Weather conditions during each production year significantly affect plants directly or indirectly through the soil. In recent decades, abiotic extremes caused by climate factors have had stress effects on filed crops. It is necessary to reconsider the following each year: the applied agricultural management systems in all crops, each cropping practice, the period of its application that is meeting deadlines, types of tools, proper selection of cultivars and hybrids for certain regions, level intensities of wheat growing practices (high and low-inputs), optimum sowing density, amounts of applied agrochemicals (fertilizers, pesticides), good agricultural practice.

Under climate conditions in Serbia, winter wheat primarily develops when there is a sufficient or even surplus amount of precipitation. The precipitation surplus adversely affects winter wheat. If there is a precipitation deficit the following indirect measures, which resulted in reduced water requirements by grain crops are employed: balanced NPK nutrition, optimum nitrogen rates, optimum density in accordance with cultivar properties and climate conditions, well developed crop free of disease and pests. The selection of a proper cultivar for certain agroecological conditions is increasingly important, because not only dry but also extremely wet years last in a longer period of time. These extremely wet years also cause problems that need to be solved with different amelioration measures.

Key words: tillage systems, climate changes, soil physical properties, winter wheat

Introduction

The studies on anthropogenic climate change performed in the last decade over Europe show consistent projections of increases in temperature and different patterns of precipitation with widespread increases in northern Europe and decreases over parts of southern and eastern Europe (Olesen and Bindi, 2002).

In many countries and in recent years there is a tendency towards cereal grain yield stagnation and increased yield variability. Some of these trends may have been influenced by the recent climatic changes over Europe. The expected impacts, both positive and negative, are just as large in northern Europe as in the Mediterranean countries, and this is largely linked with the possibilities for effective adaptation to maintain current yields. The most negative effects were found for the continental climate in the Pannonian zone, which includes Hungary, Serbia, Bulgaria and Romania. This region will suffer from increased incidents of heat waves and droughts without possibilities for effectively shifting crop cultivation to other parts of the years. A wide range of adaptation options exists in most European regions to mitigate many of the negative impacts of climate change on crop production in Europe. However, considering all effects of climate change and possibilities for adaptation, impacts are still mostly negative in wide regions across Europe (Olesen et al., 2011).

As a consequence of global climate change, changes in the intensity and frequency of climate extremes - tropical cyclones, droughts, floods, landslides, soil erosion, storm disasters, snow storm and frosts, heavy rains of short duration, waves of extremely high temperatures of air, fires, conditions for the spread of epidemics and pests.

The greatest economic damages in Serbia have been caused by droughts, floods, storms accompanied with hail, landslides, erosion caused by the torrents, and in recent years there has been an increasing number of heat waves and the conditions for the occurrence and spread of forest fires.

Taking a long-term view, the problems arise due to the fact that since the seventies of the twentieth century to the present days average annual temperatures in the country and the region have been constantly rising. However, climate change in this area so far have been reflected in the increased frequency and intensity of extremes, such as this one with the drought in the past two years and with increasingly frequent occurrences of heat waves, etc. If this trend of climate change continues as shown by the various climate change scenarios for this region, it could lead to big problems in weather and climate as well as the water supply.

The effects of a year on winter wheat cannot be avoided. Weather conditions during each production year significantly affect plants directly or indirectly through the soil. In recent decades, abiotic extremes caused by climate factors have had stress effects on filed crops (Kovacevic et al., 2005, 2012a, 2012c, 2012d). It is necessary to reconsider the following each year: the applied agricultural management systems in all crops, each cropping practice, the period of its application that is meeting deadlines, types of tools, proper selection of cultivars and hybrids for certain regions, level intensities of wheat growing practices (high- and low-inputs), optimum sowing density, amounts of applied agrochemicals (fertilizers, pesticides), good agricultural practice.

The application of cropping practices can provide the undisturbed growth and development of grain crops and can neutralise extreme abiotic climate factors (precipitation, temperature) and their stress effects on crops (Kovacevic et al., 2009, 2010a). All stated cultivation elements affect yield either individually, collectively or synergistically, but the optimum sowing date is one of the most important element. Furthermore, very important elements are fertilising and mineral nutrition necessary for cultivars of small grain crops (Malesevic et al. 2008). Irrigation is the only efficient measure against drought. However, it is known that wheat is an extensive crop with the lowest inputs, but also with the lowest income, hence irrigation under our conditions is mainly applied to intensive or seed crops that provide greater yields and income.

Characteristics of the main climate parameters in Serbia

Climate in Serbia can be described as moderate-continental, with more or less distinct local variations. As the main plant production is carried out under conditions of moderate continental climate in the lowland and undulating regions it is important to specify its main features. The average annual temperature is around 11ºC, the warmest month is July with about 23ºC, and the coldest month is January with about -1ºC of mean monthly temperature. Temperature in spring rises quite rapidly, whereas a temperature drop in the autumn is sharp as well. The length of the period with the mean temperatures above 10ºC, and these are the temperatures for the vegetation of spring crops (maize, sunflower, sugar beet, potatoes, etc.), is equal to about 200 days. The frostless period lasts approximately from 1 April to 15 November, totaling around 230 days. The annual amount of rainfall amounts to 600-750 mm. The rainfall ratio of warm to cold part of the year (warm part of the year lasts from 1 April to 30 September) is 55-60% to 40-45%. In other words, although there are more rainfalls during the vegetative period for spring crops there is often a problem of their lack during July and August. The maximum rainfall is received in June, whereas the minimum is measured in January and February. The annual rainfall rate in different parts of central Serbia is mainly satisfactory, although there are years with the extreme lack of rainfalls (drought periods) that affect a significant decrease in crop yields (*RHSS).

In Serbia the precipitation distribution in the crop cultivation under rainfed conditions has very often a decisive effect on the occurrence of longer or shorter dry spells. The favourable precipitation distribution during the year is the distribution that provides a proportionally large numbers rainy days and equal intervals between rainy and rainless periods, particularly during the growing season. The occurrence of longer rainless periods in spring and autumn, especially in years with dry summers, when drought continues from summer into autumn, regularly affects grain crops due to uneven and long emergence. Under conditions of our climate, the greatest precipitation sums are recorded in June.

Grain yields of winter wheat as well as the form and the intensity of the dependence of the yield on autumnal, winter, spring and meteorological conditions during the growing season. The analysis of the past 20 years shows that 1992/93, 1995/96, 2002/03 and 2006/07 were extremely dry years for winter wheat (Kovacevic et al., 2012e). However, observations of the whole growing season of winter wheat show that there were extremely wet years, such as 2003/04, 2008/09 and 2009/10, which also caused damages such as complete smothering of crops in heavy soil with waterlogging and outbreak of diseases, which significantly reduced the yield, aggravated harvest and decreased grain quality (Table 1). The greatest problems related to moisture is insufficient precipitation sums during October and November, as they aggravate emergence, inhibit the growth and accelerate later winter wheat getting around through in the other qualitative stages of organogenesis.

Table 1. Mean temperature and precipitation in different periods of winter wheat growing season Serbia (1991-2011)

Year	Temperature (°C)				Precipitation (mm)			
	Autumn	Wint.	Spring	Grow. season	Autumn	Wint.	Spring	Grow. season
	X-XII	I-III	IV-VI	X-VI	X-XII	I-III	IV-VI	X-VI
1991/92	6.0	3.7	17.2	9.0	178.6	48.0	258.2	484.8
1992/93	6.5	5.9	18.1	8.9	187.0	130.8	91.9	409.7
1993/94	7.4	6.0	17.4	10.3	185.5	91.1	318.2	594.8
1994/95	7.4	5.2	16.6	9.7	108.2	172.0	209.3	489.5
1995/96	6.6	1.8	16.3	7.8	124.4	146.0	217.4	487.8
1996/97	8.1	3.6	15.6	9.1	215.6	93.6	169.0	478.2
1997/98	7.8	4.9	17.1	9.9	217.0	102.8	142.6	462.4
1998/99	4.9	3.8	16.8	8.5	175.4	145.3	273.2	593.9
1999/00	6.4	4.1	19.6	10.0	273.6	85.9	95.5	455.0
2000/01	10.6	7.1	16.4	11.4	78.5	128.1	390.9	597.5
Average	7.2	4.6	17.1	9.5	174.4	114.4	216.7	505.4
2001/02	5.9	7.1	18.4	10.5	114.0	43.0	156.0	313.0
2002/03	9.0	2.1	19.6	10.2	167.0	88.0	95.0	350.0
2003/04	8.3	3.9	16.8	9.7	195.0	145.7	238.9	579.6
2004/05	9.5	2.4	17.0	9.6	210.7	172.0	195.0	577.7
2005/06	8.2	3.0	17.3	9.5	133.0	206.0	274.0	613.0
2006/07	10.1	8.8	19.6	12.9	94.0	189.0	191.0	474.0
2007/08	6.4	6.6	18.8	10.6	269.0	131.0	141.0	541.0
2008/09	10.2	4.0	19.0	11.1	147.0	201.0	193.0	541.0
2009/10	9.8	4.5	17.9	10.7	285.0	246.0	306.0	837.0
2010/11	8.4	3.9	18.1	10.1	155.0	119.0	114.0	388.0
Average	8.6	4.6	18.2	10.5	177.0	154.1	190.3	521.4
Differ.	1.4	0	1.1	1.0	2.6	39.7	-26.4	16.0

*RHSS (Republic Hydrometeorological Service of Serbia)

These analyses in which the growing season was divided into three sub periods show the increase in the average temperature of 1.4°C and 1.1°C in the autumnal and spring period in the second decade (2001/02-2010/11) in relation to the first decade (1991/92-2000/01), respectively, while the winter average temperatures were equal. At the same time, the average winter temperatures were equal in both decades. The three-month cumulative precipitations were insignificantly higher in autumn (2.6 mm), significantly higher in winter (39.7 mm) and lower in spring (26.4 mm), which is especially important as early and later spring when is a critical period for moisture for grain filling.

Possibilities for adaptation tillage systems in winter wheat technology to mitigate climate changes

Sustainable agriculture is an important element of the overall effort to make human activities compatible with the demands of the earth's eco-system. Thus, an understanding of the different approaches to ecological agriculture is necessary if we want to utilize the planet's resources wisely.

In conventional systems of tillage, tractors and implements make between 7 and 16 passes over the field for land preparation. In contrast, conservation tillage systems greatly reduce the number of tractor and implement passes required, and leave a protective blanket of leaves, stems and stalks from the previous crop on the soil surface. Less tillage means less soil compaction and lower fuel and labour costs, less wear and tear of the tractor and implements, and more time available for other activities. Moreover, the surface cover of crop residues shields the soil from heat, wind, and rain, keeps the soil cooler, and cuts down moisture losses by evaporation.

Conservation tillage systems reduce efforts spent on intensive weeding. Every time a farmer tills or ploughs to control weeds, he makes the soil more vulnerable to erosion, which is the most significant environmental problem. With conservation tillage a grower relies more on weed control by crop rotation, cover crops and mulch covers. If herbicides are to be used, then conservation tillage systems allow the use of less harmful products than those used in most conventional farming operations. They are generally low in toxicity to wildlife and beneficial insects, and break down so quickly that there is minimal risk to water quality.

Essential change of soil tillage systems, along different levels of tillage reduction until no tillage, has a great impact on soil physical and agrochemical characteristics. Reduction of soil tillage intensity or its total avoidance could affect significantly porosity, especially on heavier soils, increasing shares of micro pores in spite of macro porosity and lowering air capacity and air permeability.

The obtained results showed that tillage systems had different effect on the soil physical properties. Generally, differences in soil physical properties between investigated systems were significant at the waxy stage of winter wheat (Table 2). Bulk density is one measure of the soil physical condition. On the plots following no tillage system significantly higher bulk density (1.55 g cm^{-3}) were found, comparing to values obtained in the CT (1.41 g cm^{-3}) and MT plots (1.38 g cm^{-3}). Significant differences were found in soil physical characteristic between investigated depths as analyzed factor. Bulk density was higher in the layer 10-20 cm of depth. The differences between investigated layers were not significant for total porosity and air field capacity.

Table 2. Effects of tillage system on dynamic soil physical properties on chernozem luvic type in winter wheat

Tillage systems	Depths cm	Soil physical properties		
		Bulk density ($g\ cm^{-3}$)	Total porosity (%)	Air field capacity (%)
Conventional tillage systems	0-10	1.34	49.81	14.57
	10-20	1.43	47.09	8.70
	20-30	1.45	46.49	7.98
Average		1.41	47.80	10.42
Mulch tillage	0-10	1.37	48.69	8.64
	10-20	1.39	48.83	10.37
	20-30	1.38	49.32	13.37
Average		1.38	48.95	10.79
No- tillage	0-10	1.56	41.45	4.75
	10-20	1.58	41.58	4.60
	20-30	1.51	44.16	7.03
Average		1.55	42.40	5.46
Average	0-10	1.42	46.65	9.32
	10-20	1.47	45.83	7.89
	20-30	1.45	46.66	9.46

Reduction and, especially, elimination of agrochemical require major changes in management to assure adequate plant nutrients. The first step in transition from conventional to integrated nutrient management is reduction of chemical fertilizers (Table 3).Reduced amount of N- fertilizer in combination with reduction of tillage increase nutrient content in the soil (Oljača et al., 2002).

Disadvantage of these tillage systems is yield decrease of crops. But at the same time the inputs of such production system decrease as well, not mention the benefits in the environment. Some crop cultivars are adapted for less favorable conditions in occurring environment. Low-input cultivars are less sensitive than high-input ones, and they give better yield than high-input cultivars of winter wheat. The choice of crops and their cultivars used in such farming system is very important.

According to permanent breeding program there was a serious attempt to create concept of low input technology for rational growing practice in winter wheat under Serbian conditions (Kovačević et al., 2009b). Based on it’s sustainability this concept must accomplished several issues: conservation tillage methods, adequate mineral nutrition, ad hoc limited herbicide application and of course very strict desirable cropping system (modified Norfolk rotation: corn-winter wheat-spring barley+red clover-red clover. Under these conditions it is important to have best adopted cultivars.

Table 3. Effects of tillage systems and nitrogen level on nitrogen content (ppm) in winter wheat (0-60cm in depth)

Tillage systems	N level	NH_4-N	NO_3-N	Total N
CT (Conventional tillage)	120 kg ha^{-1}	24.50	2.62	27.12
	60 kg ha^{-1}	6.12	1.75	7.87
	control	11.38	3.50	14.88
RT (Reduced tillage)	120 kg ha^{-1}	9.62	4.38	14.00
	60 kg ha^{-1}	9.72	8.75	18.47
	control	5.75	2.62	8.37
NT (No- tillage)	120 kg ha^{-1}	39.38	13.13	52.51
	60 kg ha^{-1}	19.25	7.00	26.25
	control	7.87	4.38	12.25

Agricultural producers invested their hopes in the development of sustainable agriculture. a concept that should rely on the breeding of low-input cultivars and cutbacks in production costs. As far as wheat is concerned. we have developed in Serbia several low-input cultivars of winter wheat.

Research carried out by Kovacevic et al. (2010b) has shown that low-input cultivars according to previous experience (Pobeda, Francuska, Lasta, NS Rana 5) positively responded to reduces in tillage systems and different nitrogen amount in side-dressing. Growing practice with certain reduction of tillage, nitrogen fertilizer and weed control was more favorable for low-input cultivars which positively responded by their higher yield 3.24 t ha^{-1} compared with two cultivars created for intensive high-input technology (Pesma, Rana niska) 3.04 t ha^{-1} (Table 4). These results demonstrate potential new technologies comprehend higher flexibility of cultural practices (soil tillage. fertilization. integrated weed management. crop rotation) with proper choice of wheat cultivars adapted to these conditions.

Soils with heavy mechanical texture require processing system that ensures conservation of natural resources of fertility and prevents soil degradation processes, especially in terms of optimization of energy use, action and water.

A large number of researchers who have studied this type of soil, point out that soil heavy texture possess a number of specific characteristics, especially the unfavorable physical and water-air properties. Bearing in mind that in Serbia we have more than 400.000 ha of soil heavy mechanical texture and approximately 1 million hectares of degraded soil in different ways, this kind of researches are important and useful from the standpoint of science, and even more from the point of using this research into practice (Hadas, 1997; Kovacevic et al., 2009a; Ercegovic et al., 2010).

Table 4. Effects of different technology on grain yield different groups winter wheat cultivar (t ha^{-1}).

Tillage systems (A)	Nitrogen level (B)	Cultivars (C)						Average	
		Low-input				High-input			
		Pobeda	Lasta	Evropa	NS rana	Pesma	Rana	AB	A
Conventional tillage	control	2.52	2.46	2.69	2.54	2.56	2.57	2.56	4.03
	60 kg ha^{-1}	3.59	3.82	3.55	3.51	3.61	3.99	3.68	
	120 kg ha^{-1}	6.08	5.80	5.95	6.14	5.70	5.48	5.86	
Average	AC	4.06	4.03	4.06	4.06	3.96	4.01		
Mulch tillage	control	2.09	2.25	2.59	2.24	2.03	1.72	2.15	3.13
	60 kg ha^{-1}	3.03	2.90	2.75	2.71	2.82	2.50	2.78	
	120 kg ha^{-1}	4.30	4.04	4.66	4.46	4.44	4.88	4.46	
Average	AC	3.14	3.06	3.33	3.14	3.10	3.03		
No-tillage	control	1.79	1.48	1.59	1.50	1.49	1.41	1.54	2.37
	60 kg ha^{-1}	2.42	2.66	2.13	2.10	2.13	1.80	2.21	
	120 kg ha^{-1}	3.54	3.74	3.66	3.44	3.04	2.69	3.35	
Average	AC	2.58	2.63	2.46	2.35	2.22	1.97		
Average	BC	2.13	2.06	2.29	2.09	2.03	1.90	2.08	B
		3.01	3.13	2.81	2.77	2.85	2.76	2.89	
		4.64	4.53	4.76	4.68	4.39	4.35	4.56	
	C	3.26	3.24	3.29	3.18	3.09	3.00	3.18	
		3.24				3.04			

In the researched areas, an important and limiting factor for the successful production is over-wetting of the soil. This fact does not allow the respect optimum time for application cultural measures like tillage, seeding, and normal conditions for growth and development of plants or crop-harvesting. Poor infiltration or permeability of soil is the reason of waterlogging, which leads to suppression of crops, lack of normal operation of machinery (jamming and deterioration of the tractor up to the height of the wheels on some depressions).

According to Kovacevic et al., (2012c) ameliorative tillage with new types of machines was obtained a significantly lower bulk density in compared with control (Table 5). In the first period of this research there is a significant difference between the two examined variations and the examined soil depth, except the third (20-30 cm). Greater soil loosening in the experimental area can be seen from the higher porosity. Higher porosity allows better air flow and rapid infiltration of water. This can be seen from the moisture content. Higher moisture content on the control variants is a result of higher density of individual layers. The total amount of water has significantly contributed to this. It can be seen that the control variation at all depths has higher water stored in the soil. In loam soils it does not mean and higher availability of water. This circumstance at higher rainfall could be the limit for fast water flow. Tillage system that was used, was consisted of leveling of the field, of undermining with the drainage plough and of tillage with vibrating subsoiler, has resulted in an increased soil loosening as we can see from significantly lower values of bulk density, higher total porosity and a better connection between the solid, liquid and gaseous phases.

Table 5. Efects of ameliorative tillage on soil properties in full tillering of winter wheat

Variants	Depth in cm	Bulk density g cm^{-3}	Total porosity %	Max. water content % vol.	Moisture % vol.	Amounth of water m^3 ha^{-1}
ATS	0-10	1.31	51.4	40.5	36.7	482.9
	10-20	1.36	48.1	38.7	34.1	984.2
	20-30	1.37	51.2	38.4	32.5	1336.2
Average	0-30	1.35	50.2	39.2	34.4	∑ 2803.3
CTS (control)	0-10	1.32	50.2	39.5	34.9	459.0
	10-20	1.43	48.7	38.2	35.6	1015.6
	20-30	1.42	49.2	37.5	33.6	1439.
Average	0-30	1.39	49.4	38.4	34.7	∑ 2913.9

Abbreviation: ATS- Ameliorative tillage system ; CTS- Conventional tillage system

The soil properties were repaired in the first year and it became more favorable habitat for growing crops, also, it should be noted and the prolonged effect on the other crops (winter wheat in third year of investigations 2010. High precipitation in autumn, winter and early spring in previous year (2010) were a reason to waterlogging on the control variant.

Conclusion

On the basis of the previous theoretical but also practical knowledge some things can be listed which will certainly provoke significant changes in the field of agriculture. First of all global climatic changes will have their reflection on the territory of Serbia as well.Temperatures and precipitations have been changing faster during the past two decades. The exceedingly dry years for winter wheat were 1992/93, 1995/96, 2002/03 and 2006/07, while extremely wet years were 2003/04, 2008/09 and 2009/10.

The analysis of the last 20-year weather conditions (temperatures and precipitations) related to winter wheat shows the increase of autumnal and spring temperatures at the end of the first decade of the 21st century. There are somewhat higher precipitation sums in autumn, higher in winter and significantly lower in spring, when the critical period for moisture begins. The precipitation surplus adversely affects winter wheat.

The most powerful cropping practices related to winter wheat cultivation are: tillage systems, proper selection of fertilising methods in accordance with requirements of winter wheat plants. If there is a precipitation deficit the following indirect measures, which resulted in reduced water requirements by grain crops are employed: balanced NPK nutrition, optimum nitrogen rates, optimum density in accordance with cultivar properties and climate conditions.

Some extremely wet years also cause problems that need to be solved with different ameliorative measures. All cultivars have a high potential for yield, but resistance to stress conditions, especially to high temperatures or drought, will be a very important criterion, particularly for more arid regions.

One of the goals of the sustainable agriculture movement is to create farming systems that mitigate or eliminate environmental harms associated with industrial agriculture. That aim can be realized only in flexible cultural practices in real agroecological conditions (different regional characteristics, cultural practices for different soil types, best adapted cultivars for level of production from conventional to organic organic production. The selection of a proper cultivar for certain agroecological conditions is increasingly important, because not only dry but also extremely wet years last in a longer period of time.

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S E S S I O N I

[Soil tillage and crop management in function of environmental protection]

Chairmen:

Bojan Stipešević
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Ivica Kisić

Original scientific paper

Evaluation of spring tine harrow for soil preparation in savannah ectone of Nigeria

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Abstract

Appropriate type of soil tillage operation is essential for a given soil condition prior to planting. Soil needs to t\be prepared by some form of tillage or chemical "burn-down" to kill the weeds in the seedbed that would crowd out the crop or compete with it for water and nutrients. The major environment concern related to soil preparation is erosion. Soil erosion is a natural process that occurs when the actions of water and /or wind cause topsoil to be removed and carried elsewhere. The effect of soil erosion becomes more pronounced within the savannah ectone zone in Nigeria. This transition zone is formed by the border of forest and savannah belt in Nigeria. Environment of the tillage operation using the spring tine harrow was carried out in a row crop farm. The effect of application of spring tine harrow for tillage operation in a maize farm was investigated on formation of a plowpan, increased susceptibility to compaction and erosion. Soil Conditioning (modification of soil structure to favor agronomic processes such as soil seed contact, root proliferation and water infiltration), weed/pest suppression (direct termination or disruption of weed/pest life cycles) and residue management to minimize negative effects of crop/cover crop residue and promote beneficial effects within the soil condition in savannah ectone of Nigeria. Water infiltration is generally increased immediately after tillage, but the result indicated that tillage tends to break down soil structure by reducing soil aggregation and pore openings. The tillage effect reduces the rate of water movement into the soil. The available soil nutrient and soil organic measurement during the maize tasselling stage indicated that tillage increases nutrient losses due to erosion and oxidation of soil organic matter. Soil organic matter is important as a source of nutrients, in regulation of nutrient availability, and in maintenance of soil physical and biological conditions for optimal crop growth. The result showed that maize grain yields were higher on no-till than on ploughed plots and no-till plots yielded 3 times the ploughed plots (3.9 $tha^{-1}a^{-1-}$ and 1.3 $t\ ha^{-1}a^{-1}$ respectively).

Key words: soil tillage, spring tine harrow, bulk density, cone index, shear strength

Introduction

Tillage is the working of the soil from its natural physical condition to an acceptance condition that write facilitate crop growth. The main objectives of tillage research in the savannah ectone of Nigeria and elsewhere are to develop appropriate tillage methods that will preserver and sustain soil productivity, maintain ecosystem stability optimize the biophysical environment and allocate soil related constraints to crop production (Lal, 1982).

The story and compacted top soil in the savannah ectone of Nigeria are such that implement like disc harrows makes less than the expected pulverization of the soil at a go during the soil preparation operation with this challenge in view, appropriates spring loaded tines are expected to give the optimum pulverization and structural alignment of the top soil for agricultural production. This optimum tillage will be able to curtail soil degradation and decline in crop yields.

Materials and Methods

The six treatment evaluated are (i) No-till (NT), (ii) reduced tillage (RT), (iii) conventional tillage (PH), (iv) Rotational (T), (v) ploughed (H) and (vi) Ridges (R). the “No till” plots were not disturbed at all except that they were sprayed with insecticide. The “Reduce tillage” plots were ploughed once, while the “conventional tillage” plots were ploughed once and followed by harrowing with spring tine harrow. The “Rotational and Rigded” plot were initially both ridged with hand-hoes. However, while the “Rotational” plots were maintained in subsequent operation by hand weeding new mounds were made every season for “Mound” plots.

The Rigded” plot was ridged with hand-hoe. The plots were 8mx5m and the treatments were laid out in randomized complete block design with four replications. Fertilizer was applied at the rate of 350kg/ha by broadcasting and mixing with the soil. The seeds were planted at the rate of 17kg/ha by broadcasting after mixing with dry sand for even spread.

Crop variables measured included germination count, plant height at a week interval (for 10 randomly selected plants). Leaf area index and yield per plot.

Soil variables measured were soil bulk density, soil moisture, cone index, and shear strength each at 7 and 14cm depth. These were measured 7,14 21 and 28 days after showing.

The cone index and shear strength were measured using hand shear vane and farnell hand held soil penetrometer respectively. All data were subjected to analysis of variance to test the significance of treatment effects. Significance of mean difference for each variable was tested using the test significance difference (LSD).

Preliminary Results and Discussion

Soil moisture content was not significantly affected by tillage methods. The various effects on soil physical properties are shown in Table 1. the highest soil porosity of 37% at 70mm soil depth was recorded under the Reduced tillage method using the spring tine harrow.

Soil porosity was no longer affected by tillage methods after 30 days of planting at either of the two depths used. The bulk density of the soil was not affected by any of the tillage methods used until 30 days after planting when the head methods gave the lowest density of 1.56 gkm^3 with the Reduced tillage method (plough and spring tine harrow) recording the highest of 1.77 gkm^3 at 7cm depth.

At 14 cm depth, however, the lowest bulk density of $1.25gkm^3$ was recorded under mound methods while the highest of $1.99gkm^3$ was recorded under the disc plough tillage methods.

Cone index was generally affected by the tillage methods employed especially in the first week of the crop. The least cone index and shear strength at both the 7cm and 14cm depth was observed with the heap method.

The highest cone index value was observed at the "No till" plot also the highest shear strength at the two depths was recorded at the "No till" plot.

The height of the maize plantation was affected by the tillage methods from the early to the final stages of the crop. The crop height in the "No till" plot was comparatively lower with respect to other tillage methods used.

Tillage effect on crop performance parameters are shown in table2. very good germination was observed in "No till' plots. The leaf area was not affected by the tillage methods used and 30 days after planting when the highest index of 8.0 was observed on the "No till" plots, followed the Reduced tillage method (plough and spring tine harrowing) with index of 6.30.

From the preliminary results and analysis, "No till" and Reduced tillage" (plough and harrowing with spring tine) were observed to be optimum.

Conclusion

The data obtained so far are those obtained in 2011 further results and recommendations on the effect of the use of spring tine harrows for tillage and the resultant effect on soil physical properties and the crop performance would be presented later in subsequent field trials to commence later in the year.

The evaluation also shows that, apart from "No till" method which gave the highest crop yield, the most optimum result came from the "Reduced Tillage" method, which involves the use of **spring tine harrow** for the soil preparation.

Original scientific paper

Spatial distribution of a microbial community in sandy soil ecosystems as a tillage mediator

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Abstract

The goal of the present study was to determine the influence of fine-scale landscape patchiness on abiotic components and microbial communities and the interplay of these two systems in sandy soil ecosystems. The fieldwork was carried out in stable sandy soil ecosystems near Caesarea, Israel, with a Mediterranean climate. In order to quantify the distribution of soil microbial communities at multiple spatial scales, a survey was conducted to examine the spatial organization of the community structure at two sandy soil sites, yielding a total of 144 soil samples collected from the 0-10 cm and 10-20 cm soil layers. Soil abiotic analysis was performed by soil standard analytical methods, while the biotic components were measured by using a MicroResp™ system. The results obtained established that microbial-community distribution can be highly structured, within a habitat that appears relatively homogeneous on a plot and field scale. This is due to spatial heterogeneity associated with soil physical, chemical, and biological properties. The study provided evidence that a spatially explicit approach to soil ecology can enable identification of factors that drive the spatial heterogeneity of populations and the activities of soil organisms at scales ranging from meters to hundreds of meters.

Key words: multi-scale variation, heterogeneity, CO_2 evolution, sandy soil ecosystem

Introduction

Sandy soils are often considered as having weak or no physical structure, poor water-retention properties, high permeability, and high sensitivity to compaction with many adverse consequences. Due to its weak structure, sandy soil compaction has a negative vertical as well as horizontal effect on physical and biological components from macroscopic to microscopic scales (3). Determination of a 'scale unit' that help understand ecological processes has become one of the important and most debatable problems in recent years. Recent studies have emphasized the importance and role of environmental factors in the erratic distribution of microbial communities in terrestrial ecosystems (4, 12). Since microorganisms play vital roles in surface and subsurface soil geology, hydrology, and ecology, knowledge concerning the microbial-community structure and its composition became important in improving our conceptual and projective understanding of surface and subsurface soil-ecosystem processes, functions, and management (17, 20). Soils are considered the most microbially diverse environments on earth (18). The abundance, composition, and diversity of microbial communities within soils were found to be strongly depth-dependent, as shown by Fierer et al. (8), LaMontagne et al. (11), Agnelli et al. (1), and Kemnitz et al. (9). In their study (1, 8, 9, 11), they showed that the bacterial biomass concentration (bacterial 16S rRNA genes), number of terminal restriction fragment-length polymorphism peaks, denaturing gradient gel electrophoresis bands (representative of richness), and the proportion of Gram-negative to Gram-positive bacteria, are lower in subsurface than in surface soils. Multi-scale comparisons, in which patterns are analyzed at several different spatial scales, can be more useful when trying to identify the factors that control community development. The characterization of microbial communities on several different scales can help in explaining contradictions that arise by different investigators, studying similar communities on different scales, which reach different conclusions regarding the factors that structure these communities (13).

The present study was designed to address a general question related to multi-scale patterns of spatial organization of microbial community in two sandy soil ecosystems. The aim of the present study was to reveal the influence of fine-scale landscape-patch moisture and organic-matter heterogeneity on microbial-activity linkage in coastal sandy ecosystems. The three main questions are arising: (1) how do such heterogeneous environments affect microbial distribution, (2) how will microbial functional diversity be altered spatially and (3) how microbial community is important for the tillage processes in the sandy soil ecosystems.

Materials and methods

Study area: In order to undertake the present study, two sites were chosen: west and east, 100 and 4,000 m from the Mediterranean Sea shore, respectively, with similar plant cover and topography in a coastal sandy ecosystem. The western (32°28′N, 34°53′E) and eastern (32°28′N, 34°55′E) study sites were located in the northern Sharon region of Israel, south of Caesarea (6). The climate in the region is sub-humid Mediterranean. The annual amount of rainfall is 580 mm. The study sites are dominated by shrub associations (6, 7, 10).

Sampling: Soil samples were collected from the 0-10 cm and the 10-20 cm layers at each point of the 2 × 2 m grid-intersections in a 10/10 m plots, from each of the sites. A total of 144 soil cores from both study sites were collected, during wet season (December), from two depths using a 7-cm diameter soil auger. Each soil sample was placed in an individual plastic bag and transported in an insulated container to the laboratory, where it was stored at 4°C until biological and chemical analyses were conducted.

Laboratory analyses: All chemical and biological analyses were conducted on each replicates collected in the field from each treatment.

Abiotic parameters: Soil moisture (SM) was determined gravimetrically by drying the soil samples at 105°C for 24 h. The total organic carbon (TOC) content in soil samples was determined by muffling soil at 400°C.

Biotic parameters: Basal respiration (CO_2 evolution without the addition of any external substrate), of the microbial community, microbial biomass (MB) (2), the biomass-specific respiration rate or metabolic quotient (qCO_2), microbial functional diversity and community-level physiological profile (CLPP) in soils were measured with a MicroResp™ system (5).

Statistical analysis: Statistical analysis was conducted using JMP software (JMP version 10; SAS Institute, Inc., Cary, NC). Multivariate analysis (pairwise correlation) was used to determine differences between variables within and between layers and between two patches: east and west. The figures were created using MATLAB software (version 7).

Results

Abiotic parameters: Results of abiotic data are presented in Table 1. The soil moisture mosaic patchiness - roughness shows the dissimilarity between layers with a mean moisture level of 2.14% and 2.22% in the 0-10 cm layer and with a mean moisture level of 2.96% and 2.73% in the 10-20 cm layer for the east and west patches, respectively. Multivariate analysis of the east and west patches showed no significant (NS) ($p>0.05$) differences in the spatial distribution of SM between the two layers of the two sampling sites (east and west).

The mean values of soil organic-matter were found to be lower in the deeper soil layer in comparison to the upper soil layer (0.21% and 0.17% for the 0-10 cm layer and 0.36% and 0.35% for the 10-20 cm layer for the eastern and western sites, respectively). The spatial distribution of OM for the east patch study site showed significant differences ($p<0.02$) only for the B and F columns in the 0-10 cm soil layer and for the D and B columns ($p<0.0001$) in the 10-20 cm soil layer. The results show a relatively homogeneous distribution of OM across the sites.

Table 1. Abiotic parameters (soil moisture and organic matter) in the eastern and western patches

Soil ID	Soil Moisture (%)				Organic Matter (%)			
	Eastern patch		Western patch		Eastern patch		Western patch	
	0-10 cm	10-20 cm	0-10 cm	10-20 cm	0-10 cm	10-20 cm	0-10 cm	10-20 cm
1A	2.12	2.62	2.50	2.63	0.39	0.40	0.18	0.40
1B	2.32	2.83	2.12	2.62	0.18 *	0.20 ***	0.19	0.37
1C	1.17	1.98	2.62	2.70	0.78	0.20	0.20	0.18
1D	2.09	3.01	2.11	2.70	0.19	0.20 ***	0.19	0.39
1E	2.04	3.07	2.26	2.51	0.19	0.18	0.19	0.36
1F	2.05	3.25	2.37	3.03	0.19 *	0.20	0.20	0.00
2A	2.00	3.27	2.23	2.47	0.40	0.41	0.19	0.00
2B	2.00	3.82	2.42	2.74	0.40 *	0.38 ***	0.00	0.17
2C	2.19	2.39	2.03	2.55	0.18	0.20	0.18	0.00
2D	3.07	3.04	1.79	2.12	0.19	0.41 ***	0.00	0.19
2E	2.03	2.84	2.08	2.97	0.37	0.61	0.17	0.19
2F	2.29	2.89	2.65	2.83	0.38 *	0.54	0.00	0.35
3A	2.27	3.27	1.87	2.75	0.38	0.20	0.19	0.18
3B	2.07	3.08	1.91	2.72	0.38 *	0.17 ***	0.17	0.00
3C	2.24	3.10	2.58	2.18	0.20	0.17	0.37	0.40
3D	1.95	3.82	2.88	2.94	0.78	0.19 ***	0.00	0.33
3E	2.92	3.12	2.37	2.40	0.36	0.35	0.00	0.18
3F	1.80	2.78	1.91	2.95	0.49 *	0.60	0.17	0.18
4A	1.83	1.81	2.56	2.79	0.41	0.73	0.32	0.00
4B	2.58	2.91	1.73	2.78	0.34 *	0.58 ***	0.19	0.56
4C	2.28	2.06	2.55	2.24	0.19	0.38	0.36	0.19
4D	2.40	3.41	2.39	2.90	0.20	0.54 ***	0.18	0.19
4E	2.06	2.25	1.79	2.80	0.17	0.56	0.18	0.19
4F	2.00	3.23	1.89	1.73	0.40 *	0.38	0.24	0.35
5A	2.57	1.38	2.05	2.88	0.34	0.35	0.32	0.32
5B	2.43	2.81	2.29	2.79	0.20 *	0.20 ***	0.00	0.00
5C	2.37	3.04	2.57	2.62	0.36	0.38	0.00	0.17
5D	2.04	3.49	1.73	2.90	0.20	0.19 ***	0.35	0.18
5E	1.98	4.05	2.36	2.64	0.40	0.40	0.00	0.00
5F	2.38	3.23	1.89	2.65	0.20 *	0.38	0.19	0.00
6A	1.88	3.36	2.14	4.03	0.38	0.37	0.18	0.40
6B	1.24	3.07	2.04	3.18	0.41 *	0.61 ***	0.19	0.19
6C	1.64	2.85	2.06	2.65	0.55	0.20	0.37	0.20
6D	1.76	2.88	1.94	3.23	0.39	0.58 ***	0.35	0.38
6E	2.17	3.27	2.75	2.61	0.59	0.34	0.00	0.19
6F	2.80	3.33	2.41	3.13	0.37 *	0.21	0.19	0.20

** $p<0.01$; *** $p<0.001$

Biotic parameters: <u>CO_2 evolution</u>: multivariate analysis of CO_2 evolution in the soil samples collected from the upper 0-10 cm soil layer at the eastern site showed a significant ($p<0.03$) difference between the C and F columns (Fig. 1A), while no significant difference were obtained between the 32 samples in the 10-20 cm soil layer at this site (Fig. 1B). The spatial distribution of CO_2 evolution in soils collected from the western site showed a similar trend to that reported for the eastern site, with significant differences in the 0-10 cm soil layer for the A and D columns ($p<0.02$) and for the F and B columns ($p<0.007$) (Fig. 1A). Moreover, significant differences were observed for the deeper soil layer (10-20 cm) at the D and B columns ($p<0.02$) and E and B columns ($p<0.007$) (Fig. 1B). The mean CO_2 evolution was 0.94 µg CO_2-C g dry soil-1 h^{-1}, 0.74 µg CO_2-C g dry soil-1 h^{-1} in the upper layer and 0.30 µg CO_2-C g dry soil-1 h^{-1}, 0.42 µg CO_2-C g dry soil-1 h^{-1} in the deeper soil layer for east and west sites, respectively.

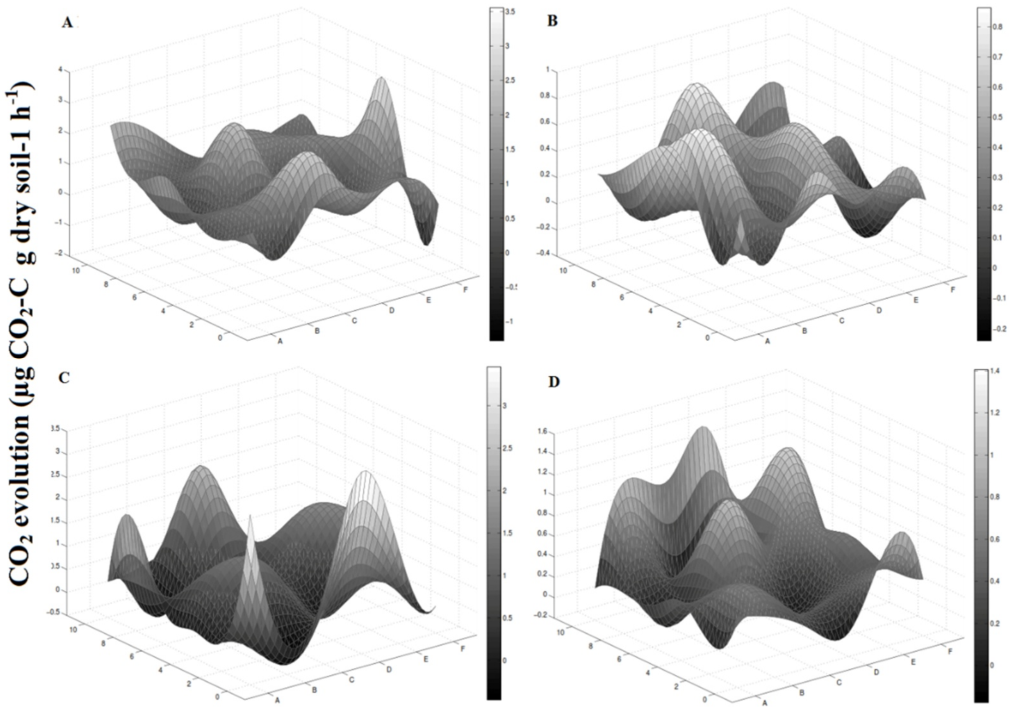

Figure 1. Spatial distribution of CO_2 evolution (µg CO_2-C g dry soil-1 h^{-1}) in the 10 × 10 m grid: **A**- 0-10 cm soil layer in the eastern site; **B**- 10-20 cm soil layer in the eastern site; **C**- 0-10 cm soil layer in the western site; and **D**- 10-20 cm soil layer in the western site.

Microbial biomass (MB): The mean microbial biomass distributed in the 2 layers showed a configuration similar to that of CO_2 evolution: high biomass in the upper soil layer (0-10 cm) and low biomass in the deeper soil layer (10-20 cm) at both sites (Table 2). The results indicate that the non-significance can reflect a homogeneous spatial distribution of MB in the two soil layers at the sites.

The spatial distribution of the metabolic quotient (qCO_2) at the eastern and western sites was represented in Table 2. The spatial distribution of the qCO_2 between the two layers showed a tendency toward homogeneity.

Changes in the community-level physiological profile (CLPP): in the east study sites, the spatial distribution of CLPP was relatively homogeneous between and within soil layers

(Table 2). The mean CLPP for the upper soil layer (0-10 cm) and the deeper soil layer (10-20 cm) were 20.97 µg CO_2-C g dry soil^{-1} h^{-1} and 18.27 µg CO_2-C g dry soil^{-1} h^{-1}, respectively. A homogeneous spatial distribution of CLPP was observed between the patches.

Table 2. Biotic parameters (microbial biomass, CLPP and qCO_2) for the eastern and western patches.

Soil ID	**Microbial biomass** (µg C g dry soil^{-1})				**CLPP** (µg CO_2-C g dry soil^{-1} h^{-1})				**qCO_2** (µg CO_2-C g^{-1} biomass-C h^{-1})			
	Eastern patch		**Western patch**		**Eastern patch**		**Western patch**		**Eastern patch**		**Western patch**	
	0-10 cm	**0-10 cm**	**0-10 cm**	**0-10 cm**	**0-10 cm**	**10-20 cm**	**0-10 cm**	**10-20 cm**	**0-10 cm**	**10-20 cm**	**0-10 cm**	**10-20 cm**
1A	57.21	96.48	149.52**	44.26	3.46	17.65	28.27	27.10	0.30	0.30	0.31	0.30**
1B	11.92**	7.71	8.03	44.39**	21.11**	24.13	13.47	9.23	0.30	0.29***	0.29**	0.30
1C	38.46	174.57	83.73	20.64	23.14	28.39	17.97	8.66	0.30	0.30***	0.30**	0.30
1D	83.49**	46.75	244.82**	1.94	9.24	6.38	34.74	18.73	0.30	0.30	0.31	0.25**
1E	117.06**	147.46	198.87	40.03**	11.30	15.56	14.92	4.61	0.30	0.30***	0.31	0.30
1F	17.22**	10.49	50.72	51.57	23.65**	28.83	17.86	6.19	0.30	0.30***	0.29	0.30
2A	56.20	4.06	5.97**	5.04	14.23	28.89	22.34	28.11	0.30	0.28	0.13	0.28**
2B	131.54**	75.15	5.29	75.78**	13.03**	21.84	15.88	8.02	0.31	0.30***	0.11**	0.30
2C	223.95	5.01	5.16	6.59	12.15	21.04	17.01	19.08	0.31	0.28***	0.11**	0.29
2D	12.07**	109.53	5.81**	6.85	22.27	22.11	24.01	20.01	0.30	0.30	0.13	0.29**
2E	44.74**	3.60	98.47	28.39	32.97	20.55	8.54	33.39	0.30	0.27***	2.27	0.30
2F	72.03**	3.87	7.78	21.52	44.85**	24.37	21.01	8.65	0.30	0.28***	0.17	0.30
3A	62.53	201.06	4.79**	73.45	19.79	18.47	19.35	17.52	0.30	0.30	0.10	0.30**
3B	59.57**	77.55	115.05	67.90**	12.26**	21.89	8.71	9.85	0.30	0.30***	2.31**	0.30
3C	52.38	2.82	131.58	54.51	29.94	25.35	11.09	14.54	0.30	0.27***	3.03**	0.30
3D	45.29**	43.83	6.45**	2.06	22.89	4.22	20.20	21.37	0.30	0.30	0.11	0.25**
3E	16.16**	5.49	22.98	21.58**	23.25	20.69	3.23	20.31	0.30	0.29***	0.52	0.30
3F	165.27**	6.34	66.27	20.42	18.40**	23.18	9.69	2.28	0.31	0.29***	1.52	0.30
4A	133.52	83.12	6.90**	91.51	40.20	19.76	22.50	14.85	0.31	0.30	0.15	0.30**
4B	70.69**	5.91	60.93	52.69**	13.10**	26.96	9.40	14.28	0.30	0.29***	1.40**	0.30
4C	202.30	5.80	4.76	78.50	19.31	23.08	22.77	8.88	0.31	0.29***	0.10**	0.30
4D	13.41**	60.51	63.02**	97.98	25.26	15.54	9.64	20.93	0.30	0.30	1.45	0.31**
4E	121.94**	28.46	193.64	47.96**	17.25	14.44	13.36	20.12	0.31	0.30***	4.47	0.30
4F	11.74	50.24	67.94	6.84	22.62**	10.65	12.60	27.20	0.30	0.30***	1.56	0.28
5A	69.79	98.66	289.30**	32.69	10.18	9.18	26.12	4.93	0.30	0.30	0.31	0.30**
5B	15.99**	5.58	63.15	14.86**	24.29**	22.65	16.47	4.16	0.30	0.29***	0.30**	0.30
5C	58.86	51.28	161.69	1.77	15.77	11.46	26.18	20.42	0.30	0.30***	0.31**	0.25
5D	70.14**	38.27	241.90**	2.46	28.23	5.03	10.48	22.44	0.30	0.30	0.31	0.26**
5E	93.22***	3.76	41.39	54.13**	23.12	12.40	21.12	14.34	0.30	0.28***	0.30	0.30
5F	14.68**	6.71	5.33	81.10	22.27**	20.37	17.06	12.95	0.30	0.28***	0.28	0.30
6A	222.90	26.75	18.18**	9.73	16.35	25.50	25.37	6.44	0.31	0.30	0.41	0.29**
6B	167.41**	31.36	54.20	86.09**	9.44**	4.33	12.76	18.06	0.31	0.30***	1.36**	0.30
6C	36.05	3.09	50.34	161.22	26.71	20.63	10.45	26.54	0.30	0.27***	1.16**	0.31
6D	12.31**	3.68	40.12**	52.01	25.30	17.23	4.05	16.90	0.30	0.27	0.92	0.30**
6E	65.92**	102.49	24.10	8.24**	38.72	11.11	26.11	21.28	0.30	0.30***	0.55	0.29
6F	17.62**	28.6	12.65	108.79	18.83**	13.87	21.25	14.96	0.30	0.30***	0.28	0.30

** $p<0.01$; *** $p<0.001$

Changes in the community-level physiological profile (CLPP in percentage) of the four detected carbon groups (aromatic acids, carboxylic acids, amino acids, and carbohydrates) represented by 14 different substrates are presented in Figure 2A, B, C, D.

Based on the data obtained in the present study, we may elucidate that, the distributions of the four utilized substrates groups, at both sites and both soil layer at the eastern and western sites are follows: carboxylic acids > aromatic carboxylic acids > amino acids > carbohydrates.

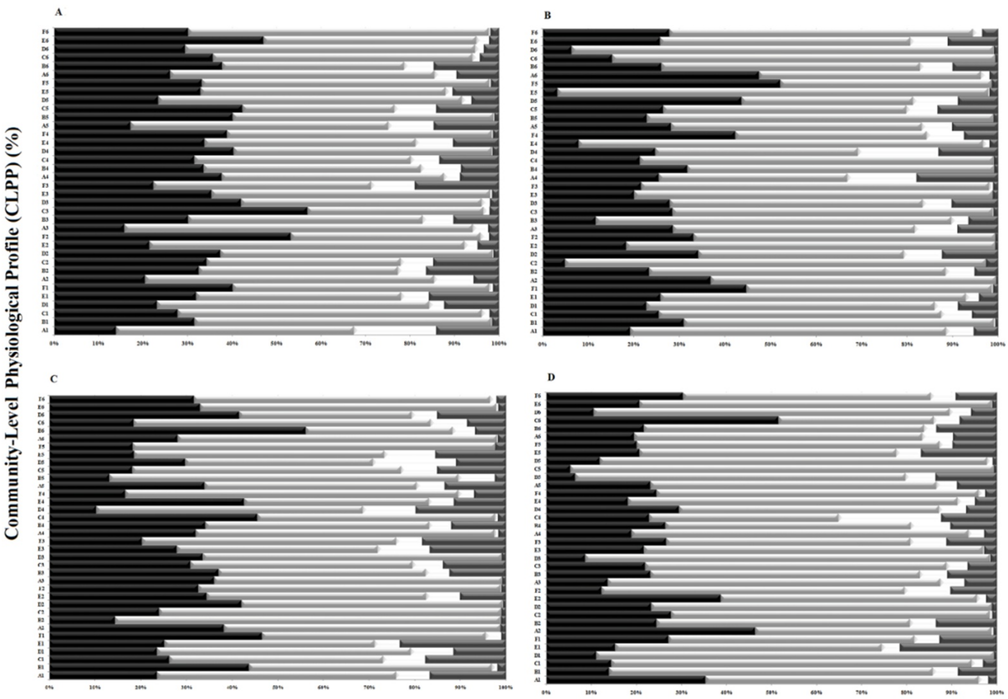

Figure 2. CLPP (%) in the eastern and western sites: **A**- 0-10 cm soil layer in the eastern site; **B**- 10-20 cm soil layer in the eastern site; **C**- 0-10 cm soil layer in the western site; and **D**- 10-20 cm soil layer in the western site. **■-** Aromatic carboxylic acids; ■- Carboxylic acids; □- Carbohydrates; ■- Amino acids.

Discussion

In the present study, the multi-scale analysis of the spatial distribution of soil microbial community revealed several different scales of organization, horizontally, ranging from 2 m to 10 m within the patches and vertically with two soil layers. The abiotic parameters exhibit similar patterns between the patches were the SM was found to be higher in the upper soil layer in comparison to the deeper soil layer at both sampling sites. A similar pattern was found for OM - were the western patch exhibited relatively higher organic matter in both layers in comparison to the eastern site patch. These two abiotic parameters are known as key factors for biotic activity (14, 15, 16). The mean values of biotic variables (microbial biomass, CO_2 evolution, CLPP) obtained for the eastern-site patch were higher than those in the western-site patch, except for CO_2 evolution in the 10-20 cm soil layer of the western site patch, which established an opposite trend. Moreover, a negative correlation was found between abiotic and biotic parameters in both site patches: the upper soil-surface layer exhibited higher biotic activity in comparison to the deeper soil layer. Based on the above, we assume that these biotic factors were triggered by the patchiness and the differences in vegetation cover.

qCO_2 undoubtedly provides a useful measure of microbial efficiency (2, 19). Our data related to *q*CO_2 distribution were found in accord with the literature data: an increase in *q*CO_2 brings a reduction in microbial efficiency. High *q*CO_2 and low microbial efficiency (microbial biomass and CO_2 evolution) were obtained for the western patch. Based on all obtained data, we assume that the richness of the microbial communities in both layers within the site patches, as well as the spatial distribution of the microbial communities between the patches, can be due to the distribution of abiotic factors, as well as the relative effect of the vegetation cover. Data obtained in the present study revealed that the overall microbial community structures on horizontal patterns are more similar among the samples within a site than among those taken between sites, since the geochemical and physical environments appear to be more similar in the former than in the latter case. It was also shown that there is variability in vertical patterns for the microbial community in these sandy soil ecosystems. As our attention in the present study focused on comparison between the spatial structure of microbial communities and environmental properties the results yield new response targeting interest on how biota communities develop in soil systems, and which factors may be important in management of soil-ecosystem. The selection of tillage system has important role in managing agroecosystems. Soil moisture saved through reduced tillage systems may be important in years with below-average rainfall. Soil organic matter tends to stabilize at a certain level for a specific tillage system used in fields with a particular soil texture. It is important to mention that sandy soils with similar particle size distribution but due to differences in mineralogy of the clay sized fraction that represents not more than a few percent of the soil mass, show very different physical properties and in sandy soils unlike other soils, the elementary fabric is easily affected by tillage practices. If greater porosity can be produced through tillage operations, the stability of these systems is very weak and compaction by wheels or other actions can in return produce a dense structure with adverse physical properties. This leads to a decrease in the water retention properties and hydraulic conductivity, an increase in the resistance to penetration and sensitivity to surface crusting. Thus, compaction results from a variation of the structure at all scales, i.e. from the macroscopic to microscopic scales. More generally, sandy soils, more than other soils, require careful management in an environmentally friendly manner. Indeed, even if most physical degradation processes are more easily reversible in sandy soils than in other soils, the physical fertility of these soils is weak. These soils require very little tillage operations in the wrong way to produce significant adverse consequences for plant development and consequently for crop yield and environment, that is the reason that microbial community can be used for the management in this type of ecosystems.

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Original scientific paper

Soil Water Content in Tillage Induced System

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Abstract

Global climate change became obvious and affects all beings on this planet. Agricultural production is no exception, and is faced with long periods of unfavorable climatic conditions for crop production. Increasing weather anomalies are evident in Croatia in the last two decades. They are characterized by ever increasing dry periods and increased average air temperature. Therefore soil management is gaining more importance with views to retain soil moisture. Longtime stationary field experiment was conducted in Central Croatia near the Daruvar (N 45°33', E 17°01'), characterized by perhumid to humid climatic conditions. Recently, Croatia faced more years with distinct water deficit in the summer months. The experiment consisted of six different tillage systems, no-tillage and five conventional tillage systems. This paper is aimed to give optimal tillage system for soil moisture retention at various depths and tillage impact on cultural plant yield. During the 2012 information about soil moisture were taken at 5 occasions since June to October. Samples were taken from the depth of 0-20 cm, 20-40 cm, 40-60 cm and 60-80 cm, in three replications. Statistical data evaluation showed significant differences in soil moisture between all tillage systems at all depths. Soil moisture content varied at depth 0-20 cm from 205.4 to 909.6 m^3 ha^{-1}, at depth 20-40 cm from 337.0 to 813.6 m^3 ha^{-1}, at depth 40-60 cm from 342.8 to 792.6 m^3 ha^{-1} and at depth 60-80 cm from 367.4 to 837.1 m^3 ha^{-1} depending on the measurement. No-till soil had from 25% less to 8% more stored soil water (0-80 cm) than other tilled plots in summer period during 2012. Results from 2012 suggest that, up to now, no-tillage could replace conventional tillage without adverse effects on soil water content in the Central Croatia. For wider application of no-tillage system in crop production of Central Croatia, further detailed research work is necessary to be able to talk about new trend.

Key words: climate change, water conservation, tillage, soil water content

Introduction

Climate change impacts are major threat for agriculture crop production. Two most important climatic factors, precipitation and air temperature, are under great changes in the last two decades in Central Croatia. Precipitation is the major source of natural water supply. There are two major characteristics of that; one is the amount of water and the other is the distribution. Depending on the crop, plants require 250-400 g of water to build 1 g of dry matter, in north geographic latitude between 45 and 47 degrees (Jolankai and Birkas, 2007). As the request of cultural plant maximum yields, it has greater water demands, especially in the period of higher transpiration. In these areas, the rainfall is highly variable from year to year and during the growing season.

Current trends in Central Croatia, around Daruvar, indicate that there has been an decrease in average annual precipitation of summer months in the last decade to 34.4 mm, with extremes in distribution. Simultaneously, there is an increase of 0.3^{0}C in the average annual air temperature in the last decade. Increasing temperatures during the summer months is even more pronounced and is 0.6^{0}C, indicating the climate change intensity (source: National Weather Service, Daruvar station, year 2001-2012). Temperature directly affects the most of life processes: photosynthesis, respiration, transpiration, water inhibition, and mineral uptake. Availability of soil water has turned into a problem in most parts of the country. Water shortages during growing season already played a critical detrimental role in winter wheat and maize yields in Croatia (Šestak et al., 2012). Majority of the adverse impact is caused by water shortages during critical phenophases. The last decades in Croatia is all more years with distinct water deficit in the summer months (Bašić et al., 2000).

The prospects of crop production development in closely connected with the soil moisture regime in soil, but tillage has great influence on soil moisture management. Water storage efficiencies varied with soil texture and soil organic matter, depending on tillage intensity. Tillage change soil water content, soil temperature, aeration, and the degree of mixing of crop residues within the soil matrix. Most farmers nurture habit of opening winter furrow for storage moisture. Due to the uncertain nature of rainfall distribution, the timing of primary tillage was a key factor for soil water conservation.

At the present time in Croatia the conventional tillage system dominates, which usually consists of two or more actions, the first of which involves moalboard plowing and others finer treatments for the seedbed preparation. Conventional tillage characterized by the tillage of the whole surface, and uses one way ploughing. No-tillage and conservation tillage is a promising alternative to traditional tillage for crop production in Moslavina region. In Croatia the trend of reduced tillage is based on the recognition of disadvantages of conventional one, including high costs. A lot of papers have been written to study the positive effects of no-tillage system on the physical characteristics of soils and moisture retention, but a small number of those who have investigated for longer period in the ecological conditions of the continental Croatia. Authors generally receive a more favorable impact on soil moisture content in the reduced tillage compared to conventional tillage (Ashraf et al., 1999; Fabrizzi et al., 2005; Hussain et al., 1999; Husnjak et al., 2002; Lampurlanes, 2001; Košutić et al., 2001; Špoljar et al., 2011). No-tillage increases infiltration and reduce evaporation compared with the conventional tillage. The adoption of these systems would reduce production costs and help to achieve the requirements for protection of soil and water resources imposed by the current Common Agricultural Policy of the European Union (Lopez et al., 1996).

Under changes of major climate characteristics in Central Croatia in the last two decades, soil and water conservation is an issue of primary concern in this region. It is necessary to assess the long-term dynamics of the available water content. This paper will try to give an answer which is the most convenient way of soil management in order to retain soil moisture for achieving high crop yields for adaptation of the agricultural practices to the climatic changes.

Material and methods

Long term tillage and crop management practices trial was established in 1994. Prior to the establishment of the experimental plots site have been conventionally tilled. Site is located 15 km southwest of Daruvar (45°33' N, 17°02' E, elevation 133 m) in Moslavina region, Central Croatia. The soil is mapped as Albic Stagnosol (according to FAO classification 1990) with a slope of 9%. The experimental design consists of six plots. Soil on the experiment belongs by its texture to sandy loam. Climate is semihumid to humid with annual precipitation of 878 mm and average annual temperature of 10.6^{0}C (Meteorological and hydrological institute of Croatia).

Tillage systems differed in tools that were used, depth and direction of tillage. Six tillage systems and implements, which were included in some system, are as follows: Check treatment (CT) – ploughing and other operations up and down the slope, black fallow; Conventional ploughing (25-30 cm) up and down the slope (CP) – other operations depending on the crop also up and down the slope; No-tillage system (NT) – no-till planter, sowing directly in mulch; Ploughing across of slope (PA) – conventional ploughing (25-30 cm) across of slope, other operations depending on the crop also across of slope; Deep ploughing (50 cm) across of slope (DP) – operation repeats after termination of prolonged effect (every 3-4 years when crop rotation allows), other operations on conventional way depending on the crop; Conventional ploughing across of slope (30 cm) with subsoiling to the depth of 60 cm (SUB) – subsoiling repeats after termination of prolonged effect (every 3 years when crop rotation allows), other operations depending on the crop.

Table 1. Particle size distribution on Stagnic Luvisols (from Kisic et al., 2002)

Soil depth (cm)	Soil horizon	Coarse sand (2-0.2 μm)	Texture (g kg^{-1})			Texture class
			Fine sand (0.2-0.02 μm)	Silt (0.02-0.002 μm)	Clay (<0.002 μm)	
0-24	Ap+Eg	18	586	242	154	Sandy loam
24-35	Eg+Btg	21	571	260	148	Sandy loam
35-95	Btg	5	545	254	196	Sandy loam

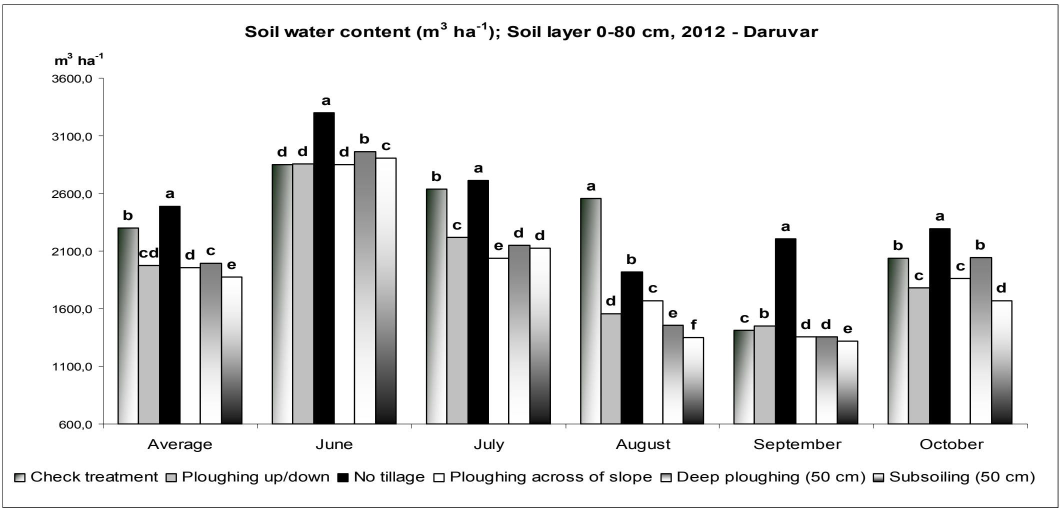
Water content measured by hand sampling probe during five terms, from June to October at selected crop growth stages, once a month. Soil water content was determined gravimetrically to a depth of 80 cm in 20 cm increments, in three replicates. Water content was converted to a volume basis using bulk densities previously determined by Kopecky's cylinders (100 cm^3) from each depth increment, in three replicates. Observed data were subjected to analysis of variance (ANOVA) using SAS Institute 9.1.3 and mean values were separated by Fisher's LSD test at $P \leq 0.05$.

Results and discussion

Average soil water content at depth 0-80 cm (Figure 1) is 2097.0 m^3 ha^{-1}. Observing the entire depth (0-80 cm), the highest average soil water content showed NT system (2487.0 m^3 ha^{-1}), while the lowest average amount of water showed SUB system 1873.0 m^3 ha^{-1}. Same results were obtained by Košutić et al. (2001) in applying no-tillage compared to other tillage systems in conditions of the northwest Slavonia. Špoljar et al. (2011) obtained more favorable results concerning the content of physiologically active and optimal soil moisture mainly on the reduced tillage treatments in similar soil and environmental conditions like this experiment.

In conventional tillage system highest soil water content showed CT system with 2299.1 m^3 ha^{-1} and SUB system had lowest results (1873.2 m^3 ha^{-1}). Statistically significant differences of whole profile (0-80 cm) were recorded between NT and conventional tillage and their different system of conventional tillage systems, except between CP, DP or PA. Observing each measurement there is a significant difference between all tillage systems in all months. Lowest soil water content had SUB (1317.3 m^3 ha^{-1}) in September and highest NT in June (3298.3 m^3 ha^{-1}). Significantly, the greatest amount of soil water contain NT in four of the five measurements, while is in August immediately after CT. In conventional tillage systems, except mentioned CT, best results showed DP system. Lowest results in soil water retention had SUB system in three of five measurements and PA system in two measurements. Results indicate that soil water recharge during growing season was greater under NT system than under different conventional tillage systems, probably due to reduced soil water evaporation because of crop residue on the soil. Soil water depletion during the growing season essentially followed the same pattern under all tillage systems, except the CT system in August. This can be justified by black fallow and rain that fell the day before sampling.

Soil water content always increased with depth to the layer of 60 cm and at depth 60-80 cm is reduced in most of tillage systems. It is similar to the situation that obtained Unger and Jones (1998) in dryland conditions of US Great Plains.



*Different letters means differ significantly ($p<0.05$)

Figure 1. Soil water content ($m^3\ ha^{-1}$) – average and separate values

The average soil water content for all tillage systems and depths (in layers of 20 cm) was 523.8 $m^3\ ha^{-1}$. The average moisture for all investigation depths (in layers of 20 cm) per particular tillage systems (Table 2) ranged from 562.3 $m^3\ ha^{-1}$ (CT), 472.3 $m^3\ ha^{-1}$(CP), 601.0 $m^3\ ha^{-1}$ (NT), 476.5 $m^3\ ha^{-1}$ (PA), 487.5 $m^3\ ha^{-1}$, (DP) to 453.6 $m^3\ ha^{-1}$ (SUB).

Statistically significant differences of water content in soil layers were recorded between NT and conventional tillage and their different variant of conventional tillage systems, at each measurement (Figure 2-5). Jabro et al. (2008) had no significant difference in soil water content between conventional tillage systems, but their research was in dryland conditions. The lowest average water content per particular tillage systems at the depth of 0-20 cm, 40-60 cm and 60-80 cm was determined in SUB systems and at depth 20-40 cm in PA system, while the highest average moisture content at all four depths were recorded in NT system. Different results are obtained from Lopez et al. (1996) suggest that soil water depletion under the NT treatment was confined more to the upper soil layers than for the conventional tillage in semi-arid areas of Spain. It is caused by different climate conditions, and at the end of growing season NT system markedly higher residual water content in the NT plots due to more rapidly depleted soil water under conventional tillage. Špoljar et al. (2011) had significant differences in moisture measurements at depth 0-30 cm between conventional tillage systems, and lowest amounts of soil water had in more intensive conventional systems. Similar results had Hussain et al., 1999; Husnjak et al., 2002; Lampurlanes, 2001; Košutić et al., 2001.

Highest average of soil water content in conventional systems recorded in CT in all four depths, followed by DP and CP (Table 2).

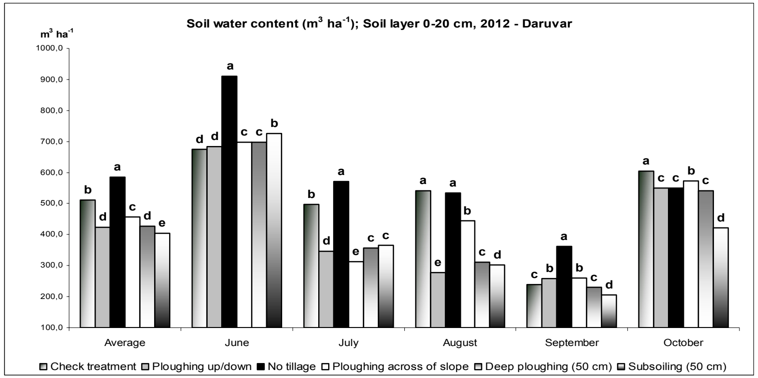
Table 2. Soil water content (m^3 ha^{-1}) in soil layers – average and separate values

Tillage system	Depth (cm)	Average	June	July	August	September	October
CT	0-20	511.9	675.6	498.1	541.5	239.2	604.8
	20-40	539.2	646.0	646.1	640.3	381.1	382.7
	40-60	635.8	768.3	733.0	680.0	401.1	596.4
	60-80	562.3	758.6	772.1	701.5	388.0	382.4
	Average	562.3	712.1	662.3	640.8	352.3	491.6
CP	0-20	422.6	682.9	346.3	277.1	257.5	549.3
	20-40	488.5	719.3	530.7	384.2	395.0	413.1
	40-60	505.9	726.7	583.1	409.7	401.9	408.3
	60-80	472.3	730.0	757.0	486.9	395.8	411.4
	Average	472.3	714.7	554.3	389.5	362.6	445.5
NT	0-20	585.6	909.6	571.7	534.3	362.7	549.5
	20-40	613.9	759.1	674.4	399.4	508.3	728.5
	40-60	603.6	792.6	708.2	491.7	641.0	384.4
	60-80	601.0	837.1	760.4	493.1	697.1	632.0
	Average	601.0	824.6	678.7	479.6	552.3	573.6
PA	0-20	457.7	697.8	313.1	445.1	259.4	573.4
	20-40	476.3	705.1	450.2	415.1	350.3	460.7
	40-60	495.3	737.5	581.2	399.2	359.8	398.9
	60-80	476.5	710.8	695.7	411.3	389.8	431.8
	Average	476.5	712.8	510.1	417.7	339.8	466.2
DP	0-20	427.2	697.5	357.3	310.6	229.9	540.8
	20-40	510.0	813.6	508.5	379.6	359.0	489.5
	40-60	525.1	692.9	575.8	372.9	360.3	623.6
	60-80	487.5	756.0	706.8	394.5	404.5	392.4
	Average	487.5	740.0	537.1	364.4	338.4	511.6
SUB	0-20	404.1	725.0	365.8	302.4	205.4	421.8
	20-40	489.7	760.2	499.2	337.0	337.6	514.8
	40-60	455.7	674.6	575.6	342.8	363.7	321.8
	60-80	464.9	747.1	682.2	367.4	410.5	410.8
	Average	453.6	726.7	530.7	337.4	329.3	417.3

*Values in the rows marked with different letters differ significantly ($p<0.05$)

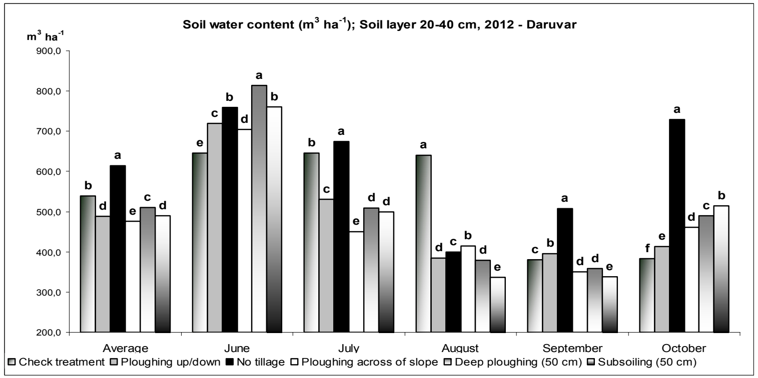
At the depths of 60-80 cm between PA, DP and SUB systems was no statistically significant difference. Average soil water values of summer months in 2012 point to the trend of increased moisture in NT and CT or DP tillage systems compared to others conventional tillage systems. In conventional tillage practice the adoption to soil moisture content is lower. This result is similar to previous papers (Greb et al., 1967, 1970; Unger and Wiese, 1979) that show improving water conservation with increasing amounts of crop residues in NT system retained on the surface.

Figure 2. Soil water content (m^3 ha^{-1}) at depth 0-20 cm



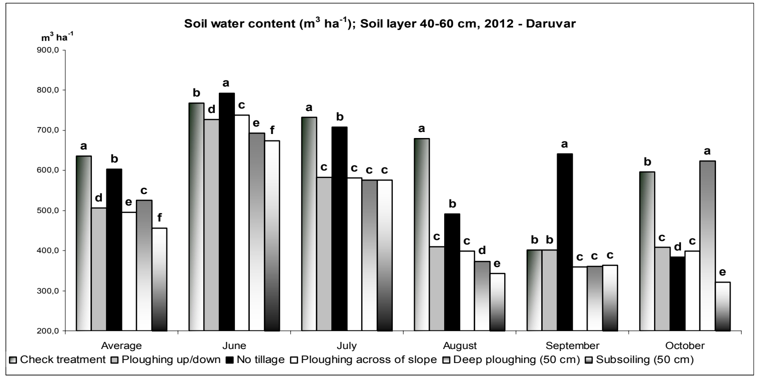
*Different letters means differ significantly (p<0.05)

Figure 3. Soil water content (m^3 ha^{-1}) at depth 20-40 cm



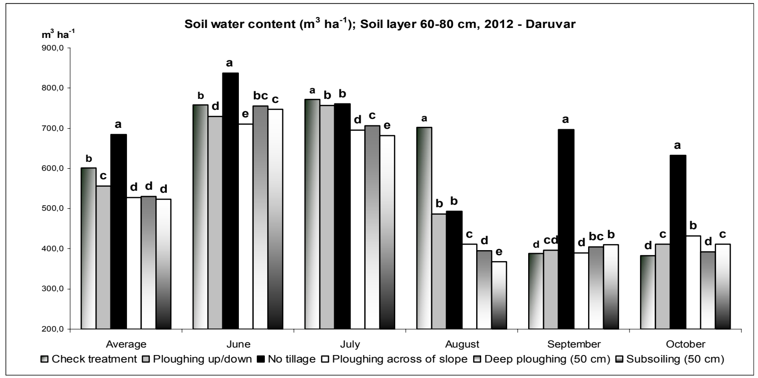
*Different letters means differ significantly (p<0.05)

Figure 4. Soil water content (m^3 ha^{-1}) at depth 40-60 cm



*Different letters means differ significantly (p<0.05)

Figure 5. Soil water content (m^3 ha^{-1}) at depth 60-80 cm



*Different letters means differ significantly (p<0.05)

Conclusions

Statistically significant differences in soil water content were determined between all tillage systems. Best results of average soil water values are in NT, and CT or DP variant of conventional tillage systems compared to others conventional tillage systems. Greater infiltration and lower surface evaporation are advantages associated with the soil structure created by non-inverting tillage in NT variant. Soil water was more limiting under CT variants than under NT system. SUB system shown the lowest soil water content. There is concern, however, whether long-term use of reduced tillage or NT will result in soil physical conditions that impair crop yields. Results from 2012 of our long-term tillage study suggest that NT, could replace CT without adverse effects on soil water content in the main cropping areas in Moslavina region (Continental Croatia). On the contrary, NT was a viable alternative to CT in the most semi-humid to humid zones due to its appropriate ability for soil water storage detected even at the beginning of the growing season. The results generally showed that tillage intensity effectively altered soil water content between NT and conventional tillage systems, but minimally affects the conventional tillage systems except the black fallow (CT) variant. SUB can improve the water infiltration and storage in year period with precipitation surplus, but cannot decrease the moisture loss in dry and average seasons. It is necessary to use adaptable tillage processes to improve water infiltration through alleviation of the compacted status (soil loosening, subsoiling) and to moderate the moisture loss (mulching). Average soil water values of summer months in 2012 point to the trend of increased moisture in NT and CT or DP conventional tillage systems compared to others variant of conventional tillage systems.

