YIELDS OF WINTER WHEAT VARIETIES BRED AT KARCAG IN DIFFERENT SOIL CULTIVATION SYSTEMS

Ágnes CZIMBALMOS; Györgyi KOVÁCS; J.ZSEMBELI; R. CZIMBALMOS; G. TUBA

Institution University of Debrecen CAAES RISF Karcag Research Institute
Karcag 5300, Kisújszállási str. 166., Hungary
E-mail: czagnes@agr.unideb.hu

Abstract: *The examination of new soil use methods started in 1997, at the University of Debrecen CAAES RISF Karcag Research Institute. Our goal was to prevent and reduce the soil degradation processes in Karcag. A lot of areas in this microregion are occupied by the "minute soils", which can be characterized by a very short period for optimal cultivation due to their unfavourable hydrological features and heavy texture. Any tillage operations applied out of this optimal period involve the risk of soil degrading effects. The cumulative effect of the past improper operations has resulted in formation of a physically degraded and dusty cultivated layer. The consequences of the structural degradation of the soil: unfavourable hydrological features, decreased nutrition supply capacity, moderated microbiological activity effects of soil protective cultivation technologies – involving direct seeding and residue management – on the soil, crop and economy of production are examined in a multiple long-term field experiment on a heavy textured soil. In lysimeters the correlation of water supply, soil moisture content and water use efficiency of crops was revealed too. We also measured the tractive power demand, the moisture content, the penetration resistance, and the CO_2 emission of the soil in the two cultivation systems. It was established that the CO_2-emission from the soil cultivated with the soil conservation technology was significantly higher in the most cases compared to conventional tillage system based on ploughing. Measuring CO_2-emission, the most important (from agricultural point of view) characteristic of the soil can be directly quantified. According to the research achievements of the first sixteen years of the experiment the applied treatments have not always significantly influenced the yield of the indicator crop (winter wheat), but considerably decreased the energy consumption and costs of cultivation.*

Key words: *Soil Protective Cultivation System, reduced tillage, winter wheat, CO_2 emission, penetration resistance, , lysimeters, GIS interpretation.*

INTRODUCTION

According to PETERSON et al. (1998), environmental factors have a significant effect on wheat quality. The winter wheat genotypes respond differently to environmental factors. Quality is a genetically determined potential of the variety which can be exploited or deteriorated by agronomical methods, but cannot be improved anyhow. Quality wheat production is the optimization of production factors according to quality parameters (JOLÁNKAI et al., 2004). From the end of March till the beginning of July, winter wheat requires 280-340 mm water as an average. Under extensive growing circumstances the subsidence of the soil results in lower compaction than of disc pan layer if direct seeding is applied even for a longer term. The shallower the compacted layer limiting the infiltration of water to the deeper horizons, the more important is the amount of precipitation covering the actual water demand of the crop (BIRKÁS-GYURICZA, 2001). The Hungarian situation slightly differs from the international one regarding the judgement of conservation tillage as mainly the energy- and costs saving requirements were the motors of the change in the soil cultivation systems. Two third of the carbon content of the organic materials getting into the soil by disturbing it is emitted as carbon-dioxide into the atmosphere increasing the global warming up (BIRKÁS, 2002). The organic material content of the soil have to be considered as one of the most important carbon stocks that influence the carbon-dioxide and methane contents of the atmosphere.

The CO_2 gas emitted from the soil mainly originates from root respiration, microbiological activity and decomposition of organic matters. The volume and intensity of CO_2-emission is in close correlation to the structural state and organic content of the soil, hence it can be considered as a parameter of soil fertility. Measuring CO_2-emission, the most important (from agricultural point of view) characteristic of the soil can be directly quantified. As the practice of soil cultivation is changing in Hungary nowadays, consequently soil properties also change that result in the change of the microbiological activity, nutrient dynamics and organic matter profile of the soil (ZSEMBELI-KOVÁCS, 2007). All these have a great influence on plant production. Applying alternative soil cultivation methods based on the reduced disturbance of the soil more favourable conditions can be created in order to increase the organic matter content of the soil and the availability of moisture for the crops. The carbon balance of terrestrial ecosystems can be changed markedly by the direct impact of human activities (BOLIN, 1981). Soil surface is covered by plant residues, so erosion is avoided and organic matters are kept in the soil. Organic matters have significant affect on soil structure, buffer capacity, water retention ability, biological activity and nutrient equilibrium (HOLLAND, 2004).

