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EFFECT OF DIFFERENT TILLAGE SYSTEMS ON GRAIN YIELD AND ITS QUALITY OF WINTER WHEAT, MAIZE AND SOYBEAN UNDER DIFFERENT WEATHER CONDITIONS

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ABSTRACT

Conventional tillage has been the most common agriculture practice in most areas of Eastern Danube Plain of Romania. This tillage system requires a high energy input and may cause water loss and also long-term soil physical degradation. The results of our research prove that adopting conservation tillage practices more or less similar winter wheat, maize and soybean yields with similar quality levels can be obtained.

The aim of this study was to assess new or additional tillage methods, which are able to maintain high crop yields and good grain quality. For this purpose, three tillage treatments (P: conventional tillage; C: chisel plough tillage; NT: no tillage), with and without deep sub-soiling, were studied during eight years (2008-2015) at Fundulea, which is located in the middle of Eastern Romanian Danube Plain. Protein content, thousand kernel weight (TKW) and grain yield of winter wheat were significantly influenced by weather conditions and soil tillage treatments. Maize protein content and grain yield were significantly influenced by weather conditions, deep sub-soiling and also by soil tillage treatments. Soybean protein content, TKW, and grain yield were also significantly influenced by weather conditions and soil tillage treatments.

Key words: winter wheat, maize, soybean, tillage methods, yield, grains quality.

INTRODUCTION

The main objective of sustainable agriculture is to protect the soil environment against degradation and to create optimal conditions for high crop productivity. Reduced and/or no tillage systems with the simultaneous application of crop residues on the ground surface can create such conditions. Laborious research showed that the application of no tillage systems improved soil physical properties (Tebrügge and Düring, 1999) and increase soil water content (Dexter, 2004). Additionally, the organic matter content in the soil is increased (Micucci and Taboada, 2006) and also the rate of soil infiltration is reduced (Lipiec et al., 2006), all these leading to increased soil water content (Lampurlanés and Cantero-Martínez, 2006). In general, no tillage systems have reduced cost of labour, fuel and machinery inputs, but increased cost of pesticides and increased management to maintain or increase yields (Yin and Al-Kaisi, 2004). Unfortunately, uncontrollable factors such as weather conditions still play an important role and should be considered (Popp et al., 2002). Conventional tillage has adverse effects on the soil, including soil erosion, soil nitrate leaching, and subsoil compaction. As a consequence, the quality of the soil may deteriorate and the crop yield may be low (Samarejeewa, 2004).

The aim of this paper was to assess tillage methods that are able to maintain high crop yield and satisfactory grain quality traits in a long-term experiment, which was carried out between 2007 and 2015.

MATERIAL AND METHODS

The field experiments were conducted at National Agricultural Research and Development Institute Fundulea (NARDI Fundulea), located at 44°27’45” latitude and 26°31’35” longitude, on the eastern side of Romanian Danube Plain. The study was conducted over 8-year period (2007 and 2015), as a bi factorial trial with randomised plots divided into blocks with three replication, and with a basic plot area of 60 m² (6 x 10 m). Soil was chernozem, which represents the dominant soil type of the Danube Plain region, with 36.5% clay, 49.2

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mm ha^{-1} permeability and with a compaction of 1.41 g cm^{-3}. It contains high-very high levels of potassium (soluble K=175 ppm), phosphorus (70 ppm), and humus (2.2%). The total nitrogen content is around 0.157, C/N=15.9 and pH=6.7. The total precipitation (mm) and temperature (°C) from October to March (winter) and during growing season (April to September) at the Fundulea site during 2008 and 2015 are shown in Table 1.

Precipitation amounts fallen in the cold season (October-March) varied largely, between 164.8 mm in cycle 2013/14 and 385.5 mm in 2014/15 (Table 1). In comparison with the multi-annual mean, precipitation deficits were recorded for the seasons: 2007/08 (32.3 mm), 2008/09 (18.7 mm), 2010/11 (18.5 mm), 2011/12 (55.3 mm) and 2013/14 (67.5 mm), and excess for 2009/10 (55.3 mm), 2012/13 (36.5 mm) and 2014/15 (153.2 mm).