Considering the complexity of applying reduced tillage or no-tillage treatments, in our case no-tillage, for application of a new soil tillage technology, further detailed research work is necessary.

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Original scientific paper

Long-term application of soil tillage systems in crop rotation and their effect on phosphorus distribution in the soil units of Haplic Chernozems

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Abstract

In a 6-field crop rotation (grain maize – wheat – sunflower – wheat – bean – wheat) initiated at Dobrudzha Agricultural Institute in 1987, the effect of soil tillage systems with and without turning of the plow layer on the content of available phosphorus in the cultivated soil horizon was investigated. All tested soil tillage systems at the end of the second rotation of the 6-field crop rotation had strong effect on the redistribution of phosphorus down the root-deep soil layer. The constant minimum and nil tilths were characterized with higher content of phosphorus in the topmost plow layer. The content of available phosphorus formed in them was with 74.3 % higher than the content established under the soil tillage systems which involved systematic or alternative turning of the plow layer. All systems which included plowing enriched the 10-20 cm layer with averagely 19.7 % of available phosphorus, and at depth 20-30 cm the content of available phosphorus increased 2.5 times.

Redistribution of phosphorus depending on the size of the structural soil units was most expressed in the 0-10 and 10-20 cm layers. Highest amounts of available phosphorus were found in the soil units with size less than 5 mm, mainly in the <0.25 mm fraction. At depth 20-30 cm the role of the size of soil units for phosphorus redistribution decreased strongly.

Key words: 6-field crop rotation, systems for soil tillage, available phosphorus, soil units

Introduction

The phosphate regime of soil is a significant trait of soil fertility, and the use of various agronomy practices is the tool for its purposeful regulation. Besides maximum differentiation of technology, simplification of the agro technology used for cultivation of the field crops is also necessary in accordance with the specificity of the soil type and the requirements of the plants (Dilkova et al., 1984).

A number of authors have reported that the long-term reduction of deep plowing leads to higher amounts of phosphorus in the soil surface layer, and to its considerable decrease in the underlying layers (Kondarev and Dimov, 1981; Klochkov, 1983; Tsvetanova-Lazarova and Stoychev, 1987; Haziev et al., 1999). Tsvetanova – Lazarova (1989) has established that fertility decrease in the 10-20 and 20-30 cm layers at plowing without turning of the layer and especially at nil tillage was primarily due to the multiple decrease of phosphorus content. According to Ivanov et al. (1988) the effect of direct sowing with tilths without turning of the layer on the phosphate regime was two-directional. On the one hand, the mobility and availability of the residual fertilizer phosphates increased under the effect of local fertilization and mulching, and on the other hand the distribution by layers in the plow horizon was unfavorable.

Nankova and Kalinov (1992) reported that long-term direct sowing and tillage without turning of the layer determined higher amount of mobile phosphorus in the surface layer and better expressed differentiation by layers in comparison to the traditional plowing used before all crops in the crop-rotation.

Dimitrov and Mitova (1997) also pointed out that the percent of the slimy fraction in the 20-40 cm layer tended to increase after annual plowing as a result from turning of the plow layer.

The aim of this investigation was to determine the effect of different soil tillage systems in a multi-field crop rotation on the redistribution of available phosphorus by soil units in the upper layers of the root-deep horizon.

Material and methods

The investigation was carried out in a stationery field trial in 6-field crop rotation under the following rotation scheme: grain maize – wheat – sunflower – wheat – bean – wheat. The trial was initiated at Dobrudzha Agricultural Institute – General Toshevo in 1987 on slightly leached chernozem soil (Haplic Chernozems, WRBSR, 2006). The trial was designed by the non-standard method, with 72 m^2 size of the plots, in 8 replications.

The mineral fertilization used in the rotation of all crops involved the same PK background - 12 kg P_2O_5/da and 8 kg K_2O/da in the form of TSP and KCl.

The norm of nitrogen fertilization was differentiated according to the type of predecessor and the crop. The direct nitrogen fertilization for grain maize was e 160 kg N/ha; for sunflower - 60 kg N/ha; and for bean - 40 kg N/ha. Depending on its position in the crop rotation, wheat was fertilizes with the following amounts of nitrogen: after grain maize - 140 kg N/ha, after sunflower - 160 kg N/ha and after bean - 120 kg N/ha. Nitrogen fertilization was done with NH_4NO_3. In the spring crops the nitrogen fertilizers were introduced early in spring with a single application, and in wheat 1/3 of the nitrogen norm was applied prior to planting, and the rest of the amount – in spring at tillering stage. At the end of each rotation the tested soil tillage systems were treated with the same amounts of nitrogen phosphorus and potassium fertilizers.

Out of the 24 soil tillage systems, seven were selected for the purpose of this investigation; they were based on different soil tillage tools and way of cultivation (Table 1).

Table 1. Tested systems of soil tillage

Soil tillage system	Depth of tillage, cm	
	Spring crops	Wheat
1. Plowing (check)	24-26	14-16
2. Disking	10-12	10-12
3. Cutting	24-26	8-10
4. Nil tillage	Direct planting	Direct planting
5. Plowing-disking	24-26	10-12
6. Plowing-nil tillage	24-26	Direct planting
7. Disking-nil tillage	10-12	Direct planting

At the end of two complete rotations since the initiation of the trial, soil samples were taken from layers 0-10 cm, 10-20 cm and 20-30 cm. The soil structure was determined through dry and wet sifting of soil, establishing the percent ratio of the structural soil units of different size (>10, 10-5, 5-3, 3-1, 1-0.25, <0.25 mm). Phosphorus available to plants was determined by the acetate – lactate method with subsequent blue colorimetric detection (Ivanov, 1984).

The statistical analysis included the use of the software BIOSTAT version 5.1 (Penchev, 1998), STATISTICA version 5.0 and SPSS 13.0.

Results and discussion

The role of soil tilths for providing optimum physical and chemical conditions for micro biological activity, which has considerable contribution to the transformation of the nutrients introduced in soil, is indisputable.

The dispersion analysis on the results obtained at the end of the second rotation revealed high statistical significance of the independent effect of all tested factors (Table 2). This tendency was confirmed for the different combinations of their interaction.

The dispersion analysis on the data for each of the investigated layers down the root-deep horizon additionally characterized the significance of the effect of the factors “soil tillage system” and “size of the soil units” on the content of available phosphorus in soil.

Table 2. Variance analysis of the available phosphorus content

Source	df	Mean Square	F	Sig.
For All factors				
Tillage systems (1)	6	37.600	21.125	0.000
Soil Depth (2)	2	1719.691	966.183	0.000
Soil Size (3)	5	95.137	53.451	0.000
1 x 2	12	297.958	167.404	0.000
1 x 3	30	8.846	4.970	0.000
2 x 3	10	5.578	3.134	0.001
1 x 2 x 3	60	8.425	4.733	0.000
In Depth 0-10 cm				
Soil Size (3)	5	51.031	13.760	0.000
Tillage systems (1)	6	359.132	96.835	0.000
1 x 3	30	17.078	4.605	0.000
In Depth 10-20 cm				
Soil Size (3)	5	44.045	43.006	0.000
Tillage systems (1)	6	58.387	57.009	0.000
1 x 3	30	5.833	5.695	0.000
In Depth 20-30 cm				
Soil Size (3)	5	11.216	18.485	0.000
Tillage systems (1)	6	215.998	355.971	0.000
1 x 3	30	2.785	4.590	0.000

The strength of the effect of the tested factors within the entire trial on the phosphate regime of soil was clearly expressed (Figure 1). This effect was highest in the interaction tillage system x soil depth, followed by soil depth. The interaction between the three factors was also very well expressed.

Down the soil layers, the effect of the type of soil tillage had stronger influence on the available phosphorus content (Figure 2). It was found that this effect was highest in the 20-30 cm layer and lowest – in the 10-20 cm layer, where the strength of the effect of the soil unit size sharply increased, as well as the combined interaction of these two factors.

At the end of the second rotation, regardless of the equal amounts of introduced fertilizers, available phosphorus content had significantly differentiated values as a result from the applied soil tillage system (Table 2). Highest values of its content, averaged for the effect of the tested factors, were determined at systematic disking and alternation of plowing with nil tillage.

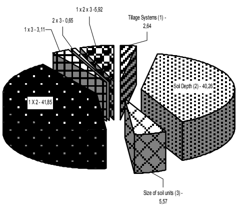

Figure 1. Strength of the effects of the tested factors

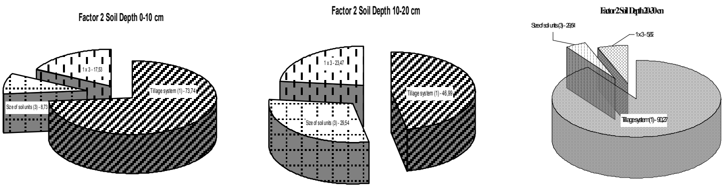

Figure 2. Strength of effect of factors Tillage system (1) and Size of soil units (3) on the content of available phosphorus according to soil depth (2)

Considering the results by soil layers, it becomes evident that most dynamic were the changes in the surface layer (0-10 cm), where, depending on the used soil tillage system, phosphorus content varied from 24.23 mg P_2O_5/100 g soil (plowing-nil tillage) to 8.00 mg P_2O_5/100 g soil (plowing-disking).

Table 2. Content of available phosphorus depending on the soil tillage system, mg P_2O_5/100 g soil

No	Tillage systems	For all factors	0-10 cm	10-20 cm	20-30 cm
1	Plowing	10.81 b	11.54 b	8.91 b	11.98 e
2	Disking	11.42 c	19.87 d	11.16 d	3.23 b
3	Cutting	9.48 a	15.10 c	9.67 c	3.68 b
4	Nil	9.17 a	16.09 c	8.92 b	2.49 a
5	Plowing-disking	9.33 a	8.00 a	10.49 d	9.51 c
6	Plowing-nil	11.62 c	12.01 b	11.96 e	10.90 d
7	Disking-nil	10.68 b	24.23 e	5.18 a	2.63 a

The 10-20 cm layer had the lowest amplitude of variation of the phosphorus values depending on the soil tillage system.

In the underlying layer (20-30 cm) the differentiation in the content of available P increased to amplitude of variation 9.49 mg P_2O_5/100 g soil, which was lower than the variation in the surface layer. This layer, too, reflected strongly the differences in the nutrition regime of soil, conditioned on the one hand by annual plowing and the systems of its alternation, and on the other – by the tillage systems without turning of the soil layer. Similar results have been reported by Hristov (2003) who found that the use of minimal tillage and tillage without turning of the layer increased the content of available phosphorus in comparison to traditional soil tillage.

There is an evident contribution of the systems involving plowing for the increase of available phosphorus at depth 20-30 cm and obtaining of values approximating to a maximum degree the values determined at annual plowing. A similar, though less expressed tendency was found at annual cutting as well. The probable reason is that at this type of tillage the soil layer is loosened without turning and mixing the soil. It is known that the phosphate ion has slow mobility in soil and therefore the main contribution for the enrichment of the underlying layers was of the factor depth of cutting.

Significant was the role of the tilths for the redistribution of available phosphorus depending on the size of soil units (Table 3). It can be definitely stated that averaged for all tested soil tillage systems the amount of available phosphorus started increasing with the soil units of size <5 mm, reaching maximum values with the fraction <0.25 mm.

Table 3. Content of available phosphorus depending on the size of soil units, mg P_2O_5/100 g soil

No	Soil size	For all factors	0-10 cm	10-20 cm	20-30 cm
1	> 10 mm	9.06 a	13.67 a	8.26 ab	5.26 a
2	10 - 5 mm	8.91 a	13.23 a	7.60 a	5.91 bc
3	5 - 3 mm	9.63 b	14.52 ab	8.61 b	5.74 ab
4	3 - 1 mm	10.32 c	15.11 b	9.41 c	6.44 c
5	1 – 0.25 mm	11.48 d	16.91 c	10.44 d	7.08 d
6	< 0.25 mm	12.76 e	18.14 c	12.49 e	7.66 e

The slimy fraction in soil carries higher amounts of available P in comparison to all other sizes of soil units in all investigated soil layers. Their amount was highest in the surface layer, gradually decreasing down the soil profile.

The complex expression of data clearly reflects the effect of each tested soil tillage system on the redistribution of available phosphorus down the soil profile according to the size of soil units (Figure 3). In the surface 0-10 cm layer highest content of available phosphorus was detected in the largest soil units (>10 mm) at the systems nil tillage and nil tillage-disking, and lowest – in the systems involving plowing. The system with annual plowing at different depths in the crop rotation was characterized with strongly expressed differentiation in phosphorus redistribution depending on the size of soil units: from 5.30 to 20.20 mg P_2O_5/100 g soil. The gradual increase of available P content with the decrease of the size of soil units was typical for this system. Similar tendency was observed in the other systems which involved plowing, too, but the amplitude of variation between the maximum and minimum values was less expressed in comparison to constant plowing.

The independent application of nil tillage also had high variations in the P values but in contrast to plowing this occurred only between the soil units with largest size (>10 mm and 10-5 mm), while with the agronomically valuable soil units the differences in the content of available P were insignificant.

In the 10-20 cm layer the distribution of P in the soil units smaller than 3 mm was subjected to lower variation within each individual system, with the exception of nil tillage and partially – of the systems which included it. P distribution in the larger soil

Regression analysis was applied to find out the relation of available phosphorus content in the structural units to the tested soil tillage systems. On the basis of the constructed model (Table 4) and the obtained experimental data, a graphic model of the respective equations was worked out (Figure 4).

With b_i are designated the respective weight coefficients: b_1 soil units with size >10 mm (%), b_2 soil units with size 10-5 mm (%), b_3 soil units with size 5-3 mm (%), b_4 soil units with size 3-1 mm (%), b_5 soil units with size 1-0.25mm (%), b_6 soil units with size <0.25 mm (%). In the graphic representation, dark green color defines negative meaning. The lighter green color corresponds to weight coefficients approximating zero. The nuances of yellow and red characterize the increasing percent of the respective factor in a positive direction (Mihova, 2000).

Based on the applied analysis it was found that in all investigated systems of soil tillage, with the exception of cutting-cutting, the percent of soil units with size <0.25 mm (b_6) had highest weight coefficient. In cutting without turning of the soil layer, the fraction >10 mm (b_1) had highest effect on the content of available phosphorus, while in the systems plowing – plowing, disking-disking and disking-nil tillage these very soil units influenced negatively the amount of the investigated nutrient in the structural soil units. Under constant direct planting and annual cutting, the fraction 10-5 mm (b_2) had lowest weight coefficient, and in the system plowing-disking the soil units with size 5-3 mm (b_3) were with lowest weight coefficient.

The higher amount of structural soil units with size <0.25 mm in the systems involving plowing and disking were a consequence of the constant soil tillage operations carried out at the same depth and of the mechanical destruction of soil by the soil tillage tools which destabilized the soil units by accelerating the processes of mineralization. Under long-term direct planting, the higher weight coefficient of the finest fraction was determined by the processes of physical and chemical erosion, the constant destructive activity of the temperature variations, the kinetic energy of rainfalls and the chemical influence of rain waters.units in all systems at this depth had more intensive dynamics of variation.

Although the differences in the content of P between the soil tillage systems remained the same in the underlying 20-30 cm layer, this content varied with lowest amplitude in the systems without turning of the soil layer, depending on the size of soil units. Annual plowing and its alternation with disking caused much higher increase of P content with the smaller soil units in comparison to the other soil tillage systems.

The comparatively low degree of soil loosening under tillage without turning of the soil layer decreased and excluded the destructive effect of the tilths on the soil structure. As a result the large-sized soil units increased. The determination coefficients (R^2) of the respective equations of linear regression for the different soil tillage systems had value 0.95-0.97, i.e. 95-97% of the total variation of the resultant trait can be explained by the factor-traits x_1, x_2, x_3, x_4, x_5 and x_6. This means that the soil structure also significantly influences the distribution of available phosphorus, i.e. this was a confirmation for its involvement in the constructed model.

The regression model allowed predicting the expected value of the specific trait under given or expected values of the factor involved in the model.

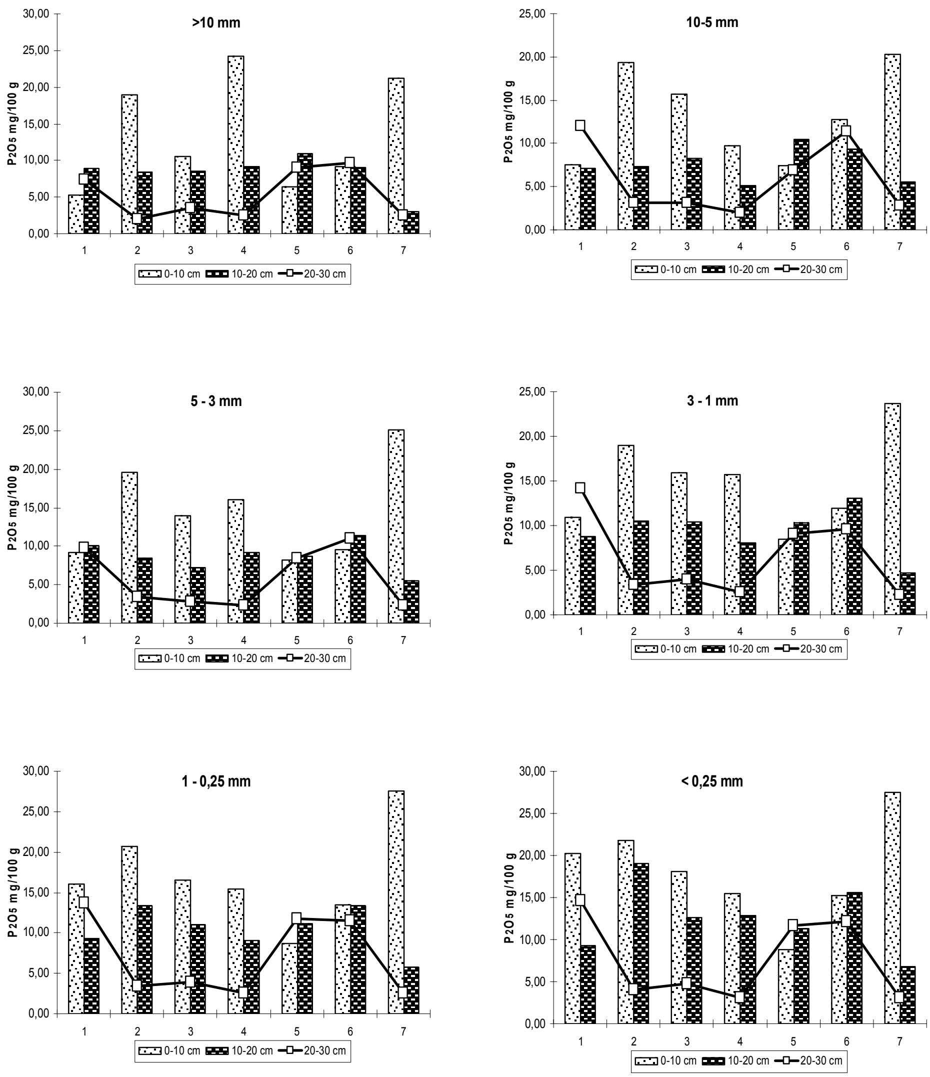

Figure 3. Redistribution of available P according to the soil tillage system and the size of soil units down the soil profile, mg P_2O_5/100 g soil

Table 4. Regression models characterizing the effect of the size of structural soil units on available phosphorus content

General regression model	$Y = a + b_1x_1 + b_2x_2 + b_3x_3 + b_4x_4 + b_5x_5 + b_6x_6$	R^2
Plowing-plowing	$Y = 0.479 + 0.178x_1 + 0.265x_2 + 0.647x_3 + 0.765x_4 + 2.405x_5 + 3.440x_6$	0.97
Disking-disking	$Y = 0.093 + 0.163x_1 + 1.051x_2 + 0.607x_3 + 1.219x_4 + 1.838x_5 + 3.214x_6$	0.97
Cutting-cutting	$Y = 0.019 + 2.298x_1 + 0.051x_2 + 0.252x_3 + 0.309x_4 + 1.403x_5 + 1.428x_6$	0.95
Nil-nil	$Y = 0.212 + 0.238x_1 + 0.164x_2 + 1.696x_3 + 0.574x_4 + 2.858x_5 + 4.789x_6$	0.97
Plowing-disking	$Y = 0.132 + 0.168x_1 + 0.215x_2 + 0.156x_3 + 0.446x_4 + 0.494x_5 + 0.642x_6$	0.95
Plowing-nil	$Y = 0.115 + 0.157x_1 + 0.198x_2 + 0.287x_3 + 0.208x_4 + 0.292x_5 + 0.309x_6$	0.95
Disking-nil	$Y = 0.078 + 0.162x_1 + 0.913x_2 + 0.643x_3 + 0.517x_4 + 1.985x_5 + 2.987x_6$	0.97

x_1 percent of soil units with size >10 mm, x_2 percent of soil units with size 10-5 mm, x_3 percent of soil units with size 5-3 mm, x_4 percent of soil units with size 3-1 mm, x_5 percent of soil units with size 1-0.25 mm, x_6 percent of soil units with size <0.25 mm

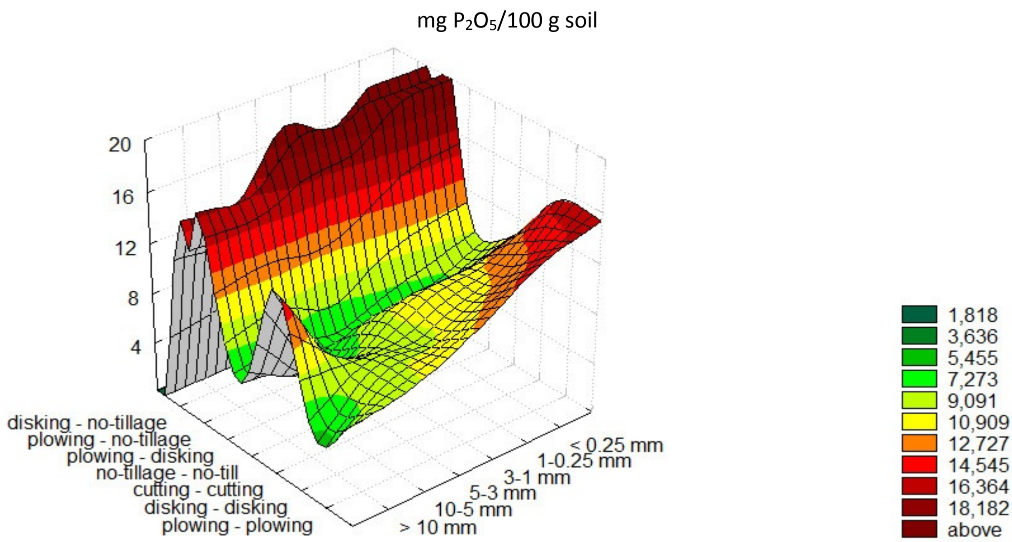

Figure 4. Graphic representation of the regression model of available phosphorus content

Conclusions

All tested systems of soil tillage at the end of the second rotation in a 6-field crop rotation had strong effect on the redistribution of phosphorus down the root-deep soil layer. The constant minimal and nil tilths were characterized with higher phosphorus content in the upper plow layer. The formed amount of available phosphorus was with 74.3% higher than the amount determined under soil tillage systems involving alternative turning of the soil layer. All systems involving plowing enriched the 10-20 cm layer with a mean of 19.7% of available phosphorus; at depth 20-30 cm the content of available phosphorus increased 2.5 times.

The redistribution of phosphorus according to the size of structural soil units was most expressed in the layers 0-10 cm and 10-20 cm. Highest amounts of available phosphorus were contained in the soil units with size <5 mm, mainly in the <0.25 mm fraction. At depth 20-30 cm the role of the size of the soil units for the redistribution of phosphorus decreased, especially under the systems without turning of the soil layer.

Under the systems involving plowing, disking and direct planting, the soil units with size <0.25 mm had highest weight due to the higher amounts of available phosphorus in them. Under tillage without turning of the plow layer, the large-sized fraction (>10 mm) had higher effect on the content of this nutrient.

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Original scientific paper

Effects of tillage systems in irrigated crops on microbiological parameters of soil in different crop rotations

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Abstract

Nitrogen (N) is the main limiting factor in crop productivity and thereby soil management systems may change the mineralization and nitrification rates. The objective of this study was to calculate the net mineralization and nitrification rates of soil N and the correlation with soil pH under management systems in irrigated crops. Randomized complete block design was used, in split-split plots, with four replications, with tillage system as main factor, crop rotations as sub-factor and fertilization as sub-sub factor. The tillage systems used were conventionally (CT) and zero or no till (NT). Crop rotation were Maize-Maize-Maize, Maize-Soy Bean-Wheat, Maize-Sorghum-Wheat. The present study was conducted to determine the effect of tillage systems on nitrogen mineralization after one year of soil management in maize crop. 96 soil samples were studied by incubation at different times (five weeks) and depths (six depths). Sampling depth was ranged from 0-100cm, at intervals of 10cm. Mineralization capacity of nitrogen was higher at the soil surface while that mineralization and availability of nitrogen decreased with deeper layers in CT and NT systems. Net mineralization was higher in thee first cm of soil under NT than CT, however, higher processing capacity of nitrogen between 20-40cm was found under CT than NT due to management soil. A first order kinetic model (R_2 = 0.79) of net nitrogen mineralization was created and the rate of mineralization (k) was obtained. The model results indicated that the rate of mineralization (k) and potentially mineralized nitrogen increased and decreased respectively with depth.

Key words: Soil mineralizable N, tillage, crop rotation, Net Nitrogen Mineralization

Materials and methods

The field experimental was established in April 2011 at the Zamadueñas Experimental Station (Valladolid, Spain). The soil of the studied area is a Cambisol with higher clay and silt loam texture and water holding capacity. The climate is a typical Continental Mediterranean with cold winter and war summers. Mean annual temperature is 12.6° C and annual precipitation is 424.7 mm.

The experimental design is a split-split-plot with four replications where the main factor is the system of tillage (CT, moldboard plow, cultivator and sowing and NT, herbicide and sowing), the second factor is the crop rotation (Maize-Maize-Maize, Maize-Soy Bean-Wheat, Maize -Sorghum-Wheat) and the third factor is the fertilization (conventional (FC) and adjusted (FR)). The study covered a total of forty-eight 240 m^2 elementary plots. In this study only results after harvest of maize crop from the first year are presented. Soil samples were collected on November 2011 (after maize harvest) at three sites on each elementary plot to obtain a composite sample per plot from 16 plots at a depth of 0-10, 10-20, 20-30, 30-40, 40-60 and 60-100 cm (total 96 samples, 4 plots x 4 replications x 6 depths). The composite samples were sealed in plastic bags and transported to the laboratory for analysis. Nitrogen mineralization of soil samples was determined by aerobic incubation without leaching. The 96 soil samples were incubated during 36 days at 60% moisture and 28°C temperature conditions, then the ammonia nitrogen (easily mineralizable) and nitrogen oxide was determined. Ammonia nitrogen extraction was determined by Keeny y Nelson (1982) method. Ammonia nitrogen determination was obtained with Nelson (1983) method. Soil nitrate extraction and nitrate from soil extracts were analyzed by Official Methods of Soils Analysis MAPA (1993) and (Norman, R.J.; Edberg, J.C. y Stucki, J.W., 1985) methods respectively.

Data analyses showed a normal distribution which was established using the Wilk–Shapiro normality test, and therefore used over parametric statistics. Spearman (Kumar, Indrayan, and Chhabra, 2012) and Pearson (Galton, 1880) correlations were made to observe the degree of association or independence between variables. These correlations were supplemented with graphs represented by linear and nonlinear regression.

The exponential: $f(y) = \alpha * e \hat{} (\beta * x)$ model was used.

Data were statistically analyzed using R programme applying Student's or the LSD Means test with $p < 0.05$.

Results

Because data analysis revealed that soil NO_3^- and NH_4^+ had non significant differences between tillage systems results were not presented. Table 1 showed the soil total nitrogen and mineral nitrogen NO_3^- and NH_4^+ accumulation along the incubation period at different depths. Soil total nitrogen was very low and decreasing with depth. Data indicated that NO_3^- content was increasing over time and decreasing with depth layers while NH_4^+ accumulated values were similar over time but decreasing with depth. NO_3^- content had major influence than NH_4^+ on the mineralization rate.

Table 1. Mineral nitrogen forms accumulation along the incubation period and soil total nitrogen (STN)

		Incubation time (NO_3^- mg kg^{-1})				**Incubation time (weeks) (NH_4^+ mg kg^{-1})**		
Depth	**N t (%)**	0	2	3	5	0	2	3
0-10 cm	0.084	7.56	26.60	42.65	70.27	13.60	13.80	13.95
10-20 cm	0.083	7.07	24.20	41.07	63.97	14.49	14.67	14.84
20-30 cm	0.079	7.20	23.29	38.39	57.09	12.67	12.86	13.00
30-40 cm	0.068	6.60	23.01	34.55	52.58	11.02	11.22	11.33
40-60 cm	0.056	8.98	23.43	32.84	47.95	10.33	10.53	10.65
60-100 cm	0.050	9.66	21.51	29.98	45.51	9.88	10.19	10.33

Figure 1a shows mineral nitrogen NO_3^- and NH_4^+ evolution along 35 days of incubation. Nitrate content increased progressively from 6.5 to 18 mg Kg^{-1} at the end of the incubation time however, ammonium, NH_4^+, was transformed and decreased during the first incubation period (day 1 to day 14) as a result of volatilization and oxidation of N-NO_2 and NO_3^- potential forms, influenced by the basic pH soil. In this study net mineralization nitrogen was significantly correlated with soil pH as observed in Figure 1b. These results are consistent with findings reported by (Barberis and Nappi, 1995) and (Harmsen et al., 1955).

a) b)

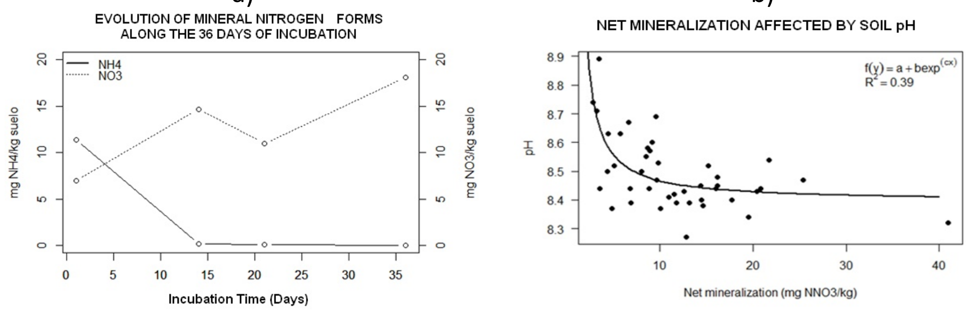

Figure 1. Mineral nitrogen forms evolution during the incubation period (a) and correlation model between nitrogen mineralization and soil pH (b)

Net mineralization nitrogen evolution at different depths along five weeks is presented in Figure 2. Results indicated that incubation time and profile depth had an important effect on net mineralization nitrogen which was higher for the shallow layers, mainly at 0-10 cm depth while for the deeper layers, 40-60 and 60-100 cm, net mineralization was lower from two weeks of incubation.

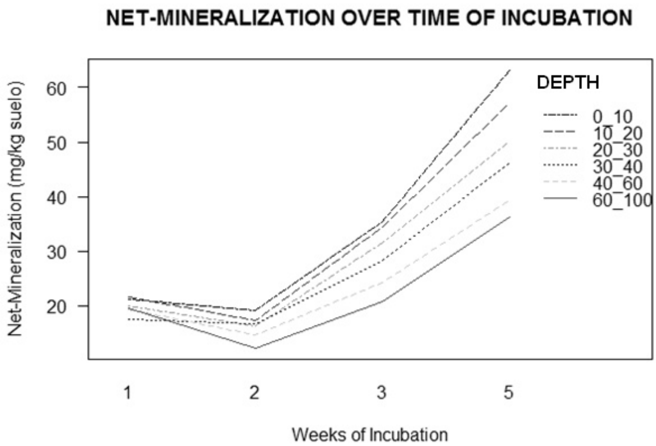

Figure 2. Mineral nitrogen evolution at different depths along 5 weeks of incubation

Net mineralization was significantly different between tillage systems; NT had 50% higher mineralization than CT at 0-10 cm depth (Figure 3). From 10 cm to 50 cm depth, tillage system behavior was opposite; CT had higher mineralization than NT. These results were due to management tillage. Surface layer had more nutrients and organic matter in NT as many researchers concluded (Lopez-Fandó and Pardo, 2009; Sombrero and de Benito, 2010) and mineralization was higher in this layer. However, in CT systems, soil organic matter and nutrients were increasing with depth (Gal et al., 2007) due to moldboard plowing and soil overturning and therefore net nitrogen mineralization was greater in these layers. Other authors also concluded that soil management alters the processes in which the microbial population is involved, such as nitrogen mineralization (García et al., 1992; Benintende et al., 2008).

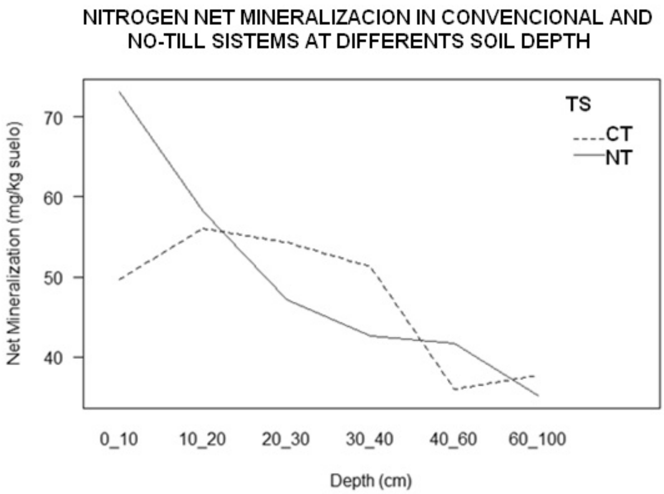

Figure 3. Net mineralization evolution along the soil profile. This was differentiated by tillage systems

Measurements of soil nitrogen were performed in function of time, therefore, the data obtained at different incubation periods follow the behavior of a kinetic model (Standford and Smith, 1972). In this model, a first order kinetic used a nonlinear regression analysis by the method of least squares (Smith et al., 1980). Mineralized nitrogen is linearly related to the square root of time (figure 4). The model followed this kinetic type: $N_m = N_o (1\text{-}e^{-kt})$, where N_m is the amount of mineralized nitrogen, N_o is potentially mineralized nitrogen (mg kg^{-1}), k is the constant of the first order of mineralization ($time^{-1}$) and t is the incubation time. N_o x k is the mineralized nitrogen per unit time.

The model describes a process of nitrogen mineralization to calculate the exponential and potentially mineralizable nitrogen (N_o) and constant of mineralization (k) representing the potential of mineralization. Nitrate amount per kg of dry soil that is mineralized weekly (N_o x k) was determined. Constants nitrogen mineralization for the samples studied was established by depth. Two models mineralization rate were created, the first corresponded to the soil layers between 0 and 30 cm and the second, from 30 to 100 cm depth.

The results showed that nitrogen mineralization potential decreased proportionally to the depth (Table 2). N_0 had 184.25 $mgkg^{-1}$ in upper layers (0-30 cm) while in deeper layers N_0 had 119.03$mgkg^{-1}$, results consistent with those of Benintende et al. (2008). Hadas et al. (1986) also determined that the N_o decreased with depth and had consistent relationship between depth and the rate of mineralization. The constant of mineralization (k) was lower at the soil surface and higher when depth increased. This parameter can be inferred on the time of potentially mineralizable nitrogen in which is degraded. K values found were similar to those determined by Benintende et al. (2008), Cassman and Munns (1980) and Hadas et al. (1986). Echeverría et al. (1994), found that the mineralization constant (k) had higher values in the deeper horizons than in the surface layers which suggested a different composition of the fraction likely to be mineralized in different layers. Stanford and Smith (1972), for a wide range of soils in USA, determined that mineralization rate was 0.054 + / - 0.009. Oyanadel and Rodriguez (1977) found a mean mineralization rate of 0.0058 + / - 0 01 in soils in Chile.

Table 2. Parameters determining the rate of mineralization: N_o= potentially mineralized nitrogen (mg .kg^{-1}), k= constant of mineralization ($time^{-1}$) and t= the incubation time. N_o x k=mineralized nitrogen per unit time.

Parametres	**Depth**	
	0-30 cm	30-100cm
NN_o (mg N-NO_3^-.kg^{-1} dry soil)	184.25	119.03
k k ($weeks^{-1}$)	0.04	0.08
NN_o x k (mg N-NO_3^-.kg^{-1} per week)	7.37	9.52
RR^2	0.78	0.79

The kinetic model created allows to predict the value of NO_3-mineralized, under laboratory conditions, with a coefficient of determination of R^2 = 0.78 and 0.79, for 0-30 cm and 30-100 cm respectively.

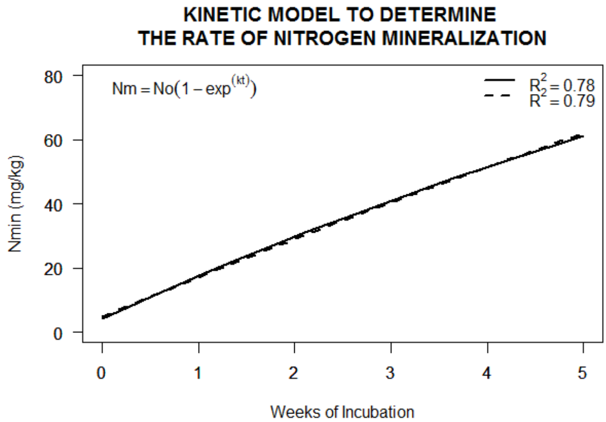

Figure 4. First-order kinetic model to determine the rate of nitrogen mineralization. R^2= 0.78 in depth 0-30cm; R^2= 0.79 in depth 30-100cm.

Conclusions

Management soil affected the net nitrogen mineralization in a year of conventional and no tilled system, NT had higher mineralization in the surface layer than CT which had higher values at deeper layers. Soil profile depth and incubation time determined the behavior of mineral forms of nitrogen. A model was created which allowed obtaining the rate of mineralization and nitrogen mineralization potential under controlled conditions with a high degree of confidence. CT caused more potentially mineralizable nitrogen accumulated in depth while NT showed greater amount of nitrogen on the surface.

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The effect of tillage system in yield and its components of bread wheat in SalahAldin – north of Iraq

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Abstract

This study carried out in order to compare the effect of the type of tillage in some crop qualities and productivity of spring bread wheat, *Triticum aestivum* L. Cham 6 var. during the 2011-2012 agricultural season in homogeneous field in district of Tuz - Salahuddin province north of Iraq in total area of six hectares (24 Iraqi Donum), RCBD design was used, the field was divided into three blocks included 2 treatments with 3 replicates, the first treatment was conventional tillage using disc plow to plowing the soil before sowing with local seeder, second treatment Zero Tillage planting method using new ZT seeder with press wheels to compact soil on seeding row. Thus we have 6 experimental units each unit area was one hectare. Except planting methods all other factors such as fertilizer dosage (80 kg N/ha and 120 kg P_2O_5/ha), weed control, supplementary irrigation, seeding rate (120 kg/ha) sowing date (27/11/2011) are the same. Plant height / cm, stem thickness / mm, number of tillers / m^2, number of spikes / m^2, spike length / cm, number of grains / spike, the weight of 1000 grains, specific weight kg / hectoliter, biological yield kg/ha, grain yield kg/ha and straw yield kg/ha traits were studied. Result showed that ZT had significance superiority in number of tillers / m^2, number of spikes / m^2, biological yield kg/ha, grain yield kg/ha and straw yield kg/ha. Traits comparing with conventional tillage, while no significant differences between 2 planting methods in the other traits.

Key words: soil tillage, seeder, crop quality traits

Original scientific paper

Fall and spring sown legume-cereal cover crops for sweet maize production

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Abstract

Sweet maize (*Zea mays saccharata* Sturt.) has been grown in a small acreage, e.g. 5 000 ha in Serbia because of limited processing and serious weed infestation as much as in a field maize crop. Sweet maize is considered a week competitor because of it's shorter and less developed habit, which makes improved weed management systems a main priority. Growing both fall and spring sown cover crops is an approach for environmental protection trough decreasing weed populations and increasing grain yield of sweet maize. The objective of the study was to determine the effect of different winter and spring grown cover crops, and legume-cereal based mixtures on yield of sweet maize. The experiment includes two control treatments: dead organic mulch - soil covered with straw in autumn and winter time, and conventional (traditional) variant – bare soil uncovered during fall and winter time.

The various cover crops and it's mixtures had significantly different effects on sweet maize yield during the period of investigations (2010/11 and 2011/12). Along legume species, favorable effect on grain yield of sweet maize had been recorded on winter hairy vetch, as well on a kind of non legume species, winter fodder kale. Spring cover crops had lowered weed infestation of sweet maize and grain yields in comparison to the winter cover crops and control treatments.

Key words: cover crops, legume-cereal mixtures, sweet maize, weed infestation, yield

Introduction

Modern society, as mach as it could must be related to sustainable management of renewable natural resources trough ecologicaly based agricultural development. An ecological production management system that promotes and enhances biodiversity, biological cycles, and soil biological activity should be based on minimal use of „off-farm“ inputs and on management practices that restore, maintain, or enhance ecological harmony. The primary goal of these systems is to optimize the health and productivity of interdependent communities of soil biota, growing plants and animals, and people. Perceived benefits of the alternative technology over conventional one, have been considered mostly in terms of grain yield of the main crop (Dolijanović et al., 2012).

Sweet maize has been grown in a small acre, e.g. 5 000 ha in Serbia, mainly because of limited processing capacities. On the other side, due to increasing usage for fresh consumption sweet maize could become another valuable cash crop for small farmers, why certain expansion of growing areas might be expected (Pajić and Srdić, 2007). Weeds infestation represents a major problem in sweet maize crops, as well as in field maize. Commercially grown sweet maize hybrids (*Zea mays saccharata* Sturt.) varying widely in competitive ability against weeds, which interference differentially affects yields and cob quality important for processing and fresh markets (Simić et al., 2012). In order to obtain high yields of good quality the scientists have been searching for the most appropriate growing practices.

Sweet maize is considered a week competitor against weeds, because of its shorter and less developed habitus, which makes improved weed management systems a certain priority. Both broadleaf and gramineae weeds could infest sweet maize fields. In organically grown sweet maize, the most dominant weeds were *Digitaria sanguinalis* (L.) Scop., *Setaria faberi* (Herrm.) *Amaranthus hybridus* L. (Silvernail, 2005). *Panicum milliaceum*, *Ambrosia trifida*, and *Sinapis arvensis,* and should considered the most troublesome weeds in sweet maize (Williams et al., 2007).

Increasing environmental problems and big concern on health issues has driven to development of new techniques and systems to deal with weeds, pests and diseases. Cover crops being often used to design new strategy that preserves farm natural resources while remaining it’s cost-effectivity. Cover crops can decrease weed infestation, increase yields and at the same time, they can reduce costs, increase profits and even create new sources of income.

Cover crops can play an important role in managing weeds by shading and interfering with weed germination and establishment. Among cereals,it is knowen that rye produces allelochemicals, naturally occuring compounds that can control or suppress weeds.

Once researchers find the appropriate combination of maize and ground cover, they believe yields will not be impacted, and soil quality will be maintained. Nevertheless, cover crops can also become weeds and must be carefully managed to prevent it's competitivity toward main crops regarding soil moisture, nutrients etc. The possibility to reduce weediness on the basis of the increased crop competitive abilities by growing high yielding hybrids that "tolerate" a higher plant density, depends on traits of each hybrid and climatic conditions in the specific growing region (Williams et al., 2007).

Many farmers viewed climatic factors as possible barriers to establish cover crops, but uncertainty was also high: rarely enough time between harvest and winter to justify use; cover crops can delay spring planting; if shorter-season varieties yielded the same as longer-season, would be more likely to plant.

The objective of this study was to determine the effect of different winter (dead mulch) and spring grown (living mulch) cover crops and their mixtures with oats on weed infestation and sweet maize grain yield.

Material and methods

The experiment included four kinds of *winter cover crops* (common and hairy vetch, oat and fodder kale, as well mixtures of legume crops with oats), another variant in which the land was covered with dead organic mulch, and traditional variant, classical plowing in the fall and keeping bare land uncovered during the winter, as well *different spring crops species* (common vetch, oat and it's mixtures) growth as a living mulch. All of the varieties being used as a cover crops belongs to Novi Sad Field Crops Institute. Crops were grown under rainfed conditions.

Field experiments were conducted in 2010/11 and 2011/12 at Maize Research Institute, Zemun Polje, in the vicinity of Belgrade (44°52'N 20°20'E). The soil was slightly calcareous chernozem with 47% clay and silt, and 53% of sand. The soil properties in layer 0-30-cm of depth were fallow: 3.22% organic matter, 0.19% total N, 1.9% organic C, 16.2 and 22.4 mg per 100 g soil of available P_2O_5 and extractable K_2O, respectively, 1.38% total $CaCO_3$ and pH 7.3. The experiments were located in different plots in each year and winter wheat was the previous crop. Fallowing nitrogen fixation rates in legume crops, as well recommended fertilization, we came up to the required amount of macronutrients for sweet maize (120 kg ha^{-1} N, 90 kg ha^{-1} P_2O_5 and 60 kg ha^{-1} K_2O). In the fall period, before planting of cover crops we have entered the entire amount of P and K in the forms of monopotassium phosphate plus additional quantity of nitrogen 50 kg/ha by ammonium nitrate, and on the two control variants, also all of P_2O_5 i K_2O and 40 kg ha^{-1} N in the form AN.

In the next spring (April 07 2011 and April 09 2012) leguminous cover crops had received another 30 kg ha^{-1} N in the form of AN (remaining 40 kg ha^{-1} considered to be provided by nitrogen fixation), oats an fodder kale 70 kg ha^{-1} N, and control plots another 80 kg ha^{-1} N, also in the form of AN.

The experimental plots being ploughed in the autumn, have followed one pass of a disk harrow and a field cultivator prior to sowing. The entire quantity of nitrogen, phosphorous and potassium for spring cover crops were applied just prior to planting, with soil preparation.

Sowing of cover crops were done manually in October 2010 and 2011. Mowing the above-ground biomass of winter cover crops were performed 7-10 days before planting of sweet maize. Planting of of sweet maize seedlings were done on May 26.th in 2011, and May 21.st in 2012 year. The estimation of weed infestation in sweet maize was conducted on early July in both years. Crops were harvested 22-24 days after pollination. In 2011 harvest was performed on August 18th whereas in growing season

2012 there was a crop failure because of extreme drought and high temperatures. The meteorological conditions during the maize growing season are presented in Table 1.

Table 1. Average air temperatures and precipitation sums from April to September at Zemun Polje

Months	Temperature (°C)		Precipitation (mm)	
	2011	2012	2011	2012
April	14.6	14.4	11	67
May	17.3	17.9	63	128
June	22.4	24.6	40	14
July	24.1	27.1	107	39
August	24.7	26.2	9	4
September	23.2	22.0	49	31
Average/Sum	21.1	22.0	279	283

Experimental design

The experiment was in factorial setting with two factors in RCBD with four replications. Sweet maize was sown in density of 65.000 plants ha^{-1}. The inter-row distance was 70 cm, while within-row plant distance was 22 cm. The new Zemun Polje (ZP) sweet maize hybrids ZP 424su (FAO maturity group 400) was sown. The basic plot size was 16.8 m^2 (2.8 m by 6.0 m).

Measurements and statistical analysis

The fresh and air dried weed biomass in sweet maize crops were analysed in this study. All stated parameters in weeds were determined from samples taken from $1m^2$. The weed infestation analysis was performed on July 3, 2011 and July 04, 2012. Following weed sampling, manual hoeing was done in order to suppress weeds pressure in sweet maize.

All ears in two inner rows of each subplot were harvested and weighed directly from the field, 25 days after silking. Furthermore, a shelling percentage, as a kernel weight to cob weight ratio, was determined in a sample of 10 randomly selected cobs.

The yield data were underwent to ANOVA for the factorial trials set up according to the plan for two years, eleven variants, where means differences were tested by the least significant difference (LSD) test (Gomez and Gomez, 1984).

Results and discussion

Results of fresh and air dried above-ground biomass of cover crops are presented in Table 2. Meteorological conditions in both years of investigations were extremely unfavorable (Table 1), as it was for winter and spring cover crops, as well for main crop of sweet maize.

Table 2. The growing season (A) and cropping system (B) effects on weed infestation of sweet maize

Cropping system (B)		Fresh biomass ($g\ m^{-2}$)		Air dried biomass ($g\ m^{-2}$)	
		2011	2012	2011	2012
Winter cover crops and mixtures (dead mulch)	Common vetch	291.4	255.1	70.2	79.3
	Hairy vetch	288.6	262.1	69.7	74.2
	Oats	311.6	302.3	78.8	80.7
	Fodder kale	301.0	296.5	80.2	78.7
	Common vetch+oats	310.1	307.4	90.6	91.1
	Hairy vetch+oats	304.5	303.9	94.2	101.8
	Average	301.2	287.9	80.6	84.3
Control treatment	Organic mulch	381.1	326.7	102.3	85.4
	Conventional system	834.1	728.8	121.1	132.6
	Average	607.6	527.7	111.7	109.0
Spring cover crops and mixtures (living mulch)	Common vetch	212.6	198.4	56.9	59.8
	Oats	304.8	299.7	65.2	61.8
	Common vetch+oats	291.3	289.7	70.2	55.6
	Average	269,6	262,6	64,1	59,1
	Average	392,8	359,4	85,5	84,1

Fresh biomass LSD A B AB Air dried biomass LSD A
B AB
0.05 0.52 1.21 1.71 0.69
1.42 2.04
0.01 0.71 1.66 2.35 0.91
1.83 2.63

Weeds species were weaker competitor in this situation. The highest total fresh weight was 834. 1 g m^{-2} (conventional system) in 2011 and 728.8 g m^{-2} in 2012 while the lowest fresh weight was measured in hairy vetch (winter cover crops) and common vetch (spring cover crops) in both years. In spring sown cover crops the fresh weight was smaller comparing to winter cover crops, mainly because of extreme conditions of drought and high temperatures, so far during the growing season 2012th there was a crop failure. By covering bare soil with straw (organic mulch) weediness becoming somewhat higher comparing plots among winter and spring cover crops, even though sweet maize yield significantly was higher using this system of growing. In addition, cost inputs were reduced, but no other common benefits in the long term were found on winter and spring cover crops (increase of organic matter, increase of biodiversity, etc.).

Favorable weather conditions during the first year of trials have resulted in an increasing weed infestation of main crop. Among all variants with winter and especially with spring cover crops, plot weediness of main crop was lower comparing to control variants in both years of investigation.

In conventional production of sweet maize at the trial location the dominant species being detected, in the first year only was: *Amaranthus albus*, *Convolvulus sepium*, and *Digitaria sanguinalis* while in the second year of investigation it was *Amaranthus hybridus*, *Chenopodium album*, *Cirsium arvense* and *Xanthium strumarium* (Simić et al., 2012). Weeds fresh biomass was dependent of density of sweet maize crops (40-70.000 plants ha^{-1}), varying from 486.7, 612.3, 257.6 and 228.9 in the year 2008. and 894.4, 772.7, 934.0 and 520.4 g m^{-2} in the year 2009.

Table 3. The cropping system effects on grain yield of sweet maize

Cropping system		Yield (t ha^{-1})		Percent shelling	
		2011**	2012	2011*	2012
Winter cover crops and mixtures	Common vetch	8.84	-	62.58	-
	Hairy vetch	9.98	-	74.69	-
	Oats	9.07	-	57.88	-
	Fodder kale	8.32	-	69.17	-
	Common vetch+oats	8.72	-	56.07	-
	Hairy vetch+oats	8.61	-	62.05	-
	Average	8.92		63.74	
Control treatment	Organic mulch	10.00	-	68.09	-
	Conventional system	8.09	-	60.79	-
	Average	9.05	-	64.44	-
Spring cover crops and mixtures	Common vetch	7.61	-	60.05	-
	Oats	7.49	-	63.70	-
	Common vetch+oats	6.21	-	56.63	-
	Average	7.10	-	60.13	-
	Average	8.36	-	62.77	-

** P=0,01;*P=0.05; Yield of grain LSD 0.05 0.41; 0.01 4.20; Percent shelling LSD 0.05 3.06; 0.01 0.57

Results of grain yield and shelling percentage of sweet maize cobs in the analyzed samples are presented in Table 3. The highest yield was obtained in the variant with dead organic mulch (10.00 t ha^{-1}), primarily due to the fact that for its decomposition was significantly more time alone and the planting of corn was thus greatly facilitated. The lowest yield was obtained following the conventional system (8.09 t ha^{-1}) as well spring cover crops. Yield of sweet maize in this study was below average yields in similar experiments (Dolijanović et al., 2012), and the main reason was the way of growing. Simic et al., (2012) reported that average yield of grain was 10.35 in 2008 and 10.04 t ha^{-1} in 2009.

The estimates of shelling percentage were at common level for particular hybrid, which is so far the best seller for many years, among range of ZP sweet maize hybrids, including recent achievements of breeding with specific properties of increased sugar content.

The variants covered by dead mulch, and especially variants being covered by living mulch mixtures gave higher yields of biomass and consequently lower grain yield of sweet maize as a main crop.

Weeds represents one of the major threats to crop production in sustainable and organic farming systems. The risk of high weed infestations is not only yield reduction of the main crop but also the decrease of the commercial quality and the feeding palatability of main crops (Rahman et al., 2006) and enrichment of the soil seed bank of weeds (Buhler, 1999), which may cause severe weed infestation in subsequent crop production (Uchino et al., 2009).

Cover crop sowing date is one of the important cover crop management issues. Abdin et al., (2000) reported that weeds could be suppressed significantly with a little effect on maize yield by sowing cover crops at 10 and 20 days after maize emergence.

Conclusions

Meteorological conditions prevailing during the trial period had an important impact on weediness and grain yield of sweet maize. Growing cover crops is one extremely important tool for the appropriate management of weeds in long-term weed control under sustainable and organic agricultural systems. Perceived benefits of the alternative technology over conventional one should considered mostly in terms of grain yield of the main crop. Currently, living mulch in spring-sown cover crops have had positive impact on lower weediness, and opositelly, negative impacts on sweet maize yield. The main crop of sweet maize was not competitive enough with ground cover, mainly because of limited soil moisture and nutrients, especially between the rows of sweet maize being possessed by living mulch.

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Original scientific paper

Soybean and barley production with conservation soil tillage systems

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Abstract

Short term experiment with different soil tillage systems in soybean (*Glycine max* L.) and spring barley (*Hordeum vulgare* L.) production was conducted at the experimental field near Našice on gleyic soil type and semi humid climate conditions. The tillage systems and implements used were: CT – mouldboard plough, disc harrow, seed-bed implement, RT 1 - chisel plough, disc harrow, seed-bed implement, RT 2 – shallow chisel, NT – no-till. Soybean production was economically efficient only with the substantial reduction or complete omission of tillage. While the production of spring barley has proven to be economically efficient at all variants of soil tillage, better economic results were achieved with the reduced tillage and no-till systems. The highest productivity regarding labour requirement per hectare and ton of grain yield was achieved with NT system in both winter barley and soybean production. Regarding the choice of tillage systems, assuming uniform level of yields, the advantage should be given to systems with lower level of tillage intensity, not only to reduce costs but also because of the possibility of simpler production organization due to less machine and labour requirement.

Key words: soil tillage, energy consumption, production costs

Introduction

Soybean (*Glycine max* L.) and barley (*Hordeum vulgare* L.) are important crops largely represented in the crop rotation on arable areas in Croatia. The mainly utilised soil tillage system in soybean and barley production is conventional system based on mouldboard ploughing as primary tillage operation, followed by secondary tillage carried out with disc harrow and seed-bed implement. The long term application of conventional tillage showed significant economic and environmental drawbacks. From an economic point of view disadvantages of conventional tillage systems are high energy and labour, large investment and maintenance costs of machinery, and ultimately higher costs of crop production (Košutić et al., 2006). According to some European researches (Tebrügge et al., 1998, Tebrügge and Düring, 1999) conventional tillage system requires 434 kWh ha^{-1} of energy and 4.1 h/ha human-machine work. In contrast, reduced tillage systems can bring about 30% -50% savings of the energy and human-machine work, and direct sowing as much as 70%, compared with conventional tillage. From an ecological point of view disadvantages of conventional tillage systems are increased soil compaction caused by excessive number of machinery passes, systematic reduction of soil organic matter (humus content) as a result of intensive and frequent tillage and the greater the susceptibility to soil erosion (Birkas, 2008). A significant CO_2 emissions from the combustion of large amounts of fuel consumed in the intensive tillage is also an environmental issue (Filipović et al., 2006).

Stroppel (1997) reported that by the end of the last century about 85% of the arable land of central Europe was under conventional tillage systems. The implementation of reduced tillage systems has not significantly increased to date, and it is estimated that there are still less than 10% (ECAF, 2013). The world leading agricultures in substitution of conventional soil tillage systems with different variations of the reduced tillage and direct sowing are United States and Canada in North America and Brazil, Argentina, Uruguay and Paraguay on the South, where conservation tillage and no-tillage systems applied to more than half of total arable crop area (Derpsch and Friedrich, 2009). Despite the mentioned trends, it is estimated that over 90 percent of the fields in Croatia are still being tilled with the conventional tillage system (Zimmer et al., 2002).

Previous studies suggest that reduced tillage is favourable for high density crops such as winter wheat, spring barley and canola, while much worse option for spring row crops such as corn and soybeans (Vratarić and Sudarić, 2000; Pospišil et al., 2002; Špoljar et al., 2009; Kisić et al., 2010). While some authors (Chatskikh and Olesen, 2007), have noticed a decrease of yield of spring barley with the degree of tillage reduction (14% lower yield at a reduced tillage and 27% lower in direct drilling), others claim that there is no significant difference in realized yields between different tillage systems (Moret and Arrué, 2007). Reduction of production costs by applying some of the reduced tillage systems, in conditions where yields were not significantly reduced due to lower tillage intensity, enables a lower profitability threshold (Stipešević et al., 2007; Košutić et al., 2008; Jug et al., 2010).

Material and methods

The experiment with four different tillage systems was established on the surface of 4 ha, and applied tillage systems and implements were as follows: 1. CT (conventional tillage) – mouldboard plough, disc harrow, seed-bed implement, 2. RT1 (conservation tillage 1) - chisel plough, disc harrow, seed-bed implement, 3. RT2 (conservation tillage 2) - shallow chisel, 4. NT (direct sowing) - no-till drill. The experiment was carried out at the experimental field near Našice (45° 30' N, 18° 06' E) on the gleyic soil type (Škorić, 1986) and semi-humid climate with 11.0°C of mean air temperature and 806 mm of total precipitation. Soil texture in ploughed layer varies from loam to silty clay loam (Table 1).

Table 1. Soil particle size distribution

Depth (cm)	Particle size				Texture[1]
	0.2-2 µm (%)	0.05-0.2 µm (%)	0.002-0.05 µm (%)	< 0.002 µm (%)	
0-10	0.80	28.80	44.60	25.80	L
10-20	2.20	8.60	69.40	19.80	SL
20-30	1.00	10.20	58.00	30.80	SCL

1) L = Loam, SL = Silty loam, SCL = Silty clay loam

Schedule of the field operations (tillage, fertilizing, sowing, crop protection, harvesting) and soil moisture content at the moment of tillage are shown in Table 2. On the experimental field previous crop was winter wheat. Working conditions regarding soil moisture content, soil compaction and post-harvest residues at the beginning of experiment were equal for all tillage treatments.

Energy requirement of each tillage system was determined by tractor's fuel consumption measurement for each implement in each tillage system applying volumetric method. Energy equivalent of 38.7 MJ L^{-1} (Cervinka, 1980) was presumed. In this experiment 4WD tractor with engine power of 136 kW was used. The working width of the tillage implements was chosen according to the pulling capacity of the tractor. The labour requirement was determined by measuring the time for finishing single tillage operation at each plot of the known area.

Table 2. Date of field operations and application rates

Description	Soybean	Barley
	Tillage & Sowing	
Primary tillage	November 28th	November 8th
Soil moisture (%) at 5; 15; 30 cm depth	21.8; 29.6; 32.5	19.8; 28.3; 30.4
Secondary tillage	May 2nd	February 5th
Soil moisture (%) at 5; 15; 30 cm depth	24.1; 41.6; 38.2	25.3; 38.6; 39.2
Sowing date	May 2nd	February 6th
Crop-cultivar (kg ha^{-1})	Anica (135)	Prestige (200)

Fertilizing		
Application date	March 29th	October 20th
Fertilizer-rate (kg ha^{-1})	NPK 0:20:30 (400)	NPK 8:26:26 (350)
Application date	April 4th	March 30th
Fertilizer-rate (kg ha^{-1})	Urea 46% (100)	CAN 27% (130)
Application date	June 7th	May 6th
Fertilizer-rate (kg ha^{-1})	CAN 27% (100)	CAN 27% (90)
Crop protection		
Application date	May 3rd	March 28th
Chemical-rate (l ha^{-1})	metribuzin (0.70) dimetenamid (1.30)	izoproturon+diflufenikan (1.7)
Application date	May 16th	April 15th
Chemical-rate (l ha^{-1})	fomesafen (0.75) tifensulfuron-metil (0.008)	aminopiralid+florasulam (0.033)
Application date	June 4th	May 7th
Chemical-rate (l ha^{-1})	propakizafop (1.00) bentazon (2.5)	metaconazole+azoxystrobin (0.8)
Harvest		
Harvesting date	October 4th	June 25th

The yields were determined by weighing grain mass of each harvested plot, and recalculated according to grain moisture content in storage conditions afterwards. Fertilization and crop protection was uniform in all tillage, determined by crop specific requirements.

Economic efficiency of different soil tillage systems was calculated based on the natural indicators of barley and soybean production (energy consumptions, labour requirement, raw materials, yields). Statistical analysis of data for all research indicators was done with computer program SAS (SAS Institute, 1990) using analysis of variance (ANOVA). The significance of differences between the observed parameters were indicated by F-test at the level of probability p = 0.05.

Results and discussion

Yield

In soybeans production the highest average yield of 2.97 t ha^{-1} was obtained with reduced tillage RT2, which was almost 20% higher than the yield recorded on a conventional tillage system (2.40 t ha^{-1}). The lowest average yield of soybeans 2.14 t ha^{-1}, or 9% less than conventional system was recorded in RT1. No-till system achieved the same average yield as the conventional tillage. Analysis of variance revealed there were no significant differences in average yields between tillage systems. Although the soil tillage had no significant effect on grain yield, below-average yields were recorded in all tillage variants, presumably due to unfavourable climate conditions.

In the spring barley production there was a statistically significant influence ($p < 0.01$) of tillage systems on grain yields ranging from 3.39 kg ha^{-1} in the variant with conventional tillage, up to 5.12 kg ha^{-1} in the no-till system (51% higher). Conservation tillage RT2 achieved 5.10 t ha^{-1} or 50% more than CT. RT1 system with 4.23 t ha^{-1} was also significantly better (25%) than conventional tillage.

Energy and labour requirement

The conventional tillage system (CT) was expectedly the greatest fuel consumer (Table 3). In soybean production the greatest fuel consumption of 62.50 L ha^{-1} was recorded in conventional tillage system. RT1 system enabled 35% saving and RT2 77% saving of fuel compared to conventional tillage.

Table 3. Energy and labour requirement of different soil tillage systems

	Soybean				Barley			
Tillage system	Fuel L ha^{-1}	Energy MJ t^{-1}	Productivity h ha^{-1}	h t^{-1}	Fuel L ha^{-1}	Energy MJ t^{-1}	Productivity h ha^{-1}	h t^{-1}
CT	Average yield = 2.398 t ha^{-1}				Average yield = 3.391 t ha^{-1} c$^{(1)}$			
Plough	33.33	537.9	1.39	0.58	25.10	286.5	1.24	0.36
Disc harrow	17.36	280.2	0.48	0.20	16.63	189.8	0.43	0.13
Seed-bed implement	5.89	95.1	0.19	0.08	7.59	86.6	0.32	0.10
Drill	5.92	95.5	0.33	0.14	8.1	92.4	0.30	0.09
Total	62.50	1008.7	2.40	1.00	57.42	655.3	2.29	0.68
RT 1	Average yield = 2.136 t ha^{-1}				Average yield = 4.227 t ha^{-1} b			
Chisel plough	20.07	363.6	0.71	0.33	13.81	126.4	0.68	0.16
Disc harrow	8.68	157.3	0.24	0.11	7.96	72.9	0.23	0.06
Seed-bed implement	5.89	106.7	0.19	0.09	7.59	69.5	0.32	0.08
Drill	5.92	107.3	0.33	0.16	8.1	74.2	0.30	0.07
Total	40.56	734.9	1.48	0.69	37.46	343.0	1.54	0.36
RT 2	Average yield = 2.973 t ha^{-1}				Average yield = 5.101 t ha^{-1} a			
Shallow chisel	8.23	107.1	0.41	0.14	10.95	83.1	0.61	0.12
Drill	5.92	77.1	0.33	0.11	8.1	61.5	0.30	0.06
Total	14.15	184.2	0.74	0.25	19.05	144.6	0.91	0.18
NT	Average yield = 2.402 t ha^{-1}				Average yield = 5.122 t ha^{-1} a			
No-till drill	5.92	95.4	0.33	0.14	8.1	61.5	0.30	0.06

(1) Different letters indicate significant ($p \leq 0.05$) differences

The greatest energy saving per hectare (90%) in winter barley was obtained by NT system. Due to relatively uniform yields of soybean over variants of tillage systems the same trend reflects to specific energy consumption. A total of 57.42 L ha^{-1} diesel fuel was spent in tillage and sowing barley with conventional system wherein the mouldboard ploughing stands out as the most significant consumer with about 44% of total energy consumption. At variant with reduced soil tillage RT1 a third less fuel/energy was spent and in RT2 two thirds less compared to the conventional system. Also, RT1 system points to 47% lower specific energy consumption and RT2 78% lower, due to significantly higher yields than CT. The lowest energy consumption was expectedly recorded in NT system.

The highest productivity regarding labour requirement per hectare and ton of grain yield was achieved with NT system in both winter barley and soybean production.

Comparing the results with allegations by other authors (Pelizzi et al. 1988, Hernanz and Ortiz-Cañavate 1999) larger deviations due to soil types, current conditions in the field, depth of tillage and implements used could be expected, but an increase in labor productivity with the degree of reduction of tillage is noticeable.

Economic analysis

Total costs include all inputs (labour, machine costs, seed, fertiliser and plant protection chemicals and grain transport within field) from soil tillage to harvest. Storage and handling costs weren't taken into account since its great variability.

In both seasons CT system resulted in the highest costs with 769.70 € ha^{-1} (soybean) and 679.84 € ha^{-1} (spring barley) mainly due to great number of field operations and large amount of labour requirement (Table 4). Soybean production has proven to be economically efficient only with the substantial reduction or complete omission of tillage. The highest income was obtained with RT2 system and that variant also showed the best economic efficiency (coefficient 1.19). Production of spring barley was economically justified in all investigated variants with the highest economic efficiency achieved in NT system (coefficient 2.34) together with the highest income due to significantly higher yield.

Table 4. Economic efficiency indicators of soybean and barley production

Tillage	Soybean				Barley			
	Gross income € ha^{-1}	Total costs € ha^{-1}	Gross margin € ha^{-1}	Income/ Costs ratio	Gross income € ha^{-1}	Total costs € ha^{-1}	Gross margin € ha^{-1}	Income/ Costs ratio
CT	731,57	769,70	-38,13	0,95	912,69	679,84	232,84	1,34
RT 1	675,68	707,41	-31,73	0,96	1096,61	625,47	471,14	1,75
RT 2	854,24	717,22	137,02	1,19	1288,89	583,77	705,11	2,21
NT	732,43	699,37	33,06	1,05	1293,51	553,65	739,86	2,34

Conclusions

Summarizing the results together with previously acquired experience it could be concluded that soybean production was economically efficient only with the substantial reduction or complete omission of tillage. Given that the reduction of tillage was a significant factor in reducing the soybean production costs, such tillage systems could be recommended as an alternative to conventional soil tillage. While the production of spring barley has proven to be economically efficient at all variants of soil tillage, better economic results were achieved with the reduced tillage and no-till systems.

As this short-term experiment showed that non-conventional tillage systems could be economically important tool to decrease production costs, in the preferred choice of soil tillage system, assuming uniform levels of yield, the advantage should be given to a system with lower level of tillage intensity, not only to reduce costs, but also because of the simpler production organization due to less machine and human labour requirement. Although the reduction of soil tillage has generally shown a positive impact on the production costs reduction, it was justified only if there hasn't led to yield reduction as was the case in RT1 system at soybean production.

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Original scientific paper

Tillage, cropping system and nitrogen fertilization effects on soil organic and particulate carbon and nitrogen in a semiarid environment of Spain

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Abstract

The present study aimed to determine the impact of three tillage systems (no-tillage (NT), minimum tillage (MT) and conventional tillage (CT)), crop rotation sequences (cereal/cereal (C/C), fallow/cereal (F/C) and legume/cereal (L/C)) and fertilization rate (conventional (FC) and reduced fertilization (FR)) on soil organic and particulate organic carbon (SOC and SPOC) and soil total nitrogen (STN) and profile distribution (0-60 cm) in a semi-arid soil in Castile-Leon, a region in northern Spain. Distribution of SOC, SPOC and STN stocks differed under different tillage system and crop rotations. NT and MT had more SOC contents than CT at 0-15 cm depth, but the mean SOC stocks were similar under all tillage systems at 0-60 cm depth. SPOC and STN stocks were higher in MT and NT than CT at 0-30 and 0-60 cm depth respectively. These parameters were greater in L/C than in F/C rotations. SPOC stocks were only affected by nitrogen rate which higher amounts in reduced fertilization plots. These findings suggest that SOC, SPOC and STN can be improved if conservation tillage is used in lieu of CT practice and intensity crops as legume/cereal is imperative for increasing C and N in soils in dryland areas.

Key words: conservation tillage, crop rotation, soil organic and particulate carbon, nitrogen

Introduction

The predominant cropping system in semi-arid Castile-Leon, a region with a yearly rainfall of 400-450 mm, is conventional tillage (CT). Used to mix topsoil to recover lost nutrients, prepare the seedbed and improve weed control, CT has nonetheless been associated with losses in soil organic carbon and significant decline in soil quality (Hernanz et al., 2002). Conservation tillage systems such as no tillage (NT) or chisel ploughing (MT) have become increasingly popular in the region over the last decades because they enhance profitability by lowering machinery and other costs (Sanchez-Girón et al., 2007; Sombrero et al., 2008). They are also more environmentally fit suitable than CT, which induces the biological oxidation of SOC (Reicosky et al., 1995).

In sustainable agricultural production systems, soil organic carbon (SOC) is essential for sustaining soil quality, promoting crop productivity and protecting the environment (Doran and Parking, 1994). SOC pool, a significant indicator of soil quality, has many direct and indirect effects on such quality. Increases in the SOC pool improve soil structure and tilth, counter soil erosion, raise water capacity and plant nutrient stores, provide energy for soil fauna, purify water, denature pollutants, enhance soil biodiversity, improve the crop/crop residue ratio and mitigate the effects of climate (Lal, 2007). Combining conservation tillage with intensive or continuous cropping has been proposed as a way of increasing the total store of SOC (Halvorson et al., 2002) because by minimizing soil disturbance, less intensive tillage reduces the mineralisation of organic matter, providing for a larger store of SOC than conventional tillage (Al-Kaisi and Yin, 2005). Some of the parameters involved include total SOC, soil inorganic carbon and particulate organic carbon (POC). POC, regarded to be a fraction of SOC midway between the active and slow fractions, changes rapidly in response to changes in management practices (Cambardella and Elliott, 1992; Bayer et al., 2001) and is associated with short-term nutrient availability. The objective of this study was to examine the effect of tillage, crop rotations and fertilization rate on soil organic carbon (SOC) and particulate (POC) and soil total nitrogen (STN) as well as production.

Materials and methods

This study was initiated in 2004 on the Zamadueñas farm in the Spanish province of Valladolid. The soil, classified as Typic Xerofluvent, is characterised by a loamy-clay texture. In 2004 pH mean was 8.1, bulk density 1.35 g cm^3 and organic matter content 1.0 %. The mean rainfall in the area from 1985 to 2009 was 409 mm. The experimental design was a split split plot with four repetitions, with tillage system as main factor, crop rotations as sub-factor and fertilization as sub-sub factor. The tillage systems used were minimum tillage (MT) and zero or no till (NT) plus six tilled conventionally (CT) plots as a control. In 2008 and 2009, the crop sequences were: fallow-cereal (F/C), legume-cereal (L/C) and cereal-cereal (C/C). Preparatory work was conducted in early November in keeping with the respective tillage system: MT (chisel plough (10-15 cm deep), harrow, sowing and roller), NT (herbicide and sowing) and CT (mouldboard plough (25 cm deep), harrow, sowing and roller). The crops were managed in accordance with local practice, except fertilization. No crop residue was removed in any of the tillage treatments. All plots, except fallow, were fertilised, at a rate of 250 kg ha^{-1} (8-15-15 NPK). Topdressing consisting in two doses, one conventional (FC) and another taking into account the nitrogen content in the soil (FR) was applied in the subsequent tillering-stem elongation phase. The standard dose was with 300 kg ha^{-1} of NO_3NH_4 and mean recommended dose was 244 and 235 kg ha^{-1} of NO_3NH_4 (26%) kg/ha, in 2008 and 2009 respectively.