In our experiment we examined the effect of conventional and reduced tillage on the yield of winter wheat varieties bred at Karcag comparing our results to the average yields of our county and country. The basic goal of the plant breeding research carried out at the Karcag Research Institute of RISF CAAES of the University of Debrecen is to breed varieties and hybrids that can tolerate the unfavourable ecological conditions (shortage and surplus of water, poor soil structure etc.) of the northern part of the Great Hungarian Plain and can be grown competitively. The winter wheat varieties bred at Karcag are applied as indicator plants in the soil cultivation experiment started in 1997 at Karcag. Their strengths are the high safety of yield, the excellent frost and drought tolerance. The test of frost and drought tolerance is predestinated at Karcag due to the extreme climatic conditions hence we examined these parameters too.

MATERIAL AND METHODS

Location of the experiment: 16 ha plots with meadow chernozem soil on the territory of the Karcag Research Institute (*Figure 1.*). Our study contains the results of the years of 2003-2010. The treatments were as follows: conventional tillage on 3.5 hectares and soil protective, reduced tillage[1] on 12.5 hectares. The main goal of the soil cultivation experiment – set in 1997 – was to determine the application possibilities and the efficiency of the applied reduced tillage system that can stop the physical degradation of the soil. We applied three winter wheat varieties: in 2003-2004 Róna, in 2006 Alex and in 2009-2010 KG Kunhalom variety (*Table 3.*). The baking quality of all the examined varieties is stable and high, two of them are in the improving quality category (Alex, certified in1999, KG Kunhalom, certified in 2002), while one almost reaches this category (Róna, certified in 1998). The frost and drought tolerance of these varieties is excellent, their gluten content is 30-35%, raw-protein content is 14-15% and fertilizer reaction is good. As the local agroecological conditions are not really suitable for the breeding activity aiming fungi resistance, therefore these varieties are slightly sensitive to stem and yellow rust, but they are more tolerant to powdery mildew, leaf rust and

[1] Reduced tillage systems leave between 15 and 30% residue cover on the soil or 560 to 1100 kg/ha of small grain residue during the critical erosion period. This may involve the use of a chisel plow, field cultivators, or other implements (Disk Ripper, Mulch Tiller etc.).

fusarium than the standard varieties. Our studies and research results of several years proved that the drought tolerance of bearded wheat varieties is higher than of the bald ones, therefore this feature was also an important aspect when the varieties were selected.

The plots of this experiment provide good opportunity to measure the CO_2-emission from the soil (ZSEMBELI et al., 2005). The effect of the changes in the soil structure and the soil cultivation system on the carbon-dioxide emission of the soil has been studied since 2002. In situ CO_2-emission of soil was measured by means of an ANAGAS 98. To calculate the CO_2-emission from soil the following formula was used:

$$\mathbf{F = d * (V/A) * (C2-C1)/t * 273/(273+T)}$$ [2]

Soil moisture content was determined with gravimetric method. The extent of soil compaction was deduced from the penetration resistance measured with a “3T SYSTEM” electronic soil layer indicator (KOVÁCS GY. et al., 2010).

We also measured the tractive power demand of applied tools is measured with the permanent detection of the GPS co-ordinates of the pulling tractor.

The effect of soil cultivation systems on the water balance of the soil was determined by means of weighable lysimeters (ZSEMBELI, 2000).

RESULTS AND DISCUSSIONS

The precipitation and temperature datas are included in *Table 1*. and the main soil specification of the H-1 plot are included in the *Table 2.*

Table 1.