Soil properties were determined at the outset. Soil samples were taken before the preparatory work in October 2008 and 2009 at three sites on each elementary plot to obtain a composite sample per plot at depths of 0-5, 5-10, 10-15, 15-30 and 30-60 cm depth. The concentration of total C of soil was determined by dry combustion analysis using a LECO CNS analyzer. Since the parent material is calcareous, all samples were treated to remove any inorganic carbon. Soil inorganic carbon was estimated using a modified pressure-calcimeter method (Sherrod et al., 2002). Soil organic carbon (SOC) was calculated as the difference between total carbon and inorganic carbon. Soil particulate organic carbon (SPOC) was measured at 0-5, 5-10, 10-15 and 15-30 cm depth by Cambardella and Elliot (1992) method. Total N was analyzed using the Kjeldahl method (Bremner, 1965).

The SOC, SPOC, and STN stocks were quantified by measuring soil bulk density in core samples taken from each tillage system and block at the same depths. The soil samples, which were taken by hand with a 67.44 cm^3 steel cylinder, were weighted after drying at 105 ºC. Chemical values from 2008 and 2009 (Mg ha^{-1}) were calculated for each tillage and crop rotations in terms of equivalent soil mass (esm) according to the methods described by Ellert and Bettany (1995).

The statistical analysis was performed with SAS (SAS Institute Inc., 2002) analysis of variance (ANOVA) or general linear model (GLM) was performed within each depth increment for a split-plot design. Differences among treatment means were tested using Duncan's test with $p < 0.05$.

Results and discussion

Effect of tillage, crop rotation and nitrogen rate on soil organic, particulate carbon and total nitrogen concentrations, C:N ratio and distribution in the soil profile

Soil organic and particulate carbon concentrations in soil profiles under three tillage systems in two years are shown in Figure 1. SOC concentration was 5% higher in 2009 than 2008. Highly significant differences in SOC and SPOC concentrations were found between tillage systems at 0-5 cm soil layer in both years, MT and CT had significantly lower SOC and SPOC concentration than did the NT system; In 2008, NT had 1.33 times more SOC and 2.10 more SPOC than CT, and 1.14 more SOC than MT. MT, in turn, had 1.60 times more SOC and 1.63 more SPOC than CT. In 2009, SOC concentration was 1.46 and 1.15 times statistically higher in NT than CT in 0-5 and 5-10 cm soil layer, and SPOC concentration was 2.73 and 1.68 times statistically higher in NT than CT in 0-5 and 5-10 cm soil layer. These results are consistent with findings reported by Hernanz et al. (2009) who observed a higher SOC content at 10 cm in NT than CT soils in semi-arid climates. The absence of soil disturbance and the presence of crop residues on the soil surface in NT plots led to an accumulation of these parameters in the 0-5 cm layer and higher values than in tilled systems where crop residues are mechanically incorporated into the soil. When a chisel is used for primary tillage at 10-15 cm depth, the resulting redistribution of SOC and SPOC across the soil profile could explain the greater SOC and SPOC concentrations at 5-15 cm depth. In 2008, at the 15–30 and 30-60 cm depths the trend for higher SOC concentration with conservation tillage (NT and MT) reversed and CT resulted in similar values. In 2009, at the 15–30 cm depth higher SOC concentration was found in CT system than in conservation tillage (NT and MT), and the 30-60 cm depth, SOC concentration was similar in all three tillage systems. Gal et al. (2007) confirmed that NT had a substantial gain of SOC at the 0–5 and 5–15 cm depth intervals, but a substantial reduction, relative to the CT system, in the 30–50 cm depth interval.

Throughout the soil profile studied (0-60 cm depth), soil total nitrogen (STN) was 9% higher in 2009 than 2008 (Figure 1). In 2009, at 0-5 cm depth, in NT and MT systems, STN concentration was 6 and 8% higher than CT which decreased by 18 %. From 0 to 60 cm depth, STN values in conservation tillage were higher in 209 than in 2008. Highly significant differences in STN concentrations were found between tillage systems at 0-30 cm and at 0-60 cm depths in 2008 and 2009 respectively, indeed NT and NT had 30 and 24% more STN in 2008 and 68 and 60% more STN in 2009 than CT. The highest concentration of N was obtained in the plots under NT and MT when the 5–30 cm and 0-60 cm layers were considered in 2008 and 2009 respectively. These results are consistent with findings reported by López-Fandó and Pardo (2009) who found higher SOC and STN in NT than CT at 0-30 cm soil depth. On the contrary, these results differed from earlier reports to which STN was higher in the top 15 cm soil depth in NT than in CT tillage being similar at greater depths in the soil profile in a long-term experiment (Gal et al., 2007).

Soil C:N ratios ranged from 8.4 to 13.8 in 2008 and from 7.3 to 10.8 in 2009. Differences in soil C:N ratios between year might be attributed to annual variation in the input amounts of carbon as well as the different dynamics of SOC and STN contents. Total means rainfall were 456 mm and 345 mm in 2008 and 2009 respectively. The highest rainfall in 2008 led to a mean grain production of 6030 kg ha^{-1} while in 2009, the mean grain production only was 2425 kg ha^{-1}. Hence the amount of residues left on the surface was greater in 2008 which led to a larger amount of the SOC and SOC and to a smaller values of the STN and C:N ratios.

Since rotation systems in the two years studied did not affect the SOC and SPOC concentrations, these results are not presented, however, in 2008, along the profile (0-60 cm depth) SOC and SPOC concentrations were 5% and 7% higher in plots with C/C than those with F/C respectively. Martín-Rueda et al. (2007) reported no significant differences in SOC by crop rotation at any depth.

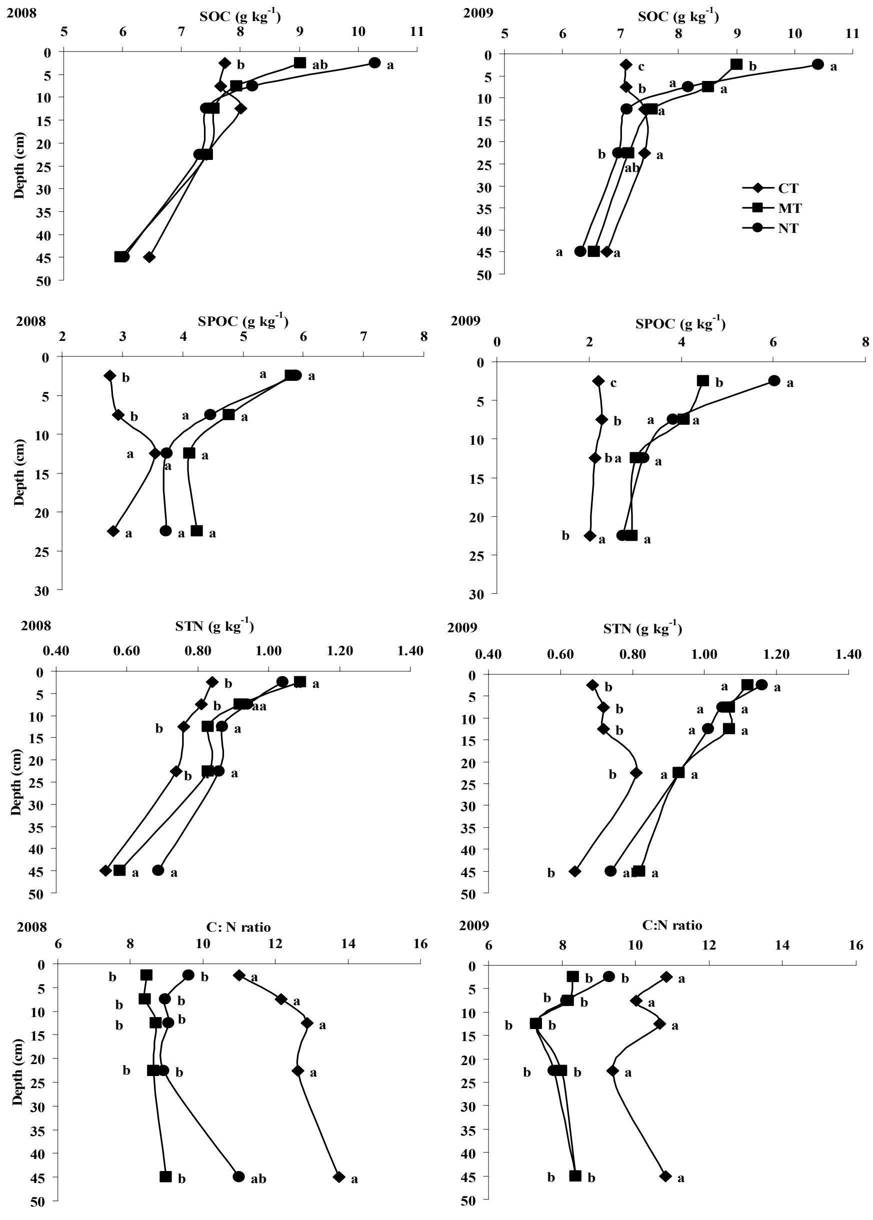

Figure 1. Vertical distribution of the soil organic and particulate carbon (SOC and SPOC) and soil total nitrogen (STN) contents and C:N ratio by tillage systems in 2008 and 2009. Lettered values mark significant differences at p<0.05 (Duncan's test). CT, conventional tillage; MT, minimum tillage; NT, no tillage.

Ortega et al. (2002) reported that SOC was not significantly influenced by crop rotation in NT system after 8 yr in the central Great Plains, even though continuous cropping returned greater biomass residue to the soil than other crop rotations containing fallow. In 2009, SOC and SPOC concentrations were 5% and 14% higher respectively in plots with L/C than those with C/C and F/C. Interactions of tillage systems crop rotation were significant for SPOC in 2008 and for SOC and SPOC in 2009. STN concentration was affected by crop rotation at 15-30 cm depth layer, STN was 10% higher in F/C plots than in those of L/C and C/C in 2008, while in 2009 only at 0-5 cm depth, STN values was 11% higher in L/C than C/C and F/C (data not presented). In 2008, C:N ratio was statistically different between crop rotation throughout soil profile, in L/C and C/C rotations C:N ratio was higher than in F/C.

SOC content was not affected by nitrogen rate, but the greatest concentration along the profile was found in plots with reduced fertilization (data not presented). SPOC concentration in different depths of two nitrogen rates in 2008 and 2009 years are shown in Figure 2. SPOC concentration trend was similar in the two years of study, SPOC was higher with reduced fertilization than in conventional fertilization along the profile studied, showing highly significant differences in the 0-5 cm soil layer. SPOC mean had 18% more in plots with reduced fertilization than those with conventional fertilization in both years. This indicates that SPOC changed rapidly with fertilization rate relative to SOC as suggested by several researchers (Cambardella and Elliot, 1992; Bayer et al., 2001; Sainju, 2008). Nitrogen rate did not affected STN concentration throughout soil profile in both year, however, C:N ratio only was significantly 6% higher in reduced nitrogen than conventional nitrogen at 0-5 cm depth layer in 2008. The greatest concentration along the profile was found in plots with reduced fertilization in 2008 and 2009.

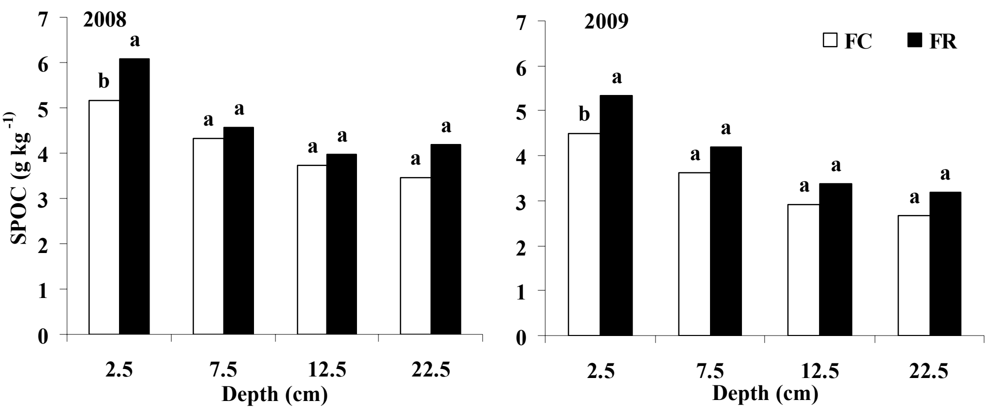

Figure 2. Soil particulate organic carbon (SPOC) concentration by nitrogen rate in different soil depths in 2008 and 2009. Lettered values mark significant differences at p<0.05 (Duncan’s test). FC, conventional fertilization; FR, reduced fertilization.

Effect of tillage, crop rotation and nitrogen rate on soil organic, particulate carbon and total nitrogen stocks and distribution in the soil profile

In general, SOC, SPOC stocks were significantly higher in 2008 than in 2009 at 0-30 cm depth (Figure 3a). The highest rainfall in 2008 led to a mean grain production of 6030 kg ha^{-1} while in 2009, the mean grain production only was 2425 kg ha^{-1}. Hence the amount of residues left on the surface was greater in 2008 which led to a larger amount of the SOC and SPOC in this year. There were significant differences in stocks of SOC and SPOC among the three tillage systems in 0-5 cm depth and at 0-30 cm depth respectively (Figure 3a). The amount of SOC in the 0-5 cm depth was greater in NT than in MT and greater in MT than CT. The SOC stocks were 2.08 and 2.73 Mg C ha^{-1} greater in NT than CT and 0.91 and 1.65 Mg C ha^{-1} in MT than CT in 2008 and 2009 respectively. At 0-15 cm depth, in 2009, SOC contents were 3.07 and 2.57 Mg C ha^{-1} greater in NT and MT than CT system. Hernanz et al. (2009) observed a higher SOC content at 10 cm in NT than CT soils in semi-arid climates. In the whole soil profile (0-60 cm depth) there were no differences in stocks of SOC among the three tillage systems, SOC stocks were a mean of 74.6 and 76.3 Mg C ha^{-1} in 2008 and 2009 respectively. Blanco-Canqui and Lal (2008) suggested that whereas NT practices increases soil C stocks in the top layer, they do not affect soil C contents across the 0-60 cm soil profile. The amount of SPOC throughout the soil profile studied (0-30 cm depth) was greater in NT and MT than in CT. At 0-5 cm depth, the SPOC stocks were 3.36 and 3.17 Mg C ha^{-1} greater in NT than CT and 2.12 and 1.98 Mg C ha^{-1} in MT than CT in 2008 and 2009 respectively. At 0-30 cm depth, SPOC stocks were a mean of 22.6 and 22.1 Mg C ha^{-1} for conservation tillage and 15.7 and 11.5 Mg C ha^{-1} in 2008 and 2009 respectively. The STN trend was similar to the SPOC, although the amount of STN was greater in 2009 than in 2008. The amount of STN throughout the soil profile studied (0-60 cm depth) was greater in NT and MT than in CT. At 0-5 cm depth, the STN stocks were 0.20 and 0.42 Mg N ha^{-1} greater in NT than CT and 0.16 and 0.37 Mg N ha^{-1} in MT than CT in 2008 and 2009 respectively. At 0-60 cm depth, STN stocks were a mean of 0.92 and 1.76 Mg N ha^{-1} greater in NT than CT and 1.67 and 2.34 Mg N ha^{-1} in MT than CT in 2008 and 2009 respectively.

There were significant differences in stocks of SOC and SPOC among crop rotations in 0-60 cm and in 0-30 cm depths (Figure 3b). In 2009, the amount of SOC in the 0-5 cm depth was 0.70 Mg C ha^{-1} greater in L/C than in C/C rotation. In the whole soil profile (0-60 cm depth), in 2008, SOC stocks were 3.86 and 2.45 Mg C ha^{-1} greater in L/C than F/C and C/C rotations and 3.84 and 4.24 Mg C ha^{-1} in L/C than F/C and C/C in 2009. These results concurred with other studies reporting the positive effect of vetch on the SOC content in soil and consequently soil quality (Katsvairo and Cox, 2000; Masri and Ryan, 2006). Bremer et al., (2008) observed that SOC can increase where reduced tillage is adopting and long fallows eliminated from cropping systems. SPOC amount was significantly different between rotations in 2008 (Figure 3b). Plots with monoculture cereal had higher SPOC content than L/C and F/C rotations throughout the study profile (0-30 cm depth). However, in 2009 the trend of SPOC was different from the previous year, SPOC content was 2.7 and 2.3 Mg C ha^{-1} greater in L/C plots than in those with F/C and C/C respectively. In general, there were not significant differences in stocks of STN among crop rotations, except at 0-5 cm depth layer, where STN values were higher for L/C than C/C and F/C in 2009. There were no differences in stocks of SOC and STN among the nitrogen rate, in 2008, SPOC only showed significant differences between nitrogen rates, reduced fertilization had 1.05 and 2.14 Mg C ha^{-1} higher amounts at 0-5 cm and 0-30 cm depth than conventional fertilization (Figure 3c). The highest rainfall in 2008 and reduced nitrogen fertilization led to a lower mineralization of soil organic carbon and consequently the amount of particulate carbon was higher. Much of the SOC lost from arable soil can be attributed to tillage, the returns of N depleted crop residue, long fallows and the excessive use of nitrogen fertilizer (Khan et al., 2007).

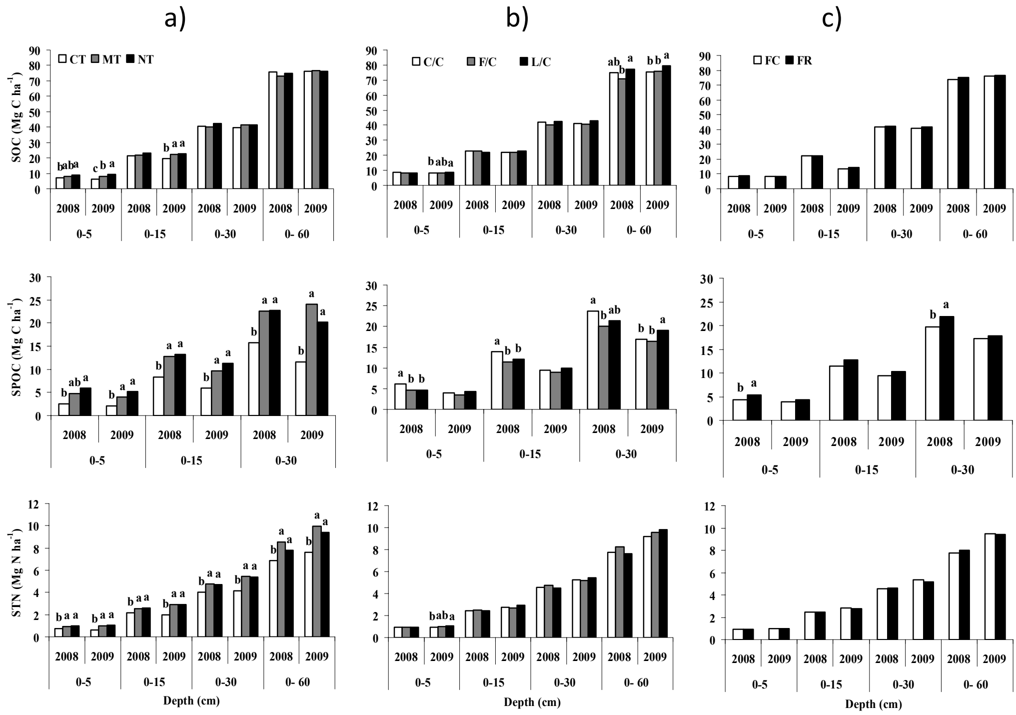

Figure 3. Soil organic, particulate carbon (SOC and SPOC) and soil total nitrogen (STN) expressed on equivalent soil mass under different tillage systems (a), crop rotation sequences (b) and nitrogen rate (c) in 2008 and 2009 years. Lettered values mark significant differences at $p<0.05$ (Duncan's test). CT, conventional tillage; MT, minimum tillage; NT, no tillage. C/C, cereal/cereal; F/C, fallow/cereal, L/C, legume/cereal. FC, conventional fertilization; FR, reduced fertilization.

Conclusions

This study examined the effect of tillage systems, crop rotations and nitrogen rate on soil organic and particulate carbon and total nitrogen in a semiarid climate of Castile and Leon (Spain). NT and MT accumulated 3.07 and 2.57 Mg C ha^{-1}more SOC than CT at 0-15 cm depth, but when the whole soil profile (0-60 cm depth) was considered, similar total SOC content was measured under all tillage systems. SPOC stocks were 12.5 and 8.7 Mg C ha^{-1} higher in MT and NT than CT at 0-30 cm depth. Throughout soil profile (0-60 cm depth), STN amounts were 2.34 and 1.76 Mg N ha^{-1} greater in MT and in NT respectively than in CT. SOC and SPOC contents were significantly affected by crop rotations, L/C had 3.8 and 4.2 Mg C ha^{-1} more SOC at 0-60 cm depth and 6.7 and 11.4 Mg C ha^{-1} more SPOC than F/C at 0-30 cm in 2008 and 2009 respectively. STN stocks were not significantly affected by crop rotations nevertheless L/C had higher values than F/C. SPOC stocks were greater in reduced than conventional fertilization along the profile studied. SPOC mean had 18% more in plots with reduced fertilization than those with conventional fertilization in both years at 0-5 cm depth. Conservation tillage as NT and MT and intensity crops (avoid fallows) practices could be effective strategies to improve C and N in soils in semi-arid areas of Spain.

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Original scientific paper

A comparative study of the winter wheat and maize effects on the changes in structural properties of Chernozem

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Abstract

In order to study aggregate fraction distribution and structure stability of the Haplic Chernozem soils from different cropping systems of winter wheat and maize were analyzed. Cropping systems were situated in a long-term experiment carried out at the Rimski Sancevi experimental station, Novi Sad. Soils from different cropping systems were analyzed in depths: 0-20, 20-40 and 40-60 cm with wet and 0-20 cm for dry sieving procedure. The following indicators of soil structure were analyzed: dry geometric mean diameter (dGMD), structure coefficient (K_s), wet mean weight diameter (wMWD) and water stable aggregates (WSA). Based on the aggregate size fraction arrangement after dry and wet sieving significant difference was found between crops - winter wheat and maize. After dry sieving both crops showed relatively stable structure, although dry geometric mean diameter (dGMD) and structure coefficient (K_s) differ in explanation of cropping system effects on structure. After wet sieving small macroaggregates (250-2000 µm) showed greater structural stability and large marcroaggregates were lower. To preserve structure it is necessary to apply proper tillage operation and to allow soil to naturally build biological maturity that facilitate favourable aggregates and affects soils properties.

Key words: soil structure, dry sieving, wet sieving, winter wheat, maize, cropping systems

Introduction

Physical properties of the soil are related to the intensity of the agricultural management and a various vegetative factors combined in environmental conditions of the production site. In the soil structure analysis particular attention is given to the fact that this property directly or indirectly affects water, air and soil thermal regime, and also serves as an indicator of the soil quality (Dexter, 1997; Pagliai et al., 2004; Hillel, 1998; Belic et al., 2004). It is important to emphasize that the soil structure is not static but very dynamic soil property with pronounced temporal dynamic. However, in respect to the changes over time, soil management must be focused to create optimal structure for early stages of plant growth and development. The agricultural soil with a favourable structure provides less resistance to field machinery, leads to a less water loss by evaporation, creating weaker and thinner crust. From the agronomic point of view, soil structure stability can be explained considering the size and the relationship of aggregate fractions, but can be conceded that formation of macro-aggregates is presumption for a favourable water-air and thermal regime of the soil (Vučić, 1987). Change of the soil structure by crops is related with morphological and physiological characteristics of roots, amount of incorporated crop residues, and the number and intensity of applied agricultural operations. Roots exudates and other gelatinous substance secreted by roots into the soil play an important role in the stabilization of soil aggregates (Chan and Heenan, 1996; Traoré et al., 2000). Proper soil tillage, use of organic fertilizers and mixed crop sequence (Kay 1990), are the presumption for preserving a favourable soil structure. However, it should be noted that the structure that is created using different tools for soil preparation is only a form of “transient cluster” in the aggregate arrangement that is very unstable and changeable. Pressure caused by various management practices (including tillage and traffic with agricultural machines) as well as natural stress such as rainfall, could accelerate aggregate breakdown and inhibit aggregate formation (Birkás, 2008). Balesdent et al. (2000) explained that tillage, by affecting the life-time and amount of aggregates wherein SOC is sequestered, is naturally suspected to influence the extent of physical protection. Therefore, aggregate distribution and arrangement must be preserved in order to protect soil physical, chemical and microbiological properties. Analysis of the stability of soil structure of Chernozem in Vojvodina begins in 1960-ies when 3-year crop rotation and winter wheat was confirm to exerts a positive effects on aggregation and stability of aggregates (Vučić, 1960). Considering temporal processes of structure formation and stabilization, that repeats in cycles, it is necessary to consider the long-term cumulative effect of different cropping systems and role of a particular crops. The aim or our research is to compare long-term effects of winter wheat and maize on aggregate distribution and structure stability of the Haplic Chernozem by using dry and wet sieving procedure.

Materials and methods

The present study was performed on a long–term experiment “Plodoredi” carried out at the Rimski Šančevi Experimental Field of the Institute of Field and Vegetable Crops in Novi Sad. Our investigation was performed on Haplic *Chernozem* (*CHha*) according to the IUSS Working Group WRB (2006). The study treatments were as follows: fertilized 3–year crop rotation (wheat–maize–soybean) D3; fertilized 2–year crop rotation (wheat–maize) D2; fertilized wheat monoculture MO; unfertilized 3–year rotation (wheat–maize–soybean), N3 and unfertilized 2–year rotation (wheat–maize) N2. The unfertilized treatments were established 1946/47, and fertilized started in 1969/70. Maize and winter wheat growing was based on conventional tillage including mouldboard ploughing and seed bed preparation with a germinator manufactured by Kongskilde. Row cultivator for maize and herbicide application was used according to recommended technology. Maize sowing took place in April at a seeding rate of 17 kg ha^{-1}, and a distance between and in rows: 70 × 25 (57.142 plants per ha). Winter wheat sowing was in October (25-30) with seeding rate of 230 kg ha^{-1}. Fertilization scheme and crop rotation sequence was described in Šeremešić (2005). The soil structure was accessed in the winter wheat (NS40S) and maize (NSSC640) cropping. Soil samples were taken in the 2008-2010 period in undisturbed state and kept in laboratory for analyses. Dry sieving was conducted on soil samples from 0-20 cm soil depth and for wet sieving 0-60 cm soil dept was analyzed. Dry aggregate size classes (ASC) was determined by the dry-sieving method (Savinov, 1936). Briefly, 500 g of air-dried, undisturbed sample is sieved through a nest of sieves having 10, 5, 3, 2, 1, 0.5, and 0.25 mm square openings so eight aggregate size classes were obtained (>10, 10-5, 5-3, 3-2, 2-1, 1-0.5, 0.5-0.25 and <0.25 mm). Dry GMD (mm) is calculated as (Hillel, 2004):

$$\mathrm{dGMD} = \exp\left[\sum_{i=1}^{n} \frac{(\mathrm{w_i} \log(\mathrm{x_i}))}{\mathrm{w_i}}\right]$$

where w_i is the weight percentage of each ASC with respect to the total sample and x_i is the mean diameter of each ASC (mm).

Aggregate size distribution, expressed as the structure coefficient (Ks), is calculated according to (Shein et al., 2001):

$$Ks = a / b$$

where *a* represents the weight percentage of aggregates 0.25-10 mm and *b* represents the weight percentage of aggregates <0.25 mm and >10 mm.

Using the weights of these ASC, dMWD (mm) is calculated (Hillel, 2004):

$$\mathrm{dMWD} = \sum_{i=1}^{n} x_i w_i$$

where w_i is the weight percentage of each ASC with respect to the total sample and x_i is the mean diameter of each ASC (mm).

Water stable aggregates were calculated as the mass of aggregates (>250 µm) divided by the total aggregate (stable + unstable) mass, and expressed as the percentage of water-stable aggregates according to the method described by Kemper and Rosenau (1986). In the formula, M_s represents the mass of stable aggregates, and M_u is the mass of unstable aggregates:

$$\mathrm{WSA} = \{\mathrm{M_s}/(\mathrm{M_s} + \mathrm{M_u})\} \times 100$$

Using the weights of these wet aggregate fractions, wMWD (mm) is calculated

$$\text{wMWD} = \sum_{i=1}^{n} x_i w_i$$

The significance of treatments was determined using ANOVA. Fisher's LSD test was used to separate means at the $p < 0.05$ level of significance.

Results and discussion

Analysis of dry aggregate size distribution

The largest difference between cropping systems were observed within the dry aggregate size classes of5-10 mm and <0.25 mm.(Figure 1). The soil samples in maize based cropping systems were abundant with the 5-10 mm aggregates whereas soils after winter wheat had more dispersed soil structure and smaller fractions. Interestingly, soil under both crops had comparable amount of 1-2 mm size aggregates. Considering the concentration of the favourable aggregate size classes, from the agronomic point (0.25 to 2 mm), soils after winter wheat had better effects on structure compared with the maize cropping. Differences between crops could be explained with root development and soil cover during the year. Winter wheat covers the soil in the most of the year and implies less supplementary soil operation after sowing that facilitates processes of soil stabilization. On the other hand maize requires tillage operation in spring that usually disperses aggregates and allows traffic induced soil compaction.

Among the maize cropping systems differences in concentration of aggregate size classes appears in >10mm, 3-5mm and 0.5-1 mm (Figure 1). The soil has more large aggregates (clods) as a consequence of compaction by agricultural machinery in long term tillage, (Wiesmeier et al., 2012). Maize monoculture had different arrangement of soil aggregates after being exposed to long-term compaction (weeding, row cultivator, herbicide application) compared with rotations. In addition to that, 2 and 3-year crop rotation showed only small difference in concentration of ASC which indicate that soil structure more depended on preceding crop (winter wheat) and less on the fertilization.

Analyses of dry aggregate size classes after winter wheat showed similar arrangement of aggregates. Similar to maize cropping systems, fertilization had less effect to concentration of dry aggregates compared with preceding crop. Topsoil of wheat monoculture has the highest concentration of the aggregates which are considered as indicators of good structure (0.25 to 2 mm). This can be explained with the possibility to perform agro-technical measures at the optimum time, the longest soilcover under crop, and proper stubble mulching and residue incorporation. As a consequence of long-term winter wheat monoculture maintenance of organic matter occurred compared with rotations (Seremesic, 2011). Regular incorporation of the crops residue is important for the maintenance of the humus level in the soil (Franzluebbers et al., 2002), which is a prerequisite for preservation of the favourable soil structure (Seremesic, 2011).

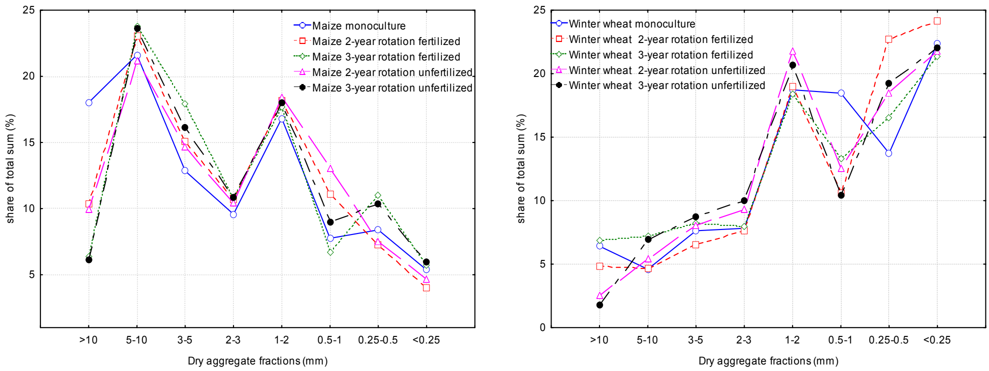

Figure 1. Aggregate size classes after dry sieving after maize (left) and winter wheat (right)

The concept of soil aggregates stability of different sizes depends on the strength of the forces which connect particles of soil, including the volume, nature and scope of activities destructive processes that are present in the soil (Beare and Bruce, 1993). Alteration in soil texture can have an effect on soil structure, although this depends also on humus and Ca^{2+}concentration (Table 1).

Soil texture analyses showed that clay fraction is lower in soil after winter wheat compared with the maize cropping systems. This could be explained with the rainfall effects on the topsoil of the winter wheat plots that washout finest soil aggregates in deeper layer. In contrary, silt fraction is higher in top soil after winter wheat compared with the maize. This indicate that the dry aggregate size classes >0.5 mm depends more on a silt concentration in top soil, since clay is ether washout or implicated in creation of the organo-mineral complex.

Unlike total dry fraction evaluation dMWD and K_S showed different result (Table 1.) Higher dMWD indicate more cohesive soil conditions and less susceptible to wind erosion (Gajić et al., 2010). In our study soil samples analyzed after maize had values of dMWD that were higher compared with winter wheat. Similar values for dMWD presented Ćirić et al. (2012) for cultivated Chernozem in temperate conditions. Higher structure coefficient (K_s) is an indicator of a better structure (Table 1). According to our study Ks was higher in maize cropping due to differences in <0.25 mm aggregate size class which is represented with more than 20% in winter wheat. Contrary to the analyses of total dry aggregate size classes, where aggregates from 0.25 to 2 mm are indicators of good structure, K_s showed different results. Higher values of Ks were found in soil of a 3-year rotation for both, winter wheat and maize, compared with 2-year rotation and monoculture. Crop rotation had more effects on this indicator compared to fertilization.

Table 1. Indicators of soil structure in maize and winter wheat cropping

	Cropping systems									
	MO		D2		D3		N2		N3	
Indicators	M	WW	M	WW	M	WW	M	WW	M	WW
Soil Texture (0-20 cm)										
Total sand	36.74	35.12	34.2	41	40	38.32	40.6	43.5	36.98	40.38
Silt	30.36	37.07	32.52	33.18	25.9	39.19	26.3	38.08	30.8	39.07
Clay	32.6	27.71	33.22	25.83	34.1	22.41	33.1	16.37	32.3	20.51
dMWD mm (0-20 cm)	7.23	2.96	5.58	2.5	4.72	3.26	5.33	2.12	4.61	2.06
K_s (+/- SD) (0-20 cm)	3.29	2.46	7.3	2.54	5.95	2.44	5.86	3.11	7.28	3.19
wMWD mm (+/- SD)										
0-20 cm	0.79	0.68	0.90	0.76	0.57	0.67	0.78	1.01	1.37	1.18
20-40 cm	1.13	0.63	0.86	0.82	0.77	0.70	0.64	0.92	1.62	1.11
40-60 cm	1.03	0.78	0.53	0.83	0.57	0.86	0.70	0.66	1.01	0.89
Average	*0.98*	*0.69*	*0.76*	*0.80*	*0.63*	*0.74*	*0.70*	*0.86*	*1.33*	*1.06*

Analysis of aggregate stability following wet sieving procedure

Higher values of wMWD imply greater aggregate stability. Within the 0-20 cm soil depth maize had higher values for wMWD at the MO, D2 and N3 compared with winter wheat and remaining D3 and N2 had opposite aggregate diameter display. The results for 20-40 cm soil depth generally showed larger aggregate diameter of maize in most cropping systems. Soil at N2 plot after winter wheat is more compacted that caused increase in wMWD in 20-40 cm soil depth. Within the 40-60 cm depth higher values of wMWD was observed in soil of the maize MO and N2 as a result of larger root development that increases the aggregate cohesion. Differences among crops, in the 0-20 cm, could be attributed to the tillage, however in the subsoil compaction or deterioration of a soil structure is related with the root activity.

We determine that the biggest difference between maize and winter wheat across all cropping systems and depths was found in 250-2000 µm and <53 µm (Table 2). Small macroaggregates (250-2000µm) in our study, represented with 46.60 and 36.55%, were found to be dominant in most cropping systems (Dameni et al., 2010). Within the two crops statistical differences between aggregate fractions of wet aggregate was found when cropping systems were compared.

In average, aggregate size class of 250-2000 µm dominated in winter wheat, and >53µm aggregate fraction was marginally represented, opposite to dry sieving. Higher concentration of aggregate fraction in different maize cropping systems was observed between 53-2000 µm, contrary to dry sieving where >2000 µm fractions dominate. Based on the obtained results soil after maize is less resistant to slaking and wet sieving. Also, long-term continuous tillage had resulted with increase in 53-250 µm and <53 µm aggregates that is prerequisite for formation of the surface crusts in the 0-20 cm soil layer. According to Le Bissonnias (1996) wMWD values for fertilized treatments indicate unstable soil that could be characterized by the frequent appearance of crust.

Table 2. Concentration of the soil aggregate fraction after wet sieving

		Aggregate fraction (µm)			
Field crop	System	>2000	250-2000	53-250	<53
Winter wheat	D2	3.78c	50.30a	34.36b	11.56bc
	D3	3.29c	45.47c	38.55a	12.69ab
	MO	2.50c	47.92b	37.12a	12.44ab
	N2	6.88b	41.07d	38.50a	13.55a
	N3	9.18a	48.22ab	31.53c	11.03bc
	Average	*5.13*	*46.60*	*36.01*	*12.25*
Maize	D2	6.21c	33.29c	52.41a	8.03d
	D3	4.00d	34.55c	30.84c	30.68b
	MO	7.88b	47.92a	34.70b	9.48d
	N2	6.54bc	29.68d	28.47d	35.39a
	N3	17.28a	37.31b	23.53e	21.45c
	Average	*8.38*	*36.55*	*33.99*	*21.01*

$^{a\text{-}c}$Values in columns of each crop followed by similar letters do not differ significantly at P≤0.05

Distribution of WSA in the analyzed treatments of the both crops indicates that the addition of mineral fertilizers and crop residue incorporation was not sufficient for soil structure preservation (Figure 2). Šimanský (2011) evaluated water stable aggregates at the Haplic Luvisol and also found that fertilization did not influence size fraction of WSA. Wagner et al. (2007) explained that crop residues are less important for structural stability, as the main role of the residue are to act as a physical protection on soil surface and as a nucleus for organo-clay aggregations. Concentration of WSA (%) showed no clear pattern among rotations. Unger et al. (1998) also noted that WSA distribution was affected with cropping system and depth but few differences were significant. Obtained results indicate that the higher concentration of WSA (%) in 0-20 cm soil after winter wheat is found in N3, whereas soil samples after maize MO and N3 were higher in stable aggregates. Accordingly, concentration of WSA is probably most affected with tillage and soil texture. These data supports the Mahboubi and Lal (1998) study in which structural changes were attributed to tillage and sampling period. Cultivation during unfavourable soil moisture content usually results with the structure deterioration in condition when period for structure consolidation is reduced (Birkás, 2009). In circumstances when optimal water content in soil is not attained tillage could amplify processes of structure impairment. It also appears that, in the temperate regions with plowing in autumn, there was no sufficient wetting and drying, freezing and thawing cycles during the winter for re-aggregation. Therefore, moldboard plowing and following soil preparation significantly contributes to deterioration of a soil structure. In a long-term this represents a considerable pressure for soil structure stability.

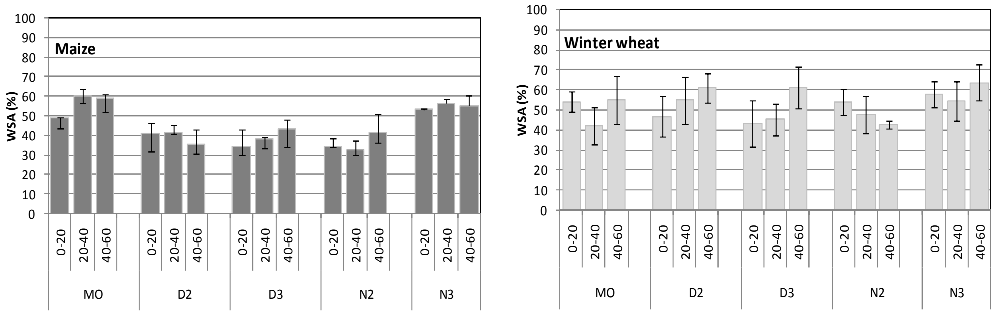

Figure 2. Concentration of WSA in winter wheat and maize cropping systems

Regardless to the dispersion induced with soil tillage the hierarchical model of soil aggregates has been observed (Šeremešić, 2012). This involves creation of the stable macroaggregateswhen microaggregates are bound together by additional organic matter (Tisdall and Oades, 1982; Oades and Waters, 1991).

Conclusion

The obtained results show relatively stable structure in the surface layer after dry sieving. Higher dGMD for maize was found under monoculture and for winter wheat in 3-year rotation. Higher structure coefficient (K_s) had 2-year rotation and unfertilized 3-year rotation for maize cropping systems and unfertilized 3-year and 2-year rotation after winter wheat. Wet sieving resulted with higher wMWD after unfertilized 3-year rotation. Small macroaggregates (250-2000 µm) were found to be dominant in most cropping systems, represented with 46.60% after winter wheat and 36.55% after maize and large macroaggregates were least stable to water treatment. Concentration of WSA % ranged from 42.2-63.56% in winter wheat and 32.57-60.32% after maize. The differences in aggregate stability between dry and wet sieving method demonstrate the sensitivity of the procedure to the initial moisture content of the soil. Significant differences was found between investigated crops and appears that tillage operation (time and soil moisture), also length of the stabilization period for soil could have primary effects of structure stabilization and preservation.

Acknowledgments

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Original scientific paper

Efficiency of wheat mineral nutrition depending on year conditions and fertilization intensity

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Abstract

Research on efficiency of mineral nutrition of winter wheat in four production years (2008/09 - 2011/12) were carried out on stationary field trial of the Institute of Field and Vegetable Crops at Rimski Šančevi. In the paper are presented the average wheat yields in 20 fertilization variants with increasing rates of nitrogen, phosphorus and potassium and agronomical use efficiency of the applied fertilizers was calculated.

Nitrogen had significantly highest impact on the wheat yield. The highest increase in the yield with one kilogram of the used fertilizer was with nitrogen (in four years average 36.19 kg of the grain/1 kg of N used); followed by phosphorus (12.65 kg of the grain/1 kg P_2O_5), and the lowest was with potassium (4.95 kg grain/1 kg K_2O). Agronomical nitrogen use efficiency differed depending upon weather conditions of the year, but in all analyzed years as well as in the average it had tendency to decrease with increasing intensity of fertilization. The highest efficiency of the applied nitrogen fertilizers was achieved with fertilization by 50 kg N ha^{-1}. However, from the aspect of joint impact on the yield of wheat grain, use efficiency and eventual loss of nitrogen and environment pollution, variant with application of the medium nitrogen rate of 100 kg N ha^{-1} proved to be especially rational.

Key words: wheat, yield, fertilization, nitrogen, nutrient efficiency.

Introduction

In several last decades in Serbia huge experimental material on mineral nutrition and fertilization of wheat was collected. However, having in mind dominant influence of mineral nutrition in synthesis of primary production of organic matter and yield formation, this problem, although it has been intensively studied, will remain in the focus of interests of scientists and practitioners until a man keeps growing plants (Sarić and Jocić, 1993). Strong incentive to the studies of different problems of mineral nutrition of wheat provides also constant improvement in selection and creation of new varieties. Thus, with the appearance of new wheat varieties (significantly different in number of useful traits, especially by significantly higher yield potential), it turns out that their requirements in regard to mineral nutrition are much higher (Sarić and Kovačević, 1981).

Up to now obtained results of trials carried out in Serbia suggest that winter wheat during vegetation uses relatively high amounts of mineral elements and that it has high demands according to soil fertility (Malešević, 2008). Concerning macro elements that it uptakes from the soil, wheat the most absorbs nitrogen, less potassium, significantly less phosphorus and much less sulphur, magnesium and calcium (Čurić, 1982). Amounts of nutritive elements that wheat absorbs from the soil during vegetation predominantly depend on grain yield and mass of the vegetative organs. In our conditions, the most frequently applied nitrogen rates for achievement of high yields in total values are from 80-120 kg ha^{-1} depending upon agrochemical properties of the soil. Based upon results of several years lasting studies, Kastori et al. (1991) stated that for the yield of 5 t of wheat grain and adequate straw mass wheat from the soil adopt about 120 kg N, 90 kg P_2O_5 and 80 kg K_2O.

Among elements of mineral nutrition, nitrogen has the greatest role in increase of wheat yield (Bogdanović, 1985; Malešević et al., 1994; Malešević, 2008; Kastori et al., 2005). Nitrogen shows the highest efficiency when it used together with phosphorous and potassium, while these two elements used without nitrogen do not provide a significant increase in wheat yield, but they even often reduce it (Sarić et al., 1973, 1993). Deficiency of nutrition, as well as too large fertilizer rates can cause reduction in wheat yield (Čurić, 1982; Kastori et al., 1991, 2005). Use of higher amounts of fertilizers than needed proved not only economically inappropriate results from the point of view of direct investments, but for higher number of plant species and varieties such rates can be also harmful (lodging and more intensive occurrence of wheat diseases, etc.), and are frequent cause of agro ecosystem pollution.

Efficient fertilization with nitrogen is of the key element for economically production of wheat, but also for protection of underground and above ground waters from pollution caused by leaching of nitrates due to excessive and inappropriate application of N (Vuković et al., 2008). Efficiency of nitrogen application in winter wheat is valuable indicator of rational N-fertilization. The term “Nitrogen Use Efficiency” *(NUE)* has several definitions and execution procedures, depending on the purpose of the study (Dobermann, 2005; Xie et al., 2007). In agricultural practice the most wide spread is use of *Agronomic N use Efficiency* (AE_N), based on the “method of difference” and it is determined as the ratio of the yield increase achieved by N-fertilization and the used amounts of N (Craswell and Godwin, 1984; Raun and Gordon, 1999; Dobermann, 2005):

$$AE_N = \Delta GY / F_N \ \textit{(kg grain / 1 kg N)}$$

where ΔGY = grain yield on the plot fertilized by nitrogen – grain yield on control plot (without N use); F_N – amount of used N in fertilized variant.

Dobermann (2005) states that typical values of AE_N in wheat are between 10–30 kg of grains per 1 kg of the applied N, and values >30 kg kg^{-1} are met in well organized growing systems or at low levels of nitrogen fertilization and on poor soils. Raun and Gordon (1999) stated that on the global level, worldwide NUE in cereal production is 33%.

Nitrogen use efficiency from mineral fertilizers in winter wheat is reduced with the increase in N fertilization level (Sieling et al., 1998). Hatfield and Prueger (2004) found that NUE depends also on water inflow (precipitations) and the availability of N to the plants during growing season. Use of nutrients from fertilizers and forming of wheat yield are significantly influenced by weather conditions during the year and specific conditions of the site (Bertić et al., 2007).

Material and Methods

Research on winter wheat (WW) mineral nutrition efficiency was conducted on a long-term stationary field trial, established in 1965/66 on experimental fields of the Institute of Field and Vegetable Crops at Rimski Šančevi. The trial is based on 4-year crop rotation (four fields) including sugar beet, maize, sunflower and wheat, as the most typical field crops in Vojvodina Province. In this paper results from last four years of experiment (from 2008/09 - 2011/12) were presented.

The trial was set up on a calcareous chernozem soil type, with slightly alkaline reaction (pH in H_2O=7.64), moderate content of humus (3.27%) and readily available phosphorus (15.98 mg/100 g of soil) and with high content of readily available potassium (25.64 mg/100 g of soil).

The experiment was set up in 4 separate fields, where different crops were grown on different fields each year. The size of each field is 1,84 ha (68 x 270 m) and is divided into 4 replication with 20 experimental plots in every replication, meaning that every field is divided into 80 plots with randomized treatments (different NPK doses and ratios), where every plot is additionally divided into more subplots, depending on the number of varieties examined.

The purpose of stationed plots in this trial was to investigate the effects of different nitrogen, phosphorus and potassium doses and ratios on wheat yield and grain quality in a continuous cropping. Considering this, founders of the trial have determined 20 different combinations of amounts and ratios of N, P_2O_5 and K_2O, according to agro-ecological conditions and biological properties of the investigated species. Fertilization treatments were:

1. Control (unfertilized plot)
2. N_2
3. P_2
4. K_2
5. N_2P_2

11. $N_2P_1K_1$
12. $N_2P_2K_1$
13. $N_2P_2K_2$
14. $N_2P_3K_1$
15. $N_2P_3K_3$

6. N_2K_2
7. P_2K_2
8. $N_1P_1K_1$
9. $N_1P_2K_1$
10. $N_1P_2K_2$
16. $N_3P_1K_1$
17. $N_3P_2K_1$
18. $N_3P_2K_2$
19. $N_3P_3K_2$
20. $N_3P_3K_3$

where index number represents doses of pure active matter of each nutrient: $_1$=50, $_2$=100, $_3$=150 kg of N, P_2O_5 and K_2O per ha.

For investigation purpose, winter wheat variety NS-40S was chosen, as one of the most widespread in Vojvodina region. It is middle late variety, with good low-temperature resistance and excellent resistance to lodging. The 1000 grains weight is in range 36-42 g and hectolitre mass is about 76-82 kg. Each year standard cultivation practice for agro-ecological conditions in Vojvodina is applied. The whole amount of P_2O_5 and K_2O and the half of the N dose were applied in autumn before tillage. Remaining amount of N fertilizers for wheat was given in spring at topdressing and before seeding for other species in the trial. Wheat straw and harvest residues of other crops are ploughed under after harvest. In all four years of investigation, sowing was done in optimal sowing time for conditions of Vojvodina (in October) with sowing density of 500 viable seeds per m^2, and spacing between rows of 12.5 cm. Application of pesticides was done sporadically, only if it was necessary.

Weather conditions in analyzed years (Table 1) indicate that the year 2008/09 was moderately hotter in relation to Long-Term Average values (LTA for period 1964-2012), mostly due to higher temperatures during winter months as well as in critical periods for wheat growth – April and May. The total amount of precipitation during this production year was similar to LTA value (-29 mm), but the severe drought in April (only 4 mm of rain), might possibly had a negative effects on grain yield. In contrary in 2009/10 year temperature conditions were more favourable with minor monthly deviations, whereby amount of precipitation were significantly higher in all months of WW vegetation period. Total rainfall amount in WW vegetation season in this year was 773 mm, i.e. 321 mm more in comparison to LTA value.

Weather conditions in 2010/11 and 2011/12 indicates that both years were moderately dry, due to low precipitation amounts in March, i.e. at the beginning of spring vegetation, and also in June, during the period of grain filling and ripening. In comparison to LTA, in 2010/11 growing season there was only 389 mm of rainfall, i.e. for 63 mm less than LTA (452 mm). In 2011/12 during WW growing season in relation to LTA, precipitations were for 88 mm lower. However, in 2011, winter reserves of moisture in the period October-March were somewhat more favourable, i.e. 266 mm in comparison to 2012 with only 200 mm (58 mm less in comparison to the LTA). Average temperature conditions in these years were on the LTA level, with higher deviations in November and December, which couldn’t have negative effects on WW. However, temperature conditions in April, period of intensive growth (stem elongation), were somewhat higher (about 2ºC), and in addition with dry April in 2011, could significantly decreased WW yield in this year.

Table 1. Precipitation and temperature conditions at Rimski Šančevi experimental station (N 45° 19`, E 19° 50`) during WW vegetation period (X-VI)

Year		Month									WW veget. period (X-VI)	Difference to LTA
		Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.		
T (°C)	2008/09	13.2	7.9	3.7	-1.5	2.2	6.8	14.6	18.6	19.6	9.5	1.1
	2009/10	11.7	8.3	3.5	-0.6	1.9	6.8	12.3	17.0	20.2	9.0	0.7
	2010/11	9.1	9.5	0.8	0.1	-0.2	6.0	13.2	16.8	20.9	8.5	0.1
	2011/12	10.7	2.8	4.2	2.0	-5.0	8.0	13.0	17.2	22.5	8.4	0.0
	LTA[1]	11.5	6.1	1.4	-0.4	1.5	6.3	11.4	16.9	20.0	8.3	-
P (mm)	2008/09	18	58	43	41	47	35	4	50	127	423	-29
	2009/10	82	63	97	76	66	39	64	114	172	773	+321
	2010/11	67	47	64	25	37	26	23	63	37	389	-63
	2011/12	35	2	49	43	67	4	83	51	31	365	-88
	LTA[1]	47	50	50	39	34	38	48	60	87	452	-

[1]LTA – Long-Term Averages (1964-2012)

Results and Discussion

Results in Table 2 shows average WW yields and its variation in trial in dependence to applied amounts and ratios of NPK nutrients in 20 different fertilizing treatments in 4 analyzed years. Average WW yield in the trial was 4.95 t ha^{-1}, ranging from 2.00 to 6.35 t ha^{-1}. Average mean yield deviation per years and fertilizing treatments from the overall mean was ±1.53 t ha^{-1} i.e. average mean relative yield deviation (CV) was 31%.

The effects of fertilization on WW yield were significant in all four years. The significantly lower yields in comparison to all other treatments were obtained on treatment without nutrient application (control), or on the treatments with only potassium applied (K_2 treatment), P_2K_2 and only P_2. In average for all years analyzed, the yield on these four treatments averaged 2.24 t ha^{-1}.

Considering the effect of a single application of nutrients, it can be concluded that N had the most significant influence on the WW yield. In average for all investigated years, applying only nitrogen (N_2) increased the yield in relation to control for over 2.6 t ha^{-1} (128%). On treatment with only phosphorus applied (P_2), yield decreased for 350 kg ha^{-1}, i.e. 17%, while the potassium didn’t have any significant effect on the WW yield. When these three elements were used in dual combinations, it can be observed that fertilization with N and P (N_2P_2) had the significant advantage in relation to combined application of N and K (N_2K_2). However, both treatments were significantly better then the treatment P_2K_2.

The highest WW yield in the trial (6,35 t ha^{-1}) was obtained on the treatment $N_3P_3K_3$, but statistically equally high yields (α=0,05; i.e. over 5,81 ha^{-1}) were obtained on other triple fertilizing variants with the highest or moderate N doses, regardless to amounts of P and especially K. By applying all three nutrients at moderate or high N amounts (all treatments with $N_2P_xK_x$ and $N_3P_xK_x$; except $N_2P_1K_1$), yield ranged from 6,00 to 6,35 t ha^{-1}, i.e. varied only 350 kg. Statistical analysis didn't show any significant differences between these treatments. Higher doses of nutrients in these treatments were not economically viable.

Table 2. The effect of mineral nutrition on winter wheat grain yield (t ha^{-1})

Mineral nutrition treatment	kg ha^{-1}			Years				Average 2009-2012
	N	P_2O_5	K_2O	2009	2010	2011	2012	
Ø	0	0	0	2.09	2.53	1.72	1.83	2.04
N_2	100	0	0	4.00	5.38	4.40	4.84	4.66
P_2	0	100	0	2.50	2.85	2.25	1.95	2.39
K_2	0	0	100	1.87	2.52	2.01	1.59	2.00
N_2P_2	100	100	0	5.29	5.97	5.31	6.09	5.67
N_2K_2	100	0	100	4.19	5.23	4.76	5.40	4.89
P_2K_2	0	100	100	2.39	2.96	2.67	2.15	2.54
$N_1P_1K_1$	50	50	50	4.44	4.53	3.74	4.38	4.27
$N_1P_2K_1$	50	100	50	5.26	5.12	4.48	4.93	4.94
$N_1P_2K_2$	50	100	100	5.33	5.05	4.43	4.54	4.84
$N_2P_1K_1$	100	50	50	5.31	5.00	5.18	5.31	5.20
$N_2P_2K_1$	100	100	50	5.57	6.51	5.78	6.13	6.00
$N_2P_2K_2$	100	100	100	6.03	6.17	6.13	6.31	6.16
$N_2P_3K_1$	100	150	50	5.99	6.11	6.03	6.26	6.10
$N_2P_3K_3$	100	150	150	6.25	5.74	6.38	6.34	6.18
$N_3P_1K_1$	150	50	50	5.51	6.28	6.18	6.16	6.03
$N_3P_2K_1$	150	100	50	5.55	6.57	6.39	6.29	6.20
$N_3P_2K_2$	150	100	100	5.71	6.66	6.31	6.32	6.25
$N_3P_3K_2$	150	150	100	5.53	6.71	6.80	6.26	6.33
$N_3P_3K_3$	150	150	150	5.73	6.68	6.55	6.44	6.35
Average:				4.73	5.23	4.87	4.98	4.95
Max				6.25	6.71	6.80	6.44	6.35
Min				1.87	2.52	1.72	1.59	2.00
Max-Min				4.38	4.19	5.08	4.85	4.35
SD				1.42	1.44	1.63	1.72	1.53
CV (%)				30	28	34	34	31
		LSD	0.05	0.30	0.46	0.49	0.53	0.54
			0.01	0.37	0.52	0.60	0.68	0.72
		r	N	0.82*	0.94*	0.94*	0.92*	0.92*
			P_2O_5	0.61*	0.52*	0.59*	0.50*	0.56*
			K_2O	0.32	0.27	0.39	0.28	0.32

*significant on the level α=0.05

In order to get more complete insight into the statistical significance of individual nutrients in WW mineral nutrition, single coefficients of correlations between increasing amounts of nutrients and WW yield were calculated (Table 2.). In all analyzed years, as well as in four years average, there was high and statistically significant (α=0.05) correlative relationship between N application and yield (r=0.82-0.94). Significant moderate correlations (0.50-0.61) was noticed between phosphorus application and WW yield, while correlation between amounts of potassium and yield was found not significant (r=0.27-0.39^{ns}).

Nutrient efficiency in WW yields formation

Complete influence of certain nutrients on plants (nutrient efficiency) is not easy to determine because of their different effects at individual and combined application. According to Sarić and Jocić (1993), with combined application of nutrients, interaction among these nutrients occurs. For this reason, single nutrient effect can't be easily and precisely determined. However, by using "difference method", i.e. by comparing yield obtained at combined application and treatment where the one of the nutrient is omitted, approximate contribution of a missing element to yield formation could be determined.

To determine the effect of each single nutrient to grain yield formation, method of difference between the yield achieved on treatment with balanced mineral nutrition ($N_2P_2K_2$) and dual combinations where one of the nutrient is omitted (N_2P_2, N_2K_2 and P_2K_2) was used. From the data presented in Table 3, it can be noticed that the nitrogen had the highest influence on yield increase per 1 kg of applied nutrient (in four years average 36.19 kg grain/1 kg N), followed with the phosphorus (12.65 kg grain/1 kg P_2O_5) and the potassium (4.95 kg grain/1 kg K_2O). Low values obtained with K application indicate good supply of this nutrient in Chernozem soil.

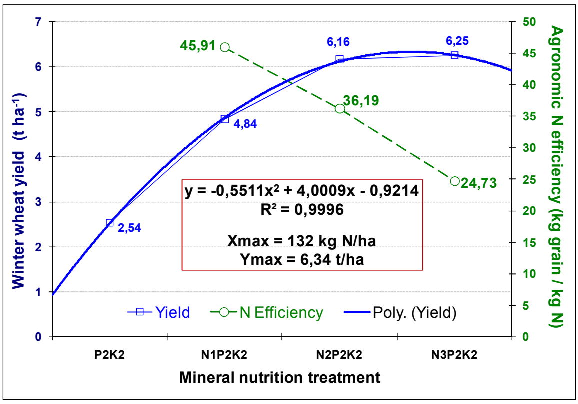
Table 3. Grain yield increasing with 1 kg of nutrients applied

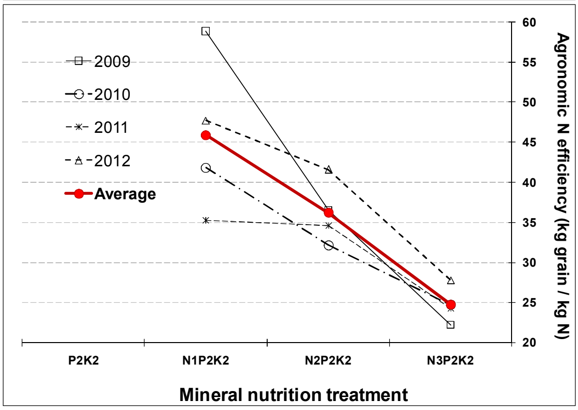
Years	Grain Yield *(t ha^{-1})*				Yield increasing with 1 kg a.m. of nutrients applied *(kg grains / 1 kg nutrient)*		
	$N_2P_2K_2$	P_2K_2	N_2K_2	N_2P_2	N	P_2O_5	K_2O
2009	6.03	2.39	4.19	5.29	36.45	18.43	7.37
2010	6.17	2.96	5.23	5.97	32.15	9.43	2.05
2011	6.13	2.67	4.76	5.31	34.55	13.63	8.15
2012	6.31	2.15	5.40	6.09	41.59	9.10	2.22
Average	6.16	2.54	4.89	5.67	36.19	12.65	4.95

Influence of nitrogen fertilization doses on its efficiency

One of the main aims of this paper was to determine how different N fertilization levels influenced WW grain yield and nitrogen use efficiency (NUE). Determination of

„Agronomic N use Efficiency"- AE_N (in this case effect of fertilization with increasing N doses on its efficiency) was done by the difference method, between yields on treatment P_2K_2 (taken as control) and $N_1P_2K_2$, $N_2P_2K_2$ and $N_3P_2K_2$. As can be seen from Graph 1, average yield increase with 1 kg of N applied was the highest on treatment $N_1P_2K_2$ (45.91 kg grain/1 kg N), then on treatment with moderate (36.19 kg/kg N), and the lowest at treatment with the highest N dose ($N_3P_2K_2$; 24.73 kg grain/1 kg N).





Graph 1. The effects of increasing amounts of N on grain yield and yield increasing with 1 kg of nitrogen applied - agronomic N use efficiency, average results (left) and for all four years (right)

Agronomic N use efficiency differed in years analysed (Graph 1, *right*). Highest AE_N values were in 2008/09 and 2011/12, and lower than average values in 2009/10 and 2010/11. Differences could be partly explained by the climate conditions. Year 2008/09 was somewhat hotter with total amount of precipitation near the LTA level, which favoured the nitrogen sorption, while in 2011/12 moisture reserve from February influenced intensive plant sorption of N applied at topdressing. Although March was dry, most N was already absorbed and more intensive absorption continued in wet April and May. In difference from these years, in extremely wet

2009/10 it is probably that the losses from N leaching were higher due to its removal to deeper soli layers.

In a specific year, as well as in average for all 4 years, AE_N had a decreasing tendency with increasement of N doses. The highest AE_N was on treatment with 50 kg N ha^{-1}, so this dose could be considered as the most rational in terms of lowest N losses and possible environmental pollution. However, in terms of mutual influence on the yield of winter wheat and nitrogen use efficiency, especially rational treatment was the one with 100 kg N ha^{-1} applied.

With moderate amounts of P and K (treatments $N_xP_2K_2$; Graph 1), the lowest N dose ($N_1P_2K_2$) increased grain yield for 2.3 t in relation to treatment P_2K_2, which was taken as control. Next N dose increased yield for additional 1.32 t of grain, while the highest N dose (treatment $N_3P_2K_2$) influenced non-significant yield increase of only 90 kg ha^{-1}. Average yield increasing for every additional dose of 50 kg N ha^{-1} was 1.25 t of grain ha^{-1}. However, the first nitrogen dose influenced the most intensive yield increase compared to control, while the effect of following N doses was less expressed. Influence of increasing N doses on WW yield had the saturating effect, i.e. followed the shape of quadratic regression curve (R^2=0.99). Based on the equation of this regression, at moderate P and K doses (100 kg ha^{-1}), theoretically calculated maximum regression grain yield of 6.34 t ha^{-1} can be achieved by applying 132 kg N ha^{-1} (Graph 1).

By analyzing the yield of winter wheat during the 50 years trial period, Kunzova and Hejcman (2009) stated that in the fifth decade of the experiment, average yield increase per 1 kg of N applied was 18,7 kg of grain. Similarly to our results, Vuković et al. (2008) for conditions of Croatia found that NUE values decreasing with higher intensity of N fertilization. NUE values ranged from 9.21 kg kg^{-1} with 300 kg N ha^{-1} up to 24.13 kg kg^{-1} on treatment with 100 kg N ha^{-1}. Authors concluded that better N efficiency was at fertilization with 100 kg N ha^{-1}, which can be considered as rational amount in terms of grain yield and harmful influence on environment. Also, NUE was influenced by soli type and climatic conditions, mainly by precipitation and temperature regime during vegetation period (Vuković et al., 2008).

According to Hatfield and Prueger (2004), NUE depended on soil moisture and N availability during vegetation. As well as in our research, Pepó (2007), concluded that the efficiency of fertilization was strongly modified by climatic conditions. Ortiz-Monasterio et al. (2001), Ortiz-Monasterio (2002) and Raun and Gordon (1999) stated that improvement in nutrition use efficiency by wheat can be achieved by two main strategies: application of more efficient cultivation practices (amount and time of fertilizers application, nutrient source, etc.) and by breeding of varieties with better efficiency of nutrients used. According to Malešević et al. (2008) in ten years investigated period, the yield of WW was increased with increasing amounts of N. The highest grain yield was achieved with the highest N dose of 180 kg ha^{-1}. However, average grain yield obtained at this treatment has not been significantly different from the yield achieved with 120 kg N ha^{-1}, so authors recommend it as optimal amount, which is in accordance with our results. Similar results are given in numerous other investigations. Therefore, Vrkoč et al. (1990), for conditions of Czech Republic recommend 120 kg N ha^{-1} as most suitable, even the highest yield was achieved by applying 160 kg N ha^{-1}.

Conclusions

In a 4-year investigation period, nitrogen had significantly the highest influence on the wheat grain yield. Fertilization with N only increase the yield compared to control up to 2.6 t ha^{-1} (128%), while fertilization with potassium only wasn't statistically significant.

When nutrients were used in dual combinations, fertilization with N and P (N_2P_2) had the significant advantage in relation to combined application of N and K (N_2K_2). However, both treatments were significantly better then the treatment P_2K_2.

The highest grain yield was obtained on treatment $N_3P_3K_3$, but statistically equally high yields (in range 6.00-6.35 t ha^{-1}) was achieved on all other triple nutrient combinations with highest or moderate N doses.

The highest yield increase with 1 kg of nutrient applied was with N, then P, and lowest with K. Agronomic N use efficiency had the decreasing tendency with increasing N doses. In terms of mutual influence on the yield of wheat and nitrogen use efficiency, especially rational treatment was the one with 100 kg of N ha^{-1} applied.

Influence of increasing N doses on wheat yield had the saturating effect, i.e. followed the shape of quadratic regression curve. Based on the equation of this regression, theoretically calculated maximum grain yield of 6.34 t ha^{-1} can be achieved by applying 132 kg N ha^{-1}.

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Original scientific paper

Activation energy and kinetic parameters of phosphomonoesterase activity in different soil types

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Abstract

In the present research we aimed to determine kinetic and thermodynamic constants of the acid and alkaline phosphomonoesterases activities such as Michaelis- Menten constant, maximum enzymatic reaction velocity (Vmax), as well as activation energy (Ea). We did it by examining different types of soil. Soil samples were collected from the humus horizon (0-15 cm) of the following soil types: 1. planosol – Ub; 2. solonetz – Kumane; 3. chernozem - Zemun Polje; 4. vertisol – Umka; 5. humogley -Makis. The Michaelis-Menten constant of acid phosphomonoesterase activity varied between 5.7 mm in planosol and 72.8 mm in solonetz. The highest acid phosphomonoesterase Vmax was found in solonetz (809.8) and the lowest in chernozem (81.2 µg p-npg^{-1} h-1). The Ea of acid phosphomonoesterase varied between 28.8 kj mol^{-1} (solonetz) and 77.54 kj mol^{-1} (chernozem). The Michaelis-Menten constant of alkaline phosphomonoesterase activity was between 7.59 mm in solonetz and 21.4 mm in chernozem. Alkaline phosphomonoesterase Vmax varied between 217.2µg p-npg^{-1} h^{-1} in planosol and 789.4 p-npg^{-1} h^{-1} in chernozem, and Ea between 28.8 kj mol^{-1} in solonetz and 59.3 kJ mol^{-1} in planosol. This research confirms the importance of kinetic and thermodynamic indicators of the active enzyme phosphomonoesterase in mineralization of organic phosphorous in soils and its uptake by plants.

Key words: activation energy, acid phosphomonoesterase activity, alkaline phosphomonoesterase activity, kinetic parameters

Introduction

Enzymes as biological catalysts play a crucial role in important biochemical processes: synthesis and decomposition of humus, hydrolysis of organic compounds, as well as in the biogeochemical cycling of nutrients (22). Activity of soil enzymes has been related to structure of microbial populations (8), vegetation (19), physical and chemical properties of soil (1) etc. Soil enzyme data provide information about coherency between microorganisms and nutrient dynamics (16).

Alkaline phosphomonoesterase (EC 3.1.3.1) and acid phosphomonoesterase (EC 3.1.3.2) are enzymes that play a major role in biological activity of soil (2), soil quality (24) and in the circulation of phosphorus as they catalyze the hydrolysis of monoesters of orthophosphoric acid and transform them into available forms for plants. The morphology and physiology of root system is directly affected by microbial activity in rhizosphere (18), especially by microbial enzymes.

Determination of kinetic and thermodynamic indicators of the active enzyme complex is important parameter for understanding of enzymatic reactions in soil. The Michaelis-Menten constant is one of fundamental constants in enzymology that enables determining the effect of substrate concentration on the velocity of enzymatic reaction. Studies of enzyme kinetics in soil are useful for understanding the activity of enzymes depending on the physical and chemical properties of soil. The Michaelis-Menten constant is often described by parameters as Vmax and Km, who shows the enzyme activity (10).

The aim of this paper was to determine the Michaelis-Menten constant, maximum velocity of enzymatic reaction and activation energy of acid and alkaline phosphomonoesterase in different soil types.

Materials and methods

Samples for determining the kinetic and thermodynamic constants of the activity of acid and alkaline phosphomonoesterase were collected from the surface (0-10 cm) of soils differing in types, localities, and consequently chemical properties (Table 1).

Table 1. Chemical properties of the tested soil types

Soil type/ locality	pH (H_2O)	Humus (%)	N (%)	P_2O_5 (mg/100g)	K_2O (mg/100g)
Planosol / Ub	5.72	1.99	0.110	14.40	16.80
Solonetz / Kumane	6.40	6.05	0.400	7.30	18.80
Chernozem / Zemun Polje	8.02	2.64	0.182	11.00	18.40
Vertisol / Umka	7.64	3.85	0.180	6.80	27.60
Humogley / Makis	7.62	4.55	0.24	11.70	21.60

The activity of acid and alkaline phosphomonoesterase was determined by the Tabatabai & Bremner (21) method. Briefly, 1 g of soil was incubated with 0.2 ml toluene, 4 ml MUB (pH 6.5 for assay of acid phosphatase or pH 11 for assay of alkaline phosphatase), and 1.0 ml of p-nitrophenyl phosphate for 60 minutes at 37^{o} C.

The effect of substrate concentration (Km) was determined by supplementing the reaction mixture with p-nitrophenyl phosphate in the amount required to make the concentration of the reaction mixture reach 1, 2, 5, 10, 15, 20 mM. Each concentration of supplemented substrate had a control. All experiments were conducted in triplicate. Km and Vmax kinetic parameters were calculated from a linear regression analysis of the initial velocity of reaction against 1/S using the Lineweaver-Burk transformation.

Using by temperature and activation energy, the rate of chemical reaction was determined according to the Arrhenius equation:

$$k= Ae^{-Ea/RT}$$

In the formula given above, ‘k’ stands for the constant rate of chemical reaction, ‘Ae’ for pre-exponential factor, ‘Ea’ for the activation energy, ‘R’ for the universal gas constant, and ‘T’ stands for the absolute temperature.

Ea was determined by linear regression analysis. Written in logarithmic form, the Arrhenius equation reads as follows:

$$\log V = \log A - Ea/2.303\ RT$$

Results and Discussion

The activity of acid and alkaline phosphomonoesterase varied in different soil types. The Michaelis constant (Km) of the acid phosphomonoesterase activity varied between 5.7 mM in planosol and 72.8 mM in solonetz (Table 2), while the values of Km of alkaline phosphomonoesterase activity varies between 7.59 mM in solonetz and 21.4 mM in chernozem (Table 2). Value of Km of acid phosphomonoesterase in planosol was lower compared to Km of alkaline phosphomonoesterase. The soil types with higher pH value have higher Km of acid phosphomonoesterase, while Km values of alkaline phosphomonoesterase were particularly low.

Maximum velocity of the enzymatic reaction of acid and alkaline phosphomonoesterase varies in different soil types. The highest Vmax of acid phosphomonoesterase was found in acid soil samples (planosol and solonetz), and the lowest was observed in chernozem. However, the highest Vmax of alkaline phosphomonoesterase was noticed in chernozem, while the lowest in planosol.

The activation energy for acid and alkaline phosphomonoesterase varies in the different soil types (Table 3). The lowest Ea of acid and alkaline phosphomonoesterase was noticed in solonetz (25.03 and 28.8 kJ mol^{-1}, respectively). The highest Ea of acid phosphomonoesterase was found in chernozem (77.54 kJ mol^{-1}), while in planosol was observed a highest value of alkaline phosphomonoesterase (59.3 kJ mol^{-1}).

Soil types with acid pH values (planosol and solonetz) have higher values of activation energy for alkaline phosphomonoesterase, compared to acid phosphomonoesterase. On the other hand, in alkaline soils we noticed the lower energy of activation for alkaline phosphomonoesterase, particularly when compared to acid phosphomonoesterase.

Table 2. The Michaelis constant (Km), maximum velocity (Vmax) and activation energy (Ea) of acid phosphomonoesterase in different soil types

Soil type/ locality	Acid phosphomonoesterase		
	Km (mM)	Vmax (µg p-NP g-1 h-1)	Ea (kJ mol-1)
Planosol / Ub	5.7	570.1	43.77
Solonetz / Kumane	72.8	809.8	25.03
Chernozem / Zemun Polje	33.3	81.2	77.54
Vertisol / Umka	26.8	290.7	40.19
Humogley / Makis	26.0	329.9	70.99

The enzymes in soil are linked with different biotic and abiotic factors and originate from animals, plants and microorganisms (14). Microorganisms provide most of the soil enzyme activity, thanks to their vigorous metabolism, diversity and biomass content (17). Several reports showed that characteristics of soil and water can influence the activity of enzymes, e.g. saccharase, protease, phosphatase etc (5, 23).

Table 3. The Michaelis constant (Km), maximum velocity (Vmax) and activation energy (Ea) of alkaline phosphomonoesterase in different soil types

Soil type/ locality	Alkaline phosphomonoesterase		
	Km (mM)	Vmax (µg p-NP g^{-1} h^{-1})	Ea (kJ mol^{-1})
Planosol / Ub	11.0	217.2	59.33
Solonetz / Kumane	7.59	759.2	28.80
Chernozem / Zemun Polje	21.4	789.4	40.50
Vertisol / Umka	8.05	444.6	34.70
Humogley / Makis	9.24	308.3	40.23

The activity of acid and alkaline phosphomonoesterase correlated with humus and nitrogen contents, pH, soil texture, microbiological and biochemical properties (4). High activity of phosphomonoesterases was obtained in solonetz and probably resulted from high content of nitrogen and humus, which is in coordinance with previous researches (3, 15).

Phosphatase activity is also correlated with pH value of soils. In our investigation we noticed the high acid phosphomonoesterase activity in acid soils. The conclusion of our research corresponds with the results of Sarapatka (13). The same author noticed negative correlation between activity of alkaline phosphomonoesterase and pH, and those particular findings significantly differ from ours, primarily because we discovered highest activity of alkaline phosphomonoesterase in most alkaline soil.

Our results are similar with observation by Pang & Kolenko (12), who reported that Km of acid phosphomonoesterase varies between 25 and 91 mM, but differs to the investigations by Tabatabai (20), who found the Km to vary between 1.3 and 4.5.

The lower Km values for alkaline phosphomonoesterase indicate a greater enzyme affinity for the substrate. In this research Km values of alkaline phosphomonoesterase in vertisol and humogley were lower compared with planosol. Similar data was obtained by Juma & Tabatabai (7), who found the Km values for alkaline phosphomonoesterase to be lower in alkaline than in acid soil. Also, in alkaline soils, Ea values for alkaline phosphomonoesterase were lower than for acid phosphomonoesterase. Tabatabai (20) reported Ea of alkaline phosphatase in alkaline soil to be significantly lower than in acid soils. The lowest Ea of acid and alkaline phosphomonoesterase was found in solonetz, resulting from the presence of water soluble cations Mg^{2+} and Ca^{2+} in the humus horizon (11). Mg ions stimulate phosphomonoesterase activity (6) by allosteric changes in the substrate (9).

This research confirms the importance of kinetic parameters of phosphomonoesterases in mineralization of organic phosphorous in soils and its utilization by plants, especially under low concentration of phosphorus.

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S E S S I O N II

[Adaptation and mitigation of climate changes in crop production]

Chairmen:

Irena Jug
Zoran Dimov
Vesna Dragičević

Original scientific paper

Alterations of maize grain yield in function of tillage and fertilization regimes in rain-fed cropping

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Abstract

Maize is one of the most important crops in the world. Successful production depends primarily on meteorological, but also on other environmental factors. The aim of this study was to define the most efficient tillage system (no-till, reduced or conventional tillage) and amount of fertilizer (Ø, 330 or 660 kg ha^{-1} of N:P:K) for high maize yield (FAO 700 maturity group) under rain-fed conditions, according to results of a long-term maize cropping experiment (1991-2010) under climate change. The present variations in the meteorological conditions induced variations in the achieved maize grain yield, indicating positive and significant dependence of all three tillage systems and fertilization regimes on amount of precipitation. Conventional tillage could diminish negative impact of meteorological factors, particularly of temperature to some extent, while the higher fertilizer inputs could increase grain yield to some level, but they are highly dependable on meteorological factors, particularly temperature. Environmental impact emphasized 330 kg ha^{-1} of N:P:K as expedient fertilization regime in reduced tillage, as well as 660 kg ha^{-1} of N:P:K in conventional tillage, as best suited practices to unfavourable environmental conditions.

Key words: maize cropping, fertilization, tillage, yield prediction

Introduction

Maize is one of the most important crops in the world. Successful production depends primarily on meteorological, but also on other environmental factors. It was found that climate change increase the disparities in cereal production between developed and developing countries (Rosenzweig and Parry, 1994) due to vulnerability of extensive technologies in developing countries (reduced fertilizer inputs and application of irrigation) to the potential impact of global warming. This could be a crucial point in some integrating systems of agricultural development, such as sustainable development of the agro-food industry (Adzic and Birovljev, 2011). According to Schlenker et al. (2002), the economic effect of climate change on agriculture requires different assessment for dryland areas, where climate change is equivalent to an exogenous shift in the fixed input associated with new supplies.

Rain-fed cropping is still the most abundant practice in the world. Variations in cropping practices, which include different measures, enable environmental factors to be overcome, especially during periods of extreme weather conditions. Different studies concerning variations in cropping measures (tillage practices, fertilization amounts and rates) indicated that under rain-fed conditions on chernozem, conventional tillage is the best practice to lower energy inputs and increase maize yield (Videnović et al., 2011). Moreover, increased amounts of fertilizer could compensate yield deprivations arising from reducing some tillage operations (Tolimir et al., 2001). According to forecasting models, some inputs could be defined as necessary, while some others have no real effect on grain yield. Mechanistic models based on systems of nonlinear differential equations can help in providing a quantitative understanding of complex physical or biological phenomena (Schlenker et al., 2002; Igesias et al., 2011). Forecasting in the variability of a complex environment could be improved by non-linear models, such as the Weibull analysis (Kress and Miller, 1985a, 1985b).

The aim of this study was to define the most efficient tillage system (no-till, reduced or conventional tillage) and amount of fertilizer (Ø, 330 or 660 kg ha^{-1} of N:P:K) for high maize yield (maize hybrid of FAO 700 maturity group) under rain-fed conditions, according to results of a long-term maize cropping experiment (1991-2010) under conditions of climate change.

Material and methods

The research was conducted in Zemun Polje (44°52'N 20°20'E), in the vicinity of Belgrade, on a slightly calcareous chernozem, within an ongoing long-term experiment, analyzing a 20-year period (1999-2010) in rain-fed conditions. The field experiment was arranged in a split-plot design with 4 replications. An elementary plot was 19.6 m^2 (2.8×7 m) with a plant density of 64,935 plants/ha. Maize hybrid ZPSC 704 was sown with a four row planter for direct maize sowing (John Deere 7200 Max Emerge II), between the 20th and 25th of April every year, depending on the weather conditions.

The effects of three tillage systems were investigated: no-tillage (NT), reduced tillage (RT) and conventional tillage (CT). In the NT treatment, sowing was performed without preceding soil tillage. In the RT treatment, tillage was performed with a rotavator in the autumn (10–12 cm deep). The CT treatment consisted of shallow ploughing (15 cm deep) immediately after wheat harvesting, autumn ploughing (25 cm deep) and seedbed preparation with Rau-combi (composed of a harrow, cultivator and rollers). The fertilizer treatments included: control - without fertilization (Ø), incorporation of 330 kg ha^{-1} of N:P:K (F1) and 660 kg ha^{-1} of N:P:K (F2). The fertilizers were spread on the soil surface in the autumn.

Statistical analysis included regression analysis for the meteorological data, as well as for dependence of grain yield on meteorological conditions (sum of precipitations and mean temperature during vegetative period, April-September).

Differences between applied treatments in grain yield were presented with Weibull analysis (Dodson, 2006):

$$F(x) = 1 - \mathrm{e}^{-\left[\frac{x}{\alpha}\right]^{\beta}}$$, for x > 0

where *β* is a shape parameter and *α* is a measure of the scale (characteristic life), which were used for the calculation of the survival probability, to predict a parameter reaching a reliability of 0.10, 0.25, 0.50, 0.75 and 0.99.

Meteorological conditions

The observed 20 year period was characterized by increasing trends of both, sum of precipitation and the average temperature (Figure 1), but only temperature had significant increase in function of time.

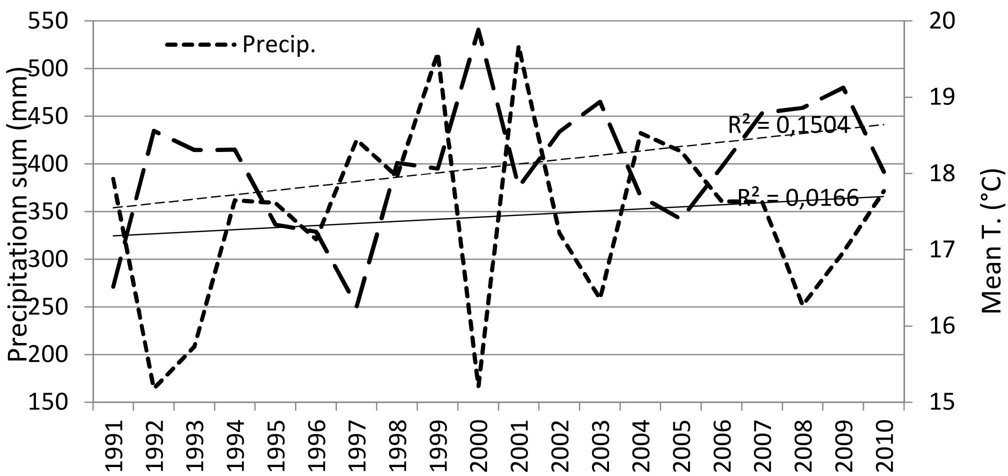


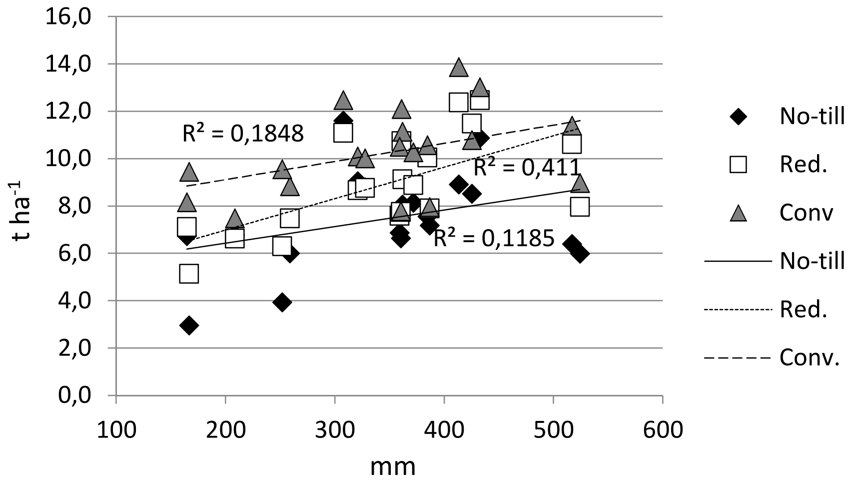
Figure 1. Precipitation sum and mean temperature during the examined period of 1991-2010

Regarding the sum of precipitation in the vegetative period, years 1992, 2000, 2003 and 2008 were unfavourable with ≤ 250 mm. The same years, together with 2002 and 2007 were also characterised with high average temperatures (≥ 18.5 °C), which were highlighted during 2000. Periods with lower temperature extremes were present during 1991, 1997-1999 and 2005, as well as high precipitation amount was present during 1999 and 2001.

Results and Discussion

Present variations of meteorological conditions induced variations of maize grain yield (Figures 2 and 3), which averaged 3.0-11.6 t ha^{-1} in no-till, 5.1-12.5 t ha^{-1} in reduced tillage and 7.5-13.9 t ha^{-1} in conventional tillage treatments; 5.1-11.5 t ha^{-1} in control, 6.2-12.5 t ha^{-1} in F1 and 6.5-13.7 t ha^{-1} in F2 treatments.

Regression function between grain yield and amount of precipitation (Figure 2) indicated positive and significant dependence of all three tillage systems on amount of precipitation (particularly in no-till, R^2 = 0.411), as well as positive and significant dependence of applied fertilization regimes on amount of precipitation (particularly F1, R^2 = 0.312).



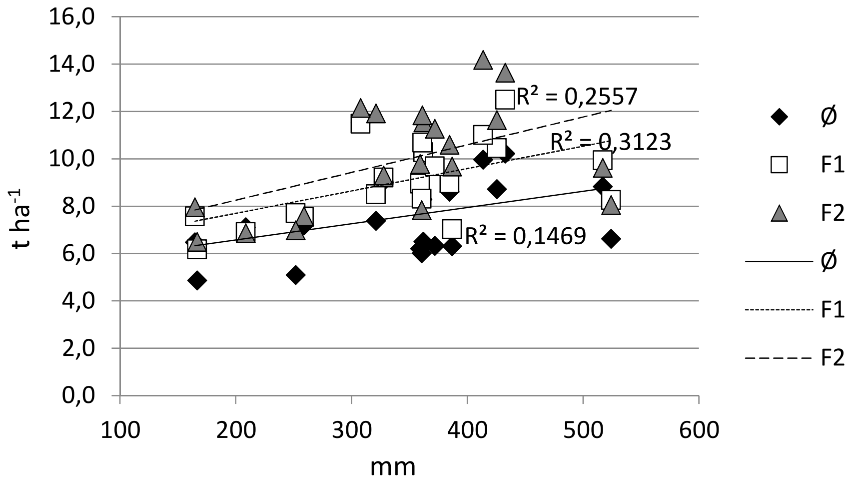
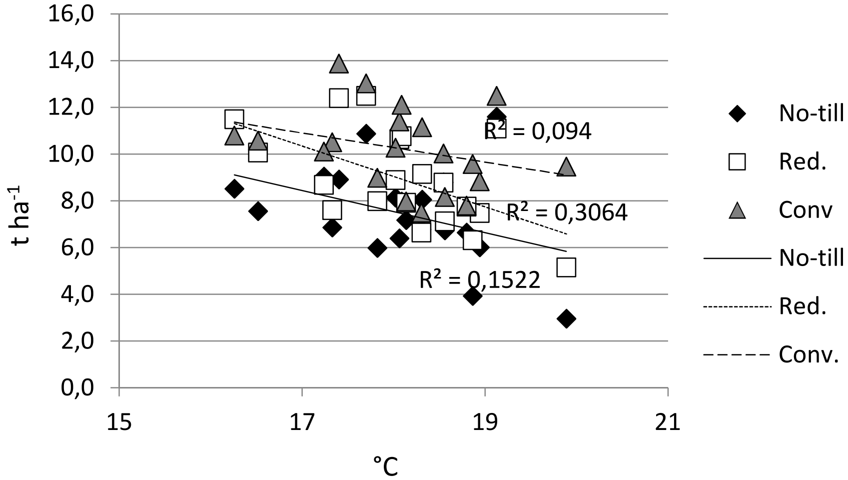


Figure 2. Dependence of average maize grain yield on precipitation in different tillage systems (no-till, reduced and conventional tillage) and fertilization levels (Ø, T1 - 330 kg ha^{-1} of N:P:K, T2 - 660 kg ha^{-1} of N:P:K)

On the other hand, the regression function between grain yield and mean temperature during vegetation (Figure 3) pointed to negative and significant dependence of no-till and reduced tillage on mean temperature (R^2 = 0.152 and R^2 = 0.306, respectively), as well as negative and significant dependence of F1 and F2 on mean temperature (R^2 = 0.151 and R^2 = 0.301, respectively). Observed results are in accordance with results of Schlenker et al. (2002) who underlined economic effect of climate change and importance of different cropping measures on agriculture production for dryland areas, which could contribute to yield increase in extreme meteorological conditions.



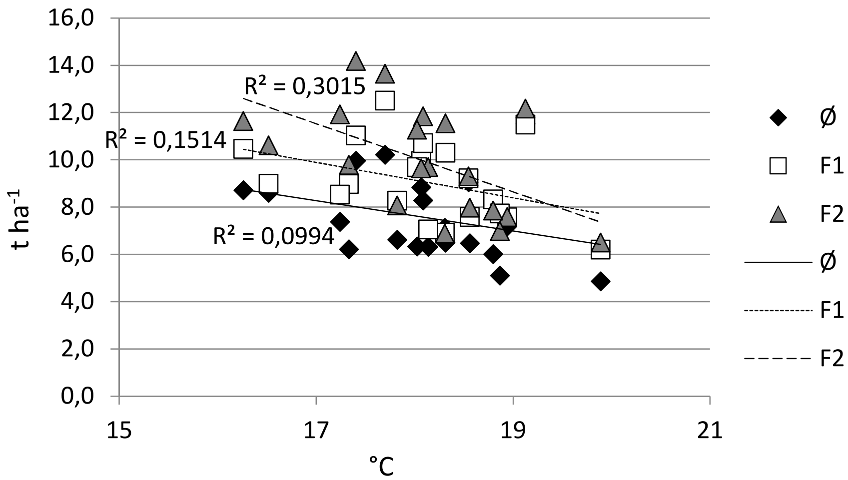


Figure 3. Dependence of average maize grain yield on mean temperature in different tillage systems (no-till, reduced and conventional tillage) and fertilization levels (Ø, T1 - 330 kg ha^{-1} of N:P:K, T2 - 660 kg ha^{-1} of N:P:K)

Aikins et al. (2012) and Gwenzi et al. (2008) indicated that ploughing and other tillage practices that conserves soil moisture could increase maize productivity in significant. That could be one of the reasons why temperature variations (as limiting factor for maize yield) insignificantly affects achieved yield under conventional tillage.

Prediction of grain yield depends on genotype and includes tolerance to many stress factors, including amount of precipitation and temperature, which also reflects to plant development. In this 20-year period, variations in meteorological factors induced variations in grain yield of examined maize hybrid. If a reliability of 0.10 is considered as the level with lowest environmental impact (sum of precipitation and temperature) and 0.99 as the reliability level with the highest environmental impact (Table 1), it could be assumed that the highest average variations between reliability of 0.10 and 099 were obtained in conventional tillage (2.33 t ha^{-1}), as well as in F1 fertilization regime (2.32 t ha^{-1}), irrespective to the fact that maximal variation did not exceed 2.46 t ha^{-1} (conventional tillage without fertilization).

At reliability level of 0.10, the potentially highest yield in the control could be achieved with conventional tillage. With the increase of environment impact (reliability level over 0.50), application of fertilizers induced yield increases, indicating that F1 had the highest impact in treatments with no-till and reduced tillage and F2 in treatment with conventional tillage. Videnović et al. (1986) and Tolimir et al. (2001) also found that increased amounts of fertilizer could compensate the yield deprivations caused by reduction in tillage intensity.

Table 1. Prediction of maize grain yield (t ha^{-1}) for different reliability levels (according to Weibull analysis), with three levels of fertilization and three tillage systems

Tillage	No-till			Reduced			Conventional		
Fertilization level	Ø	F1	F2	Ø	F1	F2	Ø	F1	F2
0.10	3.04	4.75	3.48	3.48	5.65	4.70	5.86	6.04	5.99
0.25	2.82	4.46	3.31	3.28	5.38	4.49	5.57	5.77	5.74
0.50	2.54	4.10	3.09	3.02	5.02	4.21	5.20	5.43	5.41
0.75	2.23	3.68	2.83	2.72	4.61	3.88	4.76	5.02	5.02
0.99	1.36	2.44	2.03	1.82	3.31	2.84	3.40	3.74	3.77

Greater environmental impact (increase in reliability levels) decreased differences between fertilization levels in treatment with reduced tillage, indicating that increased inputs of fertilizers could be unfounded practice during unfavourable meteorological conditions. The same tillage practice had the highest difference between fertilization levels among all three tillage practices. The lowest differences between applied fertilization levels in conventional tillage highlighted it as practice which enables better utilization of present conditions that could increase yields. In parallel, Videnović et al. (2011) also revealed the benefits of conventional tillage under rain-fed conditions, irrespective of the level of applied fertilizer.

Conclusions

According to the obtained results, it could be concluded that in rain-fed cropping conventional tillage could diminish impact of meteorological factors to some extent, while the higher fertilizer inputs could increase grain yield up to some level, but they are highly dependable on meteorological factors, particularly temperature. Environmental impact emphasized F1 as expedient fertilization regime in systems with reduced tillage, as well as F2 as expedient regime in combination with conventional tillage, which enables better utilization of present conditions that could increase yields.

Acknowledgement

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Original scientific paper

Influence of tillage methods on some agricultural properties of maize *(Zea mays L.)* and soybean *(Glicine max L.)* crops

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Abstract

The research was conducted on stagnic luvisol of loamy texture (N: 46º 01΄ 12˝; E: 16º 34΄ 28˝) on the testing ground of Križevci College of Agriculture. Research objectives were related to determining the influence of different tillage methods on the height of maize and soybean plants, number of soybean pods, average number of seeds in the pod, ear yield and maize grain yield. More intensive tillage variants hade a more favourable influence on the height of maize plants, ear yield and grain yield, i.e. the application of autumn basic soil tillage achieved better results for almost all researched agricultural properties. In the process of soybean cultivation, the most intensive tillage method indicated the biggest plant height and the biggest number of pods per plant, as well as the highest number of seeds within a pod (variant E). It was established that more intensive tillage had more favourable influence on the researched agricultural properties of maize and soybean in comparison to reduced tillage methods.

Key words: intensive and reduced soil tillage, agricultural properties, corn, soybean

Introduction

According to the cultivated agricultural land, maize *(Zea mays L.)* is one of the most frequent cereal crops in Croatia, and soybean (*Glycine max L.*) has been increasingly cultivated due to its high nutrition value, as well as its favourable influence on crop rotation. Applied tillage methods have significant influence on the allocation of nutrients within various soil levels (Gal et al., 2007), on development of root system, (Quin et al., 2006) and soil properties (Da Silva et al., 2004; Birkas et al., 2004; Rodrigues et al., 2009; Špoljar et al., 2009), as well as on the yield of maize grains and soybean seeds (Jug et al., 2010; Kisić et al., 2002; Kisić et al., 2010). The height of maize and soybean plants can be regarded as morphological indicator of grain yield, and if maize is grown for maize silage, it is desirable that the plant is as high as possible. Influence of soil tillage on the height of maize plants was researched by Najafinezhad et al., (2007). The authors established significantly bigger height of maize plants in the variants of conventional and reduced soil tillage in comparison to minimal tillage. After several years of research, Boomsma et al., (2010) established by means of regression analysis a considerable influence of corn height and climate conditions on grain yield. Lasisi and Aluko (2009) obtained bigger height of soybean plants, leaf surface and number of pods per plant in the variants of conventional soil tillage in comparison to reduced soil tillage. Rodrigeus et al., (2009) also established significant influence of various tillage methods on the height of soybean plant. It is therefore evident that soil tillage to a great extent influences the agricultural properties of corn and soybean. With reference to the above mentioned, the influence of various tillage methods on height of corn and soybean plants, number of soybean pods, average number of seeds per pod and grain yield in the ear of corn were researched at testing grounds of Križevci College of Agriculture in the period from 2006 to 2009.

Material and methods

The research was conducted on stagnic luvisol of loamy texture (N: 46º 01΄ 12˝; E: 16º 34 ΄28˝) in Križevci, and research variants with five different tillage methods in four replications are shown in Table 1.

Table 1. Variants of tillage methods

Autumn	Spring
A	Primary tillage at 30-35 cm depth, additional tillage by multi-tiller (one tillage pass), four-row seeder was used for planting maize and wheat sowing machine for soybean, herbicides according to the type of weed.
B	Primary tillage, sowing and herbicides as in variant A, additional tillage by rotary harrow (one tillage pass).
C - Primary tillage at 30-35 cm depth	Additional tillage by spike and rotary harrow, sowing and herbicides, as in variant A.
D - Primary tillage at 30-35 cm depth	Additional tillage by spike harrow and multi-tiller, sowing and herbicides, as in variant A.
E - Primary tillage at 30-35 cm depth	Additional tillage by spike harrow, disc harrow and multi-tiller, sowing and herbicides, as in variant A. (intensive tillage)

The surface area of each variant was 1.162 m^2 (83 m x 14 m). Soybean cultivar Višnja (maturity group 00) was grown in 2007 and 2009, and maize hybrid Pioneer PR 38 A 24, FAO group 380 was grown in 2008. In maturity stage 120 randomly selected soybean plants were picked in each variant, followed by measuring of plant height, establishing the number of pods per plant and the number of seeds per pod. Height of maize plants was measured in the field and measuring was conducted from the soil surface to the maize tassel. 120 randomly selected maize plants were measured according to the respective tillage method. Ears from the surface area of 10 m^2 were picked and hand shelled, whereby grains and cob were weighed. Moisture content in grain and cob was established and results were calculated in relation to 14% humidity. Percentage share of grains in the ear according to the variants of soil tillage was also calculated. Data was statistically processed by means of variance analysis based on the simple model. Mean values were tested by means of LSD test for multiple comparisons using the programme package Statistica 7.1.

Results and discussion

The total amount monthly precipitation and average monthly air temperatures during vegetation period for weather station Križevci are shown in Table 2. Results of the established height of maize plants, ear yield per hectare and percentage share of grain in the ear are shown in Table 3. Table 4 shows height of soybean plant in 2007 and 2009, number of pods per plant and number of seeds within a pod.

Mean air temperature for the vegetation period in all three years of research was higher, with less precipitation compared to the multi-annual average, Table 2. Mean monthly air temperature during vegetation period was also higher in comparison with the multi-annual average, except in September, 2007.

Table 2. Mean monthly air temperatures and monthly quantity of precipitation for respective years of research and multi-annual average for the period from 1927 to 2006 for Križevci

	Average montly temperature, ^{0}C				Total monthly of precipitation, mm			
	2007	2008	2009	1927-2006	2007	2008	2009	1927-2006
April	13.0	11.6	14.0	10.3	8.0	30.8	27.4	60.3
May	17.5	17.0	17.4	15.0	81.2	27.3	62.4	76.9
June	21.5	20.4	18.8	18.5	77.7	154.0	52.1	90.8
July	21.6	21.0	21.6	20.1	67.7	66.8	60.6	80.9
August	20.5	20.6	21.3	19.3	56.3	51.9	93.2	74.7
September	13.7	14.5	17.8	15.3	148.0	69.0	39.3	73.7
IV - IX	18.0	17.5	18.5	16.4	438.9	399.8	335.0	457.3

Vegetation period from 2007 to 2009 indicates great fluctuation of monthly precipitation quantity ranging from 8.0 to 154.0 mm. It can therefore be concluded that the research was conducted during the unfavourable drought climate conditions. Lack of water and somewhat higher air temperatures, as stated by Kvaternjak et al., (2008), significantly influenced the researched tillage methods and achieved grain yields of cultivated crops.

Significant influence of the applied tillage methods on the height of maize plants was established, Table 3. It can be concluded that maize plants achieved greater heights in the variants of intensive soil tillage in the combination with primary soil tillage in autumn. The greatest height of maize plants was established in the variant of autumn primary tillage and additional tillage with spike and rotary harrow (variant C), and the lowest height was established in the variant of spring primary tillage and additional tillage with multi-tiller (variant A). Statistical analysis indicates greater height of corn plants in C variant of soil tillage compared to other applied tillage methods, except for the E variant, where the soil tillage was most intensive ($p<0.05$). Statistical data indicates smaller ear yield per hectare in variant A compared to other researched soil tillage methods ($p<0.05$). The highest share of grain in the ear was established in variant E, and the smallest in variant A. However, statistically justified differences regarding the grain yield according to the variants of soil tillage were not established ($p>0.05$). Yusuf and Saleem (2001) established positive correlation ratios between the number of grains on the ear of corn and plant height.

Table 3. Influence of soil tillage on the height of maize plants, ear yield and grain yield

Soil tillage variant	Height of maize plant, cm	Ear yield t/ha	Share of grain, %
A	273.6[c]	12.42[b]	83.4
B	276.7[bc]	16.54[a]	83.8
C	287.6[a]	15.93[a]	84.9
D	275.4[c]	15.51[a]	84.8
E	280.2[ab]	15.96[a]	85.0
F test	*	*	ns

*values in columns marked with different letters indicate significant fluctuations ($p<0.05$)

Based on the above stated it can be concluded that autumn primary soil tillage achieved better results for almost all researched agricultural properties, i.e. more intensive tillage variants had more favourable influence on the height of maize plants, ear yield and grain yield. Favourable influence of conventional soil tillage in comparison with reduced tillage regarding the height of maize plants was established by other authors as well (Najafinezhad et al., 2007; Lasisi and Aluko, 2009). Within research regarding influence of tillage on soil, Špoljar at al., (2010) established favourable influence of reduced tillage on most physical properties of soil. However, the authors established higher yield of maize grains with intensive soil tillage. Other authors also achieved higher grain yields in intensive cultivation system in comparison with the extensive one (Jug et al., 2006; Varga et al., 2004).

During soybean cultivation in 2007 and 2009 the most intensive soil tillage indicated the biggest height of soybean plants and number of pods per plant and the highest average number of seeds per pod (variant E). In 2007 statistically justified bigger height of plants was established in variant E in comparison with the other applied soil tillage methods, except for variant B ($p<0.01$). Similar results were achieved in 2009, with justifiably higher values of height of soybean plants for variant E compared to other researched soil tillage methods ($p<0.01$). Justifiably larger number of pods per plant was observed in 2007 in variant E when compared to variants A and D, and in 2009 when compared to all other applied tillage methods ($p<0.01$). Furthermore, the application of primary tillage in autumn followed by additional tillage with by spike harrow, disc harrow and multi-tiller resulted in the highest average number of seeds within the (variant E). Statistically justified bigger number of seeds in the pod was observed in variant E when compared to the other soil tillage methods ($p<0.05$). Bigger height of soybean plants and bigger number of pods per plant in the variants of conventional soil tillage compared to the reduced tillage was also observed by Lasisi and Aluko (2009). Higher soybean grain yields with regard to the application of intensive tillage in relation to reduced tillage were observed by other authors (Jug et al., 2010; Špoljar et al., 2009).

Table 4. Influence of soil tillage on height of soybean plant, number of pods per plant and number of seeds within the pod

Soil tillage method	Plant height, cm	Number of pods per plant	Average number of seeds in the pod
	2007		
A	76.11^{c}	18.67^{c}	2.0
B	91.18^{a}	27.91^{ab}	2.0
C	87.67^{c}	26.73^{b}	2.1
D	83.92^{d}	20.38^{c}	2.1
E	94.05^{a}	30.79^{ab}	2.2
F test	**	**	ns
	2009		
A	79.34^{d}	26.48^{d}	1.88^{bc}
B	88.08^{b}	29.01^{cd}	1.95^{b}
C	83.00^{c}	30.89^{bc}	1.82^{c}
D	82.31^{cd}	31.90^{b}	1.95^{b}
E	98.08^{a}	35.50^{a}	2.30^{a}
F test	**	**	*

* values in columns marked with different letters indicate significant fluctuations (**$p<0.01$, *$p<0.05$)

Bigger height of maize and soybean plants, grain yield, number of pods, as well as the average number of seeds in the pod was observed with more intensive soil tillage methods, whereas maize ear yields were also higher with more intensive soil tillage methods. The above mentioned indicates visible and mostly favourable influence of more intensive soil tillage on the researched agricultural properties of maize and soybean.

Conclusion

Based on the above stated, it can be concluded:

- More intensive tillage variants had to a large extent more favourable influence on height of maize plants, ear yield and maize grain yield, i.e. application of autumn primary soil tillage achieved better results in almost all researched agricultural properties.
- The biggest height of soybean plants and the biggest number of pods per plant was observed with the most intensive soil tillage method (variant E).
- The research established mostly favourable influence of more intensive soil tillage on researched agricultural properties of corn and soybean.

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Original scientific paper

Tillage induced CO_2 emissions in relation to soil parameters

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Abstract

Carbon dioxide (CO_2) emissions from soil play an important role in the global carbon cycle. Tillage management can increase atmospheric CO_2 concentrations and contribute to global warming but it is uncertain to which extent tillage enhances the transfer of soil CO_2 to the atmosphere. The objectives of our research were to assess, on six different tillage treatments that have been managed since 1994 as: black fallow - BF, ploughing up and down the slope to 30 cm - PUDS, no-tillage – planting direction up and down the slope – NT, ploughing across the slope to 30 cm – PAS, very deep ploughing across the slope to 50 cm - VDPAS and subsoiling across the slope to 50 cm – SSPAS, the effects of primary tillage (ploughing to 30 cm depth) and secondary tillage (disking and harrowing) on short-term soil CO_2 efflux relative to no-tillage (NT) treatment and to determine correlation between soil CO_2 efflux and soil parameters (soil temperature, soil moisture and electrical conductivity) on Stagnic Luvisols in Croatia. Soil CO_2 concentrations were measured 0, 3 and 6 hours after primary tillage and 1 and 4 hours after secondary tillage by closed static chamber method in September 2012. CO_2 effluxes immediately after primary tillage were higher on PAS, VDPAS and SSPAS while lower on BF and PUDS treatments compared to NT treatment. Already 3 and 6 hours after primary tillage, the soil CO_2 effluxes were lower on all tilled treatments compared to NT treatment. After secondary tillage, CO_2 effluxes were lower on all tilled treatments compared to NT treatment. The highest average soil CO_2 efflux after primary tillage was determined at PAS treatment (62.30 kg $ha^{-1}day^{-1}$), followed by respectively: SSPAS (61.35 kg $ha^{-1}day^{-1}$), VDPAS (48.98 kg $ha^{-1}day^{-1}$), PUDS (35.19 kg $ha^{-1}day^{-1}$) and BF(16.65 kg $ha^{-1}day^{-1}$) treatment while average soil CO_2 efflux at NT treatment, amounted 68.48 kg $ha^{-1}day^{-1}$. The highest average soil CO_2 efflux after secondary tillage was determined at VDPAS treatment (26.39 kg $ha^{-1}day^{-1}$), followed by respectively: SSPAS (24.97 kg $ha^{-1}day^{-1}$), PAS (15.69 kg $ha^{-1}day^{-1}$), PUDS (9.99 kg $ha^{-1}day^{-1}$) and BF (8.56 kg $ha^{-1}day^{-1}$) treatment while average soil CO_2 efflux at NT treatment amounted 59.21 kg $ha^{-1}day^{-1}$. CO_2 effluxes were very weak negatively correlated with soil temperature (r=0.12) and soil moisture (r=0.16) while moderate negatively correlated with electrical conductivity (r=0.40). Electrical conductivity was weak positively correlated with soil temperature (r=0.28) and strong positively correlated with soil moisture (r=0.52) while non correlation was determined between soil temperature and soil moisture (r=0.01). Our study suggests that tillage had impact

on soil CO_2 efflux and accelerates the transfer of soil CO_2 to the atmosphere but it declined sharply within hours after tillage operations.

Key words: CO_2 efflux, tillage, soil temperature, soil moisture, electrical conductivity

Introduction

Agriculture plays an important role in the global flux of greenhouse gases. In 2010, agricultural sector contributed by 11.4% to total greenhouse gas emission in Croatia (National Inventory Report, 2012). Agricultural soils can act both as a source or a sink of greenhouse gases. The CO_2 flux from soil to the atmosphere (soil respiration) determines the extent to which plant carbon added to the soil is retained or released to the atmosphere. Soil CO_2 fluxes are strongly dependent on plant and soil microbial growth as influenced by temperature and moisture and are also sensitive to agricultural management, including selection of crop species, tillage and addition of fertilizers and manure (Ellert and Janzen, 1999). Tillage accelerates soil CO_2 emissions by changing soil climate, disrupting soil aggregates, increasing aeration, increasing contact between soil and crop residue and speeding organic carbon decomposition (Gregorich et al., 2005; Bilen et al., 2010). Tillage may have long-term influence on soil CO_2 flux but also it often increases short-term soil CO_2 flux due to a rapid physical release of CO_2 trapped in the soil air pores. It can be said that tillage management can increase atmospheric CO_2 concentrations and contribute to global warming but it is uncertain to which extent tillage enhances the transfer of soil CO_2 to the atmosphere. Due to mentioned above, the objectives of our research were to assess the effects of primary tillage (ploughing to 30 cm depth) and secondary tillage (disking and harrowing) on short-term soil CO_2 effluxes relative to no-tillage (NT) and to determine correlation between soil CO_2 effluxes and soil parameters (soil temperature, soil moisture and electrical conductivity).

Materials and Methods

Experimental site and tillage treatments

Field experiment with six different tillage treatments usually implemented in Croatia was set up in Blagorodovac near Daruvar (elevation: 133 m asl; N 45º33´937´´, E 17º02´056´´) in central, lowland Croatia. Field experiment was established in 1994 with the aim of investigation on determination of soil degradation by water erosion and later, in 2011, expanded to the research on soil CO_2 concentration measurements. Soil type at the experimental site is determined as Stagnic Luvisols (IUSS Working group World reference base for soil resources, 2006). Tillage treatments differed in tools that were used, depth and direction of tillage and planting. Size of each tillage treatment is 22.1 m x 1.87 m. Tillage treatments are:

BF: black fallow, control treatment – ploughing direction is up and down the slope, disked and harrowed (without cover crop);

PUDS: ploughing to 30 cm – ploughing and planting direction is up and down the slope, disked and harrowed;

NT: no-tillage – planting in conducted directly into the mulch with planting direction up and down the slope;

PAS: ploughing to 30 cm – ploughing and planting direction is across the slope, disked and harrowed;

VDPAS: very deep ploughing to 50 cm – ploughing and planting direction is across the slope, disked and harrowed;

SSPAS: ploughing to 30 cm plus subsoiling to 50 cm – ploughing, subsoiling and planting direction is across the slope, disked and harrowed.

Very deep ploughing to 50 cm on VDPAS treatment and subsoiling to 50 cm on SSPAS treatment are implemented every 3 to 4 years since the experimental site was established (due to their prolonged effect) and they were last implemented in 2011. In 2012, primary tillage (ploughing to 30 cm depth) was implemented on 28 September and secondary tillage (disking and harrowing) on 29 September on all tillage treatments except the NT treatment.

Measurement of CO_2 concentrations

Soil CO_2 concentrations were measured 0, 3 and 6 hours after primary tillage implementation and 1 and 4 hours after secondary tillage implementation. For the measurement of soil carbon dioxide concentrations, the closed static chamber method was used. The chambers are made of lightproof metal material to avoid the sunlight effect on the measurements, and they consist of two parts: frames and caps. The circular frames (25 cm in diameter) are inserted between the growing plants about 5 cm into the soil at the beginning of measurements. The caps are 25 cm in diameter and 9 cm high, fitted with a gas sampling port. Before the chambers closure, the initial CO_2 concentrations inside the frames near soil surface were measured. Afterwards, the chambers were closed with caps and the incubation period was 30 minutes after which the CO_2 concentrations in closed static chambers were measured. In situ measurements of carbon dioxide concentrations (ppm) in the chambers were conducted with portable infrared carbon dioxide detector (GasAlertMicro5 IR, 2011). Measurements were conducted on bare soil and when necessary (at the no-tillage treatment), vegetation was removed from frames inside before the beginning of measurement.

Measurements of carbon dioxide concentrations were conducted in three repetitions at each treatment. The soil carbon dioxide efflux (expressed as kg CO_2 per ha per day) was afterwards calculated according to Widen and Lindroth (2003) and Toth et al. (2005) as:

$$F_{CO2} = [M * P * V * (c_2 - c_1)] / [R * T * A * (t_2 - t_1)]$$

Where:
F_{CO2} – soil CO_2 efflux (kg $ha^{-1}day^{-1}$)
M – molar mass of the CO_2 (kg mol^{-1})
P – air pressure (Pa)
V – chamber volume (m^3)
$c_2 - c_1$ - CO_2 concentration increase rate in the chamber during incubation period (µmol mol^{-1})
R – gas constant (J $mol^{-1}K^{-1}$)
T – air temperature (K)
A – chamber surface (m^2)
$t_2 - t_1$ – incubation period (day)

Measurement of soil parameters

The aim of the research requires reliable data on soil temperature, soil moisture and ***electrical conductivity*** in the soil surface layer (at 10 cm depth). Soil temperature (°C), soil moisture (%) and ***electrical conductivity (dS/m)*** were determined with adequate instrument (IMKO HD2 - probe Trime, Pico64, 2011) at 10 cm depth in the vicinity of the chamber along with each measurement of soil CO_2 concentration.

Results and Discussion

On the day when primary tillage was conducted, sky was cloudy in the morning and by the afternoon it becomes sunny. Air temperature ranged from 12.8 to 22.5°C and relative air humidity ranged from 39 to 75%. On the day when secondary tillage was conducted, the weather was cloudy and windy during day. Air temperature ranged from 14.0 to 16.7°C and relative air humidity ranged from 64 to 81%.

Soil CO_2 effluxes and soil parameters after primary and secondary tillage

In general, tillage induced soil CO_2 effluxes varied widely with treatment and time of measurement (Figure 1). Emissions were greater immediately after tillage but declined sharply within hours after tillage operations. CO_2 effluxes immediately after primary tillage (at 0 h) were higher on PAS, VDPAS and SSPAS treatments while lower on BF and PUDS treatments compared to NT treatment. Already 3 (and 6) hours after primary tillage, the CO_2 effluxes were lower on tilled treatments compared to NT treatment. Reicosky and Lindstrom (1993), Ellert and Janzen (1999) and Al - Kaisi and Yin (2005) also obtained in their research that the effect of tillage on soil CO_2 emission was short-lived. The highest average soil CO_2 efflux after primary tillage was determined at PAS treatment (62.30 kg $ha^{-1}day^{-1}$), followed by respectively SSPAS (61.35 kg $ha^{-1}day^{-1}$), VDPAS (48.98 kg $ha^{-1}day^{-1}$), PUDS (35.19 kg $ha^{-1}day^{-1}$) and BF(16.65 kg $ha^{-1}day^{-1}$) treatment while average soil CO_2 efflux at NT treatment amounted 68.48 kg $ha^{-1}day^{-1}$. After secondary tillage, CO_2 effluxes were lower on all tilled treatments compared to NT treatment. The highest average soil CO_2 efflux after secondary tillage was determined at VDPAS treatment (26.39 kg $ha^{-1}day^{-1}$), followed by respectively SSPAS (24.97 kg $ha^{-1}day^{-1}$), PAS (15.69 kg $ha^{-1}day^{-1}$), PUDS (9.99 kg $ha^{-1}day^{-1}$) and BF (8.56 kg $ha^{-1}day^{-1}$) treatment while average soil CO_2 efflux at NT treatment amounted 59.21 kg ha^{-1}day^{-1}. Amount of CO_2 released into the atmosphere differed with different tillage systems and the amount of emitted CO_2 was related to the degree of soil disturbance.

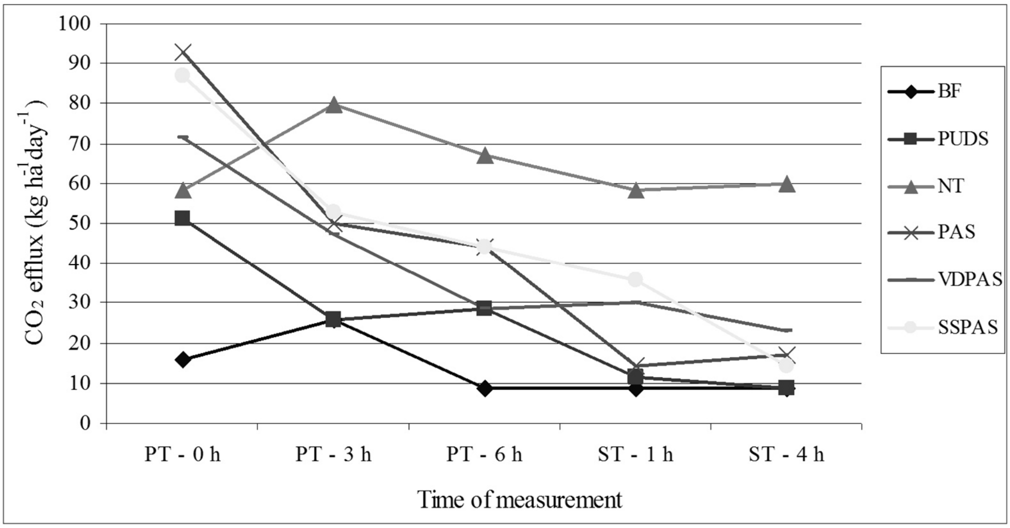

Figure 1. Short-term CO_2 effluxes after primary (PT) and secondary (ST) tillage

Correlation between soil CO_2 effluxes, soil temperature, soil moisture and electrical conductivity

CO_2 effluxes were very weak negatively correlated with soil temperatures (r=0.12) and soil moisture (r=0.16) while moderate negatively correlated with electrical conductivity (r=0.40). The weak correlation of CO_2 efflux with soil temperature and soil moisture reported in this study was in accordance with other reports from tillage experiments (Al- Kaisi and Yin, 2005; Kessavalou et al., 1998). Also, other researches (Pathak and Rao, 1998; Setia et al., 2010; Setia et al. 2011) have found a negative impact of salinity on soil CO_2 emissions. Electrical conductivity was weak positively correlated with soil temperature (r=0.28) and strong positively correlated with soil moisture (r=0.52) while non correlation was determined between soil temperature and soil moisture (r=0.01). Correlations between soil CO_2 efflux, soil temperature, soil moisture and electrical conductivity are presented at Figures 2-7.

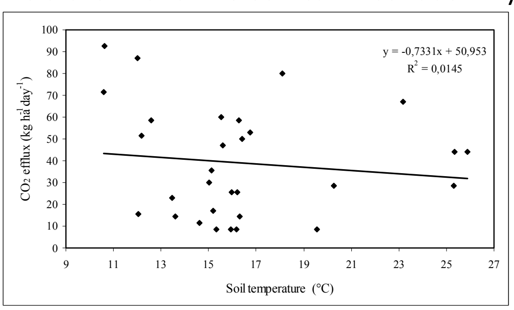

Figure 2. Correlation between soil CO_2 effluxes and soil temperature

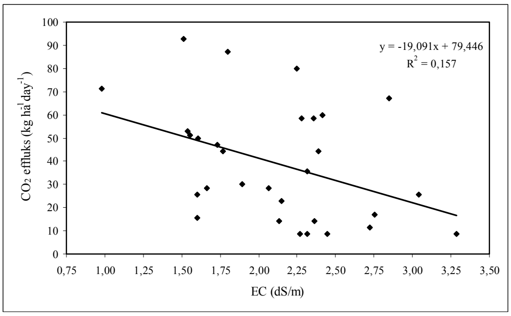

Figure 4. Correlation between soil CO_2 effluxes and electrical conductivity

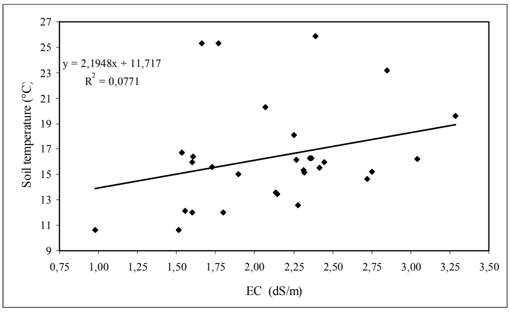

Figure 6. Correlation between soil electrical conductivity and soil temperature

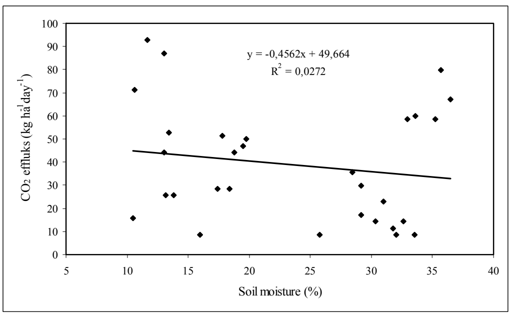

Figure 3. Correlation between soil CO_2 effluxes and soil moisture

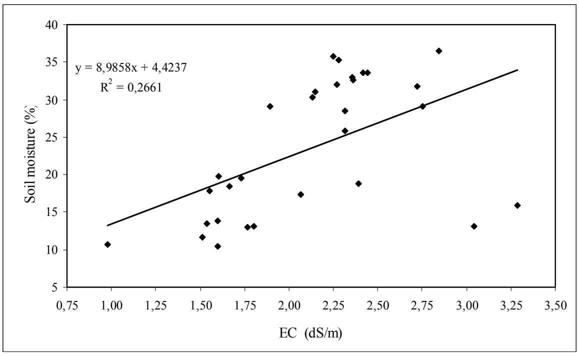

Figure 5. Correlation between soil electrical conductivity and soil moisture

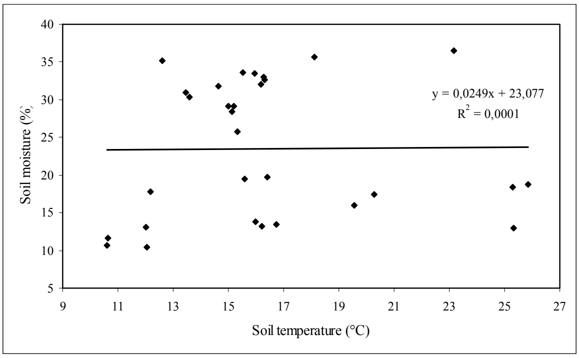

Figure 7. Correlation between soil moisture and soil temperature

Conclusions

Our study suggests that tillage had impact on soil CO_2 efflux and accelerated the transfer of soil CO_2 to the atmosphere but they were relatively short - lived. CO_2 effluxes were greater immediately after tillage but declined sharply within hours after tillage operations. CO_2 effluxes immediately after primary tillage were higher on PAS, VDPAS and SSPAS treatments while lower on BF and PUDS treatments compared to NT treatment. Already 3 (and 6) hours after primary tillage, the CO_2 effluxes were lower on tilled treatments compared to NT treatment. The highest average soil CO_2 efflux after primary tillage was determined at PAS treatment, followed by respectively SSPAS, VDPAS, PUDS and BF treatment. After secondary tillage, CO_2 effluxes were lower on all tilled treatments compared to NT treatment. The highest average soil CO_2 efflux after secondary tillage was determined at VDPAS treatment, followed by respectively SSPAS, PAS, PUDS and BF treatment. CO_2 effluxes were very weak negatively correlated with soil temperatures and soil moisture while moderate negatively correlated with electrical conductivity. Electrical conductivity was weak positively correlated with soil temperature and strong positively correlated with soil moisture while non correlation was determined between soil temperature and soil moisture. The amount of CO_2

emitted into the atmosphere differed with different tillage systems and was related to the degree of soil disturbance.

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Original scientific paper

Preliminary research of soil water availability and heat stress

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Abstract

On the eastern part of Croatian 2012. year was characterized as extremely dry and major yield losses of spring crops, especially maize, were detected. After that conclusions have been drawn that if we want quality production it is necessary to build major irrigation systems. Drought was mentioned as the only cause of the decrease in yield and damage from heat stress was not considered in detail. Although high temperature stress is usually associated with drought, extremely high temperatures and low relative humidity can cause equal or even greater damage to the primary organic production. If the high temperature (above 35^0C) matches with pollination of maize, soybeans and sunflowers in our climate, it will result in poor pollen production and viability and significant decrease in yield. In order to reliably determine the indicators of a lack of water in the soil and to realistically understand the problem, we set the automatic measuring device Datalogger Decagon's 5TE, with two measuring probes to monitor humidity and temperature at two depths (30 and 60 cm). The results of measuring the humidity and temperature of soil under the maize in the Gat area are showing the long-term heat stress, but not the water stress, because the content of available water in soil (percentage by volume) was significantly above the point of permanent wilting.

Key words: heat stress, maize, availability of water, data logger

Introduction

After the fierce summer heat in the 2012th the major yield losses of spring crops, especially maize, were detected. After that, farmers intensively started to think about the major irrigation of agricultural land in Croatia, because drought was mentioned as the only cause of the decrease in yield. Therefore, as a solution to future damage they often propose more extensive irrigation of crops. Damage from heat stress was not considered in detail. Although high temperature stress is usually associated with drought, extremely high temperatures and low relative humidity can cause equal or even greater damage to the primary organic production. Since irrigation systems for crops are extremely expensive investments and unprofitable for spring crops, we believe that this preliminary study of water availability that we have started in Veliškovci-Gat significantly indicate that heat stress can cause severe yield losses of spring crops and that irrigation systems cannot fully solve the above problem.

High temperatures cause the denaturation, desiccation and increased respiration of the plant. Temperature around 500C causes coagulation of proteins, and even at 35-400C plant organs can denature because of physiological-biochemical processes in the direction of synthesis of toxic substances (Vukadinovic, 1999). Maize reacts with yield losses already when temperatures go above 320C and in the past 50 years the prevailing opinion is that the heat stress can cause equal or greater damage than those caused by drought (Hawkins et al., 2012). If the high temperature (above 350C) matches with pollination of maize, soybeans and sunflowers in our climate, it will result in poor pollen production and viability and significant decrease in yield (Elmore and Taylor, 2011). Also, the conduction system of plants, due to high evapotranspiration, fails to compensate the loss of water from the leaves, although with adequate moisture in the soil turgor falls, which can cause high damage if such conditions persist for several days.

Material and methods

In order to reliably determine the indicators of a lack of water in the soil and to realistically understand the problem, Department of Chemistry, Biology and Soil Physics of the Faculty of Agriculture in Osijek, has set the automatic measuring device (Datalogger Decagon's 5TE, measurement error <3%) with two measuring probes to monitor humidity and temperature at two depths (30 and 60 cm). The automatic measuring device was placed in the Veliškovci-Gat area.

The automatic measuring device for measurement of humidity and temperature was set at one-hour interval and was dug in on June 15th 2012. The data from the device was collected on November 8th 2012 and measuring had been continued till the June 21st 2013. During the tests, the probe on 30 cm depth was damaged by basic soil tillage and fertilization after maize harvest, so the one-year cycle measurements were completed with only one probe put on the depth of 60 cm, so there were 8901 measurements on the depth to 60 cm and 3609 measurements on the depth to 30 cm. The results for temperature and humidity are shown in the Graphs 1 and 2. Estimation of soil suitability and fertilizer recommendations was calculated using the ALRxp calculator. (Vukadinović, 2001; Đurđević, 2010) Soil samples were grounded in a soil mill and analyzed in the laboratory to the following chemical properties of soil: the soil pH in water and KCl, humus, AL-P_2O_5, AL-K_2O (Vukadinović and Bertić, 1988).

The following agro-tehnics are applied:

a) basic fertilizer 100 kg/ha of uree and 100 kg/ha of MAP,
b) chiseling on 40 cm (heavy duty chisel),
c) spring furrow closing with heavy spike harrow,
d) seedbed preparation (spring-tooth harrow),

e) sowing of maize hybrid (FAO 300) on 24th April 2012. with pneumatic seeder (plant density 62,000 per hectare with grain spacing 23 cm,
f) top dressing with 200 kg/ha of KAN in stag of 6 leafs along with cultivation so that the total amount of added NPK was: 175:106:42 kg/ha,
g) harvested on 12th September 2012. when the grain contained 12% of moisture.

Results and discussion

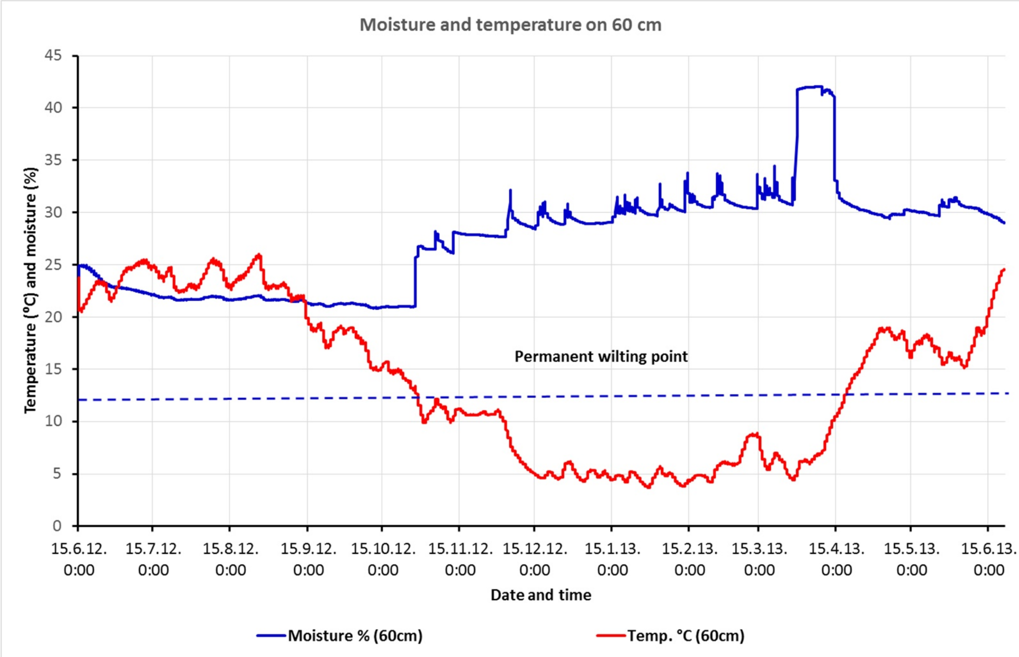
To reliably determine the level of high temperature stress on maize and to assess the damage from the heat it is necessary to analyze soil moisture, plant density and age (critical phase of the silking / pollination and grain filling), the duration of high temperature and hybrid tolerance (genetic and physiological adaptability). Production field was well supplied with available phosphorus and potassium, with silt texture and slightly acidic soil pH reactions, low on humus, with good relative soil suitability for crops from 60-80% (P2) (Table 1).

When Soil fertility control was conducted and relative suitability of soil for crops was calculated on research plot the expected yield of corn was 9.6 t ha^{-1} of dry grain. Therefore, the fertilization was targeted to yield of 10 t ha^{-1} of dry grain, and using ALRxp calculator fertilizer recommendations were calculated (NPK 175:106:42 in kg/ha).

Table 1. Chemical properties of soil

Chemical analysis of soil	0 – 30 cm
pH_{KCl}	5,76
pH_{HOH}	6,70
AL-P_2O_5 mg 100 g^{-1}	20,10
AL-K_2O mg 100 g^{-1}	27,27
Humus %	1,41

Moisture and soil temperature were measured at soil depth of 30 and 60 cm (Graph 1 and 2), and the percentage of moisture was never below the permanent wilting point (~ 12%), so drought was not as fierce as it was expected, and was not the cause of the low yield of maize which was significantly below the expected 10 t/ha of dry grain. In fact, the yield of five maize hybrids in the studied field was between 4 and 5 t ha^{-1} of dry corn.



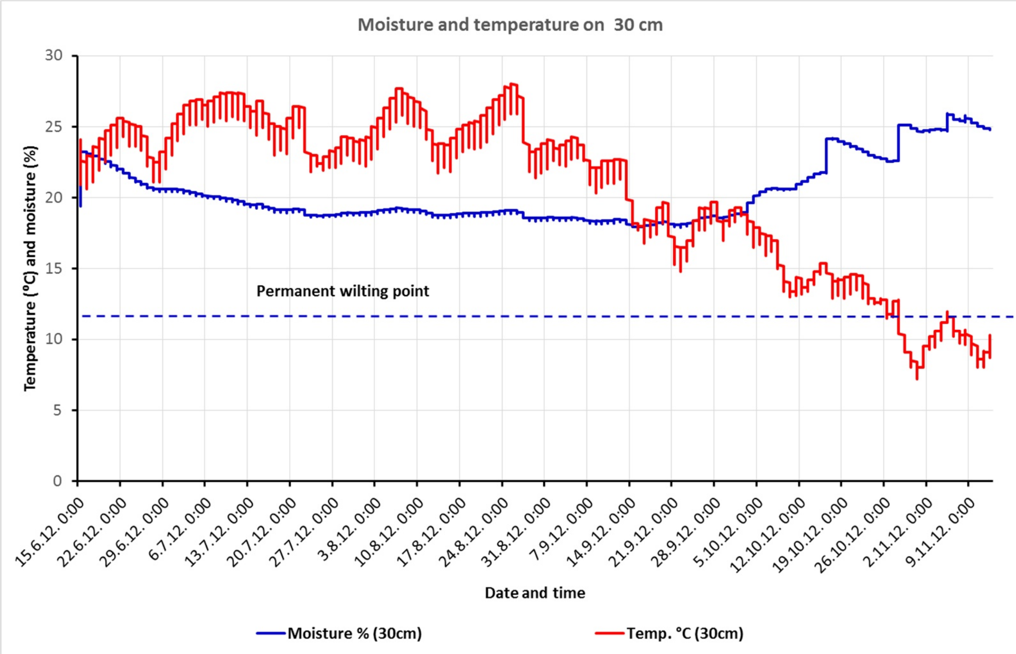
Graph 1. Moisture and temperature on 60 cm (15.06.2012.-21.06.2013. 8901 measures)

Table 2. Average monthly temperature and precipitation in Osijek

Trend	April	May	June	July	August	September	November
Air temperature							
Average [^{o}C]	11.5	16.5	19.8	21.6	20.8	16.7	11.2
Aps. Max [^{o}C]	30.9	36.0	39.6	40.3	38.9	37.1	30.5
Precipitation							
Precipitation [mm]	58.8	69.1	83.0	60.9	59.4	55.2	58.8

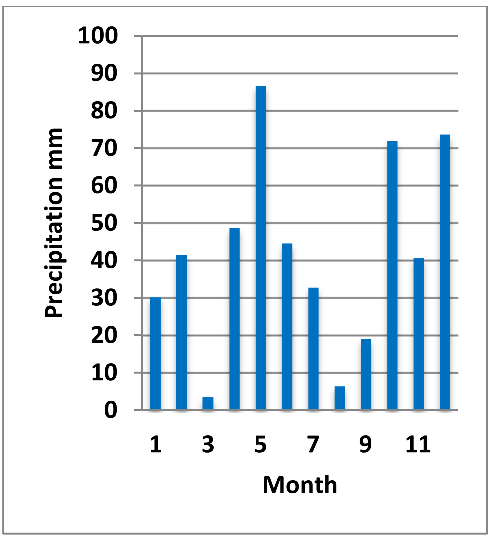
Source: Meteorological and hydrological service, http://meteo.hr/

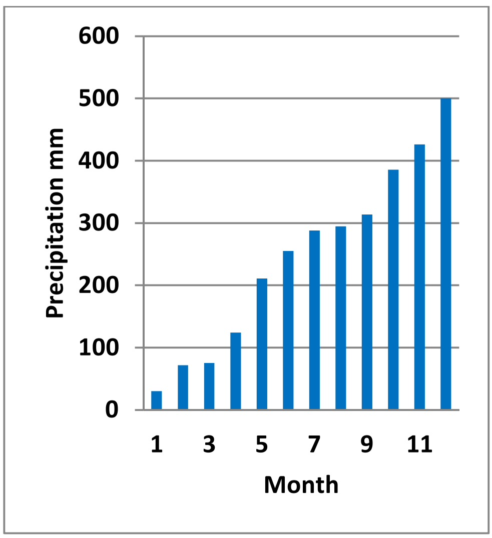
Deviation from the average monthly precipitation for Osijek is shown in Graph 2 (Monthly and cumulative). Since there were very small amounts of precipitation in March and August (Graph 3a) compering to the average, the lack of water occurred only from August until the end of the year (Graph 3b).



Graph 2. Moisture and temperature on 30 cm (15.06.2012.-12.11.2013. 3609 measures)

However, as opposed to the relatively small lack of moisture in the soil, in the critical stages of the formation of corn yield (two weeks before and four after pollination), soil temperature was very high at both measuring depths (30 and 60 cm) until mid-September, with more expressed daily amplitude (~ 3^{o}C) at 60 cm (Graph 1).





Graph 3. Precipitation values for Osijek (Source: http://freemeteo.com)

Maize is a photosynthesis C4 type of plant that efficiently use CO_2 and grows from tropical to mild climate (up to 58 °N. Latitude). Studies are showing that the optimal daily temperatures for maize are between 20 and 23°C, and night temperatures from 18 to 22°C. Maize can endure short-term high temperature up to 44^{o}C, but noticeable damage to the leaves can be reported already at 37 ^{o}C (Johnson and Herrero, 1981). When there is enough moisture in the soil, temperatures below 36.5^{o}C will not significantly affect the yield, but when air temperature is higher than 34.5^{o}C, especially when the relative humidity is low, the reduction of pollen viability (ability pollination) and poor pollination may occur. Also with timely silking, heat alone can desiccate silks so that they become non-receptive to pollen (Bean and Kenny, 2011; Elmore and Taylor, 2011). It is important to highlight that high night temperatures (above 22.0^{o}C) increase plant respiration which can significantly reduce the yield due to accelerated maturation of maize with weak intensity of grain filling (Outlook Report, 2012).

In conclusion, exposure to high temperatures (with a maximum temperature of 34^{o}C or above) can result in yield loss. It was measured that on the fifth day there is a loss of approximately 2 percent; and on the sixth day an additional 4 percent loss. After the sixth day firing of leaves becomes likely and very extensive yield losses are incurred (Elmore and Taylor, 2011).

Conclusions

The results of measuring the humidity and temperature of soil under the maize during the period between June 15th 2012 and June 15th 2013 on the depths of 30 and 60 cm in the Gat area are showing the long-term heat stress, but not the water stress, because the content of available water in soil (percentage by volume) was significantly above the point of permanent wilting point.

Since the air temperature and its relative humidity were not measured at the given parcel, data from the Meteorological and Hydrological Service of Croatia for the city of Osijek indicate a very hot summer in 2012 (15 straight days with temperatures above 34^{o}C in July), so we believe that the heat stress, enhanced by "atmospheric" drought, had resulted in very low maize fertilization which in the end lead to low yield. This paper is a contribution to a better understanding of the damage to crop production as a result of high temperatures during long period of time and does not go in favor of mass application of irrigation, at least not for crops. Specifically, the hypothesis that the larger irrigation solves the problem of low crop yields is made questionable within this study, because it was determined that there had been sufficient supply of available water in the root zone, but at the same time the air temperatures were extremely high, so the shortfall in crop yield should be largely attributed to heat stress in the year 2012.

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Original scientific paper

Prediction of vulnerability of field crops production in South-East region of Macedonia affected by climate changes

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Abstract

The main aim of these simulations was to predict future trends of the basic climatic parameters: e.g. average yearly air temperature, average growing season air temperature, average yearly rainfalls and evapotranspiration in 2025 and 2050 and thier influence to the yield of wheat, maize and sunflower. The analysis is targeted to the South East (SE) region of Macedonia which was identified as a one of the most vulnerable regions to the negative impact of climate change in agriculture.

From the simulated data for temperature, a progressive increasing of the average air temperature can be noted (2.00-2.43^{o}C). Similar increasing of the annual air temperature is notable for the average values for the SE region as a whole and for the average air temperature values for the whole territory of the country. Also, the average air temperatures during the growing season will graduate increase. The average increase of the air temperatures in growing season for the SE region are 0.14^{o}C and 1.36^{o}C for the periods 2000-2025 and 2000-2050, respectively. The rainfalls do not follow certain pattern of increasing or decreasing yearly sums which may conclude that it is very difficult to predict the rainfalls and the rainfalls regime due to the fact that on a small area (as is SE region) several rainfall regimes exist. The evapotranspiration have very similar dynamics as air temperature. There are certain periods of increasing and decreasing of evapotranspiration but there is an obvious trend of increasing over time.

Analyzed the potential effects of climate change on crops productivity, the following simulations were obtain: the wheat yield will decrease for 21% in 2025 and 25% in 2050, the maize yield is expected to be reduced by 56% in 2025 and even by 86% in 2050 respectively as well as the yield of sunflower where the reduction will be to 30% in 2025 and up to 40% in 2050.

Key words: climate changes, prediction, vulnerability, wheat, maize, sunflower, yield

Introduction

Macedonia has a diverse agricultural resource base, with the capacity to produce most continental crop and livestock products, plus many Mediterranean crops. The agriculture sector, including the value added in the processing industry, contributes 16% to country's GDP and provides employment to 36% of the workforce. The official figures understate the importance of the agriculture sector since these include only a fraction of the value of smallholders' output which is sold at the traditional farmers markets. Also, the official statistics captures only a portion of the family labor inputs, which is the dominant type of informal employment at the family farms. The most recent national census recorded 192,675 family farms in a country of 2.1 million inhabitants (State Statistical Office, 2010). Consequently, given the fact that about 45% of country's population live in rural areas where off farm employment opportunities are rather limited (active workforce unemployment rate in Macedonia is as high as 32%), a more realistic conclusion would be that the agriculture sector is of critical importance for the wellbeing of about half of country's population.

By area, wheat is clearly the major annual crop grown, with smaller areas used for barley, maize and a range of vegetable crops. Grapes are the main perennial crop in Macedonia and occupy close to 25000 ha (State Statistical Office, 2011). Although the area occupied by fruit and nut trees is relatively small, potential exists to expand this area in the future. As most crop production is rain-fed, there can be significant changes in mix and crop area planted on a year-to-year basis, depending on the timing and quantity of rainfall, as well as associated extreme events, like droughts and floods.

The sensitivity of the agricultural sector to climate has important implications in Macedonia. The recent report published "Adapting to Climate Change in Europe and Central Asia" (The World Bank, 2009) developed a series of indices to assess the exposure, sensitivity and adaptive capacity of countries in the ECA Region to climate change. These indices are based on a range of relevant parameters. The vulnerability index displayed in is a combination of the exposure, sensitivity and adaptive capacity indices. The vulnerability of Macedonia to climate change, based on this index, can be classified as medium compared to other countries in the region. In addition this report outlines that Macedonia is among the first five countries of the region which is likely to experience increases in climate extremes by the end of 21-st century.

The negative effect of Climate change impacts in the sector agriculture is increasing. Some analysis performed in the recent period suggested that under most likely climatic scenarios, agriculture in Macedonian will be the most affected structure where annual losses are estimates of ~€29 million by 2025 due to reductions on yields for winter wheat, grapes, and alfalfa if there is no irrigation (Second National Communication on CC to the UNFCCC, 2008).

The main objective of this study is to predict future trends of the basic climatic parameters: e.g. average yearly air temperature, average growing season air temperature, average yearly rainfalls and evapotranspiration in 2025 and 2050 and their influence to crops productivity in South East (SE) region of Macedonia which was identified as a one of the most vulnerable regions to the negative impact of climate change in agriculture.

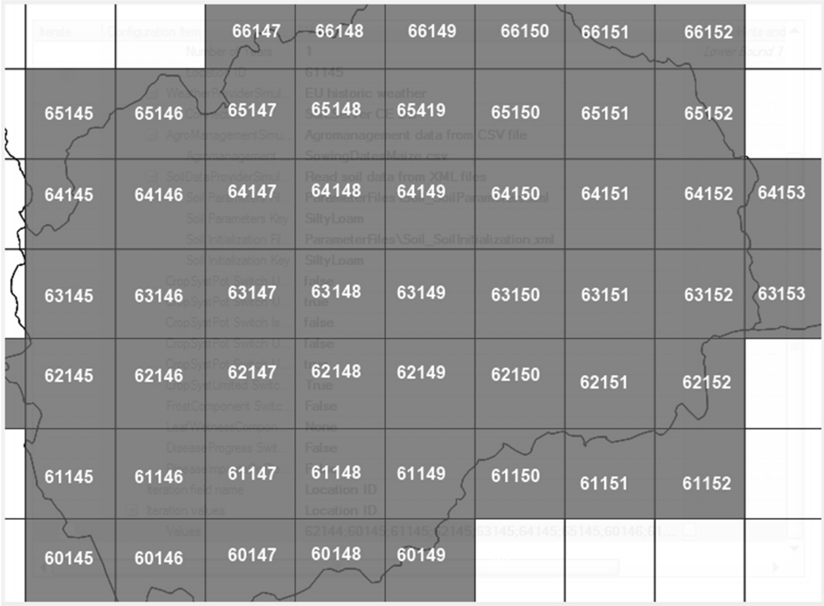
Materials and methods

UNDP and the Ministry of Environment and Physical Planning (MoEPP) of the Republic of Macedonia are implementing the project "Third National Communication to UNFCCC". The main aim of the project is to strengthen the information base, analytical and institutional capacity of the key national institutions to integrate climate change priorities into country development strategies and relevant sector programs by providing financial and technical support to prepare its Third National Communication (TNC) to the United Nations Framework Convention on Climate Change (UNFCCC).

The preparation of the vulnerability assessment of the agricultural sector, as a part of the Third National Communication, is based on totally different approach. Unlike the First and Second National Communications where the vulnerability assessment was performed on a comparison base of two long monitoring climatic datasets (1961-1990 and 1971-2000) with a main aim to show the differences of the main climatic indicators over time which have the highest effect on agriculture, and a spatial identification of the most vulnerable areas in the Republic of Macedonia to the influence of climate change, for the Third National Report it's decide to use models in order to simulate the basic climatic parameters for the period 1993-2057 with centered 2000. The main aim of these simulations was to predict future trends of the basic climatic parameters. The data obtained were further used as input parameters in the ClimIndices model. With this model the future trends of different climatic indicators, sums and indexes were simulated - the indicators which have the most direct influence on agricultural production are analyzed in details: e.g. average yearly air temperature, average growing season air temperature, average yearly rainfalls, and evapotranspiration. The analysis is targeted to the South East (SE) Region of the Country. This region in the previous reports was identified as a one of the most vulnerable regions to the negative impact of climate change in agriculture, together with the central region.

Results with discussion

Whole territory of the country was divided in a mash of 53 grids. The scope of the analysis is the SE region of the country which falls within 7 grids (64151, 63150, 63151, 63152, 62150, 62151, and 62152), (Map 1), (each grid = 25 km^2).



Map 1. Spatial grid distribution and their codes

<u>Mean annual air temperature</u>

In the agricultural sector the air temperature is a basic indicator which is significant for assessing the intensity of climate change in a certain area, as well as an elementary parameter for calculation of other indicators e.g. start and end of growing season, vegetation period length, growing degree days, and for calculation of certain indexes: aridity index, dryness, etc. The mean annual air temperatures are calculated for the period 1993-2057.

Table 1. Mean annual air temperature

Year	Row Labels							SE reg. average	Country average
	62150	62151	62152	63150	63151	63152	64151		
2000	10.40	13.56	15.34	13.82	13.53	13.95	12.85	13.35	10.95
2010	9.58	12.99	14.80	13.14	12.89	13.47	12.27	12.74	10.82
2020	9.36	12.85	14.86	13.10	12.88	13.31	11.97	12.62	10.55
2025	9.75	13.15	14.83	13.42	13.15	13.41	12.24	12.85	11.32
2030	11.10	14.34	16.08	14.69	14.47	14.76	13.59	14.15	12.29
2040	12.34	15.95	17.55	15.82	15.81	16.38	14.94	15.54	13.57
2050	10.95	14.23	16.09	14.46	14.34	14.62	13.37	14.01	12.92
Average 2000-50	10.50	13.87	15.65	14.06	13.87	14.27	13.03	13.61	11.77

From the simulated data presented in Table 1 a progressive increasing of the average air temperature in all sub localities can be noted (2.00-2.43^{o}C). Similar increasing of the annual air temperature is notable for the average values for the SE region as a whole and for the average air temperature values for the whole territory of the country. This predictions of air temperature increasing are in line with the new elaborated climatic scenarios for the country, where the expected increasing of the average air temperatures up to 2050 is 2°C (1.10-3.30). It is interesting to underline that the simulations showed increasing of air temperature up to 2040 which in average yields 2.19°C, after this point the average air temperatures start to decrease for the 2040-2050. Such trends which are against all expectations is difficult to explain. Similar decreasing are also notable for the periods 2000-2010 and 2010-2020, but still the general trend for the period 2000-2040 goes upwards. In order to analyze the decreasing of air temperatures for the period 2040-2050, we need simulated values of the air temperature for a longer period (at least 2100), on this way we would have an complete and clear picture which will enable to conclude if this 10 years period is just a short breakout of the general trend like the previous 2 periods, or it is a general trend of decreasing up to 2100. There are some theories which such a trend of decreasing is explaining with the positive effect of applied measures towards decreasing of the emissions of greenhouse gases.