Annual precipitation and annual average temperature in Karcag (2002-2010)

	2002	2003	2004	2005	2006	2007	2008	2009	2010
Annual precipitation (mm)	440.2	381.2	707.1	743.1	585.0	548.0	567.4	547.4	889.1
Annual average temperature (^oC)	12.5	10.6	10.9	9.8	10.6	12.0	11.4	11.7	10.4

Source: Karcag Research Institute

Table 2.

Main soil specification of the H-1 plot

Depth (cm)	pH/ KCl	y1	Salt content %	Humus %	Interchangeable cation				T-S
					Ca me/100g	Mg me/100g	K me/100g	Na me/100g	
0-20	5.21	12.98	0.02	3.22	22.76	5.01	0.85	0.36	3.09
20-40	5.27	13.93	0.02	3.17	24.94	5.58	0.63	0.46	3.39
40-60	6.14	4.79	0.02	2.68	22.43	4.37	1.17	0.15	1.19

Source: Karcag Research Institute’s laboratory

[2] where F: CO_2-flux (kg m^{-2} s^{-1}), d: density of CO_2 (kg m^{-3}, 1.96 for CO_2), V: volume of head space of chamber (m^3) A: area of chamber (m^2), C1: CO_2-concentration at time of start (m^3 m^{-3}), C2: CO_2-concentration at time of end (m^3 m^{-3}), t: duration of measurement (s), T: air temperature (C°).

Figure 1.: H-1 plot in Karcag Research Institute

As *Table 3.* shows, the forecrops of winter wheat were not so favourable (maize, sunflower), except for the vegetation period of 2003-2004 (chickling vetch). This factor – beyond the weather conditions – significantly contributed to the low yields both in the conventional and reduced tillage plots. The growing season of 2003-2004 was especially dry with almost 200 mm of water shortage resulting in the low yields contrary to the proper plant nutrition. The vegetation period was shortened due to the drought, hence the yield of variety Róna was far less than its genetic yield potential (6.42 t/ha). The importance of crop rotation is especially high in the years with unfavourable water supply. PEPÓ (2009) also established that in a droughty year (2003) the yield of winter wheat after unfavourable forecrops (sunflower, maize) was only 2.2-3.4 t/ha even on a high quality chernozem soil with good hydraulic properties.

Table 3.

Varieties and technologies applied in the experiment

Growing season	2002-2003	2003-2004	2005-2006	2008-2009	2009-2010
Variety name	Róna	Róna	Alex	KG Kunhalom	KG Kunhalom
Sowing date	09.10.2002	17.10.2003	15.10.2005	15.10.2008	22.10.2009
Harvest date	06.07.2003	15.07.2004	17.07.2006	14.07.2009	17.07.2010
Soil type	Meadow chernozem				
Forecrop	Maize	Chickling vetch	Sunflower	Sunflower	Sunflower
Seed dose	240 kg/ha	235 kg/ha	275 kg/ha	230 kg/ha	230 kg/ha
Seeder type	JD 1750 MaxEmerge direct planter machine				
Fertilizer (N)	200 kg/ha	—	200 kg/ha	150 kg/ha	150 kg/ha

The growing season of 2003-2004 was relatively dry too, but the high amount of precipitation fallen in the sawing period had positive effect on the germination dynamics of winter wheat.