Mean air temperature growing season

Growing season air temperatures are very important indicator having in mind that it refers to the air temperatures for the period when most of agricultural crops are growing. Each crop has a sum of temperatures need for each development stage. Due to that temperatures in the growing season are very important for crop development. In case of significant changes of growing season temperatures, a certain shift of crop growing stages might be expected, mining that some growing stages might occur earlier or latter, which on the other side is closely connected with certain crop management practices.

Table 2. Mean annual air temperature (growing season)

Year	Row Labels							SE reg.	Country
	62150	62151	62152	63150	63151	63152	64151	Average	average
2000	9.91	12.09	13.21	12.23	12.09	12.34	11.53	11.92	10.57
2010	8.67	11.18	12.43	11.25	11.13	11.43	10.55	10.95	9.61
2020	9.83	12.04	13.38	12.41	12.19	12.48	11.67	12.00	10.92
2025	9.94	12.28	13.29	12.47	12.26	12.48	11.68	12.06	10.55
2030	10.46	12.95	14.15	13.08	13.03	13.30	12.41	12.77	10.73
2040	11.98	14.27	15.27	14.41	14.41	14.69	13.95	14.14	11.54
2050	11.39	13.46	14.51	13.50	13.48	13.66	12.94	13.28	11.35
Average 2000-50	10.31	12.61	13.75	12.77	12.66	12.92	12.11	12.44	12.73

Out of the data presented in Table 2 it can be concluded that the average air temperatures during the growing season will graduate increase. This increase is visible for all sub-regions of the SE region. The average increase of the air temperatures in growing season for the SE region are 0.14°C and 1.36°C for the periods 2000-2025 and 2000-2050, respectively. If we compare the average air temperatures of the SE region with the other parts of the territory we can see that the differences for the whole period are in the ranges of 1.08-2.04°C. Such increasing of the average air temperature of more than 2.04°C can have a serious impact of the agricultural production in the SE region having in mind the intensity of the agricultural production in that region.

Rainfalls

Rainfalls considered as a sum for the whole year and a sum for the growing season are important climatic indicator for the agricultural sector. For this study rainfalls were simulated as a yearly sum of rainfalls, which does not gives us an opportunity to analyze the dynamic of rainfalls on a monthly base (Table 3).

Table 3. Rainfalls yearly

Year	Row Labels							SE reg.	Country
	62150	62151	62152	63150	63151	63152	64151	average	average
2000	448.89	399.04	449.54	473.47	411.31	438.57	413.73	433.51	527.9
2010	545.31	378.69	323.52	396.27	392.73	386.90	411.91	405.05	528.3
2020	591.06	445.44	401.80	556.93	482.67	385.82	429.49	470.46	641.8
2025	540.95	444.23	433.34	424.44	434.64	402.88	442.97	446.21	625.2
2030	369.40	318.43	314.41	376.44	360.98	379.94	400.25	359.98	496.3
2040	361.54	323.05	265.33	339.94	314.58	278.29	303.09	312.26	406.0
2050	519.57	447.42	441.42	468.16	456.19	494.90	534.04	480.24	665.2
Average 2000-50	482.39	393.76	375.62	433.67	407.59	395.33	419.35	415.39	555.80

Out of the presented data (Table 3) it can be noticed that the rainfalls in all analyzed sub regions do not follow certain pattern of increasing or decreasing yearly sums. Generally speaking it is very difficult to predict the rainfalls and the rainfalls regime due to the fact that on a small area of 26000 km^2 (as is SE region) several rainfall regimes exist. For instance, in Strumica valley, there are two rainfall regimes: modified Mediterranean and mountainous. Due to such diversity it is very hard to identify the ongoing and the future trends of rainfalls in the SE region and as well as at the whole territory of the country.

Evapotranspiration

Potential evapotranspiration was simulated using the basic climatological elements (air temperature, rainfalls, air moisture, wind speed insolation, sun radiation). This is an important indicator for vulnerability assessment of the agricultural sector, giving though that in Republic of Macedonia and more particularly in the SE region water is a limiting factor for agricultural crops. Increasing and decreasing of the evapotranspiration is primarily connected to the air temperature, rainfalls and plant growing stage.

Table 4. Evapotranspiration (mm)

Year	Row Labels							SE reg.	Country
	62150	62151	62152	63150	63151	63152	64151	average	average
2000	1105.77	1007.66	1148.4	1012.49	953.15	1037.47	977.52	1034.64	1032.16
2010	1049.32	952.84	1110.4	970.26	912.28	991.79	932.99	988.55	971.66
2020	1066.97	969.01	1133.94	976.48	936.53	1009.74	941.96	1004.95	981.69
2025	1051.29	973.83	1107.81	982.71	927.85	975.80	926.76	992.29	968.80
2030	1148.88	1036.98	1177.92	1051.89	989.91	1066.86	1014.39	1069.55	1077.10
2040	1219.71	1107.86	1259.5	1107.44	1058.73	1145.53	1078.23	1139.57	1134.80
2050	1152.65	1037.78	1178.41	1043.43	985.89	1058.81	1007.64	1066.37	1076.37
Average 2000-50	1113.51	1012.28	1159.48	1020.67	966.33	1040.86	982.78	1042.27	1034.65

Out of the data presented in Table 4 it can be seen that the evapotranspiration have very similar dynamics as air temperature (Table 1). There are certain periods of increasing and decreasing of evapotranspiration but there is an obvious trend of increasing over time. Changes of evapotranspiration mostly depends to the changes of air temperature, due to what the total difference of the average values for the SE region for the period 2000-2050 is not very significant and yields only 31.74 mm (3%) while for the period 2000-2040 the difference is much higher and is 104.93 (10.14%). If we compare the evapotranspiration of the SE and the average of the whole territory, only a slightly differences were notices of only 2.5-23.5 mm.

Crop data

The CropSyst model uses a specific set of parameters corresponding to the crop type. The Crop parameters are numerical representation of the phenology, morphology, growth, residue, harvest index etc. For the purposes of this simulation three crop files were developed that represent the crops in the South-East region in Macedonia with the parameters given in the Table 5.

Table 5. Crop characteristics

Description	Max Value	Min Value	Units	Sunflower	Wheat	Maize
Vernalization A parameter	10	0	°C	0	7	0
Base temperature for development	40	-10	°C	6	1	8
Base temperature for growth	20	-10	°C	6	1	8
Cutoff temperature for development	50	10	°C	30	28	30
Days requirement to complete vernalization	200	0	unitless	0	50	0
Days requirement to start vernalization	30	0	unitless	0	10	0
Development stage beyond which there is no re-growth	3	1	unitless	3	3	3
Development susceptibility to water stress	1	0	unitless	0	0.3	0
Extinction coefficient for solar radiation	0.9	0.1	unitless	0.5	0.48	0.47
ET crop coefficient at full canopy	1.3	0	unitless	1.15	1.18	1.25
Full canopy water uptake maximum	13	7	kg m-2 d-1	12	9	13
Harvest Index	1	0	unitless	0.31	0.4	0.5
Maximum plant height	4	0	M	2	1.2	1.5
High temperature for optimal vernalization	20	0	°C	30	30	30
Initial leaf area index	0.5	0.001	m2 m-2	0.01	0.01	0.03
Maximum leaf area index	12	0	m2/m2	6	6	5
Leaf area index initial value shape	2	1	unitless	1.5	1.5	1.5
Leaf duration	1700	100	°C day-1	1000	1300	900
Low temperature for optimal vernalization	10	-10	°C	0	4	0
Maximum radiation use efficiency	8	0.1	g MJ-1	2.88	2.5	4.5
Maximum rooting depth	200	7	Cm	190	160	150
Minimum vernalization factor	1	0	unitless	0	0	0
Maximum initial green leaf area index	0.2	0.05	m2 m-2	0.1	0.1	0.05
Night Temperature Critical	50	10	°C	15	3	10
Night Temperature Maximum	50	20	°C	25	11	25
Optimum temperature for growth	40	8	°C	20	25	24
Factor to convert global solar radiation to PAR	0.6	0.4	unitless	0.5	0.5	0.5
Daylenght to inhibit flowering	24	0	Hour	0	10	0
Daylenght for insensitivity fo photoperiod	24	0	Hour	0	18	0
Development stage critical for re-growth	2	1	unitless	1.5	1.5	1.5
Specific leaf area at emergence	40	10	m2 kg-1	20	20	20
Stem leaf partition coefficient	7	1	unitless	4	1.5	3
Thermal Time To Begin Yield Formation	1700	200	°C-d	1150	1370	1050
Thermal Time To Emergence	400	70	°C-d	110	60	93
Thermal time to end green leaf area index	1700	0	C°-d	1000	1300	900
Thermal Time To Flowering	2000	300	°C-d	925	870	760
Thermal Time To Maturity	3000	800	°C-d	1630	2200	1480
Transpiration Biomass Coefficient	10	3	(kg/m²) kPa)/m)	4.9	5.8	7.6

Wheat scenario

Figures 1 and 2 summarized the relationship between biomass and grain yield for winter wheat.

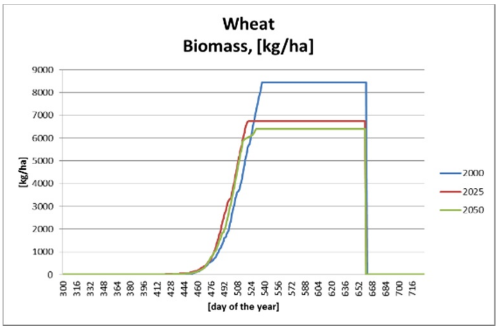


Figure 1. Total biomass produced in the South-Eastern region in the years 2000th, 2025th and 2050th, [kg/ha]

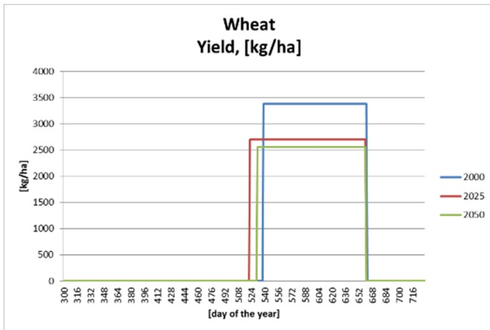


Figure 2. Total yield produced in the South-Eastern region in the years 2000th, 2025th and 2050th, [kg/ha]

The total crop biomass is cumulative biomass in the critical crop growth stages which are significant to final yield. The grain yield of wheat crop is determined by the level of biomass production and the extent of its transformation into economic product.

In the SE region in 2000, wheat occupied almost 3800 ha with average yield of around 8800 kg/ha for biomass and 3400 kg/ha for grain (Figure 1 and 2). The vegetation period (day of the year = DOY) is taken as one unit having in mind that the time of sowing is in one year and time of harvesting in the next one. In 2000, the peak for the yield of biomass was achieved 524 DOY and for grain 540 DOY. Compared those data with the targeted years, the wheat biomass will decrease for 23% in 2025 and 27% in 2050, as same as the yield where reduction is between 21 and 25% respectively. Obviously, a progressive increasing of the average air temperature in all sub localities (2 - 2.43°C), will lead to the lower yield at all, although it is difficult to explain how the slight decreasing of the temperature in the period between 2000 and 2025 and between 2040 and 2050 has negative impact on hight of the yield overall. Also, these data especially for the grain yield are inconsistent with those set out in section Project Crop Yield Impacts as a part of the Second National Communication of Macedonia where for rain-fed wheat, the major growing areas in the continental and Mediterranean agro-ecological zones are projected to experience a moderate increase in yields of up to 10% for both 2025 and 2050. One reason is that could be a trend which is strictly influence from climate change, concretely from the temperature and refers only for SE region. The other explanation in reducing of the yield may be required in the fact that the concentration of CO_2 as a variable was not taken into account in this study. Many laboratory and field experiments have demonstrated a positive influence of elevated levels of atmospheric CO_2 on the magnitude of biomass and grain production in wheat. In one study estimated the impact of typically predicted climate changes on wheat production in the 21-st century, finding that a doubling of the air's CO_2 concentration would likely enhance wheat yields between 12 and 49% in spite of a predicted 2.9 to 4.1°C increase in air temperature (Alexandrov and Hoogenboom, 2000).

Maize scenario

Figures 3 and 4 summarized the relationship between biomass and grain yield of maize.

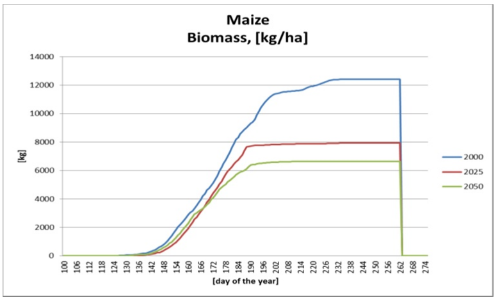


Figure 3. Total biomass produced in the South-Eastern region in the years 2000th, 2025th and 2050th, [kg/ha]

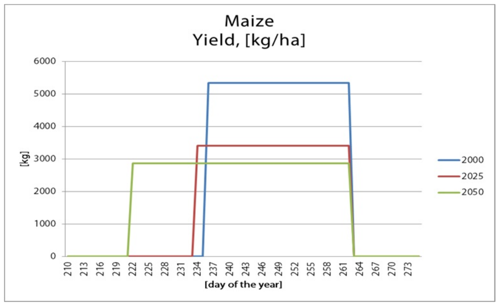


Figure 4. Total yield produced in the South-Eastern region in the years 2000th, 2025th and 2050th, [kg/ha]

In the SE region of Macedonia maize is sown on around 3200 ha from where the average yield is 5330 kg/ha which is 26% higher compared with the average level of the country obtaining from individual farmers (4200 kg/ha) and 22% lower from those of agricultural cooperatives (6500 kg/ha).

According the data presented in Figure 4 the grain yield will be significantly lower in the forthcoming period in common planting date. Under climate change scenario maize yield is expected to be reduced by 56% in 2025 and even by 86% in 2050 respectively (Figure 4), far more than the forecast presented in the Second National Communication which seeks to reduce the yield of corn by 25%. At the same time, higher temperatures will greatly affect the shortening of the vegetation of maize that is specifically expressed in 2050 where the maximum yield is noted 220 DOY, which represents a reduction of vegetation for 15 days (maximum yield in 2000 was realized from 235 DOY and further). Identical correlativity is determined on the yield of biomass where reduction ranges from 34% in 2025 to 58% in 2050, compared to 2000. It may conclude that if traditional varieties and agro-management practices are maintained, maize cycle will be shortened because of higher temperatures. The decrease in maize's ET could be caused by decreases in growing days and in Leaf Area Index due to higher temperature, and a lower transpiration due to stomata closure.

Sunflower scenario

Sunflower is not a relevant crop in SE region of Macedonia. Current sunflower production is realized on 1 ha with yield of around 1700 kg/ha (Figure 5).

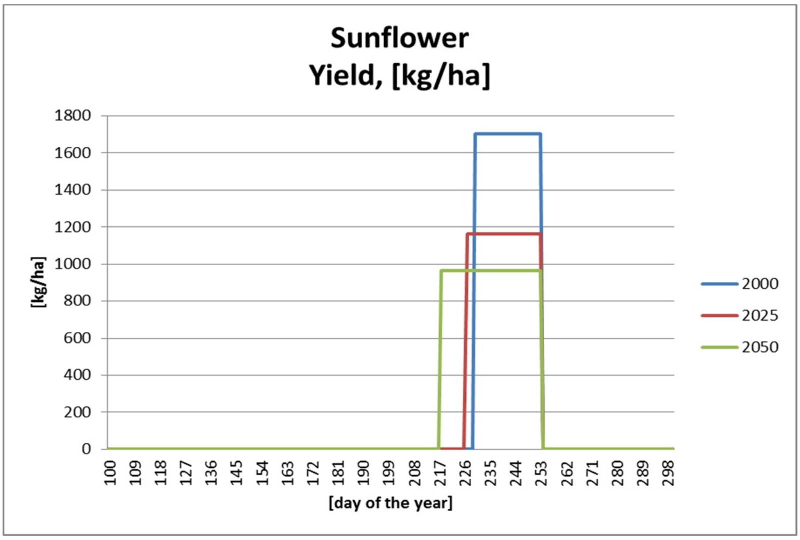


Figure 5. Total yield produced in the South-Eastern region in the years 2000th, 2025th and 2050th, [kg/ha]

The climate change analysis describes the strong effect of temperature increment on sunflower production. The achene yield will be considerably reduced with increasing temperatures up to 2°C in the area. Compared with present scenario than it can be estimated that there will be reduction in yield to 30% in 2025 (expected yield 1190 kg/ha) and up to 40% in 2050 (expected yield 990 kg/ha) for sunflower crop (Figure 5). In the same time, higher temperature affects the rate of plant development (vegetative growth), and the vegetation period will be shorter for approximately 13 days in 2050 where the peak of the yield will be 217 DOY. These data are identical with those obtaining from different regions in Europe where the yield of sunflower in Eastern Europe will be lower from 10 – 30% by 2030. The assertion can be summarized by higher evapotranspiration coupled with less rainfall compared to baseline period.

Conclusions

The sensitivity of the agricultural sector to climate has important implications in Macedonia. With a considerable proportion of the rural population dependent on agriculture for their livelihood, rural communities are particularly vulnerable to risks posed by changes that may occur as a result of climate change.

High vulnerability is due to several key factors: (a) small primary producers with low annual income and ability to implement adaptation measures which in some cases can be costly to implement; (b) small plots which prevents effective implementation of adaptive measures; (c) insufficient financial support to the farmers to cope with the negative impacts of CC; (d) low awareness among the key players about the climate change and its negative effects in agriculture; (e) weak networking and insufficient level of cooperation between scientific institution; (f) extension service and farmer associations for implementing know-how; (g) modern technologies of productions and dissemination of research results to the broader audience; (h) insufficient experience with implementation of modern approaches in assessment of impact and prediction of future effects and trends.

Climate change is expected to reduce the yields of most crops. These losses are projected to increase over time. Without adaptation, these climate change damages may become approximately the same or bigger than current net income jeopardizing the economic sustainability of farming in some areas.

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Original scientific paper

Influence of climate variations on some physiological and morphological characteristics of winter wheat

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Abstract

Temperature and precipitation regimes are the key factors affecting the agricultural productivity. The impact of climate variations on some physiological and mophological attributes of winter wheat was studied through field experiments conducted at the North-eastern Croatia over three climatic different years (2002, 2003 and 2004, respectively). Concentration of chloroplast pigments and all morphological traits were strongly influenced by climatic conditions. The highest concentration of chloroplast pigments was recorded in 2002, and the lowest value was measured in 2003. The plant height, stem length, number of fertile and sterile spikelet was higher in 2004, and the lowest values were recorded in 2003. Statistically significant differences were found between plant heights and stem length in all investigated years. All physiological parameters were highly significantly correlated, and their dependence is linear and positive. The concentration of chloroplast pigments had highly significant and positive correlations with plant height, stem length, spike length, number of fertile spikelet, number of grains per spike and yield. Very significant, positive correlations were observed between all physiological and morphological parameters of wheat with plant density and yield. Number of seeds per plant was significantly correlated with the concentration of chloroplast pigments and length of spike. The number of fertile spikelet in the spike was significantly correlated with all tested indicators except the number of sterile spikelet, which are significantly negatively correlated with the concentration of chloroplast pigments. In this study very significant correlation was determined between plant density in heading and yield.

Key words: climate variations, winter wheat, chloroplast pigments, morphological traits

Introduction

Croatia has very favorable agroecological condition for winter wheat growth, especially at the area of Slavonia and Baranja region. In crop production structure winter wheat is, together with maize, the most grown crop, covering area of around 200 000 ha each year. The growing number of researches is directly connected with winter wheat production in unfavorable weather and production conditions, with the main goal of increasing crop yield, with lesser production costs. The achieved yields are more and more connected with photosynthetic potential and photosynthetic plant activity (Sabo et al., 2002; Jug et al., 2008). 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. Chloroplast pigments concentration in the winter wheat is inherited characteristic, moderated by numerous environmental factors (Jug et al., 2010). 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. The large number of photosynthetic productivity factors has different impact at different genotypes in different agroecologic conditions (Jug et al., 2008). The most important for photosynthesis activity are light, nutrition, water supply and temperature.

The aim of this study was to examine the impact of fluctuations of temperature and precipitation regimes on winter wheat morphological (plant height, length of stalk, length of spike) and physiological properties (chlorophyll a, chlorophyll b, chlorophyll (a+b) and carotenoids) and determine the correlation between the investigated properties of winter wheat.

Materials and methods

This experiment was conducted at the north-eastern part of Croatia, in Baranja Region, at experimental field near Knezevo (N: 45°82′, E: 18°64′) for winter wheat (*Triticum aestivum* L.), cultivar Demetra, during three years (2001/2002, 2002/2003, 2003/2004). The main experimental set-up was a complete randomized block design in four replications. 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 1mol dm^{-3} KCl = 7.5; humus = 2.6%, $CaCO_3$ = 2.1%; AL-soluble P_2O_5 and K_2O = 18.7 and 28.4 mg $100g^{-1}$, respectively). The size of basic experimental plot was 900 m^2 (Jug, 2006). The winter wheat was sown at the planned rate of 700 germinating seeds m^{-2}, at the inter-row distance of 16.5 cm. The fertilization was uniform across treatments and years, and it consisted of $N:P_2O_5:K_2O$

= 120:130:130 kg ha^{-1} (500 kg N ha^{-1} 8:26:26 in autumn, 150 kg KAN ha^{-1} in tillering and 150 kg KAN ha^{-1} in period of stem elongation).

The samples of winter wheat for physiological parameters were sampled in 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 (FW) 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 per g of fresh mass (Arsenijević-Maksimović and Pajević, 2002).

The samples of winter wheat for morphological traits were sampled in different phenological stage. Plant density (number of plants of winter wheat in the earing – according to Feekes 11) was determined by counting all primary and secondary stem but also on the surface of 0.25 m^2 in four repetitions. Plant height of winter wheat, stem length, number of spikelets per spike, spike length and number of grains per spike was measured in 20 plants (2x10 plants per each plot in four repetitions). The winter wheat grain yield was achieved by weighing of the total grain mass from each plot (scale with d=1 kg t^{-1}). The final yield was recalculated for 1 ha area and standardized for 14% of the grain moisture.

All parameters were analyzed with two way analysis of variance (ANOVA) with calculation of LSD values for $P<0.05$ significance levels. Correlation between parameters was tested with standard multiple correlation analysis.

Results and discussion

Weather characteristics were mainly specific in comparison with long-term means. Total precipitation from September to July in 2002 was 441 mm, 407 mm in 2003 and 717 mm in 2004. According to long term means (30 yr.), where total precipitation was 572 mm from September to July, year 2004 was characterized as humid year. The first two years of research (2002 and 2003) were below average amount of precipitation according 30-yr means. Climate conditions in 2003 were extremely unfavorable for winter wheat primarily because the insufficient amount of precipitation in growing season (126 mm) and higher average temperatures in May, June and July (Table 1). Total precipitation in growing season was 174 mm less than 30-yr means (300 mm). Due to low amount of precipitation during the growing season this year can be characterized as dry year. Total precipitation in growing season in 2002 (270 mm) was in range of 30-yr means (300 mm). Mean air temperatures were higher for 2^{o}C in 2002 and 2003 (Table 1) then the 30-yr average. Mean air temperature in 2004 was the same as long term means temperature (15ºC).

Varying of chlorophyll a, carotenoids and chlorophyll (a+b) (Table 2) was strongly influenced by agro climatic conditions. The highest concentration was recorded in 2002 (chlorophyll a=1.753 mg per g FW, chlorophyll a+b=2.234 mg per g FW and carotenoids 0.656 mg per g FW) and the lowest value was measured in 2003 (chlorophyll a=1.269 mg per g FW, chlorophyll a+b=1.656 mg per g FW and carotenoids 0.455 mg per g FW).

Table 1. Total precipitation (mm) and temperature (º C) from September through February (winter) and the growing season (March through July) at Kneževo site during 2001/2002, 2002/2003, 2003/2004 and long-term means (LTM: 1965-2005).

	2002	2003	2004	LTM	2002	2003	2004	LTM
	Precipitation (mm)				Temperature (ºC)			
Winter season	171	281	330	272	6	9	6	6
March	10	4	35	41	9	6	6	6
April	64	9	120	46	11	11	11	11
May	86	33	77	60	19	20	17	17
June	49	19	114	92	22	25	20	20
July	61	61	41	61	24	23	22	21
Growing season	270	126	387	300	17	17	15	15

Statistically significant differences were found in the concentration of chlorophyll a and carotenoids in 2002 compared to 2003 and 2004. Concentration of chlorophyll a+b was significantly higher in 2002 compared with 2003 and 2004. Differences in chlorophyll a+b concentration were significant between 2003 (1.656 mg per g FW) and 2004 (1.911 mg per g FW). Other differences in the concentration of chloroplast pigments were not statistically significant (Table 2).

Under conditions of sufficient moisture in the soil, plants turgidity is favorable, which is a very important factor in creating leaf mass and total production of photosynthesis. In drought conditions, as it was in 2003, due to stress caused by water deficit leads to poor development of the plant. Studies have shown that the photosynthetic rate of leaves decreases as relative water content and water potential decrease (Cornic and Massacci, 1996). Limitation of net photosynthetic rate in low moisture stressed plant is mainly through stomatal closure (Cornic and Massacci, 1996; Cornic, 2000) and by metabolic impairment (Flexas and Medrano, 2002). Availability of soil moisture and nutrients for a longer period in moisture conserved plots, which resulted in increased chlorophyll synthesis. In water stressed plants, loss in chlorophyll is associated with a reduction in the flux of nitrogen into the tissue as well as alterations in the activity of enzyme systems such as nitrate reductase (Begum and Paul, 1993). Akram et al. (2010) reported that chlorophyll content in wheat leaves was significantly increased under drought conditions which are contrary to our results.

Wheat is particularly sensitive to stress injury and the crop is often grown in areas where high temperatures limit productivity. The impact of heat stress on seedling growth and leaf development has been established from the temperature sensitivity of pigmentation and the inhibition of the chloroplast function in wheat (Mohanty and Mohanty, 1988). Photosynthesis is known to be one of the most heat-sensitive processes and it can be completely inhibited by high temperature and these photosynthesis decreases could result from the inhibition of photosystem II (PSII) activity, which has been shown to be the most thermally labile component of the electron transport chain (Havaux et al.,1991, Camejo et al., 2005). In this study, the highest concentration of chlorophyll a, chlorophyll b, chlorophyll a+b and carotenoid was in the year with higher temperatures than 30-yr means. Increased temperature had a positive effect on the synthesis of chloroplast pigments.

Table 2. Physiological and morphological properties, plant density, number of grains per spike and yield of winter wheat in three climatic different years

characters	2002	2003	2004
chlorophyll a (mg g $^{-1}$ FW)	1.753 a†	1.269 b	1.472 b
chlorophyll b (mg g $^{-1}$ FW)	0.481	0.386	0.439
chlorophyll a+b (mg g $^{-1}$ FW)	2.234 a	1.656 c	1.911 b
carotenoid (mg g $^{-1}$ FW)	0.66 a	0.46 b	0.54 b
plant height (cm)	66.51 b	41.61 c	84.34 a
stem length (cm)	59.94 b	36.30 c	77.88 a
spike length (cm)	6.57 a	5.30 b	6.46 a
number of fertile spikelet	14.31 a	12.65 b	14.76 a
number of sterile spikelet	1.9 b	2.0 ab	2.5 a
number of grains per spike	35.53	29.73	31.43
plant density (plant per m^2)	559 a	426 c	511 b
yield (t ha^{-1})	6.70 a	2.52 b	6.66 a

†the means of the same lowercase letter are not statistically significant at the $P<0.05$ level

All morphological traits were under significant influence of fluctuations of temperature and precipitation regimes. The plant height was higher in 2004 (84.34 cm) and the lowest in 2003 (41.61 cm). Statistically significant differences were found in the plant height between all investigated years. The stem length was greater in 2004 (77.88 cm) and the lowest in 2003 (36.30 cm). All the differences in the length of the stem were statistically significant (Table 2). The spike length was higher in 2002 (6.57 cm) and the lowest in 2003 (5.30 cm). Statistically significant differences were found in the length of spike between all investigated years. Number of fertile and sterile spikelets was under significant influence of agroecological conditions in investigated years. The highest value was recorded in 2004 (number of fertile spikelet=14.76; number of sterile spikelet=2.5) and were significantly higher than in 2003 (number of fertile spikelet=12.65; number of sterile spikelet=2) (Table 2).

Grain yield is a complex trait and highly influenced by many genetic factors and environmental fluctuations. The highest yield was detected in 2002 (6.70 t ha^{-1}), and the lowest yield in 2003 (2.52 t ha^{-1}) (Table 2). Moisture deficits that frequently occur from March through July in 2003 reduced the yield of winter wheat, which is in accordance with numerous authors who emphasized the importance of climatic conditions during the growing season (Sabo et al., 2006; Jug et al., 2011).

Between the morphological and physiological characteristics, yield components, plant density and yield were found numerous correlations (Table 3). All physiological parameters were highly significantly correlated, and their dependence is linear and positive. Increasing concentrations of photosynthetic pigments increased productivity, and hence habitus plants were higher. The concentration of chloroplast pigments had highly significant and positive correlations with plant height, stem length, spike length, number of fertile spikelet, number of grains per spike and yield. Kaya et al. (2002) have been found a strong positive correlation between peduncle length and grain yield. In other cases, such relationship has been found inverse (Briggs and Aytenfisu, 1980) or no relationship (Villegas et al., 2006) depending on the environment.

Table 3. The correlation coefficient between all investigated parameters

	1	2	3	4	5	6	7	8	9	10	11	12
1	1.00											
2	0.94	1.00										
3	0.86	0.84	1.00									
4	0.93	0.90	0.97	1.00								
5	0.93	0.85	0.85	0.89	1.00							
6	0.65	0.58	0.44	0.48	0.62	1.00						
7	0.88	0.81	0.93	0.94	0.80	0.86	1.00					
8	-0.09	-0.10	-0.84	-0.38	-0.15	0.51	0.30	1.00				
9	0.69	0.59	0.52	0.63	0.59	0.28	0.65	-0.05	1.00			
10	0.89	0.78	0.72	0.76	0.87	0.89	0.93	0.22	0.56	1.00		
11	0.80	0.68	0.53	0.58	0.77	0.98	0.89	0.41	0.30	0.91	1.00	
12	0.98	0.92	0.80	0.88	0.94	0.70	0.92	0.01	0.73	0.91	0.78	1.00

Legend: 1-chlorophyll a; 2-chlorophyll b; 3-carotenoids; 4-chlorophyll (a+b); 5-plant density; 6-plant height; 7-number of fertile spikelet; 8-number of sterile spikelet; 9-number of grains per spike; 10-yield; 11-stem length; 12-spike length

Very significant, positive correlations were observed between all physiological and morphological parameters of wheat with plant density and yield. Number of seeds per plant was significantly correlated with the concentration of chloroplast pigments and length of spike (Table 3). The number of fertile spikelet in the spike was significantly correlated with all tested indicators except the number of sterile spikelet, which are significantly negatively correlated with the concentration of chloroplast pigments. In this study very significant correlation was determined between plant density in heading and yield. Yousaf et al., (2008) reported positive genotypic and phenotypic correlation of yield with number of spikelets and number of grains per spikelet. The same authors reported negative but highly significant correlations of yield with plant height.

Conclusion

This research has proved a highly significant influence of agro climatic conditions on the chloroplast pigments concentrations (except chlorophyll b concentration), yield traits (except number of grains per spike), plant density and yield, respectively. The lowest values of all physiological and morphological parameters were detected in drought conditions, in 2003. Grain yield in 2003 was lower than in other investigated years. All physiological and morphological parameters were highly significantly correlated with each other. Very significant, positive correlations were observed between all physiological and morphological parameters of wheat with plant density and yield.

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Original scientific paper

Influence of irrigation and variety on the soybean grain yield and quality in the no nitrogen fertilization soil condition

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Abstract

Soybean as wide spread crop in eastern Croatia is planted on 45888 ha with grain yield 2.0 t ha^{-1}. The treatments in the field trials were growing season (GS, main factor, A: A1=year 2010; A2= year 2011; A3= year 2012), irrigation rate (IR, sub factor, B: B1=control, no irrigation, B2= soil water content maintained from 60% to 100% of field water capacity (FWC), B3= soil water content maintained from 80% to 100% of FWC) and soybean varieties (sub sub-factor, C: C1=Lucija, C2=Vita, C3=Ika and C4=Tena, created at Agricultural Institute Osijek). The objective of this study was testing irrigation and genotype impact on grain yield, oil and protein content at the soybean in the no nitrogen fertilization soil conditions. Therefore, the nitrogen potential in three climatically different growing seasons in natural, field conditions has been tested. Mean soybean grain yields were 3436 kg ha^{-1}, 3678 and 3633 kg ha^{-1} in year 2010, 2011 and 2012, respectively. Irrigation and soybean variety had statistically significant impact on soybean grain yield, while growing season not. Growing season, irrigation and soybean variety resulted by statistical significant impact on oil content, while growing season on protein content, only.

Key words: irrigation, soybean, nitrogen fertilization, grain yield, grain quality

Introduction

Soybean is wide spread crop in eastern Croatia and in the ten years (2000-2009) mean soybean harvested area was 45888 ha with average grain yield 2.0 t ha^{-1} (Central Croatian Bureau of Statistic, 2010). Grain yields of soybean varied in close connection with amount and distribution of precipitation during the growing season (Vučić and Bošnjak, 1980; Josipović et al., 2006; Bošnjak 2008; Kovačević et al., 2010; Josipović et al. 2010) and N fertilization (Bharati et al., 1986), intensity and longings of dry period in different growing stage (Rao and Reddy, 1990; Dragović, 1994; Brevedan and Egli, 1978; Bošnjak, 2008), properties of cultivars (Sudarić et al., 1996; Sudarić et al., 2004;

Sudarić et al., 2009) soil properties and performing of other agro-technical measures (Sudarić et al., 2009; Fehr, 1983 and Specht et al., 1999 according to Sudaric et al., 2004). Some general aspects of irrigation effects were shown by Mađar and Vratarić (1980); Vučić and Bošnjak (1980); Bošnjak et al. (2008); Josipović et al. (2010). Studies of Bošnjak (2008), Josipović et al. (2010) and Pejić et al. (2012) confirmed that the highest soybean grain yield was when the soil water content was maintained from 60% field water capacity (FWC) to 100% FWC. The mentioned authors also confirmed that maintenance soil water content from 80% FWC to 100% FWC resulted in same or lower grain yield on the irrigation control treatment. Vučić (1976) confirmed that irrigation, in most cases of growing soybean, increased grain yield by 30% while Mađar and Vratarić (1980) achieved higher grain yield, from 23% to 49%. The „very dry and warm year“, 2012 are in accordance to Mađar and Vratarić results.

Irrigation is very important factor of stable soybean grain yield (Sorensen and Penas, 1978; Jurić et al., 1995; Josipović et al., 2010) and soybean cultivar are also important. Thus, Josipović et al. (2010) concluded that irrigation and N fertilization resulted in statistically significant difference in soybean grain yield in the four year investigations. The highest soybean grain yield, 4.13 t ha^{-1} achieved when soil moisture was maintained from 60% to 100% FWC and 100 kg ha^{-1} N. De Mooy et al. (1973) and Welch et al. (1973), according to Brevedan et al. (1978a), Brevedan et al. (1978b) confirmed that N fertilization effect on grain yield soybean reduced soybean grain yield. Bhangoo et al. (1972), Johnson and Hume (1972), Lyons and Earley (1972) and Mederski et al. (1958, cit. Sorensen and Penas, 1978) confirmed small increasing soybean grain yield (as influence of N fertilization). Opposite the mentioned results, Beard and Hoover (1971), Lyons and Early (1952), Mederski et al. (1958), Wagner (1962), Welch et al. (1973, cit. Sorensen and Penas, 1978), Jurić et al. (1995) confirmed that N fertilization did not result in growing soybean grain yield. Soybean protein and oil content are in close connection in total amount and usually is from 60% to 65%. It content is property of cultivar but growing season with soil properties and applied soil cultivation has considered impact on that. The objective of this study was testing irrigation and genotype impact on soybean grain yield under the no nitrogen soil fertilization. Thus will be tested nitrogen potential in three climatically different growing seasons in natural, field conditions.

Material and methods

In this paper influence of three growing seasons, irrigation rate (IR) and soybean varieties was tested on the grain yield and grain quality on no nitrogen (N) fertilization, under field conditions in Osijek (Croatia) humofluvisol, semi deep, no calcareous soil type. The soil had retention water capacity near 38.5% volume. The growing season (GS, main factor, A) were: A1=year 2010; A2=year 2011; A3=year 2012. Irrigation rate (IR) was sub factor, B: B1=control, no irrigation, B2=soil water content maintained from 60% to 100% of FWC and B3=soil water content from 80% to 100% of FWC.

Table 1. Irrigation water distribution on the irrigation treatments (B1, B2 and B3) during the investigation, 2010 - 2012

Growing season	No of IR and amount of water, mm A2 treatment		A3 treatment		Rainfall mm	Total water amount per trea-tment, irrigation+rainfall, mm		
	No of IR	applied water	No of IR	applied water	in GS mm	A1	A2	A3
2010	2	70	4	140	676	676	746	811
2011	4	140	7	245	246	246	386	491
2012	5	175	8	280	293	293	368	573
Mean	3.7	128	6.3	222	405	405	500	625

Amount of water added by IR was as follows: B1=control treatment; B2=twice by 35 mm and B3=four times by 35 mm (in year 2010); B1=control treatment; B2=4 time by 35 mm and 7 times by 35 mm (in year 2011); B1= control treatment; B2=5 time by 35 mm and 8 times by 35 mm (in year 2012, Table 1). Average total water amount in tree year was 405 mm, 500 and 625 mm, on the B1, B2 and B3 treatment, respectively. N fertilization was zero kg ha^{-1} (during the last 6 years). The 100 kg ha^{-1} P_2O_5 and 150 kg ha^{-1} K_2O were applied in form of NPK 0:20:30 fertilizers (500 kg ha^{-1} as a basic and pre sowing fertilization, split in twice). Soybean cultivars (sub sub-factor C) were C1=Lucija, C2=Vita, C3=Ika and C4=Tena, created at Agricultural Institute Osijek.

Table 2. Mean air temperatures (oC) and amount of rainfall (mm) in Osijek region in growing season 2010-2012, and 30-year mean (Osijek, Weather Bureau)

Osijek	Weather Bureau: years 2010-2012 and long-term mean (LTM: 1971-2000)							
Month	Rainfall in growing season, mm				Temperature in growing season, °C			
	2010	2011	2012	LTM	2010	2011	2012	LTM
April	12.4	13.2	12.5	54.1	71	20	47	11.3
May	16.5	16.7	16.9	58.9	121	81	94	16.5
June	20.4	20.8	22.5	83.5	234	50	68	19.4
July	23.2	22.2	24.8	66.6	32	74	48	21.1
Aug.	21.7	23.1	24.1	59.6	111	5	4	20.3
Sept.	15.6	20.3	18.9	51.8	108	16	32	16.6
April-June	18.3	19.4	20.0	368.3	676	246	293	17.5

The field trial experiments were designed as three factorial methods with randomized blocks design in three replications. Experimental basic plot of soybean cultivar (C) was 30 m^2, irrigation plot (B) 120 m^2. Self-propelled sprinkler for irrigation was used. Soybean was planted in the middle of April and harvested at the October. An Infratec 1241 Grain Analyzer at the Agricultural Institute Osijek was used for the analyses of protein, oil and starch concentrations with ready-to-use calibrations. Planned plant densities were 550 plants m^{-2}. Soybean grain yield was calculated on 13% grain moisture basis. The given data was statistically performed by SAS, model GLM, three factorial trial design. Growing season 2010 was very wet, 2011, dry and warm, 2012 very dry and very warm (Table 2). Rainfall shortage, especially during July is in close connection with low yields of spring crops in Croatia (Kovačević et al. 2010), but also wet years in soybean crop production (Josipović et al., 2011.).

Results and discussion

Grain yield of soybean is one of the most important properties for both breeders and producers. Seed yield is comprehensive property and it consists of many components of quantitative parameters, whose genetic base is polygenic (Sudaric, 1999). Mean soybean grain yields were 3436 kg ha^{-1}, 3678 and 3633 kg ha^{-1} in year 2010, 2011 and 2012, respectively (Table 3).

Table 3. Influence of growing season, irrigation and variety of soybean on grain yield with no nitrogen fertilization

A	B1 (control treatment)				B2 (60-100% FWC)				B3 (80-100% FWC)			
	C1	C2	C3	C4	C1	C2	C3	C4	C1	C2	C3	C4
	Soybean grain yield (kg/ha)											
A1	3505	3363	3571	3399	3470	3393	3479	3302	3595	3439	3375	3344
A2	2908	2321	2926	3145	3942	3843	4191	4462	3510	4200	4209	4477
A3	2660	3033	3183	3106	3585	4224	3786	3711	3240	4299	4357	4416
xBC	3024	2906	3227	3217	3666	3820	3819	3825	3448	3979	3980	4079

	Interaction AB				Interaction AC				Mean
	B1	B2	B3		C1	C2	C3	C4	A
A1	3460	3411	3438	A1	3523	3399	3475	3348	3436
A2	2825	4110	4099	A2	3453	3455	3775	4028	3678
A3	2996	3827	4078	A3	3162	3852	3776	3744	3633
x B	3094	3782	3872	x C	3379	3568	3675	3707	3582

Analyze of variance	A	B	C	AB	AC	BC	ABC
LSD 5%	n.s.	173	192	332	367	n.s.	n.s.
LSD 1%	n.s.	227	259	466	527	n.s.	n.s.
F test	n.s.	46.83**	5.00**	13.88**	4.52**	n.s.	n.s.

Note: growing season (A: A1=year 2010, A2=year 2011, A3=year 2012), irrigation treatment (B1=control, B2=60-100% maintenance of field water capacity, FWC, B3=80-100% FWC) and variety (C: C1=Lucija, C2=Vita, C3=Ika, C4= Tena)

Year as main factor have no statistical significant difference in only three years, in spite some investigations indicate that. But, that is expected that year 2011 was more convenient for soybean production. In very wet year, 2010 was the lowest grain yield. In spite that year 2012 was very dry and warm, soybean had moderate grain yield, which indicate that soil fertility potential is very good. These results are in close connection with Kovačević et al. (2010), Josipović et al. (2010) which proved impact of climate conditions (environment effect = clime conditions + soil conditions + agro technical practice + their interactions).

Irrigation, both treatments (B2 and B3) resulted in high statistically difference (P≥0.01), in soybean grain yield toward control treatment (B1, no irrigation, Table 3). Irrigation treatments showed statistical almost same results, that is good basis for recommend B2 treatment, well, reduced irrigation and production costs in soybean production. It is in a close connection with investigation of Mađar and Vratarić (1980), Vučić and Bošnjak (1980), but only partly with Bošnjak (2008) and Josipović et al. (2010).

Table 4. Influence of growing season, irrigation and variety on soybean oil content with no nitrogen fertilization

Influenced of on soybean grain yield												
A	B1 (control treatment)				B2 (60-100% FWC)				B3 (80-100% FWC)			
	C1	C2	C3	C4	C1	C2	C3	C4	C1	C2	C3	C4
	Soybean oil content (%)											
A1	22.0	22.0	21.6	21.3	21.7	21.2	20.8	21.0	22.0	21.3	21.1	20.8
A2	24.1	23.3	22.6	23.0	23.0	22.5	21.9	22.3	22.6	22.1	21.7	22.0
A3	23.5	23.1	22.5	22.3	23.0	23.2	22.7	22.7	23.3	22.7	22.9	22.7
xBC	23.2	22.8	22.3	22.2	22.6	22.3	21.8	22.0	22.6	22.0	21.9	21.9

	Interaction AB				Interaction AC				Mean
	B1	B2	B3		C1	C2	C3	C4	A
A1	21.7	21.2	21.3	A1	21.9	21.5	21.2	21.0	21.4
A2	23.3	22.4	22.1	A2	23.2	22.6	22.1	22.4	22.6
A3	22.9	22.9	22.9	A3	23.3	23.0	22.7	22.6	22.9
x B	22.6	22.2	22.1	x C	22.8	22.4	22.0	22.0	22.3

Analyze of variance	A	B	C	AB	AC	BC	ABC
LSD 5%	0.19	0.28	0.16	n.s.	0.30	n.s.	n.s.
LSD 1%	0.25	0.37	0.21	n.s.	0.44	n.s.	n.s.
F test	128.1**	7.81**	47.72**	n.s.	2.34*	n.s.	n.s.

Note: growing season (A: A1=year 2010, A2=year 2011, A3=year 2012), irrigation treatment (B1=control, B2=60-100% maintenance of field water capacity, FWC, B3=80-100% FWC) and variety (C: C1=Lucija, C2=Vita, C3=Ika, C4= Tena)

Cultivar effect (C) in seed yield resulted in high statistically influence (P≥0.01). Thus variety Tena (C4) yielded 3707 kg ha^{-1}, which is better than two other cultivars, and the most widespread cultivar Ika was on the same level. Interaction effect, year and irrigation and year and cultivar were statistically high significant.

Mean soybean oil content in the three year trials was 21.4%, 22.6 and 22.9% in year 2010, 2011 and 2012, respectively (Table 4). Year as main factor, irrigation as sub factor and variety as sub sub-factor have had statistical significant difference in oil content in soybean grain. Mentioned results are similar to Breene et al. (1988). B2 and B3 irrigation treatment resulted by lower oil content then control treatment, which induce that rational irrigation is good solution for practice application. Variety Lucija have the highest oil content (22.8%). Interaction of year and variety also resulted by statistical significant effect of oil in soybean grain.

Protein content resulted with statistical significant impact between all tested growing seasons and was 40.5, 38.2 and 39.0% in year 2010, 2011 and 2012, respectively (Table 5). In very wet year 2010, protein content was significantly higher than other two, dry and very dry years. Irrigation treatments have no statistical significant impact to soybean grain protein content that is recommended use B2 treatment, as cheaper. Cultivars also have no statistical significant impact in three tested years what is unusual for four varieties.

Table 5. Influence of growing season, irrigation and variety on soybean protein content with no nitrogen fertilization

Influenced of on soybean grain yield												
A	B1 (control treatment)				B2 (60-100% FWC)				B3 (80-100% FWC)			
	C1	C2	C3	C4	C1	C2	C3	C4	C1	C2	C3	C4
	Soybean protein content (%)											
A1	40.5	39.9	39.9	40.0	40.6	41.0	41.0	40.3	40.6	41.0	40.4	40.6
A2	34.8	36.9	38.1	37.2	38.3	38.6	39.3	38.5	39.4	39.5	39.0	38.9
A3	39.2	39.2	39.6	40.0	39.7	38.5	38.4	38.6	39.1	38.8	38.0	38.6
xBC	38.2	38.7	39.2	39.1	39.5	39.4	39.5	39.1	39.7	39.7	39.1	39.4

	Interaction AB				Interaction AC				Mean
	B1	B2	B3		C1	C2	C3	C4	A
A1	40.1	40.7	40.6	A1	40.6	40.6	40.4	40.3	40.5
A2	36.7	38.7	39.2	A2	37.5	38.3	38.8	38.2	38.2
A3	39.5	38.8	38.6	A3	39.4	38.8	38.7	39.1	39.0
x B	38.8	39.4	39.5	x C	39.1	39.3	39.3	39.2	39.2

Analyze of variance	A	B	C	AB	AC	BC	ABC
LSD 5%	0.40	n.s.	n.s.	1.10	0.65	0.65	1.58
LSD 1%	0.53	n.s.	n.s.	1.55	0.93	0.93	2.91
F test	63.89**	n.s.	n.s.	6.19**	4.65**	3.92**	2.05*

Note: growing season (A: A1=year 2010, A2=year 2011, A3=year 2012), irrigation treatment (B1=control, B2=60-100% maintenance of field water capacity, FWC, B3=80-100% FWC) and variety (C: C1=Lucija, C2=Vita, C3=Ika, C4= Tena)

Conclusions

Year as main factor have no statistical significant difference in soybean grain yield. Irrigation, both treatments resulted in high statistically difference, in soybean grain yield toward control treatment. Cultivar effect in seed yield resulted in high statistically influence. Interaction effect, year and irrigation and year and cultivar were statistically high significant. Year as main factor, irrigation as sub factor and variety as sub sub-factor have had statistical significant difference in oil content in soybean grain. Protein content resulted with statistical significant impact between all tested growing seasons and was 40.5, 38.2 and 39.0% in year 2010, 2011 and 2012, respectively. Irrigation treatments have no statistical significant impact to soybean grain protein content that is recommended use B2 treatment, as cheaper.

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S E S S I O N III

[Soil degradation (biotic and abiotic) in agriculture production]

Chairmen:

Boris Đurđević
Ivana Majić
Srđan Šeremešić

Original scientific paper

Changes in the total nitrogen content down the profile of slightly leached chernozem soils as a result from 40-year mineral fertilization

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Abstract

The systematic mineral fertilization for a period of 40 years with various nitrogen, phosphorus and potassium norms and ratios had high effect on the agro-chemical status down the profile of the slightly leached chernozem soil (0 – 400 cm). Systematic mineral fertilization applied for 40 years affected significantly the content of total nitrogen in soil (averaged for the 0 - 400 cm layer). There was a clear negative effect of independent fertilization with $N_{180}P_0K_0$ on total nitrogen, which is one of the stable indicators of soil fertility. The mean decrease according to the control variant was with 4.8%. Highest enrichment of soil with total nitrogen along the entire investigated depth was found after fertilization with $N_{60}P_{180}K_0$ (4.1%) and $N_{120}P_{120}K_{120}$ (6.6%).

The differentiation in the values of total nitrogen along the entire profile was well expressed, the changes in the 1st meter being most dynamic. Lowest total nitrogen content was detected in the 3rd meter.

Key words: Total nitrogen concentration, long-term mineral fertilization, soil profile up to 400 cm

Introduction

Transportation, redistribution and transformation of nitrogen down the soil profile were influenced by a number of factors such as the structure of soil units, aeration, macro pores, composition, amount and depth of post harvest residue incorporation, mineral fertilization and nitrogen norm, mineralization of organic substance, leaching, productive moisture, etc (Goldbi et al., 1995; Karlen et al., 1998). The size of the nitrogen norm is significant for agricultural production under moist, semi-dry and dry conditions to obtain acceptable balance between economic and non-economic part of the produce and avoid possible losses (Cantero-Martinez et al., 1995). It is well known that the availability of the nitrogen from the mineral fertilizers depends strongly on the type of the nitrogen source, the soil type, the crop, the fertilization norm, etc. Many farmers tend to apply higher nitrogen norms to ensure higher yields

(Franzluebbers et al., 1999). This in many cases is not necessary due to changes in the distribution of the nitrogen in the surface of the soil profile and its improved mobility (Rice et al., 1986).

The aim of this investigation was to follow the effect of the long-term agronomy practices and especially fertilization on the total nitrogen concentration of slightly leached chernozem soil in the region of South Dobrudzha after 40 years of mineral fertilization with different norms and combination between nitrogen, phosphorus and potassium.

Materials and methods

Dobrudzha Agricultural Institute-General Toshevo is situated in the north-eastern part of Bulgaria in the zone of black earth (Picture 1). The main soil type is chernozem (Haplic Chernozems WRBSS, 2006). A long-term fertilizer experiment, which was initiated in 1967, is still carried on. In a two-field crop rotation (wheat-maize), 4 nitrogen and phosphorus and 3 potassium norms were tested – 0, 60, 120, 180 and 0, 60, 120 kg/ha respectively.

Picture 1. Location of Dobrudzha Agriculture Institute (43° 40’ northern latitude and 28° 10’ eastern longitude)

The experiment was designed by the method of the “net square”, applying the full version of the design (4 x 4 x 3 = 48) in four replications.

On the 40th year from the beginning of the trial (2007) after wheat harvest, soil samples were taken every 20 cm down the soil profile till depth 400 cm. A motor-driven portable soil sampler was used (Iliev and Nankova, 1994; Iliev, 2000). The changes of total nitrogen concentration were determined in selected variants which possessed highest productivity average for the 40th year period of investigation.

Total nitrogen content was determined by the classical method of Kjeldahl. The mathematical analysis of the obtained results was performed with the help of Excel and the software SPSS 16.0 (2007). The post-hoc analyses were expressed through the Waller-Duncan test ($P<0.05$).

Results and discussions

The investigations on the ecological status of the slightly leached chernozem in South Dobrudzha included mostly the systematic and long-term effect of some agronomy practices, predominantly of mineral fertilization (Nankova et al., 1994, 2005; Nankova, 2010). For the first time in this region of Bulgaria an in-depth investigation was carried out on the influence of the long-term mineral fertilization on the distribution of total nitrogen by layers every 20 cm till depth 4 m.

The total nitrogen concentration was significantly affected by the mineral fertilization and the investigated layers up to depth 400 cm (Table 1). At the end of the studied period, averaged for the depth of the 0-400 cm profile, a significant effect was established to a maximum degree both under the independent influence of the investigated factors and under their interaction.

The depth of the investigated profile was the factor with decisive effect on soil nitrogen concentration (Figure 1).

Table 1. Variance analysis of the total nitrogen concentration for a 40-year period of investigation

Source	df	Mean Square	F	Sig.
Fertilizer variants (A)	7	225.764	19.563	0.000
Soil depth (B)	20	37302.907	3232.358	0.000
A x B	140	102.156	8.852	0.000

a R Squared = 0.997 (Adjusted R Squared = 0.995)

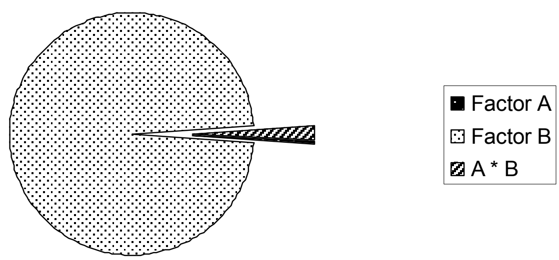

Figure 1. Power of factors influence on the total N concentration

Total N of soil was subjected to dynamic changes averaged for the entire 4 m depth. In this index the differentiation between the variants was very well expressed, similarly to total C (Nankova, 2011; Nankova et al., 2011). Its amount was lowest in the variant with independent nitrogen fertilization with 180 kg N/ha (Table 2). The established nitrogen content differences in the 0-400 cm layer in the check variant, in the variants with independent N fertilization with moderate and optimal N norms and in the variant $N_{180}P_{60}K_{60}$ were significantly smaller. Therefore they were separated into a group with well expressed similarity, with higher total N content than the variant with 40 years of systematic independent nitrogen fertilization. The variant with systematic P fertilization with 180 kg P_2O_5/ha was characterized with higher total N content averaged for the entire profile than the variants with independent N fertilization, but the results showed presence of similarity with them.

Table 2. Soil nitrogen concentration according to the fertilizer variants averaged for 0-400 cm soil profile, mg/100 g soil (Waller-Duncan N=42)

Fertilizer variants	Value	Groups
$N_0P_0K_0$	67.3	bc
$N_{60}P_0K_0$	68.3	cd
$N_{120}P_0K_0$	67.8	bcd
$N_{180}P_0K_0$	64.1	a
$N_0P_{180}K_0$	69.0	de
$N_{60}P_{180}K_0$	70.1	e
$N_{120}P_{120}K_{120}$	71.7	f
$N_{180}P_{60}K_{60}$	66.4	b

The systematic introduction of $N_{120}P_{120}K_{120}$ had most significant contribution for soil nitrogen enrichment average for the 0-400 cm layer. A similar tendency was established for dressing with $N_{60}P_{180}K_0$ but this variant formed a lower level group than the systematic balanced introduction of NPK at norm 120 kg/ha. Most probably very good conditions for microbiological activity had been created in these variants, i.e. almost neutral soil reaction, better soil structure ensuring more efficient aeration, water and nutrients supply, which contributed for improving of the soil nitrogen regime.

The distribution of the total N content after long-term mineral fertilization averaged for the fertilizer variants by the layers and meters down the soil profile showed interesting results (Table 3). The soil layers of the 1st meter had highest potential nitrogen-supplying capacity. The differentiation between the layers forming this meter was very well expressed.

Table 3. Soil nitrogen content by layers up to 400 cm depth average for the fertilizer variants (mg/100 g soil) Waller-Duncan N=16

1st meter		2nd meter		3rd meter		4rd meter	
Depth cm	Value/ group	Depth cm	Value/ group	Depth cm	Value/ group	Depth cm	Value/ group
0-20	167.5 k	100-120	65.8 f	200-220	38.4 bc	300-320	38.8 bc
20-40	156.4 j	120-140	49.5 e	220-240	37.6 bc	320-340	39.3 c
40-60	131.6 i	140-160	45.3 d	240-260	33.6 a	340-360	37.2 b
60-80	109.9 h	160-180	39.5 c	260-280	32.9 a	360-380	38.2 bc
80-100	94.0 g	180-200	37.6 bc	280-300	34.6 a	380-400	34.7 a

Total N content in the layer 0-20 cm was highest and gradually decreased from 167.5 mg N/100 g soil to 94.0 mg N/100 g soil in the 80-100 cm layer. Regardless of the of the fertilizer variants, the average total N content in the 1st meter was 131.85 mg N/100 g soil. Highest total N content was established at fertilization with $N_{120}P_{120}K_{120}$ not only in the surface layer but down the soil layers in the 1st meter – an average of 142.65 mg N/100 g soil (Figure 2).

Annual fertilization only with 180 kg N/ha lead to decreasing of the total N content averaged for the 1st meter layers (120.61 mg N/100 g soil). The results were lower than that of the control variant. Highest mean concentration of N_{total} in the first meter was determined after systematic fertilization with $N_{120}P_{120}K_{120}$ (142.65 mg N/100 g soil). The main reason for this fact is the higher concentration of nitrogen in the layers up to 60 cm depth.

In the layers forming the 2nd meter (beginning of loess horizon) total N content decreased still further. Its average content was 47.55 mg N/100 g soil and varied from 65.84 (100-120 cm) to 37.62 (180-200 cm). The $N_{180}P_0K_0$ variant had lowest content of total N among all tested variants. The differentiation between the fertilizer variants remained the same, although at a lower level. The mean values of the tested fertilizer variants for the second meter varied from 42.43 mg N/100 g soil ($N_{180}P_{60}K_{60}$) to 56.25 mg N/100 g soil ($N_0P_{180}K_0$). The systematic independent nitrogen fertilization with moderate and high norms, as well as the combination $N_{180}P_{60}K_{60}$ lead to decrease of the mean content of total nitrogen in the second meter in comparison to the check variant. The mean value of total nitrogen content in the second meter was 33.8% from the value determined for the first meter.

Along the soil profile, the sub-depths forming the 3rd meter had lowest total N content among the tested meters. Regardless of low average N content (35.39 mgN/100 g soil) in this meter differentiation between fertilizer variants is still expressed. Long-term fertilization with $N_{180}P_0K_0$ and $N_{180}P_{60}K_{60}$ caused strongly decreasing of N content comparing with other variants.

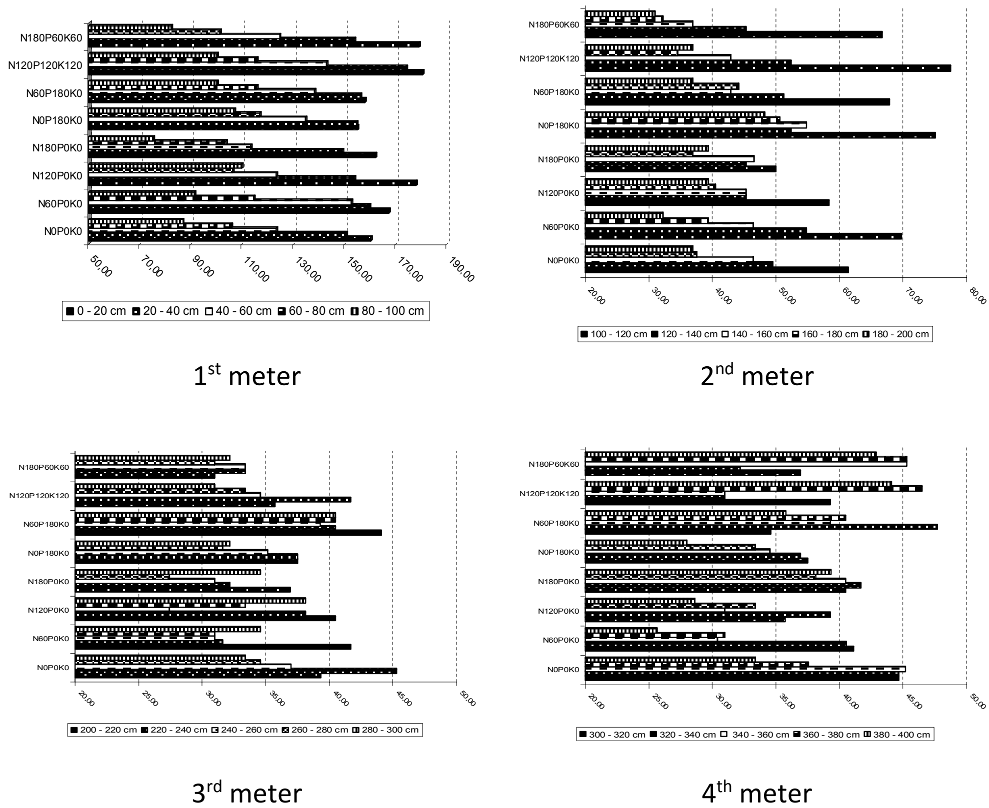

Figure 2. Total N content according to the fertilizer variants by meters, mg N/100 g soil

The variants with the participation of the highest nitrogen norm had lower mean content of total nitrogen in the third meter. From all fertilizer variants, only at systematic fertilization with $N_{60}P_{180}K_0$ the mean concentration of total nitrogen in soil exceeded the values determined for the check variant. The mean content of total nitrogen in the third meter was 26.8% from the value established in the first meter, and 74.4% from the value of the second meter.

The layers comprising the 4th meter had higher total N content in comparison to the 3rd meter, and the differentiation in its content depended on the applied fertilization variant. Its average content was 37.63 mg N/100 g soil and varied from 39.26 (320-340 cm) to 34.72 (380-400 cm) average for the fertilizer variants. The differentiation affected by the fertilization variant and layers was found in this zone.

At this depth the check variant had highest mean content of total nitrogen. The variants with systematic introduction of the highest nitrogen norm were closest to it. The combined mineral fertilization with NP and NPK lead to higher concentrations of total nitrogen in the layers 360-380 cm and 380-400 cm in comparison to the check variant. Some increase of 6.3% was observed in the concentration of total nitrogen in the fourth meter according to the value established in the third meter. The mean content of total nitrogen in the fourth meter was 28.5% from the content in the first meter.

The systematic introduction of macro elements at different norms and ratios during a period of 40 years of cultivation of the trial field lead to formation of different reserves of total nitrogen in soil at depth up to 60 cm with well expressed differentiation (Figure 3). The long-term two-field agricultural use of the trial field without mineral fertilization was characterized with lowest reserves of total N. The independent nitrogen fertilization with increasing norms caused their increase according to the control variant with 14.3%, 10.6% and 6.8% respectively. Highest reserve in absolute values at the moment of taking samples was found in the variants with 40-year fertilization with $N_{120}P_{120}K_{120}$ and $N_0P_{180}K_0$. The main reason for this fact is that besides the variation in the content of total C, respectively humus, variation in the values of the other component was found when determining reserves – volume density of soil. According to Yankov (2007, personal communication), highest values of volume density averaged for the 0-60 cm layer were demonstrated by the variant with systematic introduction of phosphorus (180 kg/ha) – 1.43 g/m^3, and lowest mean values – by the variant with $N_{180}P_{60}K_{60}$ (1.22 g/m^3).

There was a clear negative effect of independent fertilization with $N_{180}P_0K_0$ on total nitrogen, which is one of the stable indicators of soil fertility. The mean decrease according to the control variant was with 4.8%. Highest enrichment of soil with total nitrogen along the entire investigated depth was found after fertilization with $N_{60}P_{180}K_0$ (4.1%) and $N_{120}P_{120}K_{120}$ (6.6%).

The differentiation in the values of total nitrogen along the entire profile was well expressed, the changes in the 1st meter being most dynamic. Lowest total nitrogen content was detected in the 3rd meter.

All fertilizer variants at depth up to 60 cm had positive N balance according to the control variant. As a result from the systematic mineral fertilization in the 20-40 cm layer, higher reserves were formed by the layers lying above and below. Long-term independent nitrogen fertilization with medium and high norms caused negative N balance in 40-60 cm layer.

The triple NPK balanced combination ($N_{120}P_{120}K_{120}$) enriched the nitrogen reserves to a maximum degree according to the other variants (with 22.4%).

Over 36% of the total nitrogen reserves in soil at depth up to 60 cm were concentrated in the 20-40 cm layer, followed by the layer lying beneath (Table 4). Regardless of the low differentiation in the content of total N down the soil profile up to the 60th cm, the differentiation of the layers according to their reserves was very well expressed. Nitrogen reserves in soil averaged for the tested variants were highest in the 20-40 cm layer. All fertilizer variants at depth up to 60 cm had positive N balance according to the control variant.

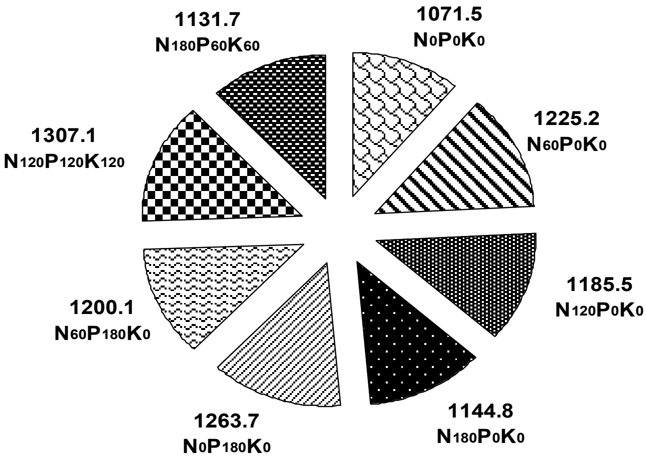

Figure 3. Total Nitrogen reserves in layer 0-60 cm, N g/m^2

The maximum increase according to the check variant in the 0-20 cm layer was established in the variants with $N_{120}P_0K_0$, $N_{180}P_0K_0$ and $N_0P_{180}K_0$ (about 13%). Nitrogen reserves in all tested fertilizer variants in the 20-40 cm layer exceeded the check variant with 110.9% ($N_{180}P_{60}K_{60}$) to 132.4% ($N_{120}P_{120}K_{120}$). The long-term independent nitrogen fertilization with moderate and high norms caused negative N balance in the 40-60 cm layer. Averaged for the investigated fertilizer variants, the increase of the established reserves of total nitrogen at depth up to 60 cm exceeded the reserves in the check variant with 12.8%.

Table 4. Increase of N reserves by depth up to 60 cm according to the check, %

Soil depth, cm	$N_0P_0K_0$	$N_{60}P_0K_0$	$N_{120}P_0K_0$	$N_{180}P_0K_0$	$N_0P_{180}K_0$	$N_{60}P_{180}K_0$	$N_{120}P_{120}K_{120}$	$N_{180}P_{60}K_{60}$
0 – 20	100.0	101.2	113.4	113.4	113.3	102.4	110.7	100.0
20 - 40	100.0	115.5	122.0	114.4	126.2	126.7	132.4	110.9
40 - 60	100.0	129.7	93.8	89.6	114.1	107.0	124.1	106.6

The correlations between the content of total nitrogen in the soil averaged for the tested variants of the trail at depth up to 400 m with the content of total carbon and the group and fraction composition of the organic substance in soil were strongly expressed (Table 5). Highest values of the investigated correlations of total nitrogen were determined with total carbon, with the total humus substances and with carbon in the insoluble residue. The correlation of total nitrogen and carbon with the humin acids was better expressed than the correlation with the fulvic acids.

Most of the correlations with the respective ratios in the fraction composition of the organic substance were also highly significant. Insignificant were only the ratios THS/TC and Humin/TC.

Table 5. Correlations of total nitrogen content with the organic substance of soil at 0-400 cm averaged for the tested variants

With percent of carbon by groups and fractions									
Total C (TC)	C in THS	C_{HA}	C_{FA}	C_{HA}/C_{FA}	C_{HA} with R_2O_3	C_{HA} with Ca	C_{Humin}	C_{AFA}	
0.988 (**)	0.969 (**)	0.960 (**)	0.716 (**)	0.437 (**)	0.916 (**)	0.918 (**)	0.965 (**)	0.665 (**)	
With the respective ratios									
AFA/TC	THS/TC	HA/THS	FA /THS	HA_{R2O3}/HA	HA_{Ca}/HA	Humin/TC	HA/TC	$C_{org}/C_{residue}$	C/N
-0.581 (**)	-0.006^{NS}	0.409 (**)	-0.409 (**)	-0.195 (**)	0.195 (**)	0.006^{NS}	0.256 (**)	-0.136 (*)	0.581 (**)

THS – Total humic substances; HA – Humic acids; FA- Fulvic acids; AFA- Aggressive fulvic acids

Conclusions

The systematic mineral fertilization applied for 40 years with different norms and at different ratios between nitrogen, phosphorus and potassium affected significantly the content of total nitrogen of slightly leached chernozem (Haplic Chernozems) down the soil profile.

The content of total nitrogen in soil decreased down the investigated profile (0-400 cm) with 167.44 mg N/100 g soil averaged for the layer 0-20 cm to 32.86 mg N/100 g soil averaged for the layer 260-280 cm. Most dynamic changes in the concentration of total nitrogen of soil occurred in the first meter. Its mean content was highest at systematic balanced introduction of nitrogen, phosphorus and potassium at norm 120 kg/ha both in the first meter and for the entire investigated depth. The increase according to the check variant was with 13.9% and 5.8%, respectively.

The use of the aggressive nitrogen norm of 180 kg/ha, independently and in combination with phosphorus and potassium (N:P:K=3:1:1) caused decrease of the total nitrogen of soil at high depth down the profile.

The formed reserves of total nitrogen by layers to depth of 60 cm varied significantly. The mineral fertilization, regardless of the type, norm and ratio of nitrogen, phosphorus and potassium ensured a positive balance of nitrogen in soil according to the check variant, averaged for the investigated depth. The reserve of total nitrogen was highest at systematic fertilization with $N_{120}P_{120}K_{120}$. Along the vertical axis, the greatest part of the reserve was concentrated in the 20-40 cm layer (36.3% from the total). The 40-60 cm layer had lowest mean reserve (28.2% from the total) and its values strongly decreased at systematic nitrogen fertilization with norms 120 and 180 kg/ha.

The correlations of total nitrogen content in soil with the amount of total carbon and with the composition of the soil organic substance had high statistical significance.

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Preliminary communication

Effect of wastewater leakage from carbonate and bicarbonate factory on some soil quality parameters

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Abstract

Accident waste water seepage from carbonate and bicarbonate factory in East Azarbaijan affected about 700ha of arable land. This study was conducted to study effects of this event on soil properties. For this purpose in three topic zones (zone 1, zone 2, and zone 3 soil samples was prepared from two depth 0-30 cm and 30-60 cm. The results of chemical soil analysis showed that waste water seepage from this factory extremely increased electrical conductivity (EC), sodium adsorption ratio (SAR), concentrations of Cl^-, Ca^{2+} and Mg^{2+}, in soil for all three studied zones. All studied zones classified in saline soils even one of the zones (zone 1) was became sodicity. Whereas physical soil analysis showed that these characteristics showed no limitation for plant growth. Despite this, undesirable chemical condition in soil caused that elimination of vegetation and trees in polluted area.

Key words: leakage, carbonate, electrical conductivity, SAR, saline soil, sodic soil.

Introduction

Industrial waste water leakage is one of the most important soil and water pollutants in many parts of the world. Accurate discharge waste water of industrial factories for prevent of environmental pollutions is vitally and necessary (Kieth and Telliard, 1979). The rules that are ordered in vicinity of these factories in order to control contaminant levels must be applied indiscriminately by these factories (Kieth and Telliard, 1979). Sometimes, regardless to this problems by factories` ownerships leading to sully these areas and extinction of high status of agricultural lands. Example of this problem was happened in vicinity of the one of the carbonate and bicarbonate factories in East Azarbaijan state of Iran. Water waste leakage from this factory destroyed 700 ha of fertile agricultural lands and gardens in this area. Necessity of amendment these area and reclamation of these lands are essential and undeniable. Because of high width of polluted area and farmer unemployed in these zones Regardless to this problem may create economical instability and social- cultural difficulties. The objective of this study was to investigation effects of water waste leakage from this factory on chemical and physical soil characteristics in vicinity of factory.

Materials and Methods

In order to study of the effects of water waste leakage on soil characteristics in vicinity of carbonate factory in three topic zones (zone 1, zone 2, zone 3) from two depth of soil (0-30 and 30-60) samples were prepared. These samples were air dried and ground to pass through <2 mm sieve. And analyzed for chemical and physical properties. The electrical conductivity (EC_e), pH, Sodium adsorption ratio (SAR), C.C.E%, soil texture, O.C% and concentrations of HCO_3^-, Cl^-, SO_4^{2-}, Ca^{2+}, Mg^{2+} and Na^+.

Results

Results of soil chemical characteristics in experimental sites were summarized in Table 1. In all regions EC_e, High Concentration of chloride and sulfate anions and Ca^{2+} and Mg^{2+} cations are higher than plant tolerance in this area and act as limited factors for plant growth. The soils of polluted area classified as extremely saline soils. High ECe in these saline soils can by decreasing the osmotic potential and damage cell membrane of plants and remove them. High concentration of Above mentioned anions and cations are toxic, and by increasing the solute suction, reduce the availability of soil water to plants (Tisdal et al, 1993).

Table 1. Some chemical and physical soil characteristics in different depth at polluted zones

depth	EC_e	pH	C.C.E	O.C	Sand	Silt	Clay	HCO_3^-	Cl^-	SO_4^{2-}	Ca^{2+}	Mg^{2+}	Na^+	SAR
cm	ds/m					%				meq/l				
							Zone 1							
0-30	15.2	6.5	-	0.64	64	28	8	1.5	2130	433	1680	100	788	6
Crust	15.39	7.1	-	0.41	26	70	4	2.75	2206	320	1580	100	858	30
							Zone 2							
0-30	16	6.6	15.3	0.89	32	56	12	1.4	2520	320	1380	140	146	5.3
30-60	11.29	6.7	4.75	0.52	74	16	10	2.6	1420	87	1100	250	49	1.9
							Zone 3							
0-30	10.24	6.8	10	0.41	66	26	8	3.6	1330	642	920	1000	56.1	1.8
30-60	10.48	6.8	3.5	0.64	70	22	8	2.4	1170	89	960	120	51	2.2

High concentration of Na^+ in depth 0-30 cm ,787.5 meq/l , and in surface crust 857.5 meq/l in region increase the alkaline risk. Future problems of this region will soil dispersion and decrease soil permeability and infiltration rates (Lauchli and Epstein, 1990). Soil texture had no limitation for crop production.

Investigation of polluted zones showed that content of pollution in this area is extremely high and improper selected situation for this industrial unit accompanied regardless to purify waste water in this factory damaged dramatically to farmers and settlement in these areas.

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Original scientific paper

Soil erosion status in Iran and clay minerals influence on soils interrill erodibility factor (a case study: Dasht-e-Tabriz)

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Abstract

Based on some estimation soil erosion in Iran is widespread problem (70% of the country) and susceptibility of the soils to erosion is mostly due to low organic matter, clay percentage, kind of clay, etc) and mismanagement of land has accelerated. For this reason, real estimation of different kind of clay influence on soils interrill erodibility factor is required for sustainable management. Clay with a wide variety of physical properties plays an important role in the soils and their erodibility. In order to investigate the effect of clay minerals on soil erodibility, this research work carried out on surface layer samples of eleven soil series with different families. After mineralogical analysis, the type and relative amount of clay minerals in each soil were determined based on qualitative and semi-quantitative methods. According to Pearson correlation coefficient, there is positive and significant correlation between soil erodibility and smectite groups, while quartz, kaolinite- chlorite and chlorite-vermiculite showed negative and significant correlation whit erodibility. Consequently there is a linear correlation $(\mathrm{k_i} = 735323.79 + 45427.913\ \mathrm{Smectite} \quad \mathrm{R} = 0.76)$ between erodiblity and minerals based on stepwise multiple regressions in these soils. Also there is between clay, sand, saturation percentage, SAR and erodibility significant correlation (P<0.01) while silt, $CaCO_3$ and pH show lower one (P<0.05).

Key words: Minerals, Erodibility, Semi-quantitative , Correlation coefficient, Dashte-e-Tabriz

Introduction

Land degradation, in the form of soil erosion and nutrient depletion threaten food security and the sustainability of agricultural production in many developing countries. It is also estimated that more than 70% of the total area in Iran is exposed to soil erosion which gives a total amount of 1 to 2 billion cubic meters sediment per year and is increased by l0 tons/hectares/ year in comparison of the last l0 years. The susceptibility of the soils to erosion is mostly due to low organic matter, clay percentage, kind of clay, etc) and mismanagement of land has accelerated. Therefore survey of the present state and its accelerated factors are important for development of the country. One of the most important factors is soil erodibility, which affected by texture, structure, organic matter, infiltration rate, content and type of clay minerals in soils (Wischmeier and Smith, 1978). Lado and Ben-Hur (2004) reported that soil mineralogy, has substantial effects on clay dispersion and also influence aggregate stability, runoff, seal formation and soil loss. The mineralogical compositions of soils have a particular influence on the erodibility of soils in dry climatic conditions (Reichert and Norton, 1994). Imeson et al. (1982) believe that in marly lands area in which physical and mineralogical properties are the main factors controlling the shape and form of erosion. Stern et al. (1991) concluded that soil mineralogy has important effect on aggregate stability and capability of soil in seal formation. Singer (1994) reported decreasing aggregate stabilities with increasing smectite and inversely with kaolinite content. Wakindiki and Ben-Hur (2002) believed the soils contains smectite in contrast the soils contains kaolinite have more susceptible to water erosion. Romkesn et al. (1995) found that the presence of highly expansive smectite clay in the soil caused a rapid reduction in infiltration rate despite the high organic matter contents and coarse texture of the soil; this indicated the importance of soil mineralogical constituents for crust development. The results obtained by researches in Iran (Khormali & Abtahi, 2003; Abbaslou and Kormali, 2007; Rezapour et al., 2009) revealed the occurrence of kaolinite, chlorite, illite, palygorskite, smectite, quartz and interstratified minerals which are the dominant clay minerals in both soil and rock samples. The presence of illite, chlorite abundance could be attributed to the parent rock samples and inherited origin. Interstratified minerals of chlorite-smectite or illite-smectite are observed in clay fraction of soils.The soil available moisture plays the major role in the distribution pattern of palygorskite and smectite clay minerals in arid and semiarid areas. Also the occurrence vermiculate in the calcareous soils is mainly related to its lower stability under high pH, low Al activity and the presence of large amounts of Si and Mg in soils. According to many researchers results, such as Elliot et al. (1989) increased clay content lead to increased aggregate stability and decreased erosion, but Ahmadi (2010) in his research found the positive correlation between interrill erodibility and clay content and also Udeigwe et al. (2007) reached to the similar results, they expressed it may be difference of clay mineralogy. However clay mineralogy in comparing with other features has got less attention. The objective of present study is not only identification of different species of clay minerals, but also determines their effect and correlation with soil interrill erodibility factor in the study area.

Material and Methods

The study was carried out on soils of Dasht-e-Tabriz area (~ 92,600 ha) in the north west of Iran, which has located between 45° 28' to 46° 14' E longitude and 37° 56' to 38° 17' N latitude in East Azerbaijan Province. The area mainly characterized by the diversity of different materials, such as marl, gypsum, and salts with high erodibility and special effect on soil quality and water sources. The present climate of region is a Mediterranean type, with hot dry summers, cold and wet winters and temperate autumn and spring with highly seasonal precipitation. The average annual precipitation is 328 mm, with mean minimum and maximum temperate of -1.9ºC and 25.1ºC respectively. Also according to Newhall software results the soil moisture and temperature regimes of the region are Xeric border to Aridic (weak aridic) and Mesic. Soils were selected based on different series used by Ahmadi (2010) research in the region (Table 1). Samples from surface horizons (A or Ap) of 11 series were selected and analyzed for physicochemical properties and clay mineralogy. The practical size distribution was determined by the hydrometer method (Klute, 1992), organic matter (Walkey and Black, 1934), CCE (Nelson, 1982), CEC (chapman, 1965), gypsum (Bower, 1982; Soil Conservation Service, 1992), and soil pH and EC were determined in saturated paste and saturated extract respectively.

For mineralogical analysis clays separation was achieved by sedimentation of dispersed soil materials. Prior to mineralogical analysis, samples (<2mm) were treated with 1 M sodium acetate and buffered at pH 5 to remove carbonate. The H_2O_2 (30%) and Na-dithionite-citrate- bicarbonate were used to oxidize organic matter and remove Fe oxides, respectively (Kunz, 1986; Mehra and Jackson, 1960). Sand was separated from silt and clay by wet sieving and clay by centrifugation and decantation. The <2 µm fraction was treated with Mg- saturation, Mg-saturation plus gleyserol-saturation, K-saturation and K-saturation and heating at 550ºC. X-ray diffraction (XRD) patterns of oriented clay were obtained using a Ziemens 1D-500 diffract meter employing a Ni-filtered Cu- Kα source. Samples were scanned from 2 to 30º 2θ, at a scan speed of 2º 2θ/ min with a 2 s time constant.

Statistical analysis of the experimental data was accomplished using the SPSS software package (SPSS Inc., 2007). Also normality analysis of the data distribution using Kolmogorov-Smirnov test and correlation analysis by Pearson correlation coefficient were carried out.

Results and Discussion

The studied soil series (Table 1) were all calcareous with a relatively large clay content, in the range of 11- 50.2 %, which led to considerable variability in soil characteristics, especially, clay minerals (Table. 2 and figures 1-11). The XRD data for clay fractions of the studied soils showed (figures 1-11) that the clay minerals species were mainly illite, smectite, quartz, cholorite and kaolinite. Their relative abundance differences (Table.3) reflecting dynamic and variable soil environments with their properties. Smectite is characterized by the d value of 18 Aº in the glycerol-treated samples. The 10 Aº peak in the Mg-treated samples showed the presences of illite. The 14 and 3.3 Aº peaks that was unchanged by any treatments identified chlorite and quartz respectively and the presence of kaolinite was characterized by disappearance of the 7.0 Aº peak for the K-550ºC treatment.

According to the X-ray diffraction results and relative amounts of minerals from semi-quantitative analysis with their interrill erodibility factor (Ki) estimated by Ahmadi (2010), in soils with high erodibility rate, smectite minerals are dominant in comparison with soils that have low erodibility rate with dominant minerals of quartz, kaolinite and chlorite (Table 4).

Normalizing the data by the Kolmogorov-Smirnov test, for Pearson correlation coefficient, showed significant correlation between clay minerals and interrill erodibilty factor (Table. 5). Based on obtained results, smectite has positive and significant correlation while quartz has negative and significant correlation with interrill erodibility factor (P< 0.01), which confirm other researches (Romkens et al. 1995; Mermut, 1997) results about positive and significant effect of smectite and negative effect of quartz (Bain, 1977).

Table 1. The series and families of studied soil

Soil Series	Family
Aji Chay	Fine loamy, mixed, superactive, calcareous, mesic, Xeric Torrifluvents
Sofian	Fine, mixed, semiavtive, mesic, Xeric Haplocambids
Baranlo	Fine, mixed, mesic, Xeric Haplocambids
Koja Abad	Fine, mixed, active, calcareous, mesic, Xeric Torrifluvents
GHaramolk	Fine, mixed, mesic, Xeric Natrargids
Zeynab	Coarse loamy, mixed, calcareous, mesic, Xeric Torriorthents
SHabestatar	Coarse loamy over sandy skeletal, mixed, calcareous, mesic, Xeric Torriorthens
Satelo	Clayey over sandy, mixed, super active, calcareous, mesic, Xeric Torrifluvent
Tazeh Kand	Fine loamy, mixed, active, calcareous, mesic, Xeric Torriorthents
SHand Abad	Fine loamy, mixed, calcareous, mesic, Xeric Torrifluvents
Kozeh Kanan	Coarse loamy, mixed, active, calcareous, mesic, Xeric Torriorthents

Table 2. The physical and chemical properties of studied soils

Soil series	depth cm	Sand (%)	Silt (%)	Clay (%)	Texture class	SP (%)	EC (dS m^{-1})	pH	OM (%)	$CaCO_3$ (%)	Gypsum (%)	SAR	CEC (cmolc (+)/kg)
Aji Chay	0-30	29.6	44.8	25.6	L	52.4	1.7	7.9	2.42	25.7	0.2	7.8	22.4
Sofian	0-25	6.5	47.5	46	SiC	67.5	0.9	7.8	1.38	18.5	0.2	5.3	43.1
Baranlo	0-23	9.2	40.6	50.2	C	69.08	8.18	7.99	0.72	21.3	0.03	34.72	25.6
Koja Abad	0-25	23.2	41.6	35.2	CL	44	1	8	1.56	14.9	0.1	6.7	18
Gharamolk	0-25	26.7	41.5	31.9	CL	36.37	1.35	7.95	0.67	18.4	0.21	4.75	17.5
Zeynab	0-25	64	25.1	11	SL	24	2.3	7.9	2.9	12.4	0.2	3.2	14.8
Shabestatar	0-25	46.5	32.5	21	L	29.9	4.7	7.5	1.56	12.5	0.1	1.3	16.5
Satelo	0-20	13.5	48.1	38.4	SiCL	57	8.6	7.8	0.8	20.0	-	22.5	21.5
Tazeh Kand	0-30	59.7	24.6	15.7	SL	24.5	1.8	7.7	3.64	10.7	0.2	2	17.8
Shand Abad	0-25	47.8	29.8	22.4	L	25.85	1.72	7.79	1.02	12.6	0.13	5.49	20.7
Kozeh-Kanan	0-30	37.8	42.8	19.6	L	23.07	2.18	7.83	0.95	20.1	0.21	4.82	15.3

L: Loamy, C: Clay, SiC: Silty clay, CL: Clay loam, SL: Sandy loam, SiCL: Silty clay loam OM: organic matter, EC: electrical conductivity, CEC: cation exchange capacity, SAR: sodium adsorption ratio

Also mixture of chlorite -vermiculite minerals have a negative and significant correlation whit interrill erodibility factor (P<0.05), while chlorite, vermiculite and kaolinite have low dispersion capability (Van Olphen, 1977). Therefore the results show a linear correlation ($k_i = 735323.79 + 45427.913\ \mathrm{Smectite}, R^2 = 0.76$) between interrill erodibility factor and minerals species with respect to Stepwise multiple regressions. A wide variation in soil physiochemical properties and clay minerals corresponding to variation in their interrill erodibility factors (Table 6). Pearson correlation coefficient between SAR, SP and clay content with interrill erodibility factors showed a positive and significant correlation (P<0.01) which confirm Udeigwe et al. (2007), Ahmadi (2010) results and Williams et al. (1983) idea about presence of plentiful expansible (2:1) clay minerals with high tendency for moisture absorption. Also according to finding of levy et al (1995) increasing of SAR cause greater dispersion and soil loss that confirm this study results. There is a negative correlation between Ki and sand (P<-0.01) that indicate resistance of sand particle to erosion (Reichert et al. 2009). Based on Gunn et al. (1988) research, with increasing of silt content, erodibility become high which refers to obtained results in soils with large amount of silt in the present study (P<0.05). In addition there is a positive and significant correlation between calcium carbonate and soil erodibility (P<0.05), which Merzouk and Black (1991) have reported the high relative erodibility of the calcareous soils that partly attribute to the occurrence of $CaCO_3$ in the silt size fraction.

Table 3. The relative amounts of clay minerals in clay fraction of soils

Minerals Soil series	IL (%)	Q (%)	Sm (%)	Ka-Ch (%)	Ch-Ver (%)
Aji Chay	35	20	25	15	5
Sofian	55	20	10	10	5
Baranlo	35	15	40	10	-
Koja Abad	35	15	25	20	5
Gharamolk	40	20	30	10	-
Zeynab	30	40	-	20	10
Shabestatar	30	35	15	15	5
Satelo	30	15	40	15	-
Tazeh Kand	40	20	-	25	15
Shand Abad	40	25	10	25	-
KozehKanan	30	20	15	25	10

IL: illite, Sm: smectite, q: quartz, Ka-Ch: Kaolinite-Chlorite, Ch-Ver: chlorite-vermiculite

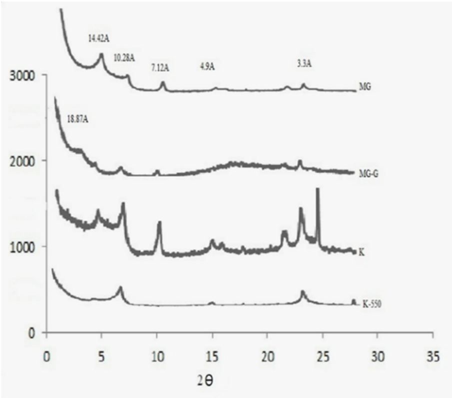

Figure 1. X-ray diffractgram of clay fraction from surface layer of Aji chay soil

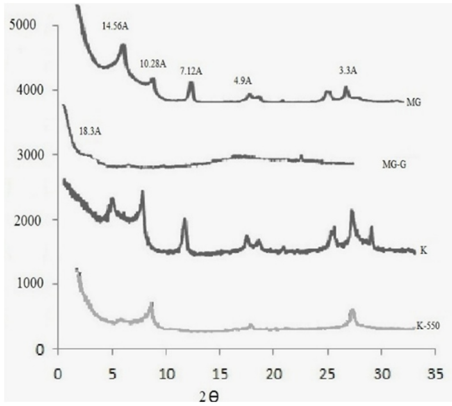

Figure 2. X-ray diffractgram of clay fraction from surface layer of Sofian soil

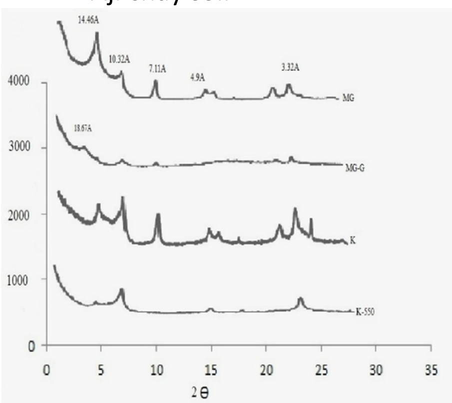

Figure 3. X-ray diffractgram of clay fraction from surface layer of Baranlo soil

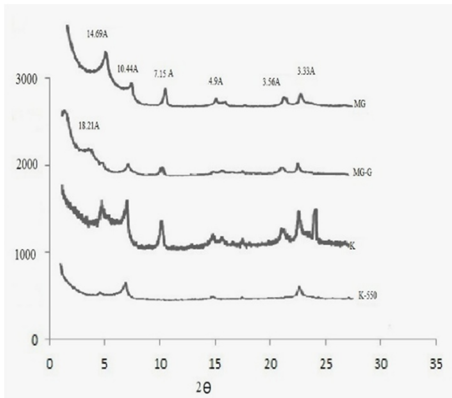

Figure 4. X-ray diffractgram of clay farction from surface layer of Koja abad soil

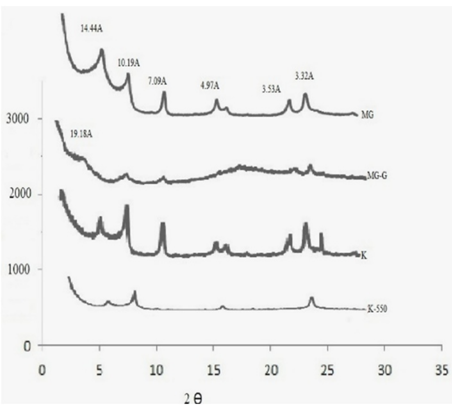

Figure 5. X-ray diffractgram of clay fraction from surface layer of Gharamolk soil

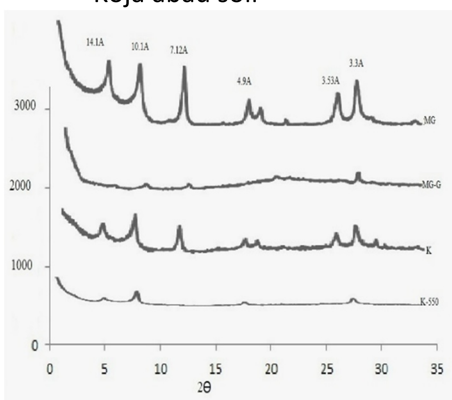

Figure 6. X-ray diffractgram of clay fraction from surface layer of Zeynab soil

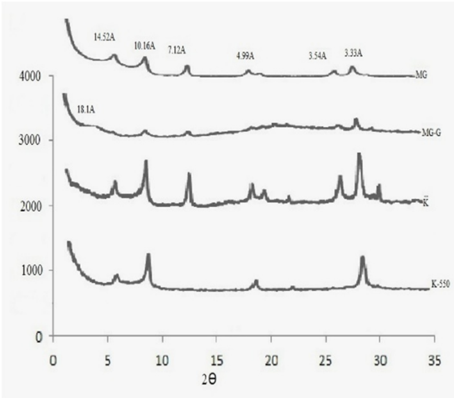

Figure 7. X-ray diffractgram of clay fraction from surface layer of Shabestar soil

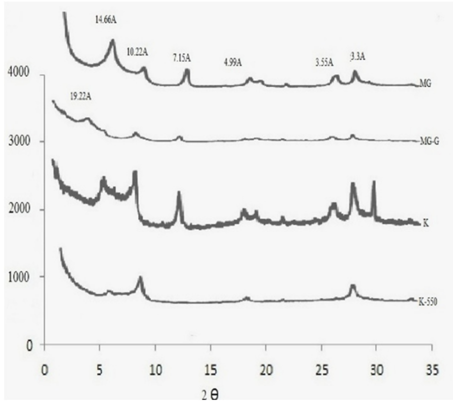

Figure 8. X-ray diffractgram of clay fraction from surface layer of Satelo soil

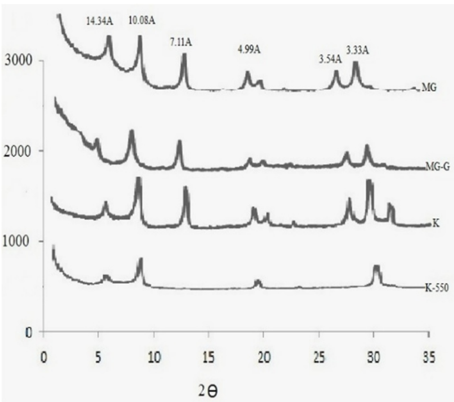

Figure 9. X-ray diffractgram of clay fraction from surface layer of Tazeh kand soil

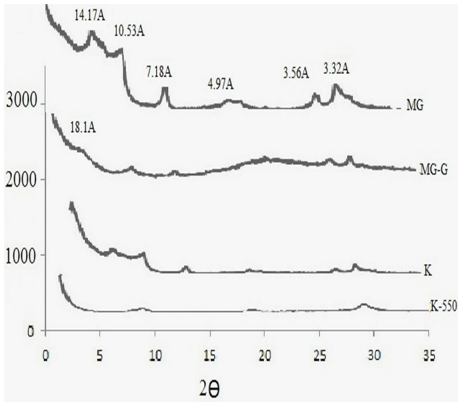

Figure 10. X-ray diffractgram of clay fraction from surface layer of Shand abad soil

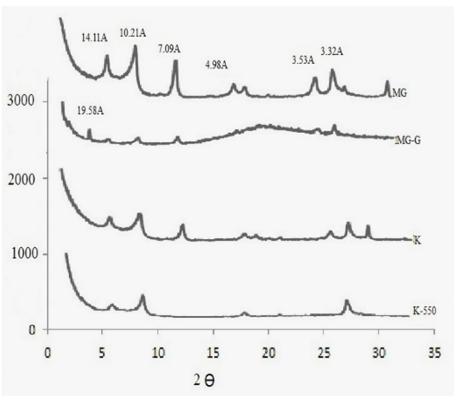

Figure 11. X-ray diffractgram of clay fraction from surface layer of Kozeh kanan soil

Table 4. Interrill erodibility factors and dominant clay minerals of soil series

Soil series	Minerals dominant	K_i (kg s m^{-4})	Soil series	Minerals dominant	K_i (kg s m^{-4})
Aji Chay	IL & Sm	1966691.058	Zeynab	Q	615192.1516
Sofian	IL	1540694.87	Shabestatar	Q & IL	8547376.4289
Baranlo	Sm & IL	2984929.921	Satelo	IL & Ka- Ch	865958.8717
Koja Abad	IL & Sm	2412283.384	Tazeh Kand	IL, Ka-Ch & Q	1291248.202
Gharamolk	IL & Sm	1721875.355	Shand Abad	IL & Ka- Ch	1187013.927
Zeynab	Sm & IL	2187799.209			

IL: illite, Sm: smectite, q: quartz, Ka-Ch: Kaolinite-Chlorite, Ch-Ver: chlorite-vermiculite, Ki : interrill erodibility factors

Finally, the results showed a positive and significant correlation between pH and Ki which is probably affected by presence of variable charge minerals and organic matter (Goldberg and Glaubig, 1987).

Conclusion

It is apparent from this study that soils with different relative amount and species of clay minerals and physical, chemical properties exhibit different correlation with soil interrill erodibility factor in all parts of Iran with different kinds of minerals(Khormali and Abtahi, 2003; Abbaslou and Kormali, 2007; Rezapour,et al. 2009). According to obtained results, soils with minerals such as quartz, kaolinate and chlorite are resistance to erodibility and in contrast soils with smectite minerals are susceptible to erosion. Therefore soils with faster infiltration rate, higher level of organic matter, developed soil structure, high sand content and so quartz and kaolinite minerals have a greater resistance to erosion in compression with soils that have higher content of silt, SAR, SP, with smectite minerals.

Table 5. Correlation coefficient between clay minerals and erodibility factors (K_i)

Parameters	K_i(kg s m^{-4})	IL	Sm	Ka-Ch	Ch-Ver	Q
IL	0.036					
Sm	0.872**	-0.225				
Ka-Ch	-0.509	-0.297	-0.587			
Ch-Ver	-0.653*	-0.019	-0.706*	0.484		
Q	-0.772**	-0.261	-0.652*	0.188	0.295	

IL: illite, Sm: smectite, q: quartz, Ka-Ch: Kaolinite-Chlorite, Ch-Ver:chlorite-vermiculite, K_i : interrill erodibility factors, * and ** mean significant at the 0.01 and 0.05 level.

Table 6. values correlation coefficient between physicochemical properties and interrill erodibility factor

Parameters	K_i	Clay	Sand	Silt	SP	OM	pH	EC	CEC	SAR
Clay	0.836**									
Sand	-0.824.**	-0.955**								
Silt	0.667*	0.730*	-0.899**							
SP	0.786**	0.919**	-0.926**	0.783**						
OM	-0.591	-0.725*	0.764**	-0.692*	-0.553					
pH	0.631*	0.396	-0.402	0.349	0.374	-0.214				
EC	0.454	0.407	-0.356	0.211	0.43	-0.354	-0.077			
CEC	0.39	0.736**	-0.698*	0.529	0.755**	-0.351	0.162	0.016		
SAR	0.799**	0.798*	-0.625*	0.405	0.705*	-0.452	0.407	0.827**	0.203	
$CaCO_3$	0.632*	0.525	-0.692*	0.824**	0.71*	-0.424	-0.083	0.258	0.281	0.504

* and ** mean significant at the 0.01 and 0.05 level

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Original scientific paper

Natural Radioactivity in virgin soils and soils from some areas with closed uranium mining facilities in Bulgaria

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Abstract

It is necessary to study the natural radioactivity levels in soil to assess the dose for the population in order to know the health risks and to have a baseline for future changes in the environmental radioactivity due to human activities. The natural radionuclide (^{238}U, ^{226}Ra **and** ^{232}Th) contents in soil were determined for three different regions in the country using high-resolution gamma-ray spectrometric analysis. A comparison of the dynamics of their behavior throughout the years is done. Bulgaria is a country with intensive uranium mining activities in the past years. That is why radiological monitoring of closed uranium mining facilities in different regions of the country are obligatory and of great interest. This work presents results from such investigations made in regions where remediation has been done. The results have been evaluated according to the Bulgarian radionuclide environment contamination legislation. The necessity of permanent environmental monitoring is assessed.

Key words: natural radioactivity, gamma-spectrometry, soil, uranium, radium

Introduction

Most of the natural and men-made radionuclides in the environment remain mainly in the soil. The radionuclides in the earth's crust are one of the main natural sources of ionizing radiation to which human beings are exposed. An important part of the radiation monitoring is the natural radioactivity in soils. The significant contributions to the dose in humans come from the radionuclides in the ^{238}U and ^{232}Th series and ^{40}K [9]. This is a type of exposure which is "neither widely variable nor relatively constant at the surface of the globe" [8].The amount of ^{238}U, ^{226}Ra, ^{232}Th and ^{40}K in soils depend on the type of rocks from which they originate and the processes of soil formation. Analysis of radionuclide content of soil, plants, water and knowledge of the behavior of the radionuclides in soil–plant system provides an important part of a data basis for dose estimation [8,9]. The assessment of activity concentration of natural radionuclides is of particular importance as the principles of long-term environmental and human protection need to take into account the natural background [6]. Human activities can cause accumulation of radioactive elements modifying in this way the natural concentrations. An example for this are areas with former uranium mining facilities The concentrations of natural radionuclides from uranium decay series in such areas are higher and the risk of higher human exposure is increased which makes them object of special interest and studies. According to the Ministry of Environment and Water in Bulgaria there are about 18 000 decare of contaminated with radionuclides grounds in the country [5]. Following the release of Resolution № 163/20.08.1992 on the cancelation of uranium mining and the related "Instruction for the termination of uranium extraction", issued November 1992, were the natural questions about the rapid and efficient recovery of the areas damaged by the uranium mining industry. In these cases regulatory target values should be evaluated against local background levels which varies within and between countries [2].

Obtaining such data is the aim of our study on the base of regular radiological monitoring of virgin soils from high mountain areas, hills and plains covering most of the territory of Bulgaria. The region around Kozloduy NPP, mountain areas and former uranium mining sites are of special interest.

Material and Methods

Sampling

Sampling of soils was done annually from referred sampling points as part of the radiation monitoring covering almost the whole area of the country. Sampling areas were specified considering the wind direction and difference in altitude. According to the altitude of the investigated areas three groups have been defined: plains – mainly North Bulgaria, (40 sampling points *[sp]*); hilly (the valleys of Struma and Mesta rivers (15 sp)) and mountains area - in South Bulgaria (25 sp). Sampling was done also in the water catchment basin on the Beli Iskar river in the Rila mountains (10 sp)) but only in one survey (in 1996) and not as a part of the regular monitoring scheme.

The soil samples were taken according to the procedure described in ISO 18589-2 for collecting samples of undisturbed soil using uniform approach, with sampling performed at depths independent of the natural variations of the soil characteristics. from the soil layer 0-5 cm.[3]The sampling sites are undisturbed, flat with minimum impact of water and wind erosion. A composite sample of at least 5 increments samples is taken from each sampling area.

Besides the areas included in the national radiation monitoring scheme sampling was done from fields with former uranium mining facilities (“Balkan”, “Buhovo”, “Sliven”, “Sborishte”).

Measurement of natural radioactivity

The soil samples were homogenized, dried at 80ºC and sieved through a 2-mm mesh before measurement with a gamma-spectrometer. The samples were stored in air-tight containers for minimum 28 days to allow ^{226}Ra to come into equilibrium with its short-lived progeny. The measurements were done following standard procedures [4].

A Canberra high-purity germanium detector with 20% efficiency an energy resolution of 1.8 keV for ^{60}Co γ-ray energy line at 1332 keV was used. The detector was calibrated with standard reference radionuclide source, type MBSS2, containing ^{241}Am, ^{109}Cd, ^{139}Ce, ^{57}Co, ^{60}Co, ^{137}Cs, ^{113}Sn, ^{85}Sr, ^{88}Y, ^{210}Pb, ^{203}Hg supplied by the Czech. Metrological Institute,. The measuring system included a multichannel analyzer DSA 1000(Canberra, USA). The spectrum was analyzed by GENIE-2000 software with measurement uncertainties less then 10%. Typical counting times were 19–24 h.

The ^{238}U concentration was derived from the weighted mean of the photopeaks of ^{234}Th (63.5 and 92.6 keV), and the ^{226}Ra concentration was derived from ^{214}Bi (609.3 keV) and ^{214}Pb (295.2 and 352.0 keV) in the same way. In addition ^{226}Ra was evaluated at its 186.1 keV line taking into account the contribution of the overlapping line at 185.72 keV of ^{235}U calculating the specific activity of ^{235}U through the specific activity of ^{238}U (ISO 18589-3,2007). For ^{232}Th, the photopeaks of ^{212}Pb (238.6 keV), ^{208}Tl (583.1 keV) and ^{228}Ac (911.1 keV) were used. Activity concentration is expressed as $Bq.kg^{-1}$ dry weight soil.

Results and Discussion

Natural radioactivity – local background values

The concentration of ^{238}U, ^{232}Th and ^{226}Ra as long-lived natural radionuclides of significance in the soil will be discussed in this paper. Summary of the data obtained for the period (1996-2010) is presented on Figures 3, 4 and 5. Here again averaged values are calculated for the same groups of samples described above. The registered concentration of ^{238}U , ^{232}Th in the soils of North Bulgaria are in good agreement with the value of 40 $Bq.kg^{-1}$ estimated in UNSCEAR, 1993 report as average concentration of these radionuclides in soils of Nordic countries. Activity concentrations of ^{226}Ra are also in the range of values stated in the same report. The slightly higher concentrations in soils from South Bulgaria and the Mesta river valley are also logical as the soils in these areas are on rocks containing shale, gneiss with higher concentration of natural radioactivity [7].

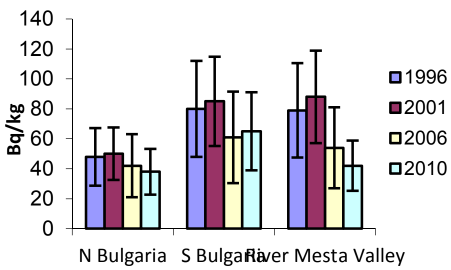
Natural radioactivity – in areas with former uranium mining facilities

All the data discussed above concern areas without former uranium mining facilities. The areas where uranium mines worked are object of special interest. In general, activities related to mining and processing of uranium ore are characterized by complex negative impact on the environmental components (soil, water and air), which is directly dependent on the extraction technology. There are several fundamental methods for extraction of uranium ore:

1. Classical methods:
a/ open-air method –via construction of quarries;
б/ classical underground method;
2. Geo-technological method – extraction of uranium concentrate by sulfuric acid.

The first of the above mentioned methods completely destroys the soil layer. Mineral masses with increased content of radioactive elements are brought to the surface of the site, the landscape of the region changes, the ecological balance is disturbed and opportunities for pollution and erosion of adjacent areas are created. These negative effects lead to serious problems in dealing with the radioactive contamination and the overall landscape shaping the territory of the site.

The classical underground method does not directly disturb the integrity of the soil layer with the exception of a small area where the shafts and stulms are. The anthropogenic impact in this case is related to large amount of geological material, which is brought to the surface and takes up a significant amount of space. These materials are unsuitable substrate for growing plants and are dangerous due to the residues of uranium ore that they contain.



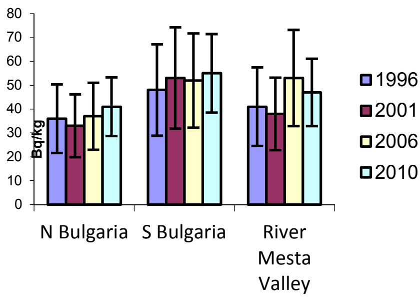


Figure 3. ^{238}U activity concentration in soil samples from different regions (1996-2010)

Figure 4. ^{226}Ra activity concentration in soil samples from different regions (1996-2010)

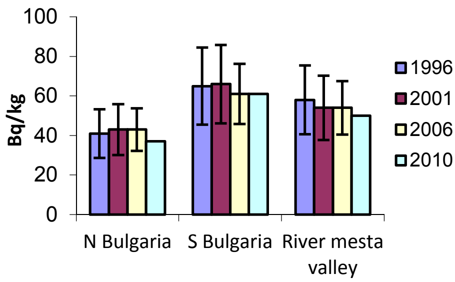
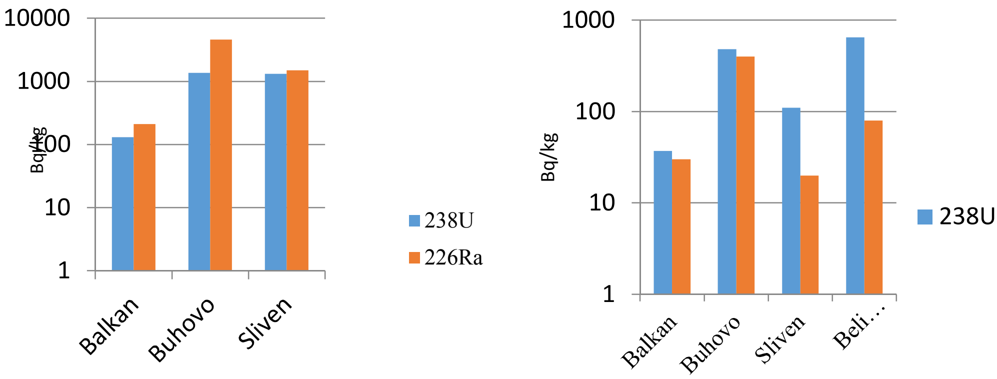


Figure 5. Content of ^{232}Th activity concentration in soil from different regions (1996-2010)

Especially large disturbances and changes in the landscape and soil layer at the site are caused by the geo-technological method for extraction of uranium - on one hand the integrity of the soil is mechanically disturbed during the course of drilling and blasting, the construction of the sorption system, the deployment of drilling pipes and other technological equipment and on the other hand - the soils are subject to the chemical effects of the solutions used during the mining process.

These changes and disturbances in the environmental components require precise and proper planning of the reclamation and restoration activities, combined with the recommended activities for usage of the damaged land. This is a complex and lengthy process that begins with a detailed survey of the area affected by mining works.

We have studied some of the objects with former uranium mining facilities [8]. The sampling included virgin soils and soils destroyed by the mining process activities. Information about the results obtained from 3 such areas is presented on Figure 6 (A, B).



A(disturbed soils) B (virgin soils)

Figure 6. ^{238}U and ^{226}Ra concentrations in destroyed (A) and virgin (B) soils from areas with former uranium mining facilities [Bq.kg^{-1}].

The activity concentration is presented in logarithmic scale because the variability of the results was quite high - ^{238}U (from 130 Bq.kg^{-1} up to 1360 Bq.kg^{-1}) and ^{226}Ra (from 210 Bq.kg^{-1} up to 4600 Bq.kg^{-1}). Results only for ^{238}U and ^{226}Ra are shown because they are members of one and the same decay series and the ratio between their activity concentrations may be indicative for the type of pollution recognizing at that the differences in their chemical behavior. In the soil hardly influenced by the uranium mining activities the activity of ^{226}Ra is considerably higher while in the virgin soils ^{238}U is with equal or with higher activity.

On Figure 6 (B) Beli Iskar is included as an example of undisturbed soil from a mountain region (Rila mountain) with high natural activity concentration (^{238}U – 650 Bq.kg^{-1}; ^{226}Ra 80 Bq.kg^{-1}) and ratio $^{226}Ra/^{238}U \approx 8$. This disequilibrium is most probably caused by the high amount of organic matter in this soil as uranium unlike radium makes compounds with the huminic acids in the soil [1].

__Measures for decontamination and restoration of soil fertility of soils disturbed by uranium mining activities__

Appropriate measures for eliminating the danger of contamination of the environment and for restoring the soil fertility on site are chosen based on the obtained results. The events can be divided into two groups according to their type:

- First group - technical activities.
  a) cleaning the site surface from large rocks, concrete foundations and other debris, leveling the surface of the piles, etc.
  b) excavation, transportation and disposal of toxic materials with high uranium concentration. Covering the less contaminated areas with substrates with specific power and appropriate physicochemical properties.
- Second group - biological events.
  a) cover disturbed areas with a layer of organic matter with a certain power;
  b) chemical reclamation of the site;
  c) planting erosion control grass and forestation of degraded areas.

Conclusions

- Caesium-137 and Strontium-90 are the main radionuclides of significance, characterizing the soil pollution with man-made radionuclides in all the areas investigated as part of this study and originate from the Chernobyl accident;
- Natural radioactivity concentrations in the investigated virgin soil are in good agreement with the values presented in the UNSCEAR reports for different soil types in the Nordic countries;
- The activity concentration ratio $^{226}Ra/^{238}U$ may be used for specifying the origin of higher natural activity concentrations in soils;
- The appropriate measures chosen for soil fertility remediation have prevented additional pollution and human exposure in the observed areas with former uranium mining facilities.

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Original scientific paper

Spatial distribution of copper in soils around the Mazraeh mine, north-west of Iran

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Abstract

Heavy metal contamination causes serious environmental and health-related problems around the world. Mazraeh copper mine has been established since 1960 in the north-west of Iran. Thus, the garden soils around the mine may be polluted by heavy metals, particularly copper. Sampling was conducted in an area of about 1500 ha, at 30 sites in a way ahead to Ahar river. Obviously, the river is influenced by the heavy metals but not addressed in this research. Total copper concentration was determined not only at the upper 0-10 cm and 10-30 cm of soil vertical section but also at surface accumulated sediments. Statistical and geostatistical analyses were carried out using SPSS and GS+ software, respectively. According to the results obtained the spherical and Gaussian models were two best fitted approaches to interpolate copper concentration for the whole study area because of their higher R^2 and lower *RSS*. The inverse distance weighting (*IDW^2*) method was used to interpolate the concentration of copper in the whole study area due to limited data. The mean copper concentration of the samples was twice compared to the world guideline value (50 mg kg^{-1}). Collapse of tailing dam may be the main reason for copper pollution which was unfortunately occurred due to heavy rainfall on 2009, from 24 May to 27 May inclusive.

Key words: spatial distribution, pollution, Mazraeh copper mine, Iran

Introduction

Paying attention not only to contamination causes and sources but also to monitoring pathways are the main objectives in rational use of soil resources and the environment. Heavy metals diffusion is increased in the last decay due to human activities. Industrial products, mines, transport, and even uncontrolled application of pesticides are the sources to establish heavy metal contamination (Hutton and De Meeus, 2001). Theses metals may be percolated to the soil by sewage and irrigation, or scattered at the space (Salomons, 1995). Disturbance of land, either by natural processes or human activity, invention contaminations exactly in open mines whose don't feel to obey from the rehabilitation laws. Mazraeh copper mine has been established since 1960 in the north-west of Iran. It's capacity is 250 ton per day. Copper concentration process led to create waste treatment which may conduct to ponds. Numerous agricultural area and orchards located in floodplains. The poor stability of soil material not only caused to be collapsed the tailing dam but also residential and industrial wastewater discharged into sewers and are treated to the orchards. In spite of that no possibility to sample in each point, geostatistics help not only to predict the spatial and temporal distribution of a variable but also to create maps (Jiachun et al., 2006). Hooker and Nathanial (2006) created contamination and lead risk maps in England using spherical model and kriging interpolation method. Gotway et al. (1996) have reported the high accuracy of inverse distance weighting (IDW) method for studying nitrogen distribution pattern. This approach is also confirmed by others to observe the spatial distribution of heavy metals in floodplain soils around the Gule River in the Netherlands (Leenaers et al., 2003). Therefore, *IDW^2* method was solely used to interpolate the concentration of copper in the whole study area due to limited data in this research. Shahbazi and De la Rosa (2009) have reported that climate change is likely to cause severe water stress in the 21st century as water management will be increasingly important. The climate change will cause the conversion of the best agricultural lands into the marginal ones as well as bioclimatic deficiency is out of monitoring while mining and manufacturing development must be perfectly controlled.

Material and methods

This study was performed in an area extension about 1500 ha located at Mazraeh region of east Azarbaijan, Iran, between 47°02′47″ to 47°03′46″ east longitude and 38°31′56″ to 38°37′12″ north latitude. There are different kinds of parent materials including limestone, old alluvium, and volcano-sedimentary rocks.

Sampling and initial analysis

Sampling was conducted at 30 sites to determine total copper concentration not only at the upper 0-10 cm and 10-30 cm of soil vertical section but also at surface accumulated sediments. Global Positioning System was used to provide the geographical coordination of sample points. Soil samples were air dried and was then sieved via mesh 2 mm. Custom physical and chemical analyses such as texture (Gee and Bauder, 1986), EC (Bower and Wilcox, 1965) pH (McLean, 1982), CEC (Bower, 1952), OC (Nelson and Sommers, 1982), CCE (Soil Conservation Service, 1992), were performed.

Copper concentrations in both soil samples and surface sediments were measured using Aqua-Regia method (Chen and Ma, 2001). Copper Pollution Index (PI) is defined as the ratio of copper concentration at the sample to the background (Fagbote and Olanipekun, 2010). It is divided to 4 classes (<1, low; 1-3, medium; 3-6, high; and >6, very high).

Statistical and geostatistical analysis

Statistical analysis was performed using the Statistical Package for Social Science (version 16.0; SPSS Inc., Chicago, IL, USA) program. Descriptive statistics for selected properties of soils and sediment were calculated.

The geostatistical analysis was performed with the GS+ package program for the environmental sciences, version 5.1. Data models require nugget (C_0), sill (C_0+C), range of parameter (A_0) whose are derived parameters excessive R^2 and reduced sums of squares (*RSS*) to decide and to present the appropriate model. The nugget effect, representing the undetectable experimental error and field variation within the minimum sampling space, was quite large relative to the sill, which represents total spatial variations. In the next step, models fitted according to hypothetical of IDW which assumes that each measured point has a local influence that diminishes with distance. Interpolation with IDW was being selected by the Geostatistical Analyst Wizard tool to digitize and mapping soil pollution. Although Inverse distance weighting and kriging are the two most widely employed interpolation tools, IDW was used due to limited number of data points while Kriging works well when data is abundant (>50 data points) and the collection points are well distributed across the study area (McKenzie et al., 2008). IDW is relatively fast and easy to compute, and straightforward to interpret. It's general idea is based on the assumption that the attribute value of an unsampled point is the weighted average of known values within the neighborhood, and the weights are inversely related to the distances between the prediction location and the sampled locations.

Geographical information system (GIS)

A file of data transferred to a congenial program (e.g. ArcGIS 9.3) that is popular package with excellent graphics. The main application in ArcGIS, ArcMap, is being used for all mapping and editing tasks in the present study. Interpolation with IDW was being selected by the Geostatistical Analyst Wizard. In digital soil mapping (DSM) the soil variables such as soil biological indices are increasingly mapped using regression-kriging to produce a typical map based on geostatistics (Shahbazi et al., 2013). Area extension of each mapping unit is then calculated to find the spatial variability of copper concentration in the field scale.

Results and discussion

Statistical descriptive analyses are summarized in Table 1. All parameters except organic carbon have normal distribution.

Table 1. Descriptive statistics for selected properties of soils at two depths (n=30)

Soil Properties	Depth (cm)	Mean	Min.	Max.	S_d	CV (%)	Skewness	Kurtosis
Sand (%)	0-10	53.8	22.1	83.5	12.3	22.8	0.1	1
	10-30	57.7	40.6	80.6	11.2	19.4	0.3	1
Silt (%)	0-10	32.4	8.7	50.8	9	27.7	0.3	0.6
	10-30	28.7	13.9	47.9	9	31.2	03	0.4
Clay (%)	0-10	13.8	6	27.1	5.6	40.4	0.6	0.5
	10-30	13.6	5.5	24.7	5.9	43.3	0.5	1.1
CCE (%)	0-10	5.3	0	13.8	3.4	64.2	0.5	0.15
	10-30	4.5	0	10.1	2.57	57.1	0.1	0.3
pH	0-10	8.1	8.4	7.7	0.2	2	0.5	0.3
	10-30	8.3	7.6	8.6	0.2	2.4	1.4	2.6
EC (dS m^{-1})	0-10	1.09	0.37	2.67	0.5	42.2	1.4	3.4
	10-30	0.9	0.5	2.1	0.4	43.9	1.8	3.3
OC (%)	0-10	1.92	0	13.16	2.3	118.7	4.3	21.9
	10-30	1.4	0	12.3	2.1	149.3	4.9	25.8
CEC ($cmol_c$ kg^{-1})	0-10	26	15.8	54.8	6.9	26.4	2.5	10.1
	10-30	23.2	12.7	36.7	5.6	30.7	0.3	0.02

Sd, standard deviation; CV, coefficient of variations; CCE, carbonate calcium equivalent; pH, soil reaction; EC, electrical conductivity; OC, organic carbon; CEC, cation exchange capacity.

Analyses of copper concentration at soils and sediments are fully presented in Table 2. Frequency distributions of all measured parameters are normal. The results revealed that the mean of copper concentration at upper 10 cm, 10-30 cm and sediments were 105.3 mg kg^{-1}, 86.4 mg kg^{-1} and 1116 mg kg^{-1}, respectively. Therefore, according to world guideline value (Kabata-Pendias and Pendias, 1994), 50 mg kg^{-1}, the mean copper concentration of the study soils was approximately twice. Decreasing of standard deviation related to soil depths show that soils have been polluted from surface to subsurface. There is significant difference between copper concentrations at two sampled depths where the same observations had been previously resulted (Fageria et al., 2002; Wenqing et al., 2005).

There is no correlation between carbonate calcium equivalent and total copper concentration on contrary there is positive correlation between total concentration copper and EC, OC, silt and clay as Chen et al. (2009) had been reported copper concentration and its distribution relation with silt and clay contents. The results are also revealed that the pollutant index in the samples near to the source of dam is high and very high as well as it is briefly diminished at surface 0-10 cm of land. This result equal to the previous research work outputs (Ahiamadjie, 2011).

There are some mines in Morocco such as Atlas and also in China such as Dabaoshan where the copper concentration in Dabaoshan mine is 1486 mg kg^{-1} (Zhou et al., 2007) while in Mazraeh mine is 5870 mg kg^{-1}. The orders of representative heavy metals are following as:

Fe>Ca>Cu>Na>K>Mg>Mn>Zn>Ni>As>Pb>Co>Cd

The mean value of PI in blank soils is about 2 but in 15 surface (0-10 cm) and subsurface soils (10-30 cm) are 4.36 and 3.36 respectively. It means that pollution is being led from vertical section of the soils as well as it more appears near the tailing dam source. Statistical analyses revealed that PI has significant differences (p<5) at two depths (Figure 1).

Table 2. Point by point copper concentration in soils and sediments

Sample No.	Longitude (m)	Latitude (m)	Copper concentration (mg kg^{-1})		
			0-10 cm	10-30 cm	sediment
1	679598	4276699	98.1	87.95	1698.45
2	679590	4276677	257.88	154.31	1854.8
3	679238	4276080	123.98	101.49	1659.02
4	679080	4275710	101.82	87.23	1566.05
5	679020	4275687	94.29	81.75	1248.83
6	678486	4574631	87.18	71.17	1351.68
7	678240	4273948	120.89	93.29	1116.94
8	678318	4273550	72.58	74.54	982.7
9	678248	4273193	87.13	62.42	1182
10	678380	4272730	119.19	100.62	973.06
11	678441	4272332	88.31	59.23	1148.83
12	678497	4272188	155.04	82.66	1006.16
13	678563	4271946	121.41	99.84	1140.7
14	678558	4271790	102.73	81.43	1031.95
15	678679	4271437	99.72	89.3	1033.65
16	678778	4270918	73.49	76.18	792.33
17	678606	4270814	90.07	71.25	964.76
18	678435	4270667	72.93	83.72	1057.52
19	678230	4270461	74.77	69	714.78
20	678211	4270172	99.92	90.93	877.13
21	678156	4269882	86.87	64.42	1034.59
22	678285	4269552	80.97	74.95	971.09
23	678265	4269307	94.88	88.56	1229.62
24	678192	4270594	102	109.25	1221.27
25	678334	4268143	121.2	80.98	998.36
26	678330	4267954	114.89	87.68	444.4
27	678381	4267200	92.46	74.78	1102.8
28	678340	4267477	111.09	98.7	973.9
29	678269	4268719	92.54	85.81	986.48
30	678248	4266931	120.71	108.84	1118.01

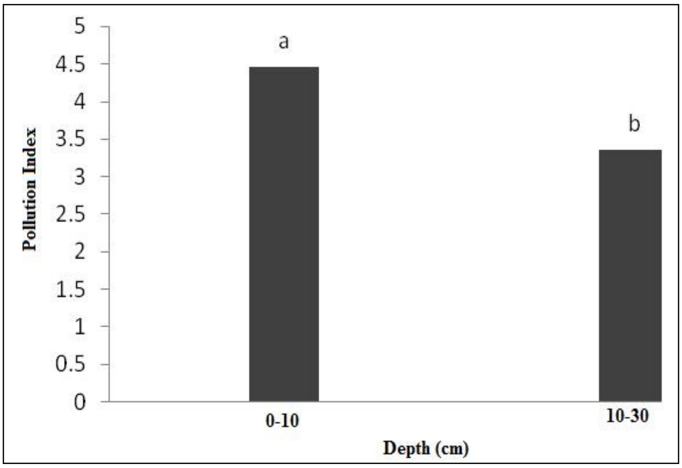

Figure 1. Depth effect on pollution index in the soils

According to the best fitted models (highly R^2 and low RSS) resulted by geostatistical analyses (Table 3 only represents for the upper 10 cm of the soil) showed that the ratio of nugget variance to sill was lower for the sediments compared to the soils. Additionally, this ratio for the upper 10 cm of the soils was lower than the next 20 cm, resulted in more spatial dependence of copper distribution in sediments and upper 10 cm than to the next 20 cm.

Table 3. The best fitted models to variograms of studied indices (0-10 cm)

Indices	Model	C0	C0+C	A0 (m)	C0/C0+C (%)	R^2 (%)	RSS
Sand	Spherical	66.85	139.32	5049	48	99.9	0.866
Silt	Spherical	69.1	255.7	4200	27	74.3	2.29
Clay	Exponential	0.01	28.01	1154	0	94.2	11.8
CCE	Guassian	4.8	6.8	2300	70.6	70.8	0.609
pH	Spherical	0.0118	0.2336	11670	5.1	98.4	0.00001
EC	Spherical	0.071	0.744	12180	9.5	95.3	0.0007
OC	Guassian	0.0093	0.0956	13140	11.8	97	0.000006
CEC	Guassian	16.1	63.2	7070	25.5	95.5	15.3
Cu[a]	Spherical	0.018	0.06	6500	30	84.5	0.0001

a, total copper concentration

Figure 2 illustrates variogram of fitted models for copper concentration estimation in the study area at two soil depths and sediments too. The Gaussian model is distinguished as the best fitted model for sediment estimation (R^2=96). ME, RMSEn, S_d and S_e of IDW approach for estimating of copper concentration at two depths are following as (0-10 cm: 1.04, 0.39, 33.94, 6.2; 10-30 cm: -0.82, 0.2, 18.6, 3.39). Created georeferenced continuous thematic maps of copper concentration are presented in Figure 3.

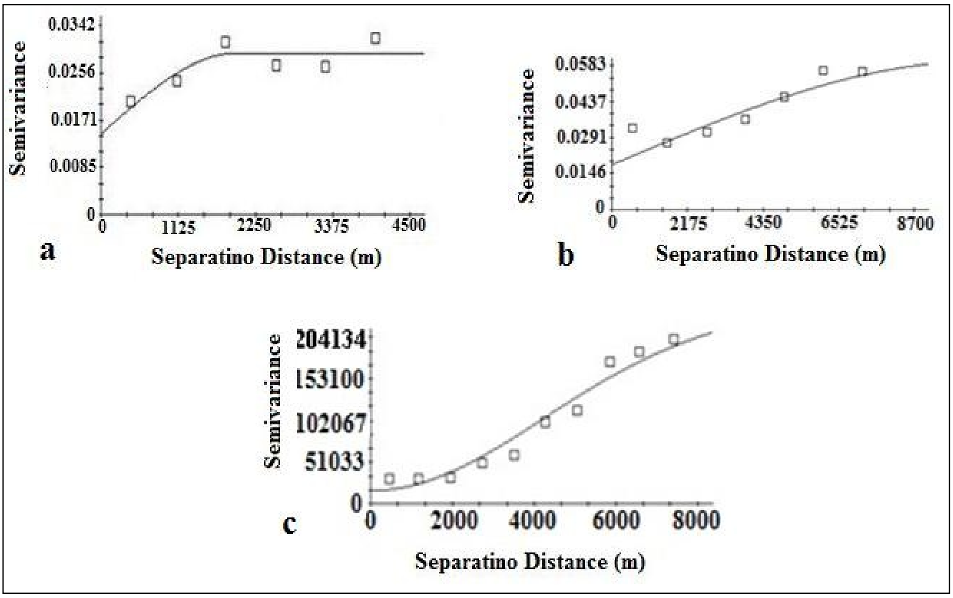

Figure 2. Isotropic model variogram fitted to copper concentration. (a) Surface soils. (b) Subsurface soils. (c) Sediment.

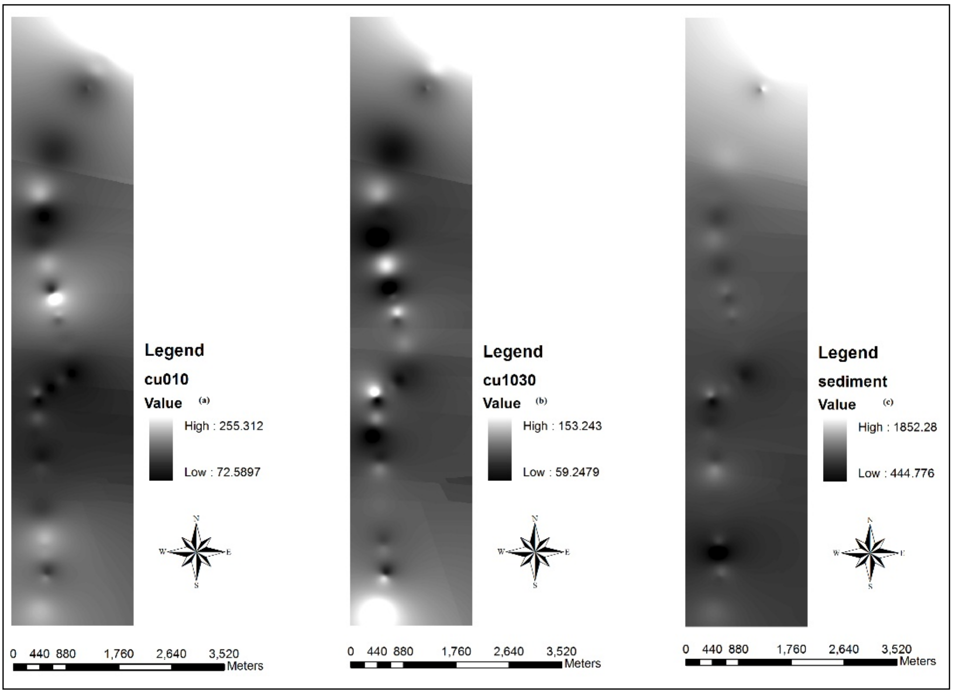

Figure 3. Raster stretching values of copper concentration /mg kg^{-1}. (a) Surface soils. (b) Subsurface soils. (c) Sediment.

Conclusions

Pollution index presents that the soils around the Mazraeh mine have been polluted.

The collapse of tailing dam is the main reason for copper pollution which was unfortunately occurred due to heavy rainfall on 2009, from 24 May to 27 May inclusive.

Copper fractionation has been studied during this research work but it is not fully addressed in this article.

IDW approach for prediction of cooper concentration at subsurface soils is over-estimation while at surface soils is under-estimation. Spherical and Guassian models are two best fitted modes. It is also understood the copper concentration decreases by increasing distances from the source. There is moderate to high spatial dependence for copper distribution in the study area.

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Original scientific paper

Free-living and plant parasitic nematodes under conventional tillage and no-tillage treatments in wheat and soybean

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Abstract

Any disturbance of soil can affect nematode community and total abundance. Tillage practices are considered as main disturbance to soil that may bring to the changes in nematode trophic structure. The aim of this preliminary study is to evaluate effect of conventional tillage and no-tillage treatments on nematode community in wheat and soybean. A split plot field experiment was conducted in 2008, in Darda, Croatia. Sampling for nematodes was done in May 2008, in wheat and soybean under conventional tillage and no-tillage treatment. Nematodes were separated to the trophic groups and plant parasitic genera were identified. The most abundant plant parasitic genus in all treatments was *Tylenchorhynchus* Tillage treatments did not have significant effect on nematode trophic structure and on biodiversity of genera of plant parasitic nematodes. This study proved beneficial role of nematode community in conventional tillage and no-tillage regimes, whereas overall effect of nematodes was postitive in terms of mineralisation of organic matter.

Keywords: Trophic structure, *Tylenchorhynchus*, tillage, mineralization

Introduction

Nematodes are abundant and diverse invertebrates (Yeates and Bongers, 1999). Trophic structure of nematode community is a functional classifcation that reveals how each group affects the soil food web (Freckman and Caswell, 1985). According to their feeding habit, nematodes can be grouped into five major trophic groups: bacterivorous, fungivorous, plant parasites, predators and omnivorous (Yeates et al., 1993). Plant parasitic nematodes are direct herbivory, while bacterivorous and fungivorous graze on decomposer microbes and enhance nutrient mineralization (Griffits, 1994; Ferris et al., 2004). Omnivorous nematodes feed on more than one type of food material, while predatory nematodes feed on nematodes and other invertebrates in the soil (Grewal et al., 2005).

Any disturbance of soil can affect nematode community and total abundance (Briar et al., 2007). Species that pass one or more stages of their life cycle in the soil are directly affected by tillage. Tillage practices are considered as main disturbance to soil which causes the relocation of plant residue and soil organic matter, change of microbial activity and population as well as nematode trophic structure. The species composition of the soil microbial community is directly affected by reduced tillage since retention of soil moisture and soil temperature is modified and this environment may be more antagonistic to pathogens due to competition effects (Krupinsky et al., 2002; Cook, 1990). Bailey and Lazarovits (2003) report that tillage treatments may change inoculum density of a pathogen and its ability to survive.

Plant parasitic nematodes were found in greater populations in conventionally tilled field plots than in no-till plots (Stinner and Crossely, 1982). However, different studies report greater population of plant parasitic nematodes in no-tillage treatments as to conventional tillage in soybean and maize (Alby et al., 1983; Caveness, 1979). Baird and Bernard (1984) found no significant differences in overall diversity and dominance among treatments and trophic groups in experiment with tillage treatments in soybean-wheat cropping. Okada et al. (2002) found that the overall effect in no tillage and conventional tillage differences was not clear, except for omnivores and plant parasitic genus *Meloidogyne.*

The aim of this preliminary study is to evaluate effect of conventional tillage and no-tillage treatments on nematode community in wheat and soybean.

Material and methods

A split plot field experiment was conducted in 2008 in Darda, Croatia (45°37’34”N, 18°41’33”E). The soil type was pseudogley. The experiment was set in area of 8 ha, with plots of 540 m^2 and subplots of 180 m^2. Plots of wheat (cultivar Srpanjka) and soybean (cultivar Podravka 95) were four times replicated and imposed on eight different tillage treatments, and three nitrogen fertilization levels. However, in this study soil cores were taken from two tillage treatments (conventional tillage (CT) and no-tillage) and with fertilization of 150 kg N ha^{-1} for wheat and 70 kg N ha^{-1} for soybean. In CT the soil was plowed, disked, and rotary tilled before planting. In NT the soil remained undisturbed. Pesticides were used in both treatments as required, mainly herbicides and rodenticide.

Sampling for nematodes was conducted on 8th May 2008. Extraction of nematodes from a 100 ml subsample of soil was processed following the Erlenmeyer method (Seinhorst, 1956). Nematodes were counted and separated according to their feeding habit to five trophic groups (Yeates et al., 1993): bacterivorous (B), plant parasites (PP), fungivorous (F), omnivorous (O) and predators (P). Plan parasitic nematodes were identified to the genus level according to Bongers (1994). Ratio B+F/PP was used to indicate the decomposition pathway (Wasilewska, 1994). The data were log(n+1) transformed prior ANOVA. Means were spearated by Tukey test (P<0,05) (SAS Institute Inc., 2000).

Results and discussion

Effect of tillage treatments on nematode trophic structure and total number of nematodes is shown in Table 1. Bacterivorous nematodes and plant parasites were the most dominant trophic groups, while no predators were detected. These results are expected as previously it has been reported (Freckman and Caswell, 1985). Omnivorous and predatory nematodes have been shown to decrease due to intensive cultivation (Bouwman and Zwart,1994: Wardle et al., 1995), Minoshima et al. (2007) did not find this results, and it was not the case in this study.

No significant differences were observed among the treatments, except for total number of nematodes in soybean. In soybean, in CT, significantly more nematodes were observed: 322,50 in 100 ml of soil, while in NT 185,00, respectively. The difference occurred since abundance of bacterivorous nematodes in CT in soybean was greater than in NT.

In CT, bacterial and fungal abundance is greater due to faster decomposition of crop residues, which provides more feeding sites and chance for reproduction and growth of bacterivorus and fungivorous nematodes. Tillage increases bacterial dominance of the microbial community and favor r-type organisms (Lenz and Eisenbeis, 2000) and that emphasize the need for more indepth analysis of bacterivorous nematodes and analysis based on colonizer-persister groups (Fiscus and Neher, 2002). Parmelee and Alston (1986) reported greater abundance of bacterivorous nematodes in CT compared to NT plots over an annual cycle, whereas fungivorous nematodes were more abundant in NT plots during the dry summer cropping season, but more numerous in CT during winters. Stinner and Crossley (1982) did not find significant differences in CT and NT for total numbers of nematodes and free living nematodes, however group of plant parasites were significantly different among the treatments.

Table 1. Mean number of nematodes according to the nematode feeding habit in soybean and wheat for conventional tillage (CT) and no-tillage (NT)

Culture	Tillage	Trophic group				Total	B +F/PP
		PP	B	F	O		
Wheat	NT	67.50a	302.50a	32.50a	30.00a	432.50a	4.96a
	CT	65.00a	215.00a	10.00a	40.00a	330.00a	3.46a
Soybean	NT	40.00a	82.50a	32.50a	40.00a	185.00b	2.88a
	CT	80.00a	145.00a	57.50a	40.00a	322.50a	2.53a

Values in columns followed by the same letter are not significantly different (P<0,05)

Similar results are achieved between the crops; however bacterivorous nematodes occurred in greater abundance in wheat. Since bacterivorous and fungivorous nematodes in soil ecosystems are important in the decomposition of organic matter and recycling of nutrients, ratio B +F/PP was used to reveal decomposition pathway (Wasilewska, 1994). Values of decomposition pathway ratio greater then 1 indicate overall positive effect of nematode community in soils, whilst lower values indicate negative effect, and dominance of plant parasitic nematodes (Table 1). The least negative effect of nematode community was observed in wheat in NT treatment (4,96 ratio value). No significant differences were determined between the treatments for this index. Since all treatments had greater abundance of bacterivorous than fungivorous nematodes, the bacterial decomposition pathway seems to have dominated in all treatments.

Plant parasitic nematodes were the second most abundant group in nematode community.

Table 2. Mean number of plant parasitic nematodes for conventional tillage (CT) and no-tillage (NT)

Rod	NT	CT
*Ditylenchus**	5.00a	6.25a
*Filenchus**	15.00a	15.00a
Heterodera	1.25a	0a
Paratylenchus	0a	1.25a
Pratylenchus	16.25a	7.50a
Scutylenchus	0a	1.25a
Tylenchorhynchus	30.00a	17.50a
*Tylenchus**	5.00a	5.00a

Values in rows followed by the same letter are not significantly different (P<0,05)

**Not obligate plant parasites*

In Table 2, eight plant parasitic genera were identified, among which three genera are not obligate plant parasites but also may feed on fungi (*Filenchus, Ditylenchus* and *Tylenchus*) (Ferris and Bongers, 2006). The most abundant plant parasitic genus in all treatments was *Tylenchorhynchus* (stunt nematodes), and no significant differences were determined between the the treatments for plant parasitic genera. Stunt nematodes feed on epidermal cells and root hairs mostly in the cell elongation region, and may cause roots to thicken and decay. Griffin (1996) reported *Tylenchorhynchus acutus* reduced growth of wheat. However, many species of stunt nematodes even in high populations do not cause economically important damages wheat and other crops.

Conclusions

This was preliminary research that provided an opportunity to compare the effects of conventional tillage and no-tillage on nematode community. Tillage practices did not have impact on nematode community regarding trophic structure and plant parasitic nematodes biodiversity. However, effect of tillage treatments was observed for total number of nematodes in soybean. The differences in results of various studies indicate that the tillage treatments should be further investigated to elucidate impact on nematode community. This study proved beneficial role of nematode community in conventional tillage and no-tillage regimes, whereas overall effect of nematodes was positive in terms of mineralization of organic matter.

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S E S S I O N IV

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Original scientific paper

The impact of tillage and fertilization on wheat grain infection

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Abstract

During two years period (2008 and 2009) effect of tillage and fertilization on fungal infection of wheat grain was examined. Research of different soil tillage was conducted at marsh gley (hipogley) hydromeliorated soil type in eastern Croatia. Twelve fungal genera were determined: *Fusarium, Alternaria Cladosporium, Penicillium*, *Epicoccum, Septoria, Helminthosporium, Acremonium Trichotecium, Gonatobotrys, Mucor* and *Aspergillus*. Regardless of the year, tillage and fertilization, majority of fungi were from *Alternaria* genus, but there were not significant differences in incidence of *Alternaria* sp. between treatments. A significantly higher grain contamination with *Fusarium* sp. was found in the no-tillage system in 2008 and reduced system tillage in 2009. Nitrogen fertilization treatments did not significant influenced of the fungal populations.

Key words: soil tillage, fertilization, wheat, fungi

Introduction

One of the most important components of soil management is soil tillage which at the same time has great influence on intensity of plant diseases. Various soil tillage systems leave different amount of plant residue on the soil surface (Jug et al., 2011) and have different effects on pests, diseases and weeds (Jordan and Hutcheon, 2003). Several authors have studied relationships between plant pathogen and no-tillage cultivation (Supronienė et al., 2012, Perez-Brandan et al., 2012). Plant residues has important role in epidemiology of plant disease since many plant pathogens can survive on plant debris (Poštić at al., 2012). Ploughing has traditionally been used to incorporate crop residues into the soil. The no-tillage system offers the best conditions to conserve and improve soil structure, contributes to the good soil quality, increases level of microbial activity, microbial diversity and enhances natural disease suppression (Perez-Brandan at al., 2012). Crop residues and disease are related but it is necessary to consider and other parameters involved in the disease epidemiology (Almeida et al., 2001).

In Croatia, Jurkovic et al. (1995) have studied relationship between reduced soil tillage for winter wheat and appearance of diseases and pests during two year period. The most severe infection of wheat roots and crowns was by *Fusarium graminearum*. Other *Fusarium* species were less established. They were concluded that reduced soil tillage for winter wheat did not significantly affect the occurrence of root and crown rot.

The aim of this research was to evaluate influence of year, tillage and fertilization on wheat grains disease incidence.

Material and methods

During two years (2008 and 2009) stationary research of reduced soil tillage was conducted for wheat, at marsh gley (hipogley) hydromeliorated soil type in eastern Croatia (Brestovac site; 45°37′ N and 18°42′ E, elevation 83 m). Research was conducted with four soil tillage treatments (mean factor, TT), with size of the basic soil tillage plot of 540 m^2, and three nitrogen fertilization treatments (sub-factor N), with basic fertilization plot size of 165 m^2, set up in split-plot design in four repetitions. The experiment was conducted on the same homogeneous field at the same location with as forecrop in each experimental year. Chemical properties of investigated soil (in plowing layer 0-30 cm) were as follows: $pH_{(H2O)}$ = 5.61; $pH_{(KCl)}$ = 4.52; OM =2.13; P = 86.0 mg kg^{-1} and K = 242.3 mg kg^{-1} (determined by the Egner-Riehm Domingo AL- method) and Hy = 8.79 mm $100g^{-1}$. The following four TT were applied in continuation: 1) Conventional tillage (CT) based on autumn mouldboard ploughing on 30 cm depth; 2) Multiple disk harrowing (MD) to a depth of 15 cm and 10 cm depth; 3) Chiselling (CH) to a depth of 25 cm and No-tillage (NT) without any tillage treatments. Nitrogen fertilization treatment had three levels of applied nitrogen: N1=35, N2=70 and N3=110 kg N ha^{-1}. Fertilization with phosphorus and potassium was uniform for all tillage treatments in all investigated years (150 kg ha^{-1} P and 90 kg ha^{-1} K as basic dressing). No-till grain drill John Deer 750A was used for all TT at a depth of 3-5 cm and inter-row spacing at 33 cm. In all experimental years, wheat was sown in optimal terms.

Health analysis of wheat grains was done by deep freezing method. Wheat grains were washed under running water, disinfected for 30 sec. with 96% ethanol and washed in distilled water three times. For each sample 4x100 grains were analysed and average value of diseases incidence calculated for each sample in percentages. Petri dishes with moisture filter paper were kept in chamber for 24 h on 22°C and light regime 12 hours day/12 hours night, then 24 h in freezer on -18°C and finally 12 days in chamber on 22°C. Examination was performed after 14 days with stereo microscope (Olympus SZX9) and microscope (Olympus BX41). Grain infection with *Fusarium* was evaluated for each sample for 4x100 grains by determining mycelia development on grain surface with stereo microscope. Mycelia developed on wheat grain was transferred to potato dextrose agar (PDA) for further determination and for growing pure fungal cultures. Identification to genus level was done based on fungal morphological characteristics. Data was statistically processed with SAS software (1999).

Results and discussion

During two year research influence of different TT, fertilization and year on mycopopulation of wheat grain, the following fungal genera were determined: *Fusarium, Alternaria Cladosporium, Penicillium*, *Epicoccum, Septoria, Helminthosporium, Acremonium Trichotecium, Gonatobotrys, Mucor* and *Aspergillus*. Presence of fungal genera depending on the treatments are presented in Tables 1 and 2. Fungi from genera *Trichotecium, Gonatobotrys, Mucor, Aspergillus* were not statistically analysed due to sporadic incidence. Regardless of the year, tillage and fertilization, majority of fungi were from *Alternaria* genus, but there were not statistically differences in incidence of *Alternaria* sp. between treatments. The genus *Alternaria* is widely distributed on many aerial plant surface and seeds/grains and it is the most common genera of wheat grains (Broggi et al., 2007; Bensassi, 2011). The fungi from this genus could be plant pathogens or represent saprophytic mycoflora.

Fusarium head blight (FHB) is the most important disease of wheat grains in our country but also throughout many of the world wheat growing areas. The highest percentage of wheat grains infected with *Fusarium* sp. was in 2009 (19,25%). Between CT and reduced tillage significant differences on infection level was determined. In 2008 year there number of grains infected with *Fusarium* species were significantly higher with reduced NT (13%) compared to CT (9.08%), as well as in 2009 year where infection level on reduced tillage system (NT, CH and MD) were statistically significant higher than on CT.

Nitrogen fertilization treatments did not significant influenced of the fungal population.

Table 1. Percentage (%) of wheat grains infection in 2008 depending of tillage treatment and nitrogen fertilization.