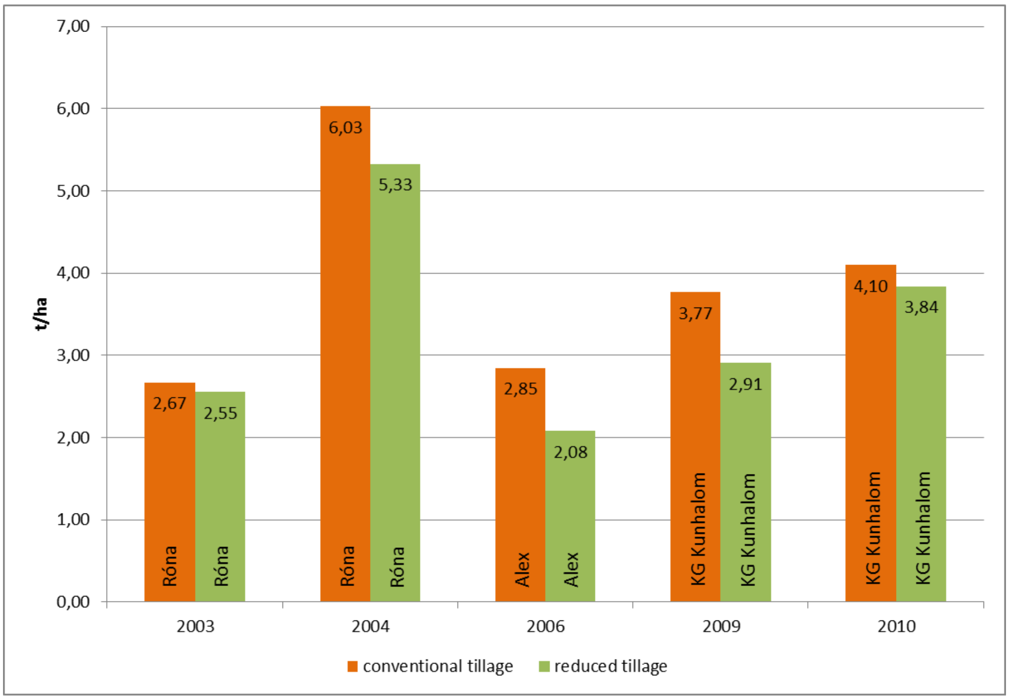

Figure 2.: Yields of winter wheat varieties in the two tillage methods

Due to the higher amount of precipitation and the favourable forecop the yield was doubled compared to the previous year and almost reached the genetic potential of variety Róna in both soil management methods. The high amount of precipitation fallen out of the vegetation period of winter wheat caused severe problems in our region in 2004-2005. Due to the unfavourable water regime of its soil, extended inland inundations appeared in the experimental plot (*Figure 1.*). Some of the tillage operations were skipped, the effect of this could be detected in the cultivation and yields of 2006 (*Figure 2.).* The depress of the yield was considerable, lower than 3 t/ha yield was detected, contrary to the 6.5 t/ha yield potential of variety Alex. Even the yields were low, the yield in the conventionally cultivated plot was almost 800 kg/ha higher than in the reduced tillage plot. One of its reason is that the conversion to a reduced tillage system is a longer procedure with a generally appearing symptom of yield depression. 2005 was followed by four years with average amount of precipitation (550-580 mm/year). Wheat variety KG Kunhalom was tested on the experimental site in the growing season of 2008-2009 after sunflower as a forecrop. The highest difference (860 kg/ha) in the yields between the two cultivation systems was detected in the case of this variety. The highest yields ever in the investigated period was measured in the last year, in 2010, even though the forecrop was not proper. The reason is the highest amount and the favourable distribution of the precipitation. The difference between the two cultivation systems was not considerable at this high yield level. It could be established that the conversion period[3] to the reduced tillage

[3] Physical and biological reclamation of the soil must be carried out before the conversion of conventional to reduced tillage in order to avoid the initial yield depression. In our long-term experiment mainly cereals suffered such yield depression.

system has been finished by that year, this was shown well by the increasing yields of winter wheat since 2006.

CO_2 emission was determined several times after the harvest of the indicator crop each year. *Figure 3.* shows the CO_2-emission values determined for the treatments of the soil tillage experiment in 2006. Four measurement dates are indicated, the first measurement was done after the wheat harvest and before the relevant tillage application, which was ploughing in the case of the conventional system and disc ripping in the reduced system. In July, which was very dry in 2006, higher emission was detected in the reduce tillage system. In August the measurements were done after a rainy period of two weeks. Due to this rainfall the differences disappeared, similar emission values were detected in all treatments, hence the effect of the tillage operations was suppressed by the effect of soil moisture content. This dominancy was experienced several times in the previous years as well and it is in correlation with the literature data (FRANZLUEBBERS *et al*., 2000; FIERER and SCHIMEL, 2003).