	Fusarium	Alternaria	Cladosporium	Penicillium	Epiccocum	Septoria	Helminthos porium	Acremonium
Tillage treatment (TT)								
CT	9.08 B	36.25 A	0.66 A	1.66 A	0.58 A	0.58 A	0.33 A	0.00 A
MD	10.00 B	35.0 A	0.65 A	1.08 A	0.50 A	0.66 A	0.35 A	0.08 A
CH	10.75 AB	36.17 A	1.25 A	1.16 A	0.33 A	0.25 A	0.38 A	0.00 A
NT	13.0 A	35.58 A	1.58 A	1.00 A	0.08 A	0.50 A	0.10 A	0.00 A
Fertilization (N)								
N1	11.37 A	35.00 A	1.37 A	1.00 A	0.43 A	0.43 A	0.37 A	0.00 A
N2	10.05 A	35.93 A	0.81 A	1.18 A	0.37 A	0.62 A	0.43 A	0.00 A
N3	10.25 A	36.31 A	0.93 A	1.12 A	0.31 A	0.43 A	0.06 A	0.06 A

(CT) - conventional tillage; (MD) -multiple disk harrowing; (CH) - chiselling to a depth of 25 cm; (NT) - no-tillage. N1=35 kg N ha^{-1}, N2=70 kg N ha^{-1} and N3=110 kg N ha^{-1}.

In June 2009 amount of precipitation during vegetation was significantly higher than in June 2008. Development of FHB is highly influenced by environmental conditions, especially temperature, rainfall and moisture during heading and flowering periods. Except stated, the number of days with precipitation from heading to the end of vegetation is extremely important. In May 2008 and 2009 the number of days with precipitation were 12 and 15, respectively, while the number of days with rainfall in June 2008 and 2009 were 16 and 23, respectively. Since the genus *Fusarium* is the most important fungal genus in our research in Table 3 percentage of grains infection with *Fusarium* sp. depending of tillage treatment and nitrogen fertilization regardlles of the year are presented. Infection level on reduced tillage system (NT, CH and MD) were significant higher than on CT.

Table 2. Percentage (%) of wheat grains infection in 2009 depending of tillage treatment and nitrogen fertilization.

	Fusarium	Alternaria	Cladosporium	Penicillium	Epiccocum	Septoria	Helminthos porium	Acremonium
Tillage treatment (TT)								
CT	13.33 B	20. 75A	0.33 B	3.08A	0.66A	0.00A	0.00A	0.41A
MD	18.58 A	21.08A	1.25 AB	4.25A	0.00A	0.00A	0.25A	0.66A
CH	16.83 A	21.75A	1.58 A	3.08A	0.91A	0.80A	0.00A	0.58A
NT	19.25 A	23.72A	0.91 AB	2.91A	0.33A	0.86A	0.00A	1.00A
Fertilization (N)								
N1	16.75A	21.12A	1.25A	2.93A	0.31A	0.60A	0.00A	0.75A
N2	17.00A	22.12A	0.87A	3.06A	0.37A	0.70A	0.07A	0.68A
N3	17.25A	22.25A	0.93A	4.00A	0.75A	0.36A	0.18A	0.56A

(CT) - conventional tillage; (MD) -multiple disk harrowing; (CH) - chiselling to a depth of 25 cm; (NT) - no-tillage. N1=35 kg N ha^{-1}, N2=70 kg N ha^{-1} and N3=110 kg N ha^{-1}.

Table 3. Percentage (%) of wheat grains infection with *Fusarium* sp. (both years) depending of tillage treatment and nitrogen fertilization.

Tillage treatment (TT)	
CT	11.20 C
MD	14.29 AB
CH	13.79 B
NT	16.12 A
Fertilization (N)	
N1	14.06 A
N2	13.62 A
N3	13.87 A

(CT) - conventional tillage; (MD) -multiple disk harrowing; (CH) - chiselling to a depth of 25 cm; (NT) - no-tillage. N1=35 kg N ha^{-1}, N2=70 kg N ha^{-1} and N3=110 kg N ha^{-1}.

Reports of results from the research the effect of tillage practice on *Fusarium* infection in wheat are contradictory. Lori et al. (2009) find out that no till may result in increased *Fusarium* incidence and severity but favourable weather for FHB is likely to be more important than tillage practice and fertilizer treatments, Fernandez et al. (2005) also concluded that environment was the most important factor affecting disease development. A significantly higher grain contamination with *Fusarium* sp. was found in the no-tillage system, but no significant effect on grain contamination with mycotoxins (Baliukoniene et al., 2011). No-tillage increased wheat grain infection by *Alternaria*, *Aspergillus* and *Cladosporium* species (Suproniene et al. 2012).

Our data indicate a significant effect of tillage system on the detection frequency of *Fusarium* sp. in wheat grain, but no significant effect on grain contamination with other fungal genera.

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Review paper

Use of agricultural and agroindustrial residues as soil amendments in Uruguay: opportunities, and challenges

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Abstract

Recently the production of agricultural and agroindustrial residues has strongly increased in Uruguay. Although their uses is not extended environmental regulations has increased the interest in their use as soil amendments. In this work we reviewed the available information about the use of agricultural and agroindustrial residues as soil amendments, and propose guidelines for their use in different production systems of Uruguay. The agronomic evaluation of different types of residues has covered the chemical and physical characterization, evaluation under controlled conditions, and field evaluation experiments. In general the materials, although variable in characteristics present relatively low dry matter and nutrient contents. Under laboratory conditions they showed rapid decomposition, but nutrient availability depended on their composition. Field experiments were used mainly to evaluate possible application rates and frequency of application, considering crop yields and nutrient losses. The most important environmental problems related to the use of waste materials are nutrient imbalances, which led to losses and soil accumulation. However it is possible to prevent these risks through a careful selection of the application sites and using moderate application rates. On the other hand the organic amendments could be used for soil organic matter (SOM) recovery, as was found in long term experiments. One of the most important aspects of waste materials use is to establish a monitoring plan, based on soil and plant analysis to avoid excessive rates, which can cause decreases in crop yields and environmental damage.

Introduction

The soil amendment with agricultural and agroindustrial residues has been long used in agriculture. However, in Uruguay this practice is not extended, except for a few situations, mainly involving the addition of different kinds of manure in horticultural production. This can be explained by many factors, among others the lack of environmental regulations, which led to a careless disposal of the agroindustrial residues. According to the recent regulations these options are not acceptable, and the companies must present a plan for residues disposal. On the other hand the production of agroindustrial residues, which was rather limited in area and time, has strongly increased. Recently increases have been reported in number and production capacity of dairy, meat, timber, sugar, biofuels, and cellulose factories (DIEA, 2012). But also the traditional beef and dairy production under pasture grazing, is being increasingly developed in shelters, with an important accumulation of manure and fodder residues. The application of the residues as soil amendments is the obvious response to the problems created, but many scientific, technological and environmental issues should be assessed before practical solutions are found.

In this work we reviewed the available information about the use of agricultural and agroindustrial residues as soil amendments, and propose guidelines for their use in different production systems of Uruguay.

Agronomic evaluation of agroindustrial residues

Although the use of agroindustrial residues as soil amendments in Uruguay is relatively new, the Soil and Water Department of the Agronomy Faculty, has produced considerable information regarding to the evaluation of different agroindustrial residues. Also the INIA Institute, belonging to the Ministry of Agriculture, has developed research in this area. The information is however dispersing, and different approaches have been used.

Given the different characteristics of the residues, one of the first steps towards the correct application is a complete characterization of the materials. According to Barbazán et al. (2011), in a survey of the most commonly used organic amendments, the materials showed a wide range of characteristics, and some of them were poorly defined. In this work the analyzed materials were collected from commercial farms, and some of them were mixed with soil, or stored in inadequate conditions. In their work the most commonly used amendments were characterized since the chemical and physical point of view. They provided tables encompassing the variability in characteristics, as a guide for users of 96 materials grouped into: i) cow and chicken manures with and without bedding (rice hull, cereal stroh, forest litter), ii) composted residues and iii) a miscellaneous group that included industrial slurry from maltery, residues of chicken slaugter, hair from tannery, wool, and ashes. The characterization showed a wide range of dry matter and nutrient contents, which make the different materials more or less valuable as soil amendments, however no one presented high levels of heavy metals, indicating that they will not produce soil contamination. Another concern in waste materials, the high Na content, was not found in the studied materials; however some of them presented moderate Na contents, which make advisable the monitoring of the exchangeable Na in the soils where the materials are applied. Although this characterization will be useful to plan the utilization of wastes generated from different activities, the final recommendation was the analysis of any given residue, previous to the land application.

Another approach to this matter was focused in the reaction of the different materials with soil, mainly through laboratory and pot studies. In laboratory experiments the mineralization patterns of different materials were determined under controlled conditions (humidity at field capacity and temperature between 20 and 25^{0}C). The studied materials were: dairy and poultry manures compared to chicken manure with rice hull bedding (del Pino et al., 2008); chicken manure, composted residues, and sheep and cattle manure mixed with forest litter (Barbazán et al., 2008), biogas sludge originated by anaerobic incubation of residues from meat and tannery industries (del Pino et al., 2012). In these studies the C mineralization of the materials mixed with the soil was rather fast, but C_2O losses reached a plateau after less than half of the materials were decomposed, which indicates that in the long term they can contribute to maintaining the soil organic matter. The N mineralization on the other hand was in general related to the C:N ratio, with large amounts of N released from materials with C:N ratios around 20. When C:N was higher than 30, the mineral N release was limited, or even lower than the control soil at the beginning of the incubation. However, after a relatively short period of immobilization (10 to 15 weeks) the mineral N release was higher than the control soil. An example of the trends in C mineralization patterns is presented in Figure 1.

The third group of studies was related to field evaluations, involving different materials and crops, and analyzing the nutrient release from the amendments. These experiments were valuable to test different application rates and frequencies. Casanova et al. (2004) investigated the effect of dairy effluents on a pasture and crop rotation. They also examined different treatments for the effluents (anaerobic lagoon vs. direct application). Barbazán et al. (2011) studied the effect of chicken manure, and sheep and cattle manure mixed with forest litter on greenhouse tomatoes. In this work the best treatments for tomato production were moderate application rates, while the highest rates applied produced decreases in yield, probably due to excessive N availability, which promotes shoot growth, decreasing fruit production. Barbazán et al. (2012) studied the effect of a single application of maltery slurry broadcasted on a *Festuca arundinacea* sward, reporting increases in nutrient absorption and forage yield in the treated plots. The effect of a single application of biogas slurry broadcasted on a *Festuca arundinacea* sward was examined by del Pino et al. (2012). Díaz (2012) studied the application of composted and fresh ckicken manures on a rotation of horticultural crops. All these studies based the application rates in N content of the slurries, finding that the N availability was in many of them, especially chicken manure, maltery and biogas slurries, comparable to the synthetic N sources. They also reported substantial increases in other nutrients availability (P, Ca, Mg, and micronutrients), which could contribute to the crop nutrition. Interestingly in most of the evaluations the effect of the amendments was extended in time beyond the effect of the synthetic fertilizers. Also the nutrient absorption by the crops exceeded in some cases the applied rates, indicating that the increase in biological activity produced by the organic amendments, made available other nutrient sources. An example of the trends in response of pastures to slurries application is presented in Figure 2.

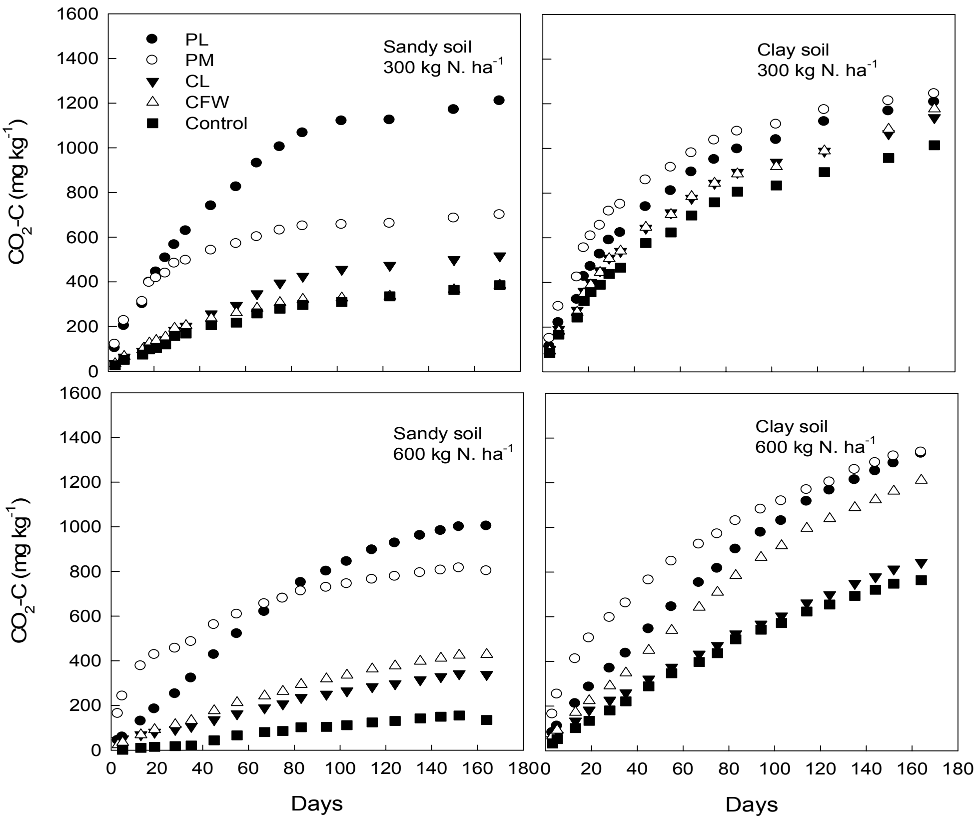

Figure 1. Carbon evolved from soils receiving poultry manure litter (PL), poultry manure (PM), cow manure litter (CL), composted waste (CFW), and control at two rates of nitrogen in two soils representative of the horticultural soils of Uruguay (Barbazan et al, 2008).

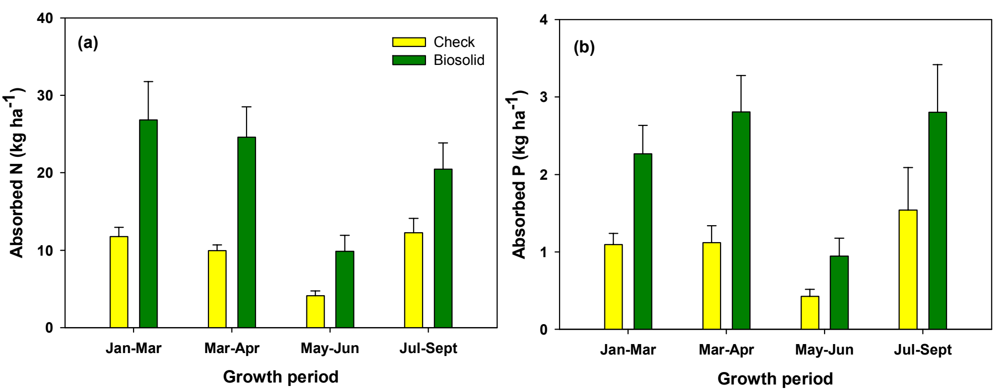

Figure 2. Absorption of N and P by *Festuca arundinacea* pasture, after a single application of 100000 L ha^{-1} of biogas slurry (del Pino et al., 2012)

Regarding to positive effects of organic amendments on soil quality, Coscia et al. (2010) studied the long term effect of different combinations of cow manures and green manures in a degraded soil. After 7 years al the treatments produced improvements in SOC compared to the control, and the best combination was a 100 m^3 ha^{-1} cow manure application with summer and winter green manures.

Environmental challenges

The application of fertilizers and soil amendments present environmental risks. One of the first challenges is to maximize the nutrient utilization by crops, and to lessen the nutrient losses to the environment. For soil amendments this adequation is more difficult than for synthetic fertilizers, because it is not always possible to predict the extent and timing of the nutrient release. Therefore, the farmers tend to apply larger amounts of amendments than the requirements of the crops. This fact was corroborated by Barbazán et al. (2010) in a survey of 30 commercial greenhouses for lettuce and tomato production, using different organic amendments. Most of the sites presented mineral N levels many times higher than the requirements of the crops, which could led to leaching and denitrification losses (Figure 3). The mineralization process depends in a great extent on temperature and water availability. Hence, to predict the nutrient release from organic amendments not only C:N ratios must be considered but also the climatic conditions, which can accelerate the process. The use of organic matter mineralization models would be a valuable tool for this purpose, and some attempts have been made, although with a limited extent (García de Souza et al., 2011).

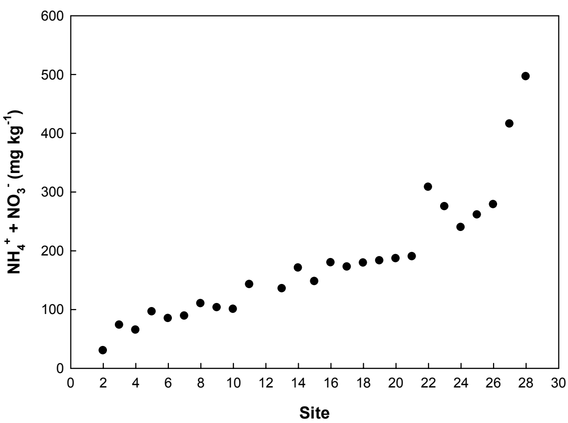

Figure 3. Mineral N in 0-20 cm soils from greenhouses, before crop planting (Barbazán et al., 2010).

Other possible negative environmental effects of residues as soil amendments, heavy metal accumulation, were not observed, probably due to the fact that the agricultural and agroindustrial wastes did not present high contents of heavy metals (Barbazán et al, 2011; del Pino et al., 2012).

Practical implications

The use of the agroindustrial residues is necessarily local. Most of the materials present a relatively low content of dry matter and nutrients, which makes the transportation cost an important component of the technological solutions. However, the characteristics of Uruguayan landscape with large availability of agricultural land in the majority of the country will facilitate the disposal of the residues.

The horticultural production, which makes at present the larger reception of amendments, has the advantage to incorporate the materials during the soil preparation. Therefore, the risk of runoff is minimized. On the other hand the pasture and cereal crop production utilize no till methodologies, which imply the broadcast of fertilizers and amendments without incorporation. This practice will represent a challenge, considering the large application rates required, due to the low nutrient contents of the amendments. In this context the selection of the application sites will require, a careful landscape evaluation, avoiding high slopes and the vicinity of water streams.

In any of the production systems the amendment rates should be selected considering the nutrient concentration. In general N and P rates can be used as a guide to recommend the amendment rates, but in parallel the other nutrient application rates should be calculated, in order to be aware of any unbalances produced.

The use of amendments, due to the uncertainty of the nutrient release, requires a monitoring program. Soils should be sampled and analyzed in order to detect undesirable accumulation of P and heavy metals and to prevent losses. The plant analysis can be also a tool in the monitoring program in order to detect any excess or nutrient imbalances.

Guidelines for the use of residues in production systems of Uruguay

1) Physical and chemical characterization of the residues, including dry matter content, bulk density, C, N, P, Ca, Mg, Na, Cu, Fe, Mn, and Zn contents, and other particular elements that are possible to be found in the residues according to the bibliography.
2) When the residues are generated during long periods the variability en characteristics and composition should also be evaluated, and the ranges in composition taken into account for planning their use.
3) Bioassays of the materials under controlled conditions in order to assess their ad equation for plant growth, and nutrient availability.
4) Careful selection of the application site, preventing possible nutrient losses (gaseous, leaching, runoff).

5) Selection of amendments rates, taking into consideration the nutrient concentrations and variation, avoiding excessive or frequent applications, which can produce losses or accumulation of nutrients or heavy metals.
6) Monitoring plan to assess the effects of the amendments in the long term.

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Original scientific paper

Analyze of drift loses in plum and apple orchards and measures for their reducing

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Abstract

In this paper work are shown results of ground drift losses during plum and apple orchard chemical protection. Measure of drift losses was on quantity level with measuring plates. Plum and apple are two most commonly grown types of fruit in Serbia, so ground drift was measured in these orchards. Generally all orchard treatment following important losses because drift which depend of many factors: weather condition, shape and size of orchards, fruit sort, air assisted sprayer features, nozzle types, application rate and capability of agregate drivers.

From the aspect of quantity, results shown that smaller application rate means less liquid to reach the ground but this reduction will be pointless unless all working parameters and weather conditions are adjusted. Weather conditions under which the treatment is performed (wind speed, temperature and relative air humidity) along with the size of droplets are the most important factors influencing the liquid loss and treatment efficiency. Wind strength is especially important because it can cause large motions and poor coverage inside the tree.

Key words: drift, plum and apple orchard, air assisted sprayer.

Introduction

Very important agro technical measure in the fruit production is the mechanized chemical protection against diseases, pests and weeds. As regards the crops and vegetables, they are generally treated from a smaller distance, while fruits, which medium or large part is treated, are treated at variable distances from air assisted sprayer and a number of protection treatments (apple) are required, ranging from 12 and more treatments during a year (Bugarin, 2011).

Quality and precision of chemical protection are preconditions for efficiency, cost-effectiveness and drift, which is the occurrence of loss of liquid over the ground and outside the treated area.

Negative effects of drift can often result in: increased costs of protection, inefficient treatment, less time and possibilities for adequate treatment and protection of environment, with especial attention paid to soil contamination. Out of all chemicals sprayed by air assisted sprayer during the treatment of one orchard is minimum 20% and goes up to 40% of pesticides which falls on the ground (Kaul et al., 2002). 15 to 20% goes into air and 5% evaporates.

For drift loses it is especially important applying of medium and low application rate because there characterization is spray with fine and extra fine drops and higher concentration of pesticides comparing with high application rate treatment (Bugarin et al. 2010).

In Serbia, medium (500 – 100 l/ha) and high application rates (over 1000 l/ha) are typically used, and small application rates (below 500 l/ha) are still not fully exploited. Treating with large droplets can reduce drift but also reduce plant coverage's and efficacy because of that applying of medium and low application rate demands nozzles who have better technical characteristics and less drift potentials (Sedlar et al., 2008).

Plum and apple are two most commonly grown types of fruit in Serbia, so ground drift was measured in these orchards.

Material and method

Loss of liquid in apple and plum orchards due to ground drift was tested with a standard air assisted sprayer „Caffini" model Orange 1000, Figure 1, mounted onto a tractor „IMT – 539".

Figure 1. Air assisted sprayer „Caffini"- model Orange 1000

The tested air assisted sprayer had cone nozzles, 2 x 6 pieces manufactured by „Albuz" with three different capacities (lower D10 x 1, middle D12 x 4, upper D15 x 1). In the treatment, the used application rates were high, 1289 l/ha, and medium, 801 l/ha, with aggregate's travel speed of 6.16 km/h, operating pressure of 15 and 8 bar.

The investigation was performed in private apple and plum orchards on July 6, 2011. At the time of research, the apple orchard was 7 years old and plum orchard was 5 years old. There were several apple varieties in the apple orchard: idared, granny smith, golden delicious, red delicious and jonagold, and in the plum orchard čačanska variety prevailed. Average height of the apple trees at the time of treatment application was 3.43 m, average width of tree crown was 2.31 m. Average plum tree height was 3.33 m, and tree crown was 2.40 m.

The treatment was performed at 24^{0}C, relative air humidity was 85%, and the wind was blowing occasionally at a speed of 0.9 – 1.3 m/s during the treatment in the apple orchard, and 1.5 to 3 m/s during the plum orchard treatment.

Liquid losses due to ground drift were measured in special vessels with dimensions of 500 x 100 mm. The measuring vessels were positioned in special order at a distance of 1-7 m from the central part of air assisted sprayer, Figure 2, before the aggregate passed.

Figure 2. Measuring vessels

Immediately after the pass of the aggregate labeled measuring vessels were collected and measured on electronic scales that measure the third decimal. After the measuring, the labeled vessels were wiped with a dry cloth and returned to specified positions for repeated measuring. Measuring was repeated three times and the result is expressed in liters, considering the specific weight of water and prepared liquid.

Results and discussion

Table 1 shows average liquid losses from all measurings during the treatment of apple and plum orchards with high application rates (1289 l/ha).

In the apple orchard, which was quite a dense one, average liquid loss measured on the left side of the aggregate was 1.81 ml per vessel, 32.53 m l/m^2, that is 325.3 l/ha or 25.24% of the application rate. On the right side of the aggregate, average liquid losses were much lower amounting 133 liters. This result was the consequence of wind blowing direction which was from the right to the left side, with respect to the aggregate’s movement.

During the plum orchard treatment, wind strength was increased so the exposure of orchard was different and recorded losses on the left side of the aggregate were lower than on the right side. Liquid loss on the right side was 231.2 liters which was 17.9% with respect to the treatment rate.

By reducing the application rate (801 l/ha) much better results related to ground drift were recorded, Table 2. Average loss in the apple orchard was 50.3 l/ha, and in the plum orchard the loss was 172.7 l/ha.

From the aspect of application rate, liquid losses due to ground drift in apple orchard were only 6.3% of the application rate. However, those losses were higher in case of plum orchard and they were 21.5% of the application rate. When compared to high application rate in the plum orchard, medium application rate had 6.05% more ground drift. Average value of liquid loss in case of high application rate was 15.45%.

The increase in percentage can be expected with reduced application rate because smaller application rate means more small droplets in the jet. From the aspect of quantity, smaller application rate means less liquid to reach the ground but this reduction will be pointless unless all working parameters and weather conditions are adjusted.

Table 1. Spray drift depozit on the soil treating with high volume application rate

	liquid losses- left			liquid losses - right		
Drift loses in apple orchard						
Position the measuring vessel	The vessel (ml)	ml/m^2	(l/ha)	The vessel (l)	(ml/m^2)	(l/ha)
1	1.2	21.57	215.7	0.59	10.61	106.1
2	0.1	1.80	18.0	0.09	1.62	16.2
3	2.8	50.34	503.4	0.19	3.42	34.2
4	1.8	32.36	323.6	1.7	30.56	305.6
5	3.0	53.93	539.3	2.07	37.21	372.1
6	1.6	28.76	287.6	0.01	0.18	1.8
7	2.16	38.83	388.3	0.5	8.99	89.9
Average	1.81	32.53	325.3	0.74	13.30	133.0
Drift loses in plum orchard						
Position the measuring vessel	The vessel (ml)	ml/m^2	(l/ha)	The vessel (l)	(ml/m^2)	(l/ha)
1	1.16	23.04	230.4	1.28	23.04	230.4
2	0.96	17.28	172.8	1.66	29.97	299.7
3	1.22	21.96	219.6	1.31	23.67	236.7
4	0.91	16.47	164.7	1.2	21.60	216.0
5	0.92	16.65	166.5	1.47	26.55	265.5
6	0.48	8.37	83.7	1.25	22.59	225.9
7	0.71	12.87	128.7	0.8	14.4	144.0
Average	0.93	16.70	167.00	1.28	23.12	231.20

The best example for that is the medium application rate that apple orchard was treated with. The treatment was performed during nice weather with adjusted air current of a fan and travel speed, thus resulting in a loss of only 50.3 l/ha. Still, plum orchard did not show the same results with medium application rate because the wind was blowing up to 3 m/s during the treatment. Weather conditions under which the treatment is performed (wind speed, temperature and relative air humidity) along with the size of droplets are the most important factors influencing the liquid loss and treatment efficiency. Wind strength is especially important because it can cause large motions and poor coverage inside the tree. In larger orchards and with air assisted sprayers that have more fan capacity treatment is possible even with the winds blowing 3 m/s, and in smaller orchards with treatment performed by sprayers of smaller capacity the allowed wind speed is up to 2 m/s.

Table 2. Spray drift depozit on the soil treating with medium volume application rate

	liquid losses- left			liquid losses - right		
Drift loses in apple orchard						
Position the measuring vessel	The vessel (ml)	ml/m^2	(l/ha)	The vessel (ml)	(ml/m^2)	(l/ha)
1	1.27	22.83	228.3	0.07	1.26	12.6
2	0.1	1.80	18.0	0.38	6.83	68.3
3	0.21	3.78	37.8	0.24	4.31	43.1
4	0.15	2.70	27.0	0.25	4.49	44.9
5	0.05	0.90	9.0	0.08	1.44	14.4
6	0.03	0.54	5.4	0.28	5.03	50.3
7	0.03	0.54	5.4	0.78	14.02	140.2
Average	0.26	4.67	46.7	0.30	5.39	53.9
Drift loses in plum orchard						
Position the measuring vessel	The vessel (ml)	ml/m^2	(l/ha)	The vessel (ml)	(ml/m^2)	(l/ha)
1	1.15	20.79	207.9	1.11	19.98	199.8
2	1.07	19.35	193.5	1.11	20.97	209.7
3	0.92	16.65	166.5	1.31	23.58	235.8
4	0.77	13.95	139.5	1.05	18.90	189.0
5	0.77	13.86	138.6	0.92	16.56	165.6
6	0.66	11.97	119.7	1.06	19.17	191.7
7	0.70	12.69	126.9	0.76	13.68	136.8
Average	0.86	15.60	156.00	1.05	18.94	189.40

Apart from the wind, the second factor causing the increased liquid loss in plum orchard was inter-row distance (4.5x4m) which was larger in comparison to the apple orchard (3.6x1.2 m), which means more space between the trees.

Person who decides on the protection measures and aggregate's operator should take this into consideration and, accordingly, specify the capacity of air current, travel speed and type of nozzles. If speed of the wind is high, injection nozzles should be used. By using venturi air injection nozzles, larger drops resistant to drift are formed with air bubbles.

When in contact with a plant, larger drops break into lots of smaller drops, thus ensuring good coverage of plant (Sedlar et al., 2009). Size of the drops can be selected from large to very small, depending on the pressure, and waving can be reduced up to 90% (Agrotop Spray Technology, Banaj et al., 2010).

Conclusion

Out of all chemicals sprayed by air assisted sprayer during the treatment of one orchard is minimum 20% of pesticides which falls on the ground and facts in this paper confirm that. During treatment of apple orchards with high (1289 l/ha) and medium (801 l/ha) application rate drift loses on the ground was 229.15 l/ha and 199.1 l/ha. During treatment in plum orchard with medium application rate drift loses was 172.7 l/ha.

So reducing of application rate was not enough alone to provide drift decrease. Reducing of application rate also mean higher number of smaller droplets in spray which means higher drift potential. So if we wont to reduce drift losses it should harmonize a lot of factors and measures like: doing chemical treatments in good wether condition, using of inspected calibrated air assisted sprayer, precise pesticide application with correct application rates and using of antidrift nozzles. The best example for that is the medium application rate that apple orchard was treated with. The treatment was performed during nice weather with adjusted air current of a fan and travel speed Thus resulting in a loss of only 50.3 l/ha.

Plum orchard did not show the same results with medium application rate because the wind was blowing up to 3 m/s during the treatment and as notice before weather conditions under which the treatment is performed is one of the most important factors. Apart from the wind, the second factor causing the increased liquid loss in plum orchard was inter-row distance (4.5x4m) which was larger in comparison to the apple orchard (3.6x1.2 m), which means more space between the trees. Person who decides on the protection measures and aggregate's operator should take this into consideration and, accordingly, specify the capacity of air current, travel speed and type of nozzles.

Aknowlegement

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Original scientific paper

COMPARATIVE MEASURING OF DRAFT OF SLATTED MOLDBOARD AND MOLDBOARD PLOW WITH A NEW MEASURING SYSTEM

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Abstract

This paper presents the results of research on the draft of two four-furrow plows with moldboard and slatted moldboard, on tilled and untilled soil. Both plows were of the same type and same manufacturer. Same working parameters were used for measuring (depth, working width, speed) so that the slatted moldboard as a factor could be completely excluded.

New device was used for measuring draft of mounted and semi mounted implements of II and III category. The device has a frame with three force transducers for measuring horizontal load on three point hitch of the tractor.

Draft measuring in the field was done with frequency of 10 Hz and 52000 data was obtained during the test. The lowest average value of draft was 19.73 kN measured in the 10th passing on tilled soil with slatted moldboard, and the highest value was measured in the 3rd passing and it was 28.10 kN. Average values of draft and speed for all passings were similar. The results of variance analysis showed that there was statistically significant difference between the mean values of draft of two tested plows, for both treatments, at a confidence level of 95%. Comparison of mean values of draft for slatted moldboard and moldboard plow, for both treatments, showed a difference of 6% in favor of the slatted moldboard plow on untilled soil, and the difference of about 7% was determined on the tilled soil.

Key words: moldboard plow, slatted moldboard plow, draft, measuring, three-point-hitch frame

Introduction

Soil tillage is the most efficient way of improving physical properties of soil and, in conventional tillage, this is performed evenly over the entire surface by a moldboard plow (Siefken et al., 2005) which significantly reduces the presence of weed and other pests on the plot. In the technological chain of field crops production, soil tillage is the most energy consuming activity which implies that, with high fuel price, the possibilities of reduction of fuel consumption should be considered seriously. One of the options is certainly the acquisition of machinery which would generate minimal costs and offer maximum quality for a given size of land, type of soil, structure of production, etc. In that sense, farmers have become increasingly interested in this issue but they are still unable to decide due to the lack of information. Wrong decision in acquiring machinery can have huge negative effect on both fixed and variable expenses (Grisso et al., 1996). In order to make the right choice of tillage machinery it is necessary to have enough information about drafts for certain types of soil (Alimardani et al., 2008; Al-Janobi et al., 1998). Currently, farmers in Serbia do not have such information available so they rely on their experience and intuition. Development of new implements with increased working width and speeds makes farmers' knowledge and experience of little or no use. Measuring of draft for specific soil conditions is important for the assessment of an agricultural machine (Naderloo et al., 2009). Measuring of draft of different implements provides useful information on power requirements for different tillage and different management systems in field (Perfect et al., 1997). Research performed by numerous authors successfully determined the consumption of energy based on draft force. Energy savings with changeable tillage reach up to 42.8%, i.e. 28.4% of fuel (Gorucu et al., 2001). Data available on implement draft during tillage in different soil conditions can help farmers make rational choices about tractors and tillage machines and their efficient exploitation (Alimardani et al., 2008; Kheiralla et al., 2003; Onwualu et al., 1998; Sahu et al., 2006).This measuring can also help to understand better soil-implement interaction (Upadhyaya et al., 1987; Owen et al., 1990).

One of the methods to increase field efficiency of a tillage machine is to increase its capacity. In order to achieve this it is necessary to increase the working speed. However, main problem in soil tillage with a moldboard plow at higher working speeds is high draft which increases exponentially with increased speed. Hunt (1973) showed that draft of moldboard plow at speed of 20 km/h was 150% bigger than at speed of 5 km/h. Research made by Iowa State University indicated that dependence of plow draft on the working speed is not universal for all types of moldboards (Eidet, 1974).

Numerous authors are focused on determining the draft of moldboard plow. Most of them got the results which showed that draft was square function of working speed (Gill and Vanden Berg, 1968; Kepner et al,. 1982; Goryachkin, 1968; Godwin, 2007). Up to now, the described mathematical models, which are used to estimate the draft of moldboard plow of tillage machines, cannot predict precisely the intensity of draft due to complex interaction of a machine and soil. The most commonly used equation for validation of the values obtained for draft of moldboard plow is in accordance with ASAE standard (ASAE D497.6):

$$D = F_i [A + B (S) + C (S)^2] W \times T \qquad (1)$$

where *D* is horizontal draft force, *F* is the parameter related to soil texture, *A*, *B*, and *C* are specific parameters for tool (for moldboard plow A = 652, B = 0, C = 5.1). *S* is forward speed of tractor, *T* is width, *W* is working depth of implement.

Two types of dynamometers are used for measuring draft in field tests: towed dynamometers and three-point-hitch dynamometers. Towed dynamometers are used for measuring draft at one point and they are usually used on towed machinery or mounted and semi-mounted machinery, but with use of an additional tractor for towing machines (Naderloo et al., 2009). These dynamometers have long been a subject of research of numerous authors (Godwin, 1975; Zoerb, 1983; Godwin et al., 1993; Kirisci et al., 1993; Chen, 2007). The second category of a measuring system represents the measuring frames attached between a tractor and its implement. The frame is a measuring element with force transducers and it is attached between a tractor and its implement (Kheiralla et al., 2003; Askari et al., 2011; Alimardani et al., 2008; Sholtz, 1966). The advantage of measuring draft force with a frame is that it can easily be divided into horizontal, vertical and lateral force. Also, it can be used on different types of tractors and implements. Disadvantages of this type of measuring are the increase in total weight and different geometry of the system.

The aim of this paper was to test the drafts of two identical plows, with moldboard and slatted moldboard, and determine their influence on total drafts.

Material and method

A new three point hitch measuring device (Figure 1) was used in this research. The device was intended for the measuring of draft force of tillage implements that can be mounted, semi-mounted and towed. Lateral forces were not measured because they are insignificant under normal working conditions, that is, when an implement is properly attached. According to the above given classification this device belongs to a category of frames that are equipped with force transducers and placed between a tractor and an implement. The frame was designed in AutoDesk Inventor 2012. The implement was installed 692 mm back from tractor three-point-hitch. The frame mass, together with the measuring elements, was 125 kg. Vertical eccentricity of front lower link points with respect to the rear lower link points was 116 mm. Structure of the frame enables its attachment to tractors and implements of II and III category in accordance with ASAE standard [38].

The device is a frame with front and rear three point hitches for II and III category of tractor and implements. Lower points for connection of the frame with tractor 1, 2 are pins with changeable cross section. Exterior, wider part 1 is envisaged for the connection with III category tractors. Interior, narrower part 2 is envisaged for the connection with II category tractors. The pins are fixed onto the consoles 3. Consoles 3 are connected to the frame structure by pin 4 directly and by pin 5 indirectly, i.e. measuring cells 6 and pin 7. Pins 4 and 5 eliminate the possibility of free vertical movement of the console, and the side plates 8 welded to the front square shaped beam 9, block horizontal movement. Stiffening of lower points that link the frame with tractor enables simultaneous lifting of a machine and frame without any additional protection measures which would protect the force transducers from overload which is possible in case of transport of heavy machinery. Figure 1 (cross section, view A-A) shows that the points of connection of the frame to tractor 1 and 2 are in the same horizontal plain as well as the pins 5 and 7, and axis of measuring cells 6. This kinematic connection transfers all horizontal draft force in link points 1 and 2 to the measuring cell 6 which implies that the detected force in measuring cells 6 represents the actual value of draft force.

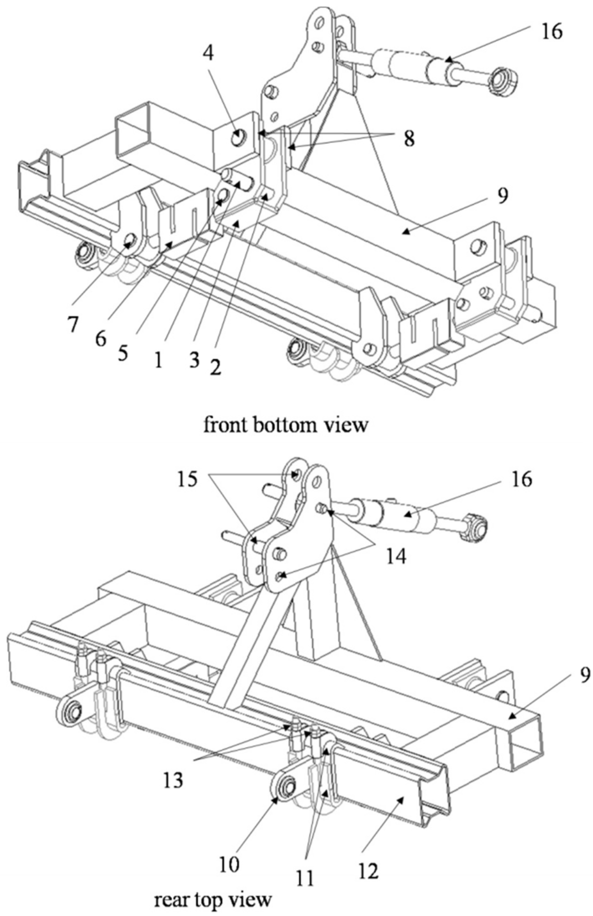


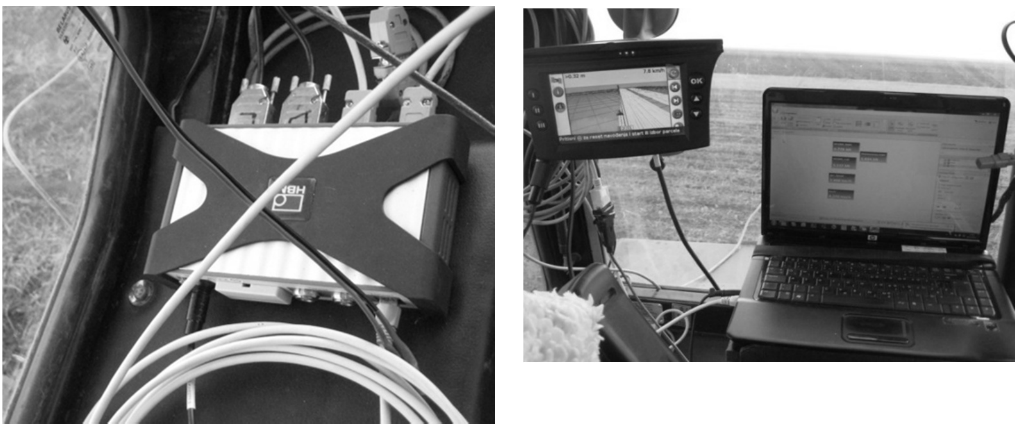
Figure 1. Three-point hitch frame for draft measurement:1, 2-lower link to tractor; 3-console; 4, 5, 7-pin;6-force transducer; 8-side plate; 9-square shaped beam; 10-lower link to implement; 11-decomposable clamp; 12-profile beam; 13-screws; 14-upper link II cat.;15- upper link III cat.;16-top link force transducer

Lower links for implement attachment to the frame 10 are designed as the ends of the lifting lever for tractor with spherical elbows that have adequate diameter of the opening. Two sets of rear lower levers for connection to the machinery of II and III category are envisaged. They are located on the decomposable clamps 11. The clamps are fitted to the beam 12 where they can move crosswise and, when necessary, be replaced in order to adjust to the structure of the II and III category implements. The clamps 11 are fixed with screws 13. Upper points of connections of machine with the frame, and frame with the tractor have two openings, one link 14 for II category and one link 15 for III category. The top link lever for connecting tractor with frame is a standard dynamometer which measures the load in the upper point of connection. The length of a top link lever-dynamometer can always be changed with a leadscrew.

Sensors and data aquisition

Lower link force transducers were of „S“ type, 100 kN capacity, 0.1 N resolution and accuracy of ±0.5% , and tractor top link force transducer had a capacity of 200 kN, 0.1 N resolution and ±0.5% accuracy. Force transducers were connected to a general purpose measuring amplifier/ system for data acquisition (HBM-MX440A). Measuring acquisition was high resolution acquisition (24bit) with possibility of adjustment of sampling speed (to 19200 Hz). Data acquisition and a PC had Ethernet connection.

GPS device Trimble EasyGuide 500 (EGNOS/WAAS) was used for measuring speed and determining geographical position of tractor and its imlement, and the device had standard external port RS232 for communication and data transfer to PC. The GPS reading frequency was 10 Hz (maximum).The frequency was adjusted to 10 Hz during the test. In order to reduce the high frequency variations of short-range force Bassel’s filter was used for eliminating the signals of more than 2 Hz frequency from force trasducers.



a) b)

Figure 2. Data acquisition equipment in the tractor cab: a- DAQ device; b-GPS reciever and Laptop data logger

Field test

Filed experiment was conducted in November, 2012 in the Province of Vojvodina, North Serbia (19.1^0 E, 45.4^0 N). The test was performed on an area of 1.12 ha. The type of soil was humoglei. Forecrop on the plot was soybean that was grown conventionally. Measuring was done on untilled and tilled soil. After forecrop removal the tillage was performed at depth of 35 cm. Tillage gave one new additional variant of soil physical condition with neutralized local specificities. Untilled field was named ''plot A", and tilled field was named "plot B"; the moldboard plow was marked „MP", and slatted moldboard plow was marked „SMP". Soil condition was evaluated using the samples from randomly chosen locations on the plot. The samples were used for determining average texture and moisture. Moisture of the taken samples was determined by a method of drying in the drier at 105^{0}C for 24 h. In the „plot A" it was 19.3%, and in the „plot B" it was 17.3%. Electronic penetrometer made by *Finland, Irvine Ltd.* was used for determining the level of soil compaction. The penetrometer had a diameter of 12.83 mm in the cone base and an angle of 30^0 which is in accordance with the ASAE Standard (ASAE S313.3). The speed of cone penetration into soil was 35 mm/s and reading of draft was done at every 3.5 cm. Diagram of soil compaction presented in layers can be seen in Figure 3.

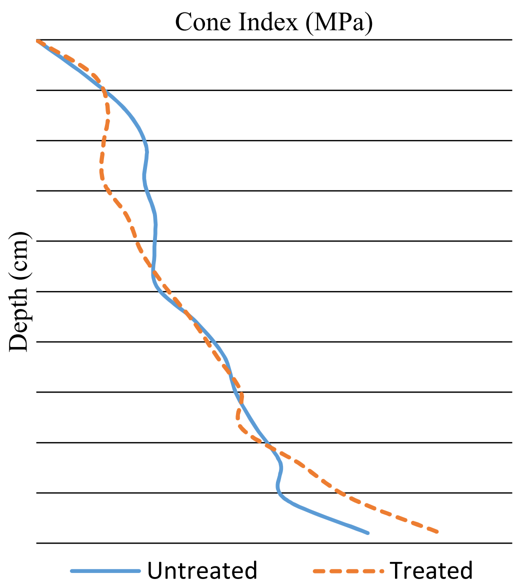


Figure 3. Cone penetration field data

John Deere 6930 tractor was used in the field test. It had engine power of 98kW and two four-bottom moldboard plows of the same type, manufacturer and form of universal body, but the one was equipped with slatted moldboard and the other with moldboard (Figure 4). The working speed can be adjusted within a range of 1.44-1.92 m. Both plows were operated at same working parameters which were constant during the test so that the effect of each universal body could be assessed for drafts. The average depth achieved by both plows was 0.25±0.03 m, and the working width was 1.47±0.08 m. Some authors indicated that uncontrolled variations in the working width of the first body, especially if it is a multi-furrow plow, does not affect the draft significantly (Van Bergeijk et al., 2001). The control of tillage depth and working width was done in every passing in ten replications. The tillage depth of rear universal body was limited by land wheel. The speeds achieved during measuring for both treatments are given in Table 1.

Table 1. Achieved working speeds during test

	GPS speed (m/s)			
	Plot A		Plot B	
	MP	SPM	MP	SPM
Min	1.16	1.32	1.57	1.53
Max	2.16	2.09	2.57	2.34
Mean	1.76	1.71	2.24	2.06
STD	0.16	0.15	0.16	0.17

The hypothesis of the experiment was based on the possibility that if we towed the implement through soil at constant depth, working width and speed, average draft would depend on the design of universal bodies of the plow and local variations in soil physical properties. Both plows were equipped with new moldboards in order to avoid negative effect of uneven bluntness of the blades on the final result of the test.

Figure 4. Draft measuring system (tractor+three-point-hitch device) and tested plow (slatted moldboard plow)

Data analysis

Data were collected during the test and stored on a PC with data collection software (HBM-CatmanEasy-AP3.4.1.). The first step was to eliminate the data collected at the moment of aggregate's turning (at the end of the plot) as well as the data collected at the beginning of the passing until stable work parameters (speed, working depth) were reached. Also, errors from GPS receiver resulting from signal interferences were eliminated. By eliminating the atypical values, signals for individual neighboring passings were obtained.

Total draft force was calculated by adding the values obtained from lower force transducers with corrected top-link values. Value of tractor top link force was corrected in accordance with the angle that was covering top-link with surface during measuring. Considering that the speed of tillage is impossible to keep absolutely constant (due to wheel slippage and abrupt change of draft) a correction of draft was made for standardized velocity. Since the speed varied in narrow intervals, linear pattern was used (2) simple correction of draft values. Correction factor was 5 kN m^{-2} for every 1 m s^{-1} of speed increase. Referential speed was determined based on the average speed during the test, and it was 1.8 m s^{-1}:

$$F=F_0+(5.0*1.8) \quad (2)$$

where: F_0 is the specific plow draft in kN/m^2 at a velocity v_0 of 1.8 m/s; F is the specific plow draft in kN/m^2 at velocity v; and v is the actual velocity in m/s.

Statgraphics Centurion XV.I. software was used for data processing.

Results and discussion

Draft measuring in the field was performed at frequency of 10 Hz and around 52000 data was obtained during the test.

Results of draft with respect to the type of moldboard for both plots are given in Table 2 as mean value ± standard deviation (Mean±SD), coefficient of variation (CV) and minimal (maximal) achieved values.

Table 2. The test results of draft

Passing	Plow	Plot	Mean±STD	Min	Max	CV
1	MP	A	27.04±2.73	10.68	32.98	17.89
2	MP	A	27.84±2.60	15.55	36.92	18.10
3	MP	A	28.10±3.10	10.63	32.79	19.93
4	MP	B	21.35±2.11	14.35	24.92	20.86
5	MP	B	21.66±2.62	10.96	26.73	24.22
6	MP	B	22.95±3.29	8.04	40.16	25.36
7	SMP	A	27.41±2.40	14.80	27.19	13.29
8	SMP	A	24.86±2.74	6.99	32.19	18.98
9	SMP	A	26.16±2.49	13.80	27.50	15.41
10	SMP	B	19.73±2.08	12.54	22.76	19.44
11	SMP	B	21.16±1.90	14.21	17.94	15.69
12	SMP	B	20.82±2.10	12.25	24.44	16.94

The lowest average value of draft was 19.73 kN and it was measured in the 10th passing on tilled soil with slatted moldboard, and the highest value, 28.10 kN, was measured in the 3rd passing. Average values of draft and speed were similar for all passings. Standard deviation was the highest in the 6th passing (3.29 kN), while all other passings showed similarities in this parameter. As regards the speed, more similarity was observed in the mean values and standard deviation in passings.

Still, big differences between minimal and maximal values of draft force in passings imply significant changes on the draft amplitude in time (Hayhoe et al., 2002, which can be easily observed on the graph (Figure 5).

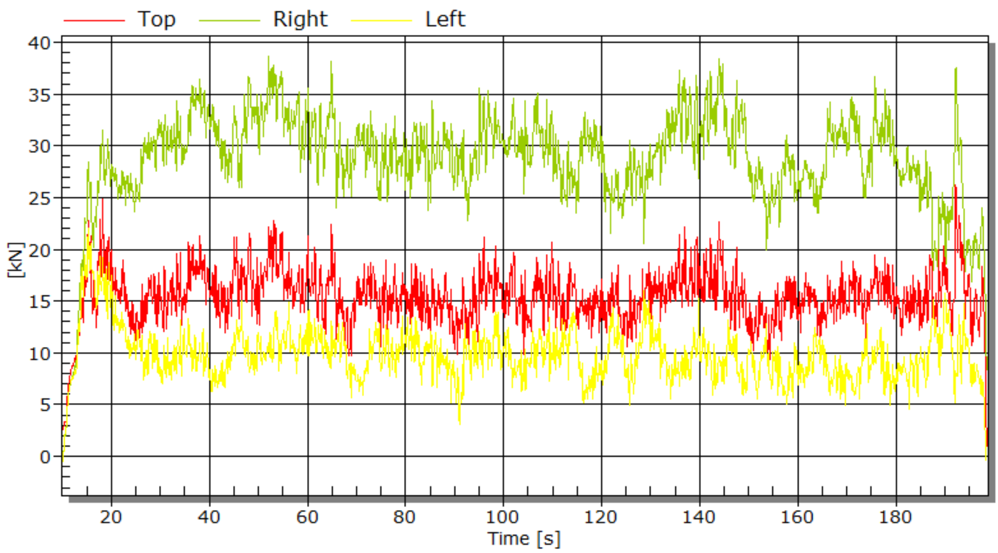


Figure 5. Real-time graph of recorded draft force for one passing

Table 3. Analysis of Variance for draft force

Source	*Sum of Squares*	*Draft force*	*Mean Square*	*F-Ratio*	*P-Value*
MAIN EFFECTS					
A:Moldboard type	6.45333	1	6.45333	8.04	0.0219
B:Plot	94.8656	1	94.8656	118.24	0.0000
INTERACTIONS					
AB	0.0075	1	0.0075	0.01	0.9254
RESIDUAL	6.41833	8	0.802292		
TOTAL	107.745	11			

The results of variance analysis showed that there was statistically significant difference between the mean values of draft of two tested plows, for both treatments, and for the level of confidence of 95%. Table 3 shows that in this case the soil was more important factor for draft than the type of moldboard.

Figure 6 shows diagram of interaction of this type of moldboard and soil pre-treatment and its effect on the draft. It is clearly seen that on both types of soil moldboard has bigger draft than the slatted moldboard, which was expected considering the smaller contact area in case of slatted moldboard and less friction between soil and moldboard.

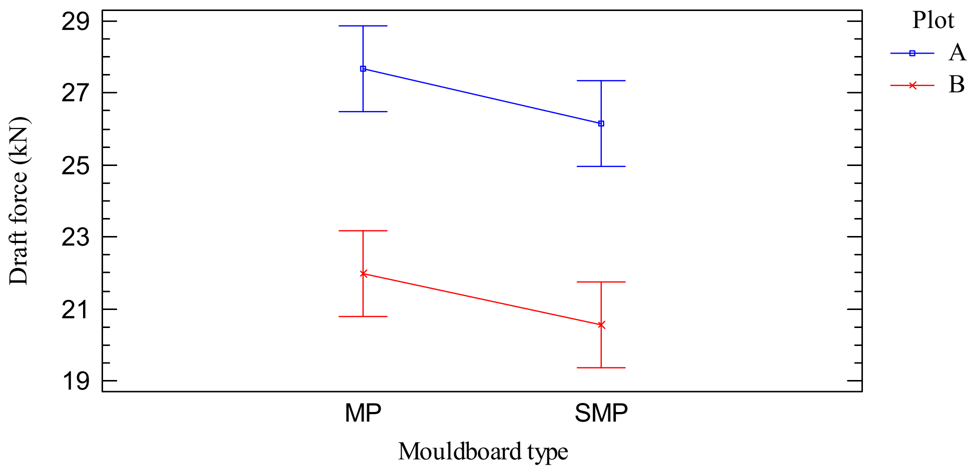


Figure 6. Interaction of type of moldboard and soil and its effect on the draft

By comparing the mean values of drafts of moldboard and slatted moldboard, for both treatments, a difference of 6% was observed in favor of the slatted moldboard on untilled soil, while the difference on tilled soil was on average about 7%. These results confirm the difference between slatted moldboard plow and moldboard plow of similar dimensions on tilled and untilled soil, which confirms the hypothesis that draft depends not only on the physical properties of soil and working parameters, but on the design of tool elements as well (Askari et al. 2013; Al-Janobi et al. 1998).

Conclusion

The following conclusions could be drawn according to the results of measuring the draft of moldboard plow and slatted moldboard:

- the measuring equipment used in the test met all the requirements,
- the values obtained for the draft of both types of plow were within the expected range,
- mean values of draft in passings were similar which confirmed stability and reliability of the measuring system,
- the measuring system is extremely sensitive and is able to detect the slightest changes of draft in time,

- difference between the draft of slatted moldboard and moldboard plow on untilled soil was 6% in favor of the slatted moldboard, and 7% on the tilled soil.

In order to come to more reliable conclusions about the influence of the design of moldboard on the draft, it is important to:

- repeat the measuring on different types of soil,
- measure the draft at different working speeds,
- consider the intensity of soil crushing (size of the aggregate).

Acknowledgment

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Original scientific paper

Effect of inoculation with *Azotobacter chroococcum* on dynamics of the number of microorganisms in the rhizosphere of maize

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Abstract

Successful production in monoculture requires intensive cropping, especially intensive tillage and fertilization with organic and mineral fertilizers. Microbial community composition can also respond differently to agricultural management practices. Monitoring changes in microbial communities induced by long-term fertilization regimes is suggested to be an important step towards sustainable agriculture. The aim of this study was to investigate dynamics of the number of microorganisms in the rhizosphere of maize in long–term monoculture. A two-level factorial split–plot experiment was set where the first factor was the fertilization (mineral and organic fertilizers) and the second factor was the inoculation with *Azotobacter chroococcum*. The inoculation with *Azotobacter chroococcum* increased the number of azotobacters, the total number of microorganisms and the number of P-mobilizers in maize rhizosphere. The highest increase (%) in the abundance of all examined microbial groups was obtained on variants NPK and NPK + manure. The best effects of inoculation were achieved in the second and third date of sampling.

Key words: *Azotobacter chroococcum*, microorganisms, rhizosphere, maize, yield

Introduction

In modern agricultural production growing crops in monoculture is widely present practice because it allows the maximum harvest with minimal labour. Successful production in monoculture requires intensive cropping, especially intensive tillage and fertilization with organic and mineral fertilizers. However, long periods of growing crops in monoculture reduces soil quality in terms of its physical and chemical properties, but also affect the diversity and structure of microbial communities as well as presence of certain soil borne pathogens (Nannipieri et al., 2003).

Soil beneficial rhizobacteria have been used in crop production for decades because of the role they play in supply nutrients to crops, stimulate plant growth through the production of plant hormones, control or inhabit the activity of plant pathogens, improve soil structure, and bioaccumulation or microbial leaching of inorganics (Hayat et al., 2010). The dynamics of soil microorganisms is affected by many abiotic and biotic factors: soil type, plant species, soil cultivation, application of organic and mineral fertilizers, irrigation, use of pesticides, etc. Microbial community composition can also respond differently to agricultural management practices. Monitoring changes in microbial communities induced by long-term fertilization regimes is suggested to be an important step towards sustainable agriculture (Wu et al., 2011).

Complex relations that exist among the plant, the soil microorganisms and the soil itself are the determinants of plant health and soil fertility and can have a significant impact on plant growth and its yield. Knowledge of these relations is essential for the development of a cropping system which is based on the application of biofertilizers, phytostymulators and biopesticides that allows reduced use of chemicals in crop production, especially in long-term monoculture (Mrkovački et al., 2012).

The aim of this study was to investigate dynamics of the number of microorganisms in the rhizosphere of maize in long–term monoculture.

Material and Methods

The study was conducted in the multi–year stationary field experiment at the Institute of Field and Vegetable Crops, Novi Sad at Rimski Šančevi. The field is located on a calcareous chernozem on loess terrace. The experimental design was a randomized, complete block design (split-plot design experiment) with four replications. A two-level factorial split-plot experiment was set where the first factor was the fertilization (mineral and organic fertilizers) and the second factor was the inoculation with *Azotobacter chroococcum*. The study treatments were: Ø – control variant (maize in monoculture without fertilizer or organic fertilizers); Monoculture: NPK – maize in monoculture, fertilized only with mineral fertilizers; Monoculture: NPK + manure – maize grown in monoculture, with application of manure and mineral fertilizers; Monoculture: NPK + crop residue – maize grown in monoculture, with plowing crop residues (maize) and the application of mineral fertilizers; Treatments included two variants, inoculated and non–inoculated. Inoculation was performed with a mixture of *Azotobacter* strains, with the concentration of 10^9 per ml, incorporated into the soil before planting. The experiment was grown with maize hybrid NS 6010. Soil samples were taken for microbiological analyses at three dates (20th May, 7th June and 2nd August). Total number of microorganisms was determined by the dilution method on agarized soil extract (dilution 10^7). Nitrogen–free medium and the method of fertile drops was used for number of azotobacters (dilution 10^2). The number of P-mobilizing bacteria was done in glucose-asparagine agar (dilution 10^5). All microbiological analyses were performed in three replications and the average number of microorganisms was calculated at 1.0 g absolutely dry soil (Jarak and Đurić, 2004).

Results and Discussion

Effects of the different types of fertilization and maize inoculation are presented in Tables 1, 2 and 3. Table 1 shows the number of azotobacters, Table 2 the total number of microorganisms and Table 3 the number of P–mobilizers in maize rhizosphere.

The number of azotobacters was increased by inoculation from 26.60% to 36.43% in the first and second sampling date. The largest increase was obtained on variant NPK + crop residue (88.15 and 82.30 x 10^2 g^{-1}). In the third sampling date number of azotobacters was increased on all variants of fertilization. Significantly higher increase over the control was obtained on variant NPK + manure (190.65 x 10^2 g^{-1}) (Table 1).

Table 1. Number of azotobacters in maize rhizosphere depending on fertilization treatment and inoculation (x 10^2 g^{-1})

Sampling	Inoculation	Fertilization Treatment					Increase (%)
		NPK	NPK + M	NPK + CR	Control	Average	
I	-	5.80	6.00	107.80*	21.80	35.35	36.43
	+	27.20	7.90	68.50	89.30	48.23	
	Average	16.50	6.95	88.15	55.55	41.79	
II	-	3.80	17.20	102.30*	21.50	36.20	26.60
	+	11.70	13.70	62.30	95.60	45.83	
	Average	7.75	15.45	82.30*	58.55	41.01	
III	-	109.90	229.10*	108.70	84.70	133.10	-0.75
	+	139.60	152.20	140.70	95.90	132.10	
	Average	124.75	190.65*	124.70	90.30	132.60	

$LSD_{0.05}$	I	II	III
I	25.41	15.86	35.23
T	35.94	22.42	49.82
I x T	50.83	31.71	70.45

The total number of microorganisms on average was increased by inoculation in all sampling dates. The biggest effect of inoculation was achieved in the second sampling (64.31%). In the second and third sampling date, significant increase in the total microbial number was obtained on variants NPK and NPK + manure (202.80 and 154.60 x 10^7 g^{-1}) (Table 2).

Table 2. Total number of microorganisms in maize rhizosphere depending on fertilization treatment and inoculation (x 10^7 g^{-1})

Sampling	Inoculation	Fertilization Treatment					Increase (%)
		NPK	NPK + M	NPK + CR	Control	Average	
I	-	198.00	246.00	155.00	221.00	205.00	9.27
	+	229.00	218.00	196.00	253.00	224.00	
	Average	213.50	232.00	175.50	237.00	214.50	
II	-	184.40*	115.10	92.60	100.50	123.15	64.31
	+	203.40*	290.50*	168.20	147.30	202.35*	
	Average	193.90*	202.80*	130.40	123.90	162.75	
III	-	128.50*	162.30*	111.10	63.00	116.23	2.24
	+	122.90	146.90	106.50	99.00	118.83	
	Average	125.70*	154.60*	108.80	81.00	117.53	

		I	II	III
$LSD_{0.05}$	I	47.2	25.83	26.75
	T	66.7	36.54	37.83
	I x T	94.3	51.67	53.51

Table 3. Number of P-mobilizers in maize rhizosphere depending on fertilization treatment and inoculation (x 10^5 g^{-1})

Sampling	Inoculation	Fertilization Treatment					Increase (%)
		NPK	NPK + M	NPK + CR	Control	Average	
I	-	243.20*	158.30	137.10	157.20	173.95	-1.75
	+	229.60*	163.80	127.10	163.30	170.95	
	Average	236.40*	161.05	132.10	160.25	172.45	
II	-	184.00	161.00	91.00	156.00	148.00	6.59
	+	171.00	199.00	131.00	130.00	157.75	
	Average	177.50	180.00	111.00	143.00	152.88	
III	-	331.00	277.00	316.00	307.00	307.75	27.86
	+	439.00	312.00	372.00	451.00	393.50*	
	Average	385.00	294.50	344.00	379.00	350.63	

		I	II	III
$LSD_{0.05}$	I	28.34	44.6	71.7
	T	40.08	63.1	101.4
	I x T	56.68	89.2	143.4

The number of P-mobilizing bacteria was increased by inoculation in second and third date of sampling (6.59 and 27.86%). The significant increase in the number of P-mobilizers in the first sampling on average for both variants of inoculation, was obtained on NPK variant and amounted to 236.40 x 10^5 g^{-1} i.e. 47.5%. On this variant of fertilization the best effect in the third sampling was recorded (385.00 x 10^5 g^{-1}), while at second sampling equally good results were ontained on variants NPK and NPK + manure (Table 3).

Mandić et al. (2005) showed that the use of *Azotobacter* in the maize mineral nutrition did not significantly increase the yield of maize silage and grain. The results of their study showed that lower doses of nitrogen and solid manure during the growing season stimulated number of azotobacters in the soil, while liquid manure showed a smaller effect. High doses of fertilizers repressed number of investigated micobial groups, especially at the beginning of growing season, as well as during low soil moisture and drought period, which is in agreement with our results. Many authors state that the total number of microorganisms varies depending on the time of sampling. Mandić (2011) recorded that the total number of microorganisms on average for year, hybrids and methods of biofertilization, was the highest in samples taken at the stage of waxy ripeness. Regarding the fertilization treatment, the smallest total number of microorganisms was obtained in the control variant and the highest in variant of seed inoculation. The number of azotobacters was a statistically significantly higher ($P < 0.01$) in samples taken at the stage of waxy ripeness than in the silking stage. In the three–year period, the highest number of azotobacters was achived in the case of hybrid NS 6010 than in the case of hybrids ZP 684 and Dijamant–6.

Conclusions

The inoculation with *Azotobacter chroococcum* increased the number of azotobacters, the total number of microorganisms and the number of P-mobilizers in maize rhizosphere. The highest increase (%) in the abundance of all examined microbial groups was obtained on variants NPK and NPK + manure. The best effects of inoculation were achieved in the second and third date of sampling.

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Professional paper

Popularization of soil fertility control among landusers

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Abstract

Institute for soil – Osijek has started a project „Soil fertility control on family farms"in 2003 with Faculty of agriculture Osijek and Osijek – Baranja County. Main goals of this project was that land users get soil analysis and fertilizations recommendations for low prices, also increasing popularization of soil fertility control through soil chemical analysis among land users and establishing the information system of the soil features. For over 10 years it has taken about 17400 of soil samples and covered about 108000 ha of arable land. Interest for this project increased each year; crop producers get chemical analysis and fertilizations recommendations at low prices (they paid 20% of total price and rest is cover with budget of Osijek - Baranja County) and savings in costs of mineral fertilizers with positive effects on their management inputs. Project involved arable land with different types of crops and farmers with different management of soil cultivation. This project has retained in its basic concept until today and these activities are being conducted on the basis of contracts with other counties as well.

Key words: soil fertility control, soil chemical analysis, soil degradation

Introduction

Soil testing has been an accepted agricultural management practice for decades. Interpretations and fertility recommendations based on soil analyses and the information obtained with soil samples on cropping systems, tillage practices, soil types, manure use, and other parameters have contributed to the increased efficiency of agricultural production (Sims et al., 2000).

Soil fertility is defined as the ability of a soil to provide the conditions required for plant growth. It is a result of the physical, chemical and biological processes that act together to provide nutrients, water, aeration and stability to the plant, as well as freedom from any substances that may inhibit growth. (Stockdale et al., 2002).

Soil fertility management is described under 3 headings: (1) appropriate crop husbandry practices to maintain and/or improve the condition of the soil; (2) organic fertilizers and inorganic fertilizers that can be applied to achieve quicker results but at a higher cost; and (3) an explanation of scientific terms that are often used in texts about soil science to help those who want to read more about soils (Scholl, 1998). Establishing the information system of the soil features from database that was formed we get multiply useful for the user (fertilization recommendation for a specific culture) and for local self-government and a county when planning the production and considering the possibilities of agricultural production. By connecting the data on the way of soil usage and chemical analysis results with coordinates of sampling spots, the Institute of soil creates GIS data base enabling spatial interpretation of all data of analyzed land plots.

Material and methods

Average soil samples for soil analysis are taken by probe. Average soil sample makes 25 subsamples took at random locations throughout one field or area. For areas in which field crops are grown, samples were collected at the same depth that the field is plowed (0-30cm) because this is the zone in which lime and fertilizer have been incorporated. Soil sampling sites are located with Global positioning system (GPS) and all data are in GIS database.

Soil analysis was with emphasis on amount of phosphorus, potassium, percentage of organic matter and soil reaction in top layer (0-30 cm). The AL-method - extraction with ammonium-lactate was used for determination of available phosphorus (Test method: Determination of ammonium lactate extractable phosphorus express as P_2O_5-spectrophotometric determination-In house method) and potassium (Test method: Determination of ammonium lactate extractable potassium express as K_2O –-flamefotometric determination-In house method).

The percentage of organic matter (%) was determined spectrometricaly using bichromate method (Test method: Determination of humus bysulfochromic oxidation spectrophotometric determination – In house method) and the results were classified according to Gracanin (Skoric, 1992). Soil reaction, pH was determined according to HRN ISO10390:2005).

Results and discusion

Perhaps the most important property of soil as related to plant nutrition is its hydrogen ion activity, or pH (the term "reaction" is also used, especially in older literature). Soil reaction is intimately associated with most soil-plant relations. Consequently, the determination of pH has become almost a routine matter in soil studies relating directly or indirectly to plant nutrition. Knowledge of soil acidity is useful in evaluating soils because pH exerts a very strong effect on the solubility and availability of many nutrient elements (Thomas, 1967).

Over a 37% of soil samples from this project had pH strongly acid, 18% moderately acid and rest of the soil samples had neutral to slightly alkane (Figure 1). From this data we can see different between western, which is largely strongly acid and moderately acid, and eastern part of named county which is most neutral to slightly alkane.

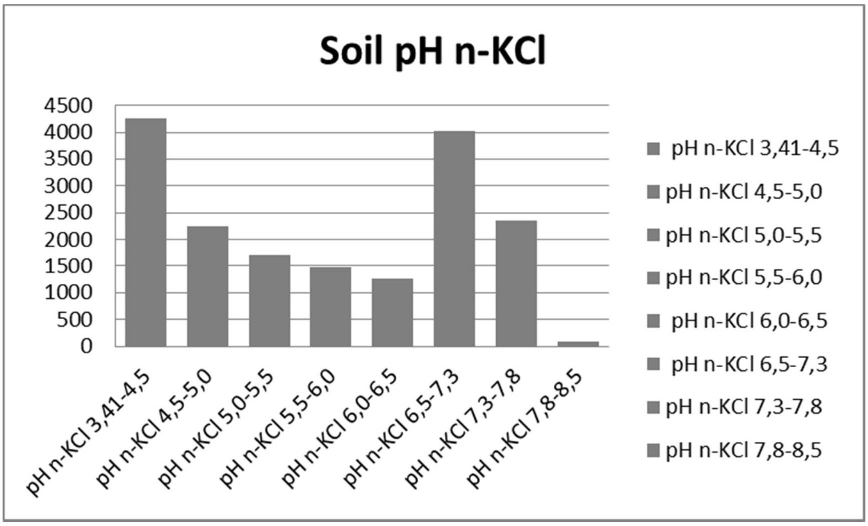

Figure 1. pH range of soil (Vukadinović and Vukadinović, 2011)

Phosphorus (P) is an essential element classified as a macronutrient because of the relatively large amounts of P required by plants (Figure 2). Phosphorus is one of the three nutrients generally added to soils in fertilizers. One of the main roles of P in living organisms is in the transfer of energy (Busman, 2009).

15% of soil samples had low values of available phosphorus less than 10 mg /100g of soil, 41% of soil samples had between 11 and 20 mg/100g of available phosphorus, 44% of samples had over 20 mg /100g of available phosphorus

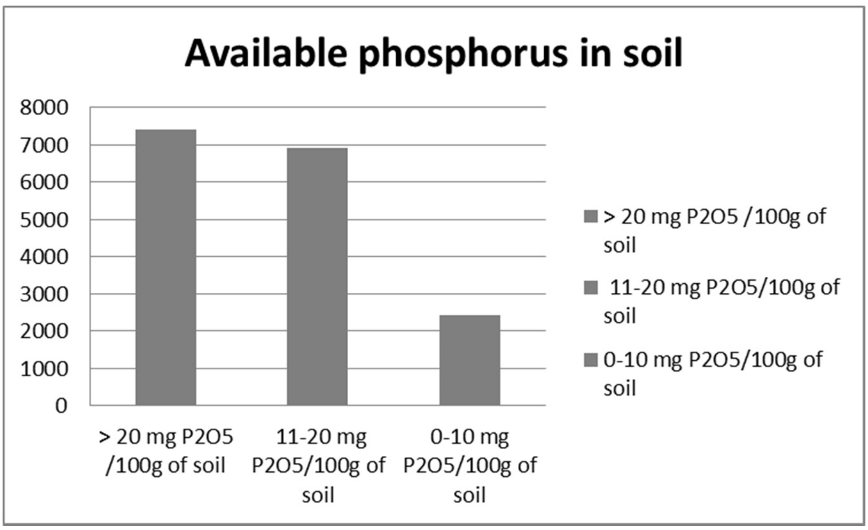

Figure 2. Soil phosphorus availability (Skoric, 1992)

Potassium is one of the principle plant nutrients underpinning crop yield production and quality determination (Figure 3). While involved in many physiological processes, potassium's impact on water relations, photosynthesis, assimilate transport and enzyme activation can have direct consequences on crop productivity. Potassium deficiency can lead to a reduction in both the number of leaves produced and the size of individual leaves (Pettigrew, 2008).

Available potassium situation is a little bit better. Only 4% of samples had less than 10mg/100g, 31% of samples had 11 to 20mg/100g of soil, 64% samples had over 20 mg/100g.

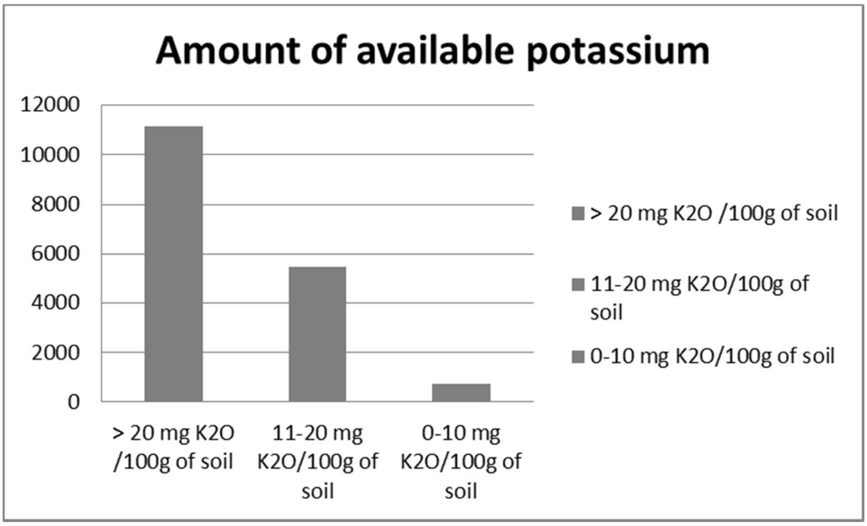

Figure 3. Soil potassium availability (Skoric, 1992)

There is more reason for unevenness in availability of phosphorus and potassium. The factors can be relate to pH of soil (soil acidity can affect P-sorption), soil mineral type, temperature or it could be because of excessive use of mineral fertilizers.