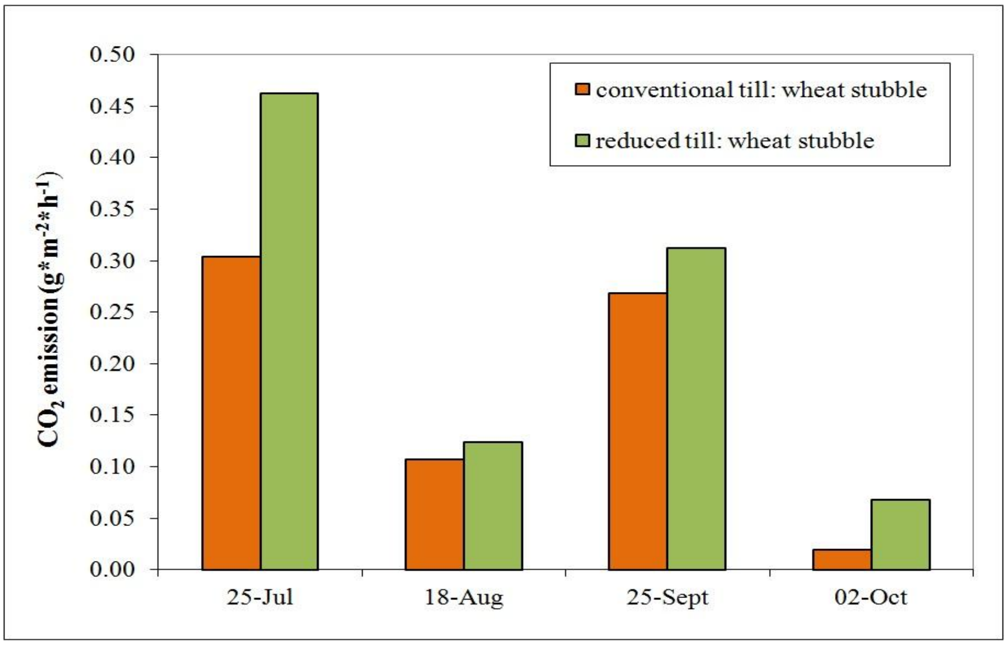

Figure 3.: The CO_2 emission values in H-1 plot, in 2006

Nevertheless we consider the absolute values of emission quite low, as considerable increase was detected due to such an amount of water input in the previous years. Nevertheless the autumn and the early winter periods of 2006 were extremely dry in the region of Karcag, it is only 55.7 mm of rainfall in 4 month's time, which resulted in the shortage of moisture in the soil. As a consequence of this low CO_2-emission values were determined in October. The highest values were detected in the reduced tillage plot and this highest value was characteristic all along the investigated period. Applying our reduced soil cultivation methods based on the reduced disturbance of the soil more favourable conditions can be created in order to increase the organic matter content of the soil and the availability of moisture for the microbiological activity. The penetration resistance and soil moisture measurements carried out also after the harvest of winter wheat in several years prove that no harmfully compacted layer was formed in the soil of the plot with reduced tillage even under extremely dry soil conditions (2009).

Nevertheless the soil was compacted under 40 cm in the case of conventional tillage (*Figure 4.*).