Land using and management practices can affect dramatically on losses of humus and decreases of soil organic matter also very little or no application of manure. (Skoric, 1992; Bot, 2005). Various types of human activity decrease soil organic matter contents and biological activity (Seput et. al., 2006). For 90% surfaces that have been sampled had humus content between 1 and 3 percent. The maintenance of soil organic matter levels and the optimization of nutrient cycling are essential to the sustained productivity of agricultural systems (Bot, 2005).

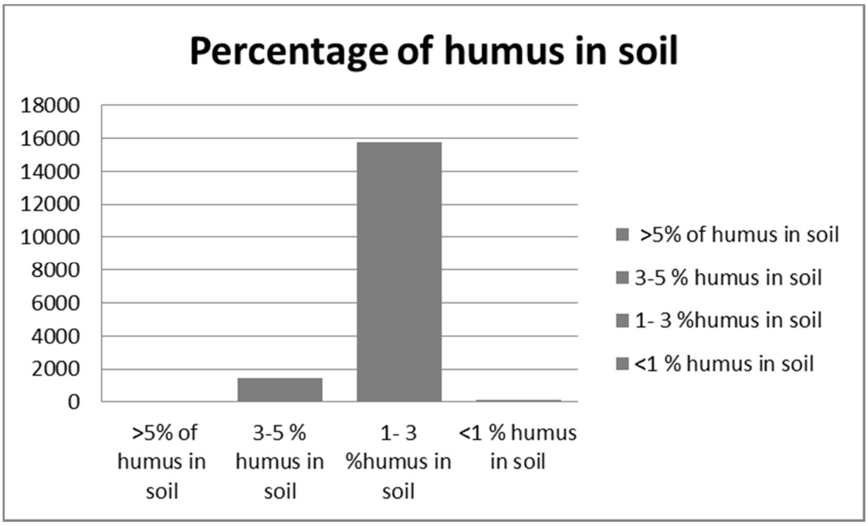

Figure 4. Humus content in agricultural soils (Skoric, 1992)

Conclusion

Main goals of this project was that land users get soil analysis and fertilizations recommendations for low prices, also increase popularization of soil fertility control through soil chemical analysis among land users and establishing the information system of the soil features. After 10 years of doing this project is still going and the farmers are well satisfied. They get chemical analysis and fertilizations recommendations at low prices (they paid 20% of total price and rest is cover with budget of Osijek – baranja County) and savings in costs of mineral fertilizers with positive effects on their management inputs. Also they learned importances of different chemical properties of a soil interact in complex ways that determine its potential fitness or capacity to produce healthy and nutritious crops.

In scientific way what we have noticed that are increased amount of available potassium is closely linked with intensive fertilization. Low values of available phosphorus can be linked with strong acidity of more than half soil samples. Also results for content of soil humus is a very disturbing, 90% surfaces has humus content between 1 and 3 percent, average 1,7%. Therefore, low soil organic matter has influence on soil compatibility, friability, and soil water-holding capacity while aggregated soil organic matter has major implications for the functioning of soil in regulating air and water infiltration, conserving nutrients, and influencing soil permeability and edibility.

Results and data that we got from this project serve us and to crop producers, farmers to get early warning indicators of soil degradation and how they relate to the sustainability of agricultural systems.

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Original scientific paper

Geostatistical model evaluation for soil tillage suitability II

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Abstract

This paper presents the development of a computer model for estimation of suitability for soil tillage in eastern Croatia. Model are based on GIS geostatistical analyses of physico-chemical data of Interpretative base of soil resources of Osijek-Baranja county, which currently accounts 24 536 soil samples with over 1,000,000 soil information. As a cartographic basis, but also a source of data were used the Croatian soil map in digital form, and the data of size and position of agricultural land units (parcels) have been taken from ARKOD. Previous model of soil tillage suitability has been upgraded and now uses seven indicators of suitability of which four are determined exactly (pH, humus content, plot size and elevation), soil type and type of wetting (automorphic and hydromorphic) are taken from the Digital Soil Map of the Republic of Croatia as and the rank of general workability which is an inherent property of each pedosystemic units. Required power or *Power Index* is calculated from the 3D function whose variable concentrations of humus and soil bulk density, while the geographical position and elevation used for estimation of the plot slope, average annual temperature and rainfall. The model calculated the average relative workability of land 59.75% (min. 35.82, max. 89.78%) and the total number of samples in the interpretive basis of land resources Osijek-Baranja County, 5.82% are in the class S1; 27.57% in S2; 66.49% in S3, and only 0.11% are in class N1 or N2, which is not suitable for soil tillage.

Key words: Geostatistical model, soil tillage, soil suitability

Introduction

Methodology of evaluation of soil suitability for specific purpose as well as for its tillage, are very complex because it must take into account a number of relevant indicators that its quality can be defined as a measurable value (Vukadinović et al., 2009). The complexity of such a methodology imposed simplification and reduction on the attributes that describe the critical properties of the soil, although neither they, in many cases, can not be directly measured. Therefore, the model includes only those indicators of the relative land suitability that are measurable and sensitive to variations in soil with relatively low analytical or measurement error (MacEwan and Carter, 1996).

The proposed model generally determines the relative suitability of agricultural land as the basis for estimating the required tractor power. Further research and development model should determine the actual power required, the type and capacity of tillage equipment for a different level of land workability, easily by measuring and comparing the performance of the same or similar equipment, or agrotechnics.

Selection of tools for soil tillage and optimum power tractors are extremely important for the effectiveness of each farm. In fact, in every system of crop production machines represent the largest single item, and almost 60% of total expenditures (Dash and Sirohi, 2008). The decision on the optimal size of the machine so it is complex because it is a critical and very risky capital investment, not only because of the high initial investment, but also a significant share of the total costs and the irreversibility of such a decision. In any system of crop production soil type, the number of operations required for each crop, crop rotation, time available and other factors are very delicate and extremely important in selection of the optimal size of the tractor and tillage equipment's. On tractor market and equipment machinery, on the one hand it is a great offer considering the type, strength, capacity, cost, etc., while on the other, should take into account climate (e.g. the variability of weather conditions), land (e.g. towing strength due to the soil type, moisture, etc.) and agricultural management requirements (e.g. timeliness for soil tillage, fertilization, planting, plant protection, soil cultivation, etc.). Therefore, investment in agricultural mechanization is still more on intuitive than on scientific-expert bases.

Though the analysis, evaluation and prediction with GIS today irreplaceable, many models of land suitability assessment based on it are still imperfect, lacking the appropriate tools for data entry and data management, and have sufficiently reliable prediction of certain soil properties, and they are still with small application value. Therefore, the focus of this paper is not only just a presentation of the conceptual aspect or inventarisation land resources, but the integration of GIS, primarily geostatistical methods and mathematical-computer model for evaluation of land suitability for soil tillage in experimental model subjected for validation in the specific conditions of the eastern Croatian (Vukadinovic et al., 2008 and 2009; Vukadinovic and Jug, 2010).

The paper describes the geostatistical computer model for evaluation of soil workability in Osijek-Baranja County, and the data were analyzed and visualized by GIS tools (ArcMap v10.1). As a cartographic basis, but also as a source of information used data of Digitad Croatian Soil Map (Bogunović et al., 1997), ARKOD and online data of State Geodetic Administration, and as a source of exact physical and chemical indicators of fertility, information about the arrangement of soil, crop rotation, organic fertilization, soil biogenity, climate, etc. are used Interpretation Base of Land Resources of Osijek-Baranja County, which was created in the Department of

Chemistry, Biology and Physics of soil from Faculty of Agriculture in Osijek (http://pedologija.com.hr/karte.htm).

Methodology

As a GIS background, and as a source of information related to pedophysical properties of soils are used Digital Croatian Soil Map (DCSM). From CSM are taken types of soils and their inherent physical and chemical properties on the basis of which is ranked general land workability. Since it contains a modest number pedophysical and chemical analysis, and basic pedosystemic units are aggregated into digital form (often on inadequate way), Digital Soil Map is enough reliable. Also, as the cartographic basis are used DOF and TK25 maps (http://geoportal.dgu.hr/viewer/) and ARKOD as source of geopositioning and size of land units (production) plots (http://preglednik.arkod.hr).

Since each model is only an approximation of reality, in the evaluation of the soil workability are involved only relevant aspects of the data available from DCSM, ARKOD and Interpretative Base of Land Resources (IBLR) of Osijek-Baranja County respectively following indicators:

1) General soil 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) Index modes of soil wetting - automorphic (includes pH) or hydromorphic soil type (4 class, logical function, f5),
6) Altitude (Six classes, f6),
7) Plot (unit) size (seven classes, f7).

Tables of ranks are adjusted relative to the first version of the evaluation of the relative workability of land (Vukadinovic and Jug, 2010), and negative values of workability indicators ranks are abandoned. Table 1 shows the value and description of the ranks (more is better) and the rules for their application:

Table 1. General soil workability

General workability (f1)	rank
1) soil suitable for tillage	15
2) soil moderately suitable for tillage	12
3) limited soil suitable for tillage	10
4) soil temporarily unsuitable for tillage	5
5) soil permanently unsuitable for tillage	2

Workability in the unfavourable soil moisture (f2)	rang
1) tillage possible in a wide range of moisture levels	15
2) tillage possible in optimum range of moisture	10
3) tillage possible in the narrow limits of humidity	5
The possibility of direct seeding (f4, No-tillage)	**rang**
1) without restriction	10
2) after agro- and hydro technic measures of	8
3) permanently restricted	5
Altitude (f6, m)	**rang**
1) <100	10
2) 100-150	8
3) 150-200	6
4) 200-250	4
5) 250-500	2
6) >500	1
Plot size (f7, ha)	**rang**
1) <1	2
2) 1-2	3
3) 2-3	4
4) 4-5	6
5) 5-10	8
6) 10-20	9
7) >20	10

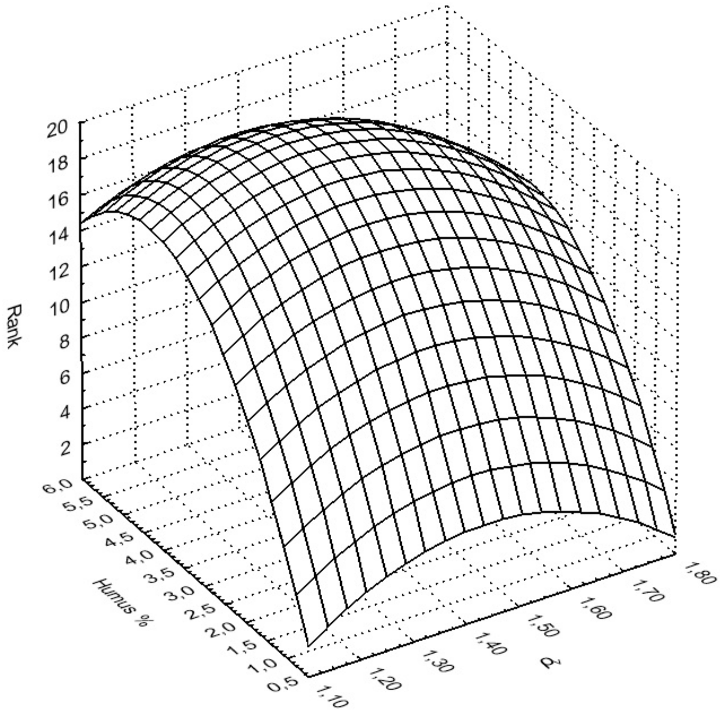
Index of the required power (*Power Index*, PwI) for soil tillage are very similar to Power Index explained in *ISPAID Database*, 2006, and is determined based on soil bulk densities (6 classes, field assessment of soil texture groups with feel method, calculated to bulk density (ρv) and exactly defined concentration of humus using 3D function (Graph 1):

$$PwI = -65.74 + 92.66 \times \rho v + 10.54 \times humus - 32.14 \times \rho v^2 - 1.09 \times tgr \times humus - 1.08 \times humus^2$$

Index modes of soil wetting (f5) including pH_{KCl} soil reaction, and is defined by the logical expression:

IF (soil tipe = automorphic and pH-KCl > 5)
THEN rank = 20
ELSE rank = 10
ELSEIF (soil tipe = hydromorpfic AND pH-KCL > 5)
THEN rank = 5
ELSE rank = 2
ENDIF

Index modes of soil wetting (automorphic ili hydromorphic) are determined according Škorić (1986).



Graph 1. Function of Index of the required power for soil tillage

Model of evaluation for soil tillage suitability has been created based on 24,536 soil samples taken in the eastern Croatian in period from 2003 to 2012 year, of which 17,681 samples from Osijek-Baranja County. Since each sample exactly geopositioning in WGS 1984 projection (lat, long, alt), with the DCSM (Bogunović et al., 1997) were obtained by overlapping layers (*intersect layer*, ArcMap v10.1) data about pedosystemic units on which they are automatically ranked general workability and other indicators of inherent soil type (type of wetting).

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 in laboratory. *"feeling method"* are used because the DCSM of Osijek-Baranja County contains only 20 soil profiles with the needed information.

Geoposition and each plot site are taken from ARKOD which are overlapping with GIS layers. Average annual precipitation and average annual temperature for each location (plot) are calculated with regression model (Zaninović et al., 2005; Gajić-Čapka et al., 2004.). Soil type is defined with overlapping layers from DCSM and Workability model. 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 discussion

Basic statistics indicators of evaluation of relative soil workability are shown in Table 2. Results of analyses are indicate on predominantly lowland character of Osijek-Baranja County with average altitude of all analyzed samples (locations-plots) of 91.86 m. A small number of samples from the mountainous area Krndija not significantly affect the average altitude. The average size of the analyzed plots was 17.2 ha (median 5.2 ha), which clearly indicates that larger farmers often analyze their own soil and participate in the control of fertility. In fact, the situation is very bad because the ARKOD in Osijek Baranja County has a total of 113,652 plots with an average size 2,175 ha (median = 0.479 ha). Fragmentation of agricultural land in the whole territory of Croatia is much worse, so the total of 2,285,638 plots their average size are only 0.800 ha, and the median only 0.286 ha.

Table 2. Basic statistical data of modeling suitability for soil tillage

	Lat.	Long.	Alt. (m)	Temp. (ºC yr^{-1})	Precip. (mm yr^{-1})	pH_{KCl}	Humus %	ρ_v g cm^{-3}	Area (ha)	Rel. suitab. crops (%)	Rel. work. (%)
Average	45.4895	18.511	91.86	10.55	835.03	5.67	2.13	1.43	17.20	65.04	59.75
Sd	0.23	0.33	17.94	0.36	151.25	1.21	0.74	0.10	25.82	10.39	9.36
Median	45.52	18.53	87.10	10.50	856.33	5.56	1.95	1.40	5.20	66.30	57.50
Kv%	0.50	1.79	19.52	3.37	18.11	21.26	34.61	6.77	150.11	15.97	15.67
Max.	46.32	19.24	428.20	11.59	1376.27	8.23	7.70	1.70	383.21	87.34	89.78
Min.	44.87	16.86	74.70	8.09	413.16	3.16	0.32	1.20	0.00	2.50	35.82

The humus content in the studied soils was on average 2.13% (0.32 do 7.70%) with a high variability of 34.61%. Average soil bulk density (ρv) are 1.43 g cm^{-3} (medium heavy soils) with small variability, what considering the number of 30 pedosystemic units indicates unreliability of *“Feeling method”* and the needed for introduction more reliable methods for mechanical soil analysis (classical sedimentation method or fast laser method). Statistical analysis of data showed that 48.75% of the samples (11,962 out of 24,536) has a pH in KCl less than 5.5, and even 21.98% or 5,394 samples less than 4.5. Since the 7,110 soil samples (or 28.98%) have hydrolytic acidity (Hy) higher than 4.0 $cmol^{(+)}$ kg^{-1}, it is a reliable indicator for the implementation of liming, especially in the western part of the Osijek-Baranja County. In fact, reduction conditions in the soil promotes eluviation of clay in the deeper layers and deteriorate workability due to poor structure of "leached" soils, as well as the formation of impermeable barrier for water in the subsoil layer with a high risk of

Table 3. Distribution workability according to the number of analyzed samples

Relative workability	Number of soil samples	Percent in total (%)
S1	1.428	5.82
S2	6.765	27.57
S3	16.315	66.49
N1/N2	28	0.11

compacting in use of machinery, but also the formation of tillage pan (plow pan and / or disk pan).

Average workability of soil in the study area was estimated by the model on 59.75%, which is between S3 and S2 class of suitability (limited to moderate suitability) with a moderate coefficient of variation (CV = 15.67%, Table 3). This estimate is significantly higher than the original, but also more realistic in relation to the initial research(Vukadinović and Jug, 2010). Specifically, negative ranking is further lowered assessment of workability hydromorphic soils that already have much lower rank to automorphic soils. It was found that in the Osijek-Baranja County has very few permanent and temporary unsuitable soils (0.11% N1 and N2), while the S3 (limited suitable) represents 66.49% of the samples, the S2 (moderately suitable), one sixth (27.57%), and excellent soil for tillage (S1, very suitable), only 5.82% (Table 3).

Osijek-Baranja County is a typical agricultural area with 59.72% percent of the agricultural area (arable land on 50.70%), a quarter are covered with forest (27.34%) and 87.06% of its area are under primary organic production. Therefore, a reliable estimation of the required traction for soil tillage, transport, the choice of tillage implements, as well as adequate tillage systems are very important from agrotechnical, and economic aspects. Geostatistical interpolation by kriging (Malvić, 2005) is limited only to the Osijek-Baranja County (Figure 1) where it is the largest number of analyzed soil samples, and all available data are very useful for the elimination of border effect. Also, the evaluation of workability was performed on all plots from which soil samples were taken for physical and chemical analysis and presented on maps of ARKOD, DOF and TK25 (Figure 2).

Table 4. Distribution of workability of land to the surface in ha

Class of workability	Area (ha)	Area (%)
< 50.0	1.723	0.42
50.1-55.0	76.178	18.40
55.1-60.0	200.924	48.53
60.1-65.0	55.717	13.46
65.1-70.0	52.639	12.71
70.1-75.0	19.695	4.76
75.1-80.0	6.814	1.65
> 80.0	320	77.29
Total	414.011	100.00
Forest	113.198	27.34
Arable land	209.886	50.70
Agricultural land	247.243	59.72
Other	53.57	12.94

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

Conclusions

Results of the evaluation of workability of land resources in the Osijek-Baranja County, carried out on 24,356 samples according Geostatistical-computer development model, suggest the following conclusions:

1 The model is fast and easy to use due to the implementation of the GIS, and taking the necessary indicators of the benefits of digital soil maps, ARKOD, Interpretative base land resources in Osijek-Baranja County, as well as mapping layers from the internet is automated (*intersect layer*) and enables:
   a) calculation of the relative soil workability,
   b) visualization benefits for soil tillage with thematic maps,
   c) prediction of workability with geostatistical interpolation methods and the use of other indicators of soil productivity as well as the relative suitability for crops, the expected amount of crop yield, the need for fertilization, soil conditioning, etc.,
   d) outline planning for supply of adequate machinery due to the demands of the size of the plots and power required,

2. Practical application of computer model evaluation workability of land, due to the still insufficient reliability "input" must be gradual and cautious, limited to areas where the model will be tested and then calibrated (measured) to model parameters were adjusted so that the prediction is closest reality and within acceptable error and risk.

3. Because the model is spatially oriented, comparing estimates workability of different plots (parcels) by the same machinery and the same tillage systems will probably give very good support to make the right decisions in supply and completing the tools for soil tillage.

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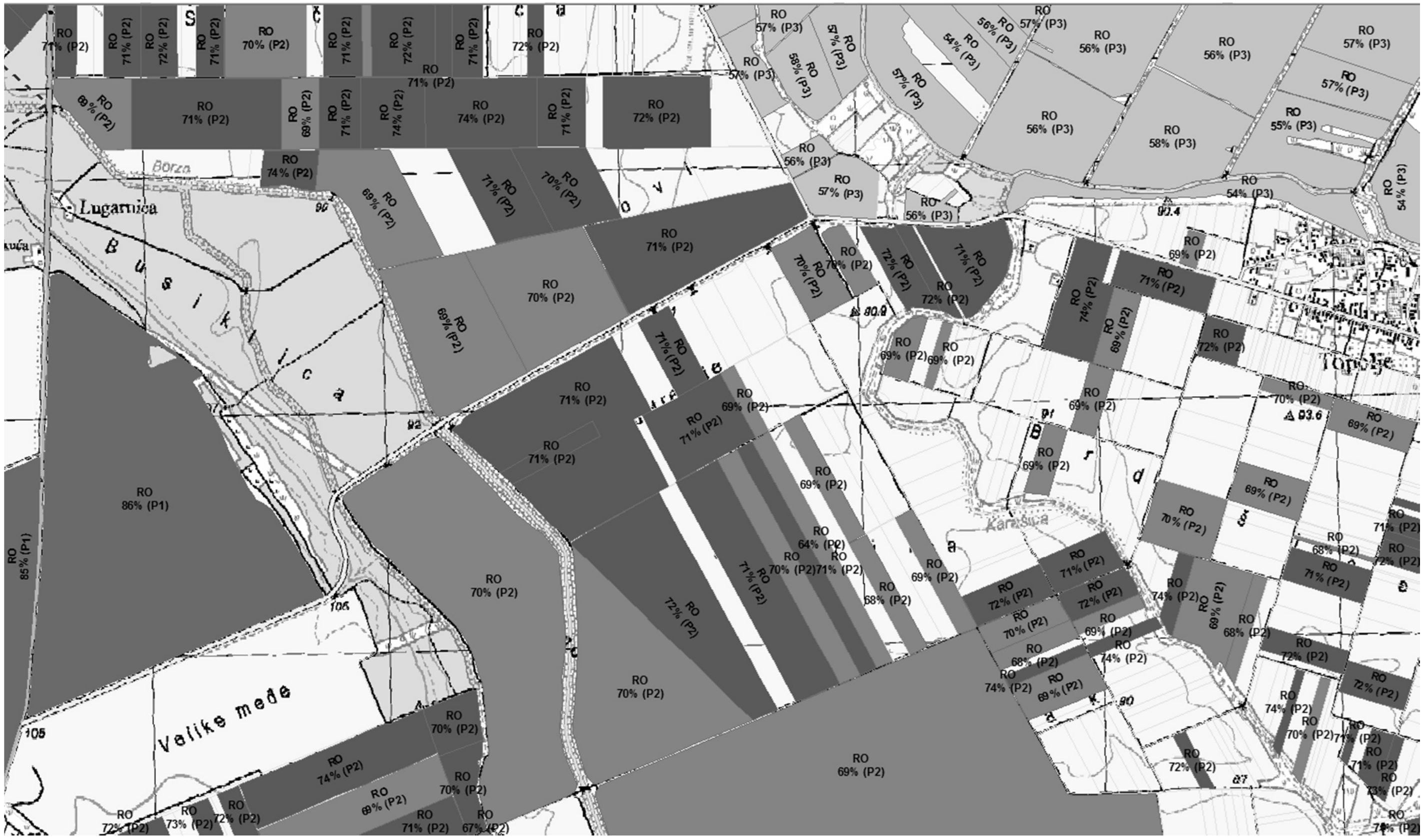
Figure 1. Kriging of relative land workability in Osijek-Baranja County (M 1:350.000)

Figure 2. Relative plots workability based on ARKOD and TK25 (M 1:15.000)



Review paper

Utilization of Cover Crops for Sustainable Agriculture

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Abstract

Modern agricultural production is showing growing interest in the use of cover crops, mainly short-season annual crops grown either as winter pre-crops for main summer crops or summer post-harvest crops. Cover crops are usually grasses and legumes, regarding its purpose. Planting cover crop needs to be fast, in order to provide as much time as possible for the vegetation, together with preservation of soil resources. Advantages of cover crop can be achieved by savings through reduced fertilizers and pesticide applications can influence substantially lower costs for subsequent cash crop, whereas long-term savings through better soil quality, reduced soil erosion, increased organic matter content, improved soil physical properties, reduced nitrate leaching and enhanced nutrient cycling are still poorly observed as the real benefit for growers.

Keywords: cover crops, grasses, legumes, establishment, termination

Introduction

Modern agricultural production is showing growing interest in the use of cover crops, mainly short-season annual crops grown either as winter pre-crops for main summer crops or summer post-harvest crops. Beside two usual reasons for establishing cover crops, such as additional yield and bio-mass between two main crops (Stipešević et al., 2011), cover crops can presents many additional functions, thus improving sustainability and biodiversity of traditional crop rotations (Bavec et al,. 2012). The most important fact is that agricultural land does not have to be taken out of production of main cash crops in order to incorporate cover crops into cropping systems, and new trend of growing bio-energy crops is less jeopardizing food production security if cover crop is utilized as the source of bio-mass for bio-energy (Kemp, 2011). The best use of cover crops maximizes the benefits of cover crop usage, without reducing the yield or quality of commercial cash crops. Potential drawbacks, such as cooler soils in the spring, or additional cost of seeding the cover crop, must be also considered for each cover crop – cash crop combination.

Cover crops roles in sustainable crop rotations

Soil surface coverage and soil physics improvement

It has been estimated that the USA has lost 30% of its agricultural soil in the past 200 years due to agricultural practices that do not return organic matter to the soil and that leave bare fallow soils for a significant part of the vegetation season (USDA, 1965). Erosion has long-term impact at society costs due to loss of agricultural productivity, pollution of water and aquatic habitats as well as sedimentation of rivers, fresh water catchments and reservoirs, river estuaries and sea water in coastal parts. There are also short-term costs of erosion for farmers, where USDA estimates around 80 USD worth of fertilizer per hectare yearly through the soil runoff from arable fields. Cover crops can help reduce soil erosion by keeping the soil covered during high rainfall periods when it would normally be bare. Different sources also report improved soil structure, stability and permeability, decreased crusting, and increased water infiltration (Wilson et al., 1982; Stipešević and Kladivko, 2005).

Addition of organic matter to the soil

Organic matter provides benefits to the soil and the subsequent crop in many different ways (Prunty, 2009). Organic matter improves the physical condition of the soil by improving soil tilth, stability of soil aggregates, water infiltration, air diffusion, and by reducing soil crusting. The addition of organic matter can also increase the populations of soil microbes and earthworms, which in turn, contribute to efficient nutrient cycling and improvements in soil structure (Bautista-Zuniga et al., 2008). Finally, organic matter additions can also increase nutrient retention in the root zone.

Nitrogen soil enhancement

Grass or non-leguminous cover crops can help keep N in the plant-soil system by utilizing residual N that would otherwise be leached into ground water. Leguminous cover crops, such as cowpea, soybean, and velvetbean, can "fix" higher nitrogen amounts for use by subsequent crops by symbiotic *Rhizobium* bacteria, which convert atmospheric nitrogen into a form that the legume can use for its own growth. In both cases, when cover crop decomposes by soil bacteria, the nitrogen is released to subsequent cash crops.

Nitrogen in the aboveground biomass of the cover crops varies considerably within species, where nitrogen available from cover crops can be in the range from 30-200 kg N per hectare. This nitrogen is mineralized over an extended period of time, with an average of 50% of the total N contained in the cover crop available to subsequent crops.

Achieving synchrony of N release from decomposing cover crop residues and cash crop nitrogen demand is expected to enhance the overall efficiency of use. Timing of cover crop termination can substantially affects N availability. Generally, the more mature the cover crop, the higher the C:N ratio and the slower the decomposition. Better utilization of N is important to prevent N pollution of surface and groundwater through runoff and leaching.

Leaving cover crop residues on the soil surface, rather than incorporating them, has advantages and disadvantages with regard to efficiency of utilization of cover crop N. Maintenance of surface residues can result in increased losses of cover crop N to the atmosphere through denitrification, but, on the other hand, immobilization and slower residue decomposition can result in reduced leaching losses. Also, a higher concentration of crop residues and organic matter near the soil surface can increase the diversity of microorganisms and fauna at the surface, which can result in greater recycling of N in the soil ecosystem.

Weed suppression

While the cover crop is growing, its pure development will suppress the germination and growth of some weeds through competition and shading. When killed and left on the surface as a mulch, cover crops continue to also suppresses weeds, primarily by blocking out Sun radiation, both light and heat. Cover crops can also suppress weeds through chemical release, either by decomposition or by active release of chemicals (allelopathy), and praxis of using cereal cover crops such as rye, wheat, barley, oats, sorghum, and sudangrass to suppress weeds is very frequent. Weed suppression is also detected by legumes, such as crimson clover, hairy vetch and others, which residues and leachates also can depress weed germination (Teasdale et al., 1991; Johnson et al., 1993). Weed suppression by cover crops gains on its importance, especially in the light of building weed resistance against herbicides, even ones based on glyphosates (Simić et al., 2013).

Impact on plant diseases

Pathogens can either be enhanced or inhibited by cover cropping systems, because soil microorganisms that cause disease can by affected by decreases in temperature, increases in moisture, reductions in soil compaction and bulk density, and changes in nutrient dynamics (Hartz et al., 2005). The taxonomical relation of cover and cash crops is also important, due to common diseases, which cycles can be either interrupted or prolonged. Some cover crops have also been shown to reduce nematode populations, including velvetbean, sorghum-sudangrass, and sunhemp (Hagan et al., 1998; Stone, 2012).

Impact on insect populations

Cover crops may both attract or repeal beneficial and pest insects into cropping system. Both can disperse to cash crops when the cover crop matures or dies (Altieri and Schmidt, 1986; Tillman et al, 2004). Prior to the arrival of important insect pests, beneficial insects attracted into an area by a cover crop may reach sufficient population densities to maintain pest populations in adjacent crops below economic threshold levels. Also, attraction of honeybees and bee pasture can be crucial for better sustainability of a whole farm.

Decision which cover crop(s) to use

The desired purpose of the cover crop will determine the most appropriate crops for cover crop. If the purpose of a cover is to provide readily available, biologically-fixed N for subsequent crops, which is obligatory for some farming systems, such is organic production, then cover crop choice should be a legume like cowpea, soybean and wetch, which fixes nitrogen and has a low C:N ratio. If the cover crop will be managed as a surface mulch for weed suppression, then the choice of cover crop is in crops with high C:N, heavy biomass production and previously demonstrated weed suppression characteristics, such as sorghum-sudangrass, rye and other grasses.

Mixtures of cover crop species should be also observed, in order to optimize the benefits associated with cover crop use. Mixtures which include species that establish quickly can reduce soil erosion. Above-ground biomass, and consequently N in the above-ground biomass, can be increased by a mixture that can utilize more below-ground and above-ground niches for nutrients, water, light and heat. For example, a deep rooted cover crop can be combined with a shallow rooted cover crop to utilize water and resources in different soil profile depth, or even to penetrate through the plough pan, in order to increase available water resources for subsequent cash crop.

Competition for soil N in mixed stands results in increased biological nitrogen fixation by the legume. Cereal crops usually germinate and establish effective root systems more rapidly than legumes and effectively lower soil N concentration. Since nodulation of legume roots and fixation of atmospheric N_2 by legumes is generally greater when soil N concentration is low, nodulation and nitrogen fixation is increased in mixtures.

Nitrogen cycling can also be manipulated with mixed cover crop species. Combining plants with high C:N ratios (mature cereals) with plants that have low C:N ratios (legumes) can influence mineralization of cover crop residues. The release of nitrogen from residues can be more properly timed with subsequent crop uptake. Therefore, both nitrogen immobilization and large flushes of nitrate can be moderated. This can help to optimize the efficiency with which fixed nitrogen is used by subsequent crops.

Planting mixtures of cover crops can take advantage of the allelopathic potential of the cover crops to suppress weeds. Allelopathic suppression of weeds has been shown to be a species specific phenomenon, therefore a broader spectrum of weed control may be possible by growing a mixture of cover crop species, each contributing allelopathic activity towards specific weed species.

Mixtures can also be planted to influence insect populations. Cover crop species, regardless of biomass or biomass-N production potential, could be included a mixture if they were known to attract important beneficial insects into the cropping system.

This is also exploited in so called biodiversity belts, which can be proliferated by cover crop mixtures. Also, some production systems, such as organic and integrated crop production, have requires and/or stimuli for environmental benefits achieved on this way. Importance of different mixture cover crops and their rooting also can be expressed in reduced soil tillage systems, where is possible buildup of certain less mobile nutrients at certain depths, due to lack of inverting soil, such is the case with mouldboard ploughing (Jug et al., 2013). Cover crop growth would be viable strategy in the uptake and distribution of these nutrients closer to rizosphere of the cash crop.

Establishment of cover crop

In many cases, planting cover crop needs to be fast, in order to provide as much time as possible for the vegetation, together with preservation of soil water reserves (Birkas et al., 2008). Therefore, soil tillage for cover crop needs to reflect these requirements, and reduced soil tillage, or even no-till seeding (Fuhrer, 2013), can be the best possible choice for cover crop soil preparation. Cover crop population density in some cases can be satisfactory even by broadcasting seed at the soil surface in previous crop stubble (Stipešević et al., 2008). Today's modern concepts of soil tillage tools can integrate also need for cover crop quick establishment in different type's multitiller, where seeding apparatus is an integral part of the tool. So, only one pass by this type of the tool suffices for soil preparation and cover crop seeding.

Cover crop termination methods

Cover crop purpose defines its termination. If it is purpose seed production, cover crop can be harvested by combine with needed adaptations for seed size. Cover crops that will be left on the surface as a mulch for no-till production need to be killed, either with chemicals or mechanical ways. In systems where the goal is to reduce chemical use, mechanically killing the cover crops is desirable. These methods for cover crops mechanical killing can be different, such as mowing, undercutting, or rolling with regular or special rollers, all of them showing different quality of cover crop termination and possibility of cover crop regrowth, regarding different environmental factors. In some cases, termination by cattle grazing is also viable option.

Conclusion

Cover crops are definitely part of sustainability of modern crop production, regardless whether grown for the yield, biomass or some other benefits. The highest issue growers can face is additional cost for seed and planting cover crops, especially where some cover crop seed is not readily available. But, savings through reduced fertilizers and pesticide applications can influence substantially lower costs for subsequent cash crop, whereas long-term savings through better soil quality, reduced soil erosion, increased organic matter content, improved soil physical properties, reduced nitrate leaching and enhanced nutrient cycling are still poorly observed as the real benefit for growers.

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S E S S I O N V

[Sustainable production systems for food and bioenergy]

Chairmen:

Marko Josipović
Željko Dolijanović

Original scientific paper

Azospirillum inoculation alters nitrate reductase activity and nitrogen uptake in wheat plant under water deficit conditions

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Abstract

Water deficit stress usually diminishes nitrogen uptake by plants. There are evidences that some nitrogen fixing bacteria can alleviate this stress by supplying nitrogen and improving its metabolism in plants. Four *Azospirillum* strains, *A.lipoferum* AC45-II, *A.brasilense* AC46-I, *A.irakense* AC49-VII and *A.irakense* AC51-VI were tested for nitrate reductase activity (NRA). In a pot culture experiment using a sandy loam soil, wheat plants (*Triticum aestivum* L. cv. Sardari) were inoculated with these bacterial strains and three ranges of soil water potential (-10 to -20, -40 to -50 and -65 to -75 kPa) were applied to the pots. All strains were positive in NRA test and the highest (7.63mg NO_2-N.L^{-1}.48h^{-1}) was recorded for AC49-VII and the least (0.23mg NO_2-N.L^{-1}.48h^{-1}) was belong to AC51-VI. Leaf and root NRA, root and shoot nitrogen concentrations, and dry weights of root and shoot decreased by increasing water deficit stress. All four bacterial strains caused a significant enhancement in root NRA and in each water deficit level, the higher root NRA was recorded in AC46-I and AC49-VII inoculated plants. The highest leaf NRA was achieved by AC49-VII. The mean increment of root NRA by bacterial strains was 171% compared to the non-bacterial plants. Moreover, at the highest level of water deficit stress, the highest dry weight and nitrogen concentration in root and shoot were obtained by AC46-I and AC49-VII treatments.

Key words: *Azospirillum,* nitrate reductase, water deficit, nitrogen fixation, wheat

Introduction

Water is expected to be one of the most critical natural resources in the twenty-first century. Twenty-six countries are now classified as water deficient, and nearly 230 million people are affected with water shortage and the prediction is that by 2025, one quarter of the world's population will face severe water shortage (Seckler et al., 2003).

Nitrogen is one of the most important mineral nutrients for plants and is taken up by the root system predominantly in inorganic forms (NH_4^+ and NO_3^-). Nitrogen is mainly absorbed as nitrate, which is the most common nitrogen source available for higher plants. Nitrate assimilation is the primary pathway by which reduced nitrogen is accumulated in plants; that involves a consecutive action of two enzymes: nitrate reductase, a cytosolic enzyme that reduces nitrate to nitrite using NADPH as electron donor, and nitrite reductase, a plastidic enzyme that reduces nitrite to ammonium (Druart et al., 2000).

It is generally accepted that water deficit has a negative effect on N concentrations, free amino acids or soluble protein contents accompanied with a decline of nitrate reductase activity (NRA) in many plant species, such as wheat (Xu and Yu, 2006), potato (Ghosh et al., 2000), maize (Foyer et al., 1998) or other plants (Xu and Zhou, 2005). The nitrate reductase activity decline during water stress is mainly attributed to low NO_3^- absorption and availability resulting from water uptake deprivation (Ferraria-Méry et al., 1998). In a field experiment two barley varieties and one durum wheat variety were subjected to irrigation at different rates in relatively dry Mediterranean environment with different nitrogen fertility. Although decreasing irrigation water in soil caused a drop of plant leaf water potential from –1.5 to –3.0 MPa, nitrate reductase activity of the leaves in these plants in the stage of heading was unaffected or slightly increased; on the other hand, it was the highest in the plants growing with an ample nitrogen supply irrespective of water regime (Smirnoff et al., 1985). In maize plants, desiccation leads to a steady decrease of NRA with a concomitant decrease in leaf water potential, leaf NO_3^- flux (Wasnik et al., 1988). When rewatered, water-stressed maize plants recovered partially and showed an increase in NRA and NO_3^- flux (Shanner and Boyer, 1976). To overcome, at least partially, the effect of water deficit stress, some measures have been suggested. By increasing soil fertility, especially with nitrogenous fertilizers the adverse effect of water stress can be alleviated substantially (Lahiri, 1980).

Azospirillum has been reported to improve nitrogen supply in association with cereals, although the mode of interaction between plants and bacteria is not fully understood (Bashan and Holguin, 1997; Ilyas and Bano, 2010). It is not clear whether bacteria provide an excess of fixed nitrogen that is supplied to the plant. An alternative to N_2 fixation as an explanation for N accumulation following *Azospirillum* inoculation is bacterial nitrate reductase theory. Field experiments with *Azospirillum* inoculants demonstrated an increase of uptake and assimilation of soil nitrogen and other plant nutrients (Kapulnik et al., 1982; Lin et al., 1983; Boddey et al., 1986b). This was confirmed with a nitrate reductase negative mutant of strain Sp245, which had no effect. Wheat inoculated with two *A. brasilense* strains Sp245 and Sp107 repeatedly showed increased plant growth and N-uptake (Baldani et al., 1987). Considering these results, it is not clear that the increased nitrogen assimilation in water-stressed plant is a action of bacterial NRA, induced NRA of plant or both.

The aim of this work was to investigate the effect of four *Azospirillum* strains on nitrogen nutrition, root and shoot dry weights, leaf chlorophyll content, and root and shoot nitrate reductase activities of wheat plant under water deficit stress conditions.

Materials and Methods

Bacterial strains

Four *Azospirillum* strains including *A.lipoferum* AC45-II, *A.brasilense* AC46-I, *A.irakense* AC49-VII and *A.irakense* AC51-VI supplied by Soil Science Department, Gorgan University of Agricultural Sciences and Natural Resources, and were tested for nitrate reductase activity as described by Dubey and Maheshwari (2005). Auxin production and nitrogenase activity of these strains were reported by Ghaderi Golezani (2010). These bacterial characteristics are shown in Table1. Bacterial strains were propagated in liquid malate medium supplied with 0.2 $g.L^{-1}$ yeast extract for 24h at 28°C on a shaker-incubator at 120 rpm (Dobereiener, 1995). Bacterial cell density was adjusted on 10^8 CFU/ml using OD determination at 540 nm. Bacterial suspensions were mixed with micronized (<10 µm) and sterile expanded-vermiculite and then used as inoculums.

Plant material and bacterial inoculation

Seeds of wheat (*Triticum aestivum* L. cv. Sardari) were surface sterilized by immersion in ethanol 96% for 5 sec, followed by immersion in sodium hypochlorite 0.5% for 5 min and rinsed with sterile distilled water for 10 times. Seeds were kept on wet sterile filter papers in Petri dishes for 24h at 18°C in dark, then transferred to refrigerator (4°C) and kept for further 17 days for vernalization. Six germinated seeds were transplanted into each pot containing 2.4 kg sterile sandy loam soil. The main characteristics of the soil were: pH 7.6, ECe 1.6 dSm^{-1}, 0.49% organic carbon, 17% clay, 22.3% silt, 60.7% sand, 6.66 mg kg^{-1} Olsen P, 224.1 mg kg^{-1} available K and 11.2% $CaCO_3$.

Bacterial inoculums were used at a rate of 10^7 CFU/g per seed. Non-bacterial controls received sterile vermiculite mixed with bacteria-free malate medium. Based on soil test, all pots equally received K (as K_2SO_4) and P (as triple superphosphate).

Water deficit treatments

At the beginning of the second week after sowing, plants were thinned down to three per pot and soil moisture content was adjusted to three ranges of soil water potential including, -10 to -20 kPa (no water deficit), -40 to -50 kPa (medium water deficit) and -65 to -75 kPa (high water deficit). Soil moisture content (w/w) at each range was determined using pressure plate method, and pots watered by weighing each day. Pots were arranged in a factorial randomized complete block design with four replications. Plants were kept in a greenhouse under a 16 h photoperiod, 25/20 ± 3°C (day/night, temperatures) and 40–60% relative humidity.

Chlorophyll index, plant nitrogen and dry weight

After 80 d of sowing, chlorophyll index was measured using chlorophyll meter (Hansatech CL-01). Shoots and roots were dried in an oven at 60°C to constant mass, then weighed and ground for further analysis. Root and shoot nitrogen concentrations were measured using Kjeldahl method.

Nitrate reductase assay in leaf and root

Nitrate reductase activity was determined by the method of Jaworski (1971) as follows: one-gram sample of fresh plant tissue was incubated for 30 min at 30 °C in assay medium (pH 7), then boiled at 100°C for 5 min. The nitrite was then determined colorimetrically using sulphanilic acid and α-naphthylamine solution at 520 nm.

Results and Discussion

Bacterial NRA

As shown in Table 1, all four bacterial strains were positive in NRA test and the highest (7.63mg NO_2-N.L^{-1}.48h^{-1}) and least (0.23mg NO_2-N.L^{-1}.48h^{-1}) were recorded for AC49-VII and AC51-VI, respectively.

The maximum and minimum nitrogenase activities were seen in AC49-VII and AC45-II, respectively. Accordingly, the highest and least auxin production were achieved by AC46-I and AC45-II, respectively. As it appears, the strains are markedly different in these criteria and one strain is not efficient in all cases.

Table 1. Some characteristic of bacterial strains

Bacterial strains	Nitrogenase (nmol C_2H_4 h^{-1} ml^{-1})	Nitrate reductase (mg NO_2-N L^{-1} 48h^{-1})	Auxin production (mg L^{-1} 120h^{-1})
AC45-II	25.81d	5.82b	01.67d
AC46-I	38.56c	3.23c	17.33a
AC49-VII	60.64a	7.63a	09.25c
AC51-VI	56.71b	0.23d	15.73b

Means in each column followed by same letter are not significantly different at P<0.05

Chlorophyll index

Regardless of bacterial strains, chlorophyll index was significantly decreased by increasing water deficit stress. However, in each water deficit level, the chlorophyll index of bacterial treated plants was higher than non-bacterial controls. The strain AC49-VII with higher nitrogen fixing capacity and nitrate reductase activity, was the efficient bacterium in enhancing chlorophyll index (Figure 1). Nitrogen is an essential nutrient in chlorophyll synthesis, and soil water depletion causes a marked decline in nitrogen transport in soil and its uptake by plant (Arzanesh et al., 2010). Higher nitrogen fixation and nitrate reductase activity of AC49-VII may compensate these problems and promote chlorophyll synthesis in each soil moisture level.

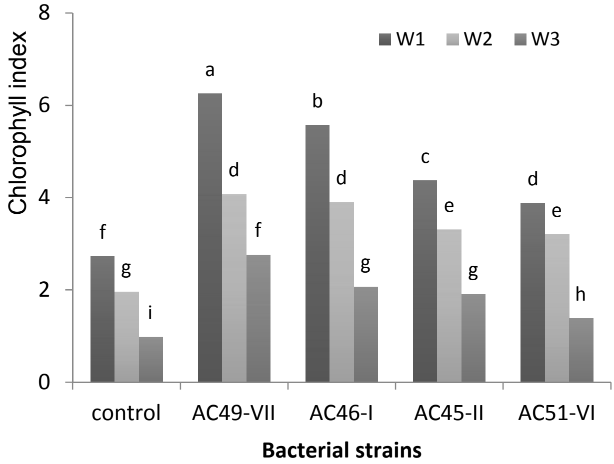

Figure 1. Effects of water deficit levels and bacterial strains on chlorophyll index of leaf

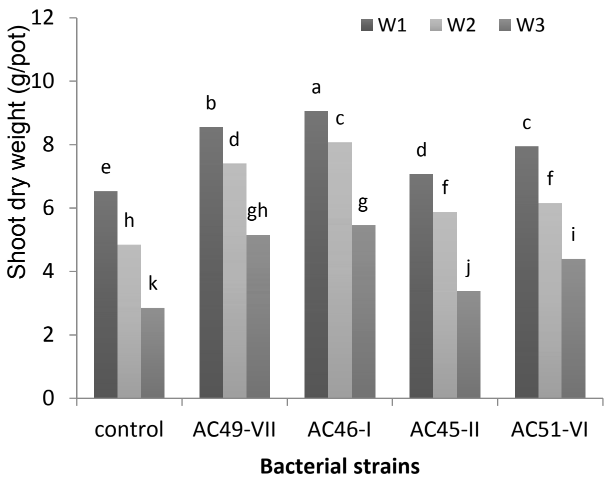

Figure 2. Effects of water deficit levels and bacterial strains on shoot dry weight

Shoot and root dry weights

Inoculation with bacterial strains led to an increase ($P<0.05$) in shoot and root dry weights compared to the non-bacterial control. Although root and shoot dry matters decreased by increasing water deficit, but in each soil water level, bacterial inoculated plants had significantly higher dry weight than non-bacterial treatments. At all soil moisture levels, the highest shoot and root dry matters were recorded in AC46-I and AC49-VII treated plants (Figures 2 and 3). These bacterial strains exert their beneficial effects through nitrogen fixation, nitrate assimilation, auxin production and likely other plants growth promoting effects. There appears to be a positive relation between bacterial NRA and plant growth promotion perhaps by supplying easily metabolizable nitrogen to the plant roots. Abdel-Samad et al. (2005) pointed out that the water deficit in soil is the most limiting factor in nitrogen flux toward the root and N_2 fixation by *Azospirillum* in vicinity of roots can overcome this problem.

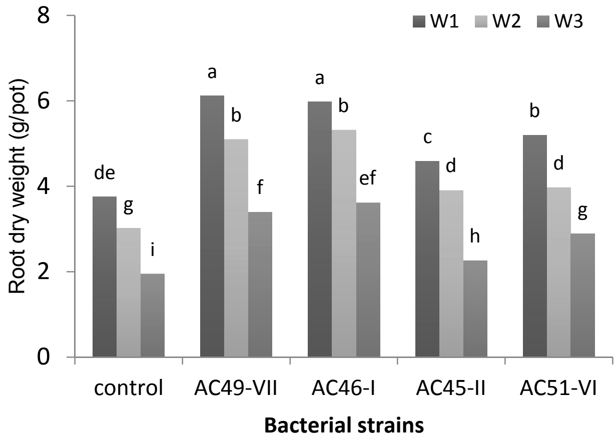

Figure 3. Effects of water deficit levels and bacterial strains on root dry weight

Shoot and root N concentrations

Except for AC45-II with lower nitrogenase activity and auxin production, three other bacterial strains significantly enhanced N concentration in shoot and root compared to the non-bacterial controls. The highest shoot N was recorded in AC49-VII treated plants while both AC46-I and AC49-VII were the efficient strains in enhancing root N. Regardless of bacterial strains, decreasing soil water potential caused a marked decrease in shoot and root N, although at each soil matric potential level, shoot and root N were higher ($P<0.05$) in bacterial than non-bacterial plants. The rate of decrease in plant tissue N by soil water depletion was stepper in shoot than root part (Figures 4 and 5). Strain AC51-VI with relatively higher nitrogenase but very low NR activities (Table 1), could only slightly increased shoot and root N. It seems that the NRA of bacteria is also necessary in N incorporation into plant. Dannerberg et al. (1986) stated that wheat plants inoculated with *Azospirillum*-NR^+ had more N content than *Azospirillum*-NR^- treated plants.

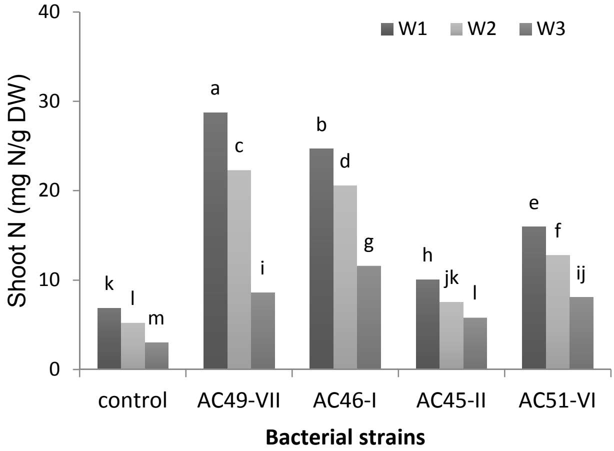

Figure 4. Effects of water deficit levels and bacterial strains on shoot N concentration

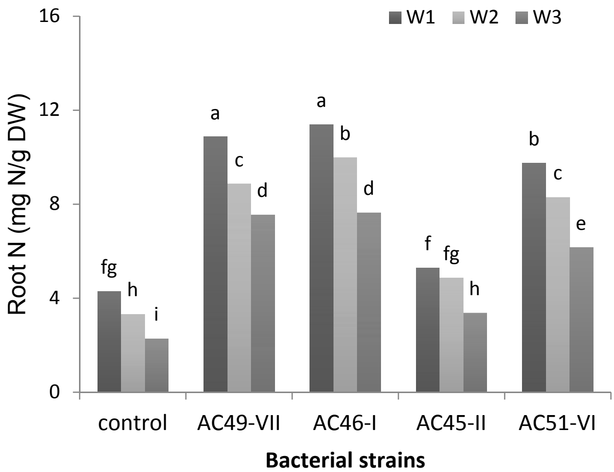

Figure 5. Effects of water deficit levels and bacterial strains on root N concentration

Leaf and root NRA

Leaf nitrate reductase activity diminished by increasing soil water deficit. At W1 and W2 levels, all bacterial strains caused a significant increase in leaf NRA compared to the non-bacterial controls, but at higher water deficit (W3) only AC49-VII was the efficient strain (Figure 6). Relatively same trend was found in root NRA, but the strains were also efficient at W3 level and showed a significant increment in root NRA in all soil water levels compared to the non-bacterial controls (Figure 7). Relatively higher NRA in root than leaf is due to higher supplying of NO_3^- (as substrate for nitrate reductase) to the root. Warembourg et al. (1987) indicated that in associative and free living N_2 fixers, the nitrogen products (ammonium or amino acids) are usually converted to the NO_3^- by soil microorganisms and this ion is preferable nitrogen source for nearly all plants. EL-Komy et al. (2003) pointed out that the higher NRA in root can reduces NO_3^- to lower oxidation states and then these reduced forms of nitrogen are transferred to the leaf. Hence, nitrate concentration and nitrate reductase activity diminish in green part of plant.

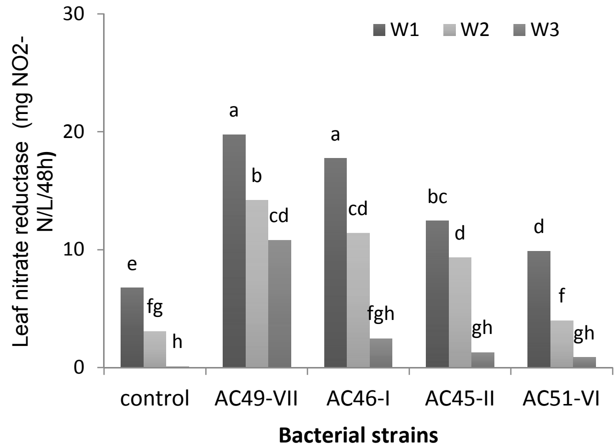

Figure 6. Effects of water deficit levels and bacterial strains on leaf nitrate reductase activity

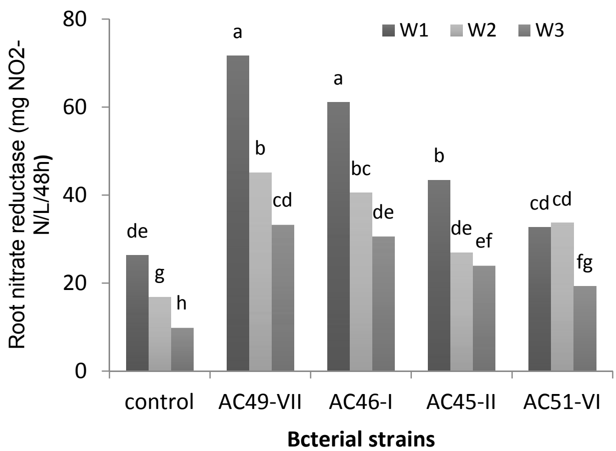

Figure 7. Effects of water deficit levels and bacterial strains on root nitrate reductase activity

Conclusions

A considerable amount of wheat is produced in dry land systems, worldwide. Water deficit and lower nitrogen supply are the most limiting factors affecting wheat yield in these systems. In sustainable agriculture, application of chemical fertilizers are not recommended due to their adverse impacts on ecosystem and also due to economical viewpoints. Application of effective N_2 fixers in these systems is an environmentally friendly solution for N supplying. However, finding of this study and other reports (Baldani et al., 1983; Boddy et al., 1986) indicate that higher N_2 fixation alone could not be sufficient for this purpose but a higher nitrate reductase activity is also essential for incorporation of nitrogen into plant. Among the strains tested in this study, AC49-VII with the highest nitrogenase and NR activities was the superior strain for wheat production, even in higher water deficit conditions. However, field experiments are necessary for its recommendation as a nitrogen biofertilizer for wheat plant.

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Original scientific paper

The effect of different tillage methods on grains quality of soybean under different weather conditions

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Abstract

In the northeastern Croatia mainly use conventional tillage to soybean production. Such a tillage system requires a high energy input and may also causes water loss and long-term soil physical degradation. The aim of this study was to assess tillage methods which are able to maintain high soybean yield and satisfactory grain quality properties, based on differences in oil content, protein content, crude fibre % and ash % under different weather conditions. For this purpose four tillage treatments (CT: Conventional tillage; DH: Disc harrowing (fine till); CH: Chisel ploughing; NT: No-tillage) were studied during four years (2002-2005) in the Baranya region of northeastern Croatia. The soybean oil, protein content, crude fibre content, ash content, plant density and grain yield were under very significant influenced of weather conditions and soil tillage treatments.

Key words*:* Soybean, soil tillage, yield, protein, oil, crude fiber, ash

Introduction

In general, NT systems have reduced cost of labor, fuel and machinery inputs but increased costs of pesticides and increased management to maintain or increase yields (Yin and Al-Kaisi, 2004). But, uncontrollable factors such as weather still play an important role and should be considered (Popp et al., 2002). Conventional tillage (CT) 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 may be low (Samarejeewa, 2004). In the most of undeveloped countries, the conventional tillage treatments and lake of efficient information about no tillage methods which have lower energy requirement, lower soil erosion and lower soil moisture losses, led to more abiotic stress impact on the crop productivity (Abdipur et al., 2012). In dry conditions using appropriate tillage methods according to climate and soil properties is very important, because the effect of different tillage methods on soil properties varies from region to region (Mujdeci et al., 2010).

Grain legumes are widely recognized as important sources of food and feed proteins (Duranti and Gius, 1997). Farmers have been encouraged to adopt no-tillage (NT) because of its environmental advantages compared with other conservation tillage systems (Yin and Al-Kaisi, 2004). Soybean [*Glycine max* (L.) Merr.] plants grown with no-tillage (NT) often appear smaller than those grown with conventional tillage (CT), yet they produce a similar grain yield (Yusuf et al., 1999). No-tillage production results in changes in soil physical properties, including increases in soil organic matter content (Douglas and Goss, 1990), aggregate stability (Heard et al., 1988) and macroporosity (Lal et al., 1990). The changes may be detrimental, neutral or beneficial for crop growth and yield, depending on the soil texture and structure (Dick and VanDoren, 1985) and on climatic factors such as rainfall (Morrison et al., 2000). According to Wilhem and Wortmann (2004) the soybean grain yield was less responsive environments with a soil loosening than in other tillage treatments.

Soybean is known for its high protein and oil contents, with typical US cultivars averaging 410 and 210 g kg $^{-1}$ for protein and oil, respectively, on a dry weight basis (Leffel and Rhodes, 1993) However, Breene et al. (1988) reported a gradual decline in the protein content of soybean grown in the northern latitudes over a period of 10 to 15 years. Because of this decline, more emphasis has been placed on increasing the soybean protein content, but this goal has faced setbacks such as the negative relationship between seed and protein content (Escalante and Wilcox, 1993).

Nitrogen is considered to be a yield-determining factor in soybean production (Frederick and Hesketh, 1994; Sinclair, 1998) postulated that the high demand for N in growing seeds, of high protein grain crops, such as soybean, cannot be satisfied by the daily N accumulation rates, so N must be remobilized from vegetative tissue. Most grain crops remobilize some vegetative N into the seed: In soybean, remobilized N has been estimated to contribute 20 to 60% of the N in the seed (Egli et al., 1988; Zeiher et al., 1982).

The aim was to assess tillage methods which are able to maintain high soybean yield and satisfactory grain quality properties, based on differences in oil content, protein content, crude fibre % and ash %.

Materials and methods

Field experiments were conducted at Kneževo, in the Baranya region of northeastern Croatia (N:45°82′97.80″, E:18°64′31.93″, 90 m evolution). The study was conducted over a 4–year period (2002 and 2005) as a monofactorial trail with randomized plots divided into blocks within four replications, and with a basic plot area of 900 m^2 (18 x 50 m), on a chernozem soil the dominant soil type of the Baranya region, with pH / 8.1 (pH $_{(KCl)}$ /7.53), 2.61% organic matter, 187.0 mg kg^{-1} P and 284.2 mg kg^{-1} K, determined by Egner-Riehm Domingo method (Page, 1982) and 2.12% $CaCO_3$. The total precipitation (mm) and temperature (ºC) from October to March (winter) and during growing season (April to September at the Kneževo site during 2002 and 2005 are shown in Table 1.

The conventional tillage consisted of autumn ploughing (30-35 cm deep), the summer disking of wheat residues (7-10 cm deep), spring disc harrowing (15 cm deep), and disc harrowing to a depth of 10 cm and field cultivation in preparation for soybean. The disc harrowing (fine till) consisted of spring disc harrowing to a depth of 10-15 cm and followed by seeding. The chisel ploughing (DH) consisted of autumn disc harrowing performed with a soil loosening to a depth of 25-30 cm, spring disc harrowing to a depth of 15 cm and seeding. The no-tillage treatment by definition, involves no tillage or cultivation. A Johan Deer 750A grain drill was used for all tillage systems at a depth of 4 cm. The soybean cultivar Tisa was planted on 27 April 2002, 24 April 2003, 29 April 2004 and 3 May 2005 in 16.5-cm rows at a seeding rate of 100 kg ha^{-1}. In 2002 soybean emerged on May 17, in 2003 May 13, in 2004 May 12, in 2005 May 17. Fertilization was uniform for all tillage systems and both years (40 kg ha^{-1} N, 130 kg ha^{-1} P and 130 kg ha^{-1} K as basic dressing). In all experimental years the forecrop was winter wheat.

The grain yields of soybean for determent of oil and protein content were sampled in harvested at maturity. The grain yield was adjusted to 13.2% moisture. Several hundred seeds were selected randomly from the harvested grain of each plot and dried in a forced-air oven at 60ºC for 24 h. A 12-seed sub sample from each experimental unite was than ground to pass through a 1-mm screen. The total N of the seed was determined using a micro-Kjeldahl digestion procedure (Nelson and Sommers, 1980) and grain protein was estimated as 6.25 x N. The oil content of the grain from each tillage systems was determined using a Soxhlet extraction method (AOAC, 1985). The crude fiber and ash of the grain was determined using conventional methods (Šuko and Petek, 1970).

Quality traits of soybean grains [*Glycine max* (L.) Merr] under different reduced soil tillage treatments was investigated by variance analysis and tested using the F-test ($P<0.01^{**}$; $P<0.05^{*}$).

Results and discussion

The long-term monthly precipitation and air temperature means at Kneževo, in the Baranya region, and the average total precipitation and temperature during the growing season of 2002 to 2005 are presented in Table 1. In general, 2002 was wetter and cooler than the long-term mean. In contrast, with the exception of April, 2003 was drier than the mean during the growing season and slightly warmer than the mean, particularly in May and September (Table 1).

The increased drought stress in 2003 was probably responsible for the lower seed yields observed in 2003 (Table 2), by exacerbating the negative effects of NT on soybean yield. Analysis of variance indicated that the soybean yield was affected the main effects of all the year and the tillage system (Table 2). Grain yields were similar for the CT and NT treatments in the study of Yusuf et al. (1999). In the present study the yield of soybean was significant lower under NT than in the CT, DH and CH treatments in all years (Table 2). No-tillage is detrimental to early-season plant growth, but does not usually substantially decrease the grain yields of soybean (Kladivko et al., 1986).

Table1. Total precipitation (mm) and average temperature (°C) from October through March (winter season) and from April through September (growing season) at Kneževo in period 2002-2005 year.

	2002	2003	2004	2005	25-yr average	2002	2003	2004	2005	25-yr average
	Precipitation (mm)					Temperature (°C)				
Winter season	182	222	332	384	266	4.8	3.5	4.3	3.8	4.5
April	64	9	119	54	43	11.4	11.2	12.0	11.5	11.0
May	86	33	77	55	56	18.8	20.0	14.9	17.0	16.6
June	49	19	114	88	90	21.7	24.5	19.5	20.4	19.7
July	61	61	41	168	60	23.8	22.8	21.9	21.4	21.2
August	111	23	52	155	45	21.5	24.7	21.6	19.7	21.3
September	63	34	43	82	53	15.9	16.4	15.9	17.5	16.6
Growing season	434	179	447	602	346	18.9	19.9	17.6	17.9	17.7

The soybean protein and oil contents were similar in all the tillage systems over a 4-year average, which is in accordance with previous experiments (Yusuf et al., 1999). The soybean protein content and oil content was significantly affected by the main effects of all year and all tillage systems (Table 2). Oil content was the highest in 2005, when the yield was the best, and the lowest was in dry 2003, but not significantly lower in comparison with 2002 and 2004 (Table 2).

Soybean grain contained more protein and oil in 2005 than in other years investigated (Table 2). The inverse relationship between grain oil and grain protein is well known (Scott and Aldrich, 1983). Differences in the grain protein and oil responses between the years were probably due to the temperature. Cool conditions during grain fill generally results in a decrease in grain oil and an increase in grain protein (Calvin, 1965). In the present study the air temperature during the grain-filling period (mid - to late August and early September) and during the wet period in September was cooler in 2002, 2004 and 2005 than in 2003 (Table 1).

Tillage method showed to be also very significant for all tested parameters. The highest impact was on grain yield and protein content. CT and CH variants of tillage gave the best yield and the lowest was obtained in no-till (NT). Norwood (1999) stated that among four tested crops (soybean, sunflower, corn, grain sorghum) soybean seems the least likely to show a yield increase with no-till and that soybean responded least often to no-till, in contrary to corn. However, Yin and Al-Kaisi (2004) reported that in their long-term research, no-tillage soybean grain yields were similar to those under MP, RT, CP or other tillage systems on well-drained soils, with differences usually within 5%. In our research, NT resulted with 14.6% lower yield compared to DH, and 22% or 23% lower compared to CT and CH, respectively.

Table 2. Analysis of variance and means for examined parameters and soybean grain yield by reduced tillage at East Croatia in the 4-yr average period (2002 – 2005)

Variable		Grain protein (%)	Grain oil (%)	Crude fiber (%)	Ash (%)	Number of plant spacing per sq m	Grain yield kg ha^{-1}
Year							
	2002	32.47a†	20.40a	5.73a	4.97a	60a	4.27a
	2003	30.36b	20.06a	5.71a	5.05ab	22b	3.01b
	2004	31.73c	20.43a	5.78a	5.06b	41c	3.77c
	2005	36.14d	22.74b	6.39b	5.54c	53ad	3.39d
LSD	0.01	0.2141	0.5390	0.2848	0.0892	9.3576	0.2634
	0.05	0.1490	0.3752	0.1982	0.0621	6.5129	0.1834
Tillage							
	CT	33.13a	20.90a	5.56a	5.03a	49a	3.83a
	DH	32.34b	20.49b	5.91ab	5.11a	46a	3.60b
	CH	32.92a	21.08a	5.82ab	5.27b	44a	3.87a
	NT	32.31b	21.15a	6.32b	5.22b	36b	3.14c
Average		32.68	20.91	5.90	5.16	44	3.61
LSD	0.01	0.2953	0.3450	0.5160	0.1222	5.5906	0.1588
	0.05	0.2244	0.2621	0.3920	0.0928	4.2472	0.1207
F – values							
Year		2811.150**	110.604**	28.035**	179.203**	65.008**	87.415**
Tillage		25.938**	9.934**	5.045**	10.252**	13.062**	58.916**
Year×tillage		2.857*	n.s.	n.s.	n.s.	n.s.	5.518**

Abbreviations: CT: Conventional tillage; DH: Disc harrowing (fine till); CH: Soil loosening (chisel); NT: No-tillage; Y x TS: Year x tillage system; Ash: Mineral content.

** Significant at the 0.01 level; *Significant at the 0.05 level; $^{n.s.}$ No significant.

† – means with the same lower case letters are not significantly different at P<0.01 level

Regarding tillage, the highest oil content was obtained by NT, and the lowest with DH. Differences among NT, CT and CH were not significant.

The crude fibre (%) was affected by main effect of tillage. Averaged over 4-years the crude fibre (%) of soybean grain was greater under NT than in the CT, DH and CH treatments (Table 2). The crude fibre content was the highest in the most humid year 2005, while in other years was lower without significant differences among years. NT gave the highest grain crude fibre content which was significantly higher than that obtained with CT. Ash content was also the highest in 2005 and the lowest in the CT.

Crop density expressed by number of stems per sq m was the lowest in driest year (2003) and NT (Table 2). However, other tillage methods increased crop density but there was no significant difference among them regarding the number stem per sq m. Vyn et al. (1998) observed delayed growth and reduced yields in no-till soybean and assumed that unfavorable in-row seedbed conditions were influenced by wheat residues. The no-till treatments with wheat residues took the longest time to achieve 50% emergence and resulted with the lowest biomass yield 5 week after planting. However, fall tillage treatments tended to have an average of 10% higher plant densities compared with no-till. In our investigation, stem number per sq m was 22% higher in the CH, 28% higher in the DH and 36% higher in the CT, in comparison with NT.

It is questionable if the previous crop residues in no-till influences crop density and yield through delayed emergence or later throughout the soybean vegetation. In the research of Pedersen and Lauer (2004), management system did not affect time of emergence, but did affect subsequent DM accumulation. They stated that yield stability in the no-tillage system at Arlington compared with the conventional tillage systems were achieved through maintenance of a greater LAI, CGR, LER and total DM accumulation during the seed filling period.

After Wilhelm and Wortmann (2004), planting corn and soybean without tillage results in increased yield in some environments but less in other environments. In their research, the main effects of rotation and year, as well as the tillage x year and rotation x year interactions, were significant for soybean yield. On the contrary, in the research of Yusuf et al. (1999) soybean yield was not affected by either the main effects of tillage and year or by the year x tillage interaction.

The year had greater influence than tillage in all tested parameters in our research. The strongest influence of year was detected by protein content, which was the highest in grain harvested in 2005 (Table 2) (the highest moisture and average temperature Table 1). Dry conditions in 2003 resulted with the lowest protein content and yield. The yield was the highest in 2002, when the precipitation and temperature were above 25-years average (Table 1). Year significantly affected soybean oil and protein content in the research of Yusuf et al. (1999), who stated that differences in grain oil and protein response between years was probably due to temperature.

Year x tillage system interaction was significant for grain yield and for soybean protein. The other parameters were not influenced by this interaction (Table 2).

This indicates that the ranking of the soybean cultivars for protein and oil content, crude fiber and ash was unaffected by the tillage system (Table 2). The response of soybean quality traits to the tillage system, varied with the prevailing weather conditions in the particular growing season.

Conclusions

The dry conditions experienced in 2003 have caused exacerbated any negative effects of no-tillage on soybean yield. The 4-year average yield of soybean was significantly lower under no-tillage (NT) than in the conventional tillage (CT), chisel plow (CH) and disc harrowing (DH) treatments. The soybean oil and protein contents significantly varied in all of investigated tillage systems over the 4-year average. Soybean crude fibre (%) was affected by the main effect of tillage. Averaged over 4–years the crude fibre (%) of soybean grain was greater under NT than in the CT, DH and CH treatments. The ash (%) generally increased as tillage declined. Chisel plow treatment compared with other tillage treatments, especially conventional tillage with save soil moisture and prevent to high impact of moisture and heat stress on soybean at the end of the season has led to yield stability. Seems, chisel plow treatment compared with conventional tillage is suitable tillage treatment for soybean under different weather conditions.

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Abstract paper

Determining the quantity of nitrates in green leafy vegetable on Croatian market

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Abstract

Nitrates are compounds that occur in nature as part of the nitrogen cycle in the soil-plant-atmosphere system, and as approved dietary supplements. They play an important role in the diet and functionality of plants. Part of the nitrogen enters in the soil by the application of fertilizers, and it is involved in many biological processes. It can be assimilated and immobilized by edaphic microorganisms, forming nitrogen that is available for the following cultures only after the process of mineralization of organic matter.

The main sources of nitrate in foods are fruits and vegetables. Nitrates and nitrites are very water soluble and mobile in the environment. On nitrate accumulation in vegetables affects a number of factors, such as type and amount of nitrogen fertilizer, geographic location and time of ripening as well as the and conditions, such as temperature and light. The amount of nitrate is different in different parts of the plant, and there are the highest in the petiole and stem plants, slightly less in the leaves and roots, and at least in flower and fruit. Microbial conversion of nitrate to nitrite may take place during storage of fresh vegetables, especially at room temperature, when the concentration of nitrite can reach a very high level of 3600 mg / kg dry matter. Like nitrates, nitrites themselves are not particularly toxic to the human body, however, products that may arise from them, such as nitrosoamines showed carcinogenic effect on animals.

Human exposure to nitrates is largely exogenous origin, through the consumption of vegetables and to a lesser extent, water and other supplies. Exposure to its metabolite nitrite is endogenous origin due to the conversion of nitrate and reduction of nitrate to nitrite formed body. Nitrate *per se* showed little toxic effects (oral lethal dose for humans is 330 mg / kg body weight (Walker, 1990). Metabolites of nitrate and reaction products (nitrite, nitric oxide, nitrite compounds and secondary amines) are a matter of concern for adverse effects health as methaemoglobinemia and carcinogenesis.

On the other hand, scientific studies emphasize the positive effect of nitrite in antimicrobial activity and nitric oxide in the physiological effects on the regulation of blood pressure (Ahluwalia et al. 2010). While the vegetables are a major source of nitrates, increased intake of vegetables greatly recommended due to the generally

accepted views on the health benefits of vegetables WHO (2003b.) recommended daily intake of vegetables together with fruits of at least 400g.

Based on the above, research goal was to determine the level of nitrates in leafy green vegetables on the Croatian market. In this way, the conformity with national legislation harmonized with the EU that determines the maximum level (MRL) of nitrite in vegetables will be checked. As samples for the analysis green leafy vegetables were selected: lettuce, spinach, kale, chard, cabbage and arugula. Samples were collected during the two seasons - spring and autumn, and at four locations: Osijek, Zagreb, Split and Rijeka, in order to achieve regional representation in terms of sampling. Each sample was prepared for chromatographic analysis in atomic sampler for HPLC.

The results of this study concluded that the analyzed samples of spinach and lettuce meet the requirements of the Ordinance on maximum levels for certain contaminants in food, because all individual values, and all the mean values in these samples were lower than allowed, regardless of the period were sampled. It is worth to mention that the maximum levels for the other samples of leafy green vegetables are not regulated with the mentioned Regulations. Commission Regulation from 2011. determine the maximum levels of nitrates in the arugula, which provides for the proposal for a new Regulation on maximum amounts of contaminants in food. Precisely for this reason, in this project were sampled and samples arugula in the autumn period, and the results indicate that the specified leafy vegetables contain the highest amounts of nitrate in relation to other types of analyzes, but these values do not exceed those prescribed by the Regulation. For other types analyzed green leafy vegetables (kale, cabbage and chard), there is no maximum permitted levels, so the results in this study cannot be compared in this way. From the available literature data it can be seen that the individual member states of the European Union have prescribed maximum values of nitrate in certain types of vegetables that are determined based on the results obtained by extensive research of certain types of products and an assessment of their daily intake in the human body.

Given the results of the analyzed samples depending on the sampling period, it is evident that the amount of nitrate in the samples analyzed from the autumn period is much higher than of those sampled in the spring. Differences in the amounts are expected, since the maximum permitted levels of nitrates laid down in the Regulation vary depending on the period of maturation and harvesting.

Key words: nitrates, vegetables, Croatian market

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