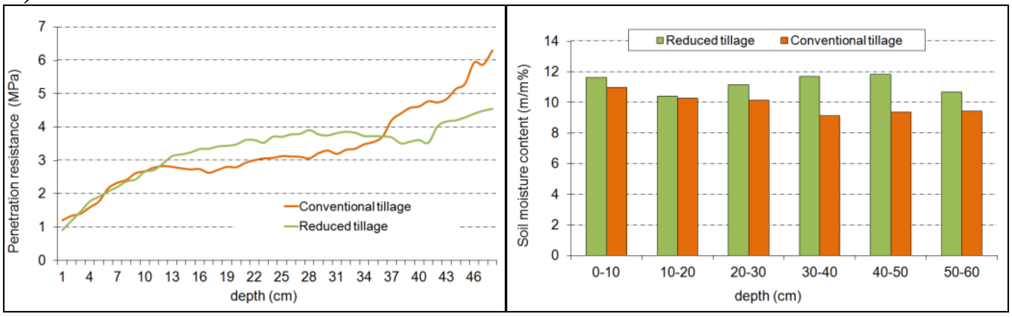

Figure 4.: Effect of tillage systems on the penetration resistance and moisture content of the soil (July 2009)

After processing the data bases of the measurement series it was proved that the tractive power demand of plough and disc representing conventional tillage is very high (*Table 4.*). It can be as high as 80 kN in the case of ploughing (FORGÁCS-CZIMBALMOS, 2011). Nevertheless, we measured higher tractive power values when Disk Ripper was used, if compared with disc application.

Table 4.

Measured tractive power values in different application tools

	Volume of cultivated soil along 1 m length (m^3)	Average tractive power demand (kN)	Specific tractive power demand (kN)
Plough (RW Kondor 6/5)	0.5625	80	142.22
Disc (IH-6.6)	1.296	70	54.01
Disk Ripper (JD-510)	0.95+0.57=1.52	30	19.73

Source: Karcag Research Institute

These results can be cozening as the moving speed of the two tractor-tool connections was almost the same, contrary to the fact that the Disk Ripper is heavier with its ripper shanks behind the disc gangs. Furthermore, the high quality and even work of the Disk Ripper must be emphasized and also the fuel consumption was lower when this tool was used. While ploughing, the high horsepower tractor sometimes lost some speed, contrary to the fact that it has high performance reserves, some slip often occurred. In this case the even moving speed needed for the continuous, high quality soil work could be maintained only by changing to lower gears. All these are well demonstrated in the data base of the measurement series, the tractive power demand values moving hectically up and down indicate the performance lost of the tractor very well. In case of Disk Ripper application, the curve is more even, slip seldom occurred during the measurements. Taking all these into account and analysing the fuel consumption data, the advantages of the application of Disk Ripper are obvious. On the base of the fuel consumption data the advantage of reduced tillage can be obviously concluded. 410 MJ/ha fuel consumption was measured when Disk Ripper was used in reduced tillage, while 1630 and 835 MJ/ha were the consumption in conventional tillage based on plough and disc operation respectively.

On the base of the water balance data determined in weighable lysimeters the effect of different soil surfaces created by the examined soil cultivation treatments on the soil water balance could be evaluated. By means of the method of regression analyses we could find a correlation between the amount of water input (precipitation) and output by evaporation of the soil columns. We found close exponential correlation between the examined variables (*Figure. 5*). According to the results reduced tillage has evaporation decreasing effect in the lower water input range. Conventional tillage and black fallow cannot preserve the soil moisture content under dry condition due to the lack of the isolation layer that reduced tillage has. In case of water load higher than the average, the soil surface looses more water by evaporation if reduced tillage is applied protecting the soil surface against surplus water due to the crop residues remaining on it.

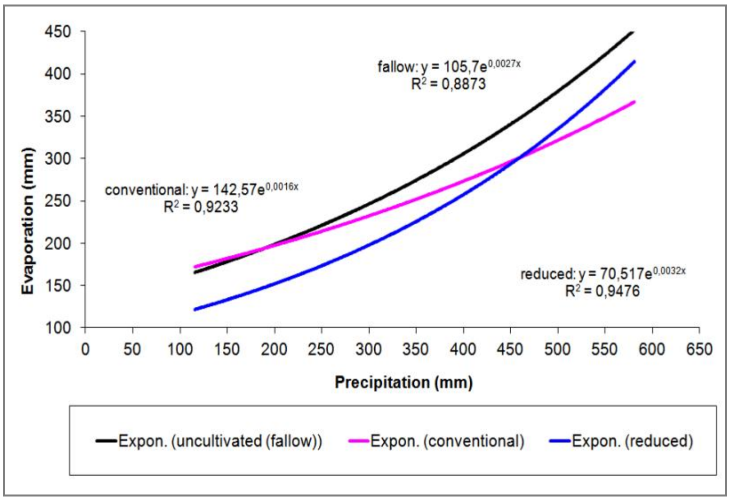

Figure 5. Correlation of soil cultivation system, precipitation and evaporation determined on the base of lysimeter data in Karcag

CONCLUSIONS

Figure 6. shows well the similarity in the tendencies of the yields of winter wheat achieved in conventional tillage at Karcag and the county-and country specific data in the investigated years, except for the year of 2006 due to the above explained anomalies.

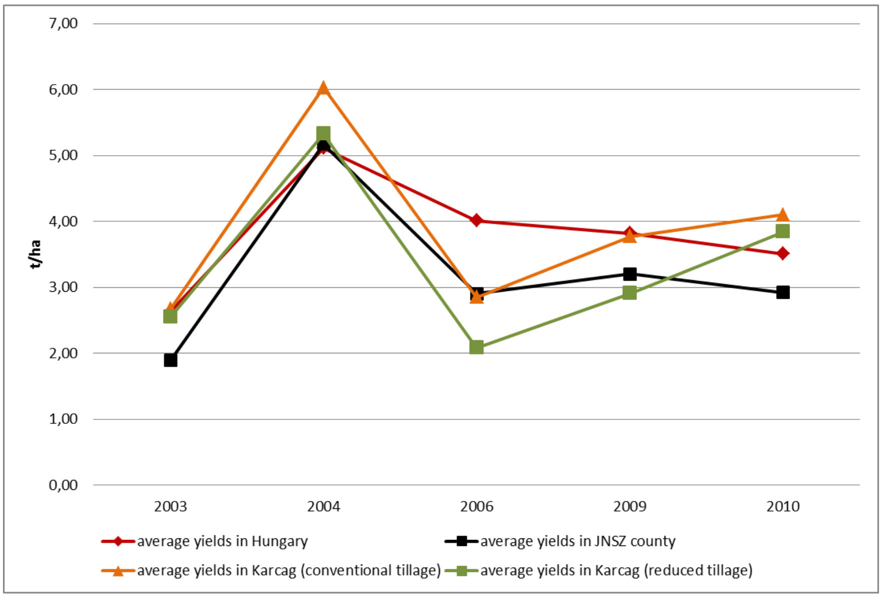

Figure 6.: Average yields of winter wheat in Hungary, in JNSZ county and in Karcag

Nevertheless it can be established that the yields of the winter wheat varieties bred at Karcag exceed the county- and country averages (or are at the same level). These data also prove the necessity of region specific plant breeding under the given ecological circumstances of a given region in order to improve the accommodating capacity of crops to the environmental stresses providing a higher safety of yield for the practice.

We have established that the Disk Ripper can be considered as the basic tool of primary tillage of the reduced tillage methods and can fully substitute plough and heavy discs applied in conventional tillage. Based on our measured data it can be concluded that the tractive power demand of Disk Ripper is only 35% of the tractive power demand of the plough, while 38-40% of the disc. After processing the measured data it can be established that there was a big difference in the pulling resistance of the machinery applied in conventional and reduced tillage. As the number of tillage operations is much lower in case of reduced tillage, the soil compaction caused by the machinery as well as fuel consumption are lower resulting in decreased environmental load, lower costs and labour use (higher profitability!).

There is no doubt that we gained remarkable results about the correlation between the soil status and the CO_2-emission from the soil. On the base of the water balance data determined by means of weighable We proved and quantified that reduced tillage has considerable water preserving effect comparing to conventional cultivation management in dry years, while protects the soil surface against extra water load when the weather is wetter than the average.

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