Table 1. Total precipitation (mm) and average temperature (°C) recorded in winter season (October-March), and in growing season (April-September), at Fundulea, during 2007-2015

	2007-2008	2008-2009	2009-2010	2010-2011	2011-2012	2012-2013	2013-2014	2014-2015	1960-2015
Precipitation (mm)									
October	46.2	25.9	60.1	47.0	27.0	30.8	67.0	56.7	**40.5**
November	52.7	27.5	19.1	9.0	1.5	9.4	20.7	59.1	**42.2**
December	62.4	33.2	54.9	92.5	28.1	87.9	0.2	119.4	**46.3**
January	15.0	69.2	45.4	43.7	73.5	49.2	37.1	30.8	**34.5**
February	2.3	25.5	69.8	16.5	42.2	52.5	1.7	40.8	**31.7**
March	21.4	32.3	38.3	5.1	4.8	39.0	38.1	78.7	**37.1**
Winter season	**200.0**	**213.6**	**287.6**	**213.8**	**177.1**	**268.8**	**164.8**	**385.5**	**232.3**
April	61.6	22.1	41.8	28.9	35.1	38.5	82.8	46.9	**44.6**
May	59.9	35.8	31.2	76.8	159.5	97.1	100.6	30.0	**61.5**
June	30.6	103.6	104.5	102.4	20.7	126.7	136.2	51.9	**74.1**
July	57.5	119.5	95.0	59.0	2.0	96.1	52.1	36.8	**70.1**
August	1.6	24.6	34.4	29.7	47.8	22.2	27.3	94.4	**50.2**
September	59.2	43.2	28.6	13.8	49.1	91.4	37.0	89.3	**50.3**
Growing season	**270.4**	**348.8**	**335.5**	**310.6**	**314.2**	**472.0**	**436.0**	**349.3**	**350.8**
Temperature (°C)									
October	11.7	12.6	12.1	8.9	10.3	13.9	15.0	10.9	**11.3**
November	3.3	5.8	7.5	10.7	3.3	6.8	8.1	5.0	**5.3**
December	-0.6	2.5	0.5	-0.7	2.8	-1.9	-0.5	0.6	**-0.2**
January	-3.1	-0.9	-3.9	-3.2	-1.4	-2.2	-0.7	-1.3	**-2.3**
February	2.4	2.4	-0.8	-2.5	-7.3	2.5	1.0	2.1	**-0.3**
March	8.2	5.9	5.0	5.0	5.5	4.9	8.5	5.9	**4.8**
Winter season	**3.7**	**4.7**	**3.4**	**3.0**	**2.2**	**4.0**	**5.2**	**3.9**	**3.1**
April	12.7	11.5	11.9	10.3	14.2	13.2	11.4	11.0	**11.2**
May	16.6	17.6	17.4	16.3	18.0	18.9	16.5	18.3	**17.0**
June	21.9	21.8	21.7	27.3	23.3	21.7	19.8	21.2	**20.8**
July	23.3	24.0	23.5	23.7	27.3	23.1	23.0	25.0	**22.7**
August	25.0	23.3	25.4	23.2	25.0	23.8	23.9	23.9	**22.2**
September	16.6	18.5	18.2	20.8	19.5	16.8	18.2	19.6	**17.4**
Growing season	**19.4**	**19.5**	**19.7**	**20.3**	**21.2**	**19.6**	**18.8**	**19.8**	**18.6**

The mean temperatures registered for this period varied between 2.2°C in 2011/12 and 5.2°C in 2013/14 (Table 1). With the exception of 2010/11 and 2011/12, in which the mean temperatures recorded for the periods without vegetation were below multi-annual means, in the other six years the mean temperatures of this period were over the multi-annual means.

Total precipitation during April – September of the year 2008 was substantially under the multi-annual means. This vegetation period started well, with April and May rich in precipitations, but it was followed by a dry June – August period, with mean temperatures much higher than the multi-annual mean. In 2009, the precipitation amount during the vegetation period was quite similar to the multi-annual value, but with a very different distribution: the dry April – May period was followed by a very wet June – July one. August and September were drier again. Air temperature means during June – August was higher than the average values. The total precipitation of 2010 vegetation season was close to the multi-annual amount, with a distribution more or less like that of 2009. Air temperature mean recorded for August was much higher than the average. The total rainfall during 2011 growing season was lower than the long-term average, but it was well distributed. May and June came with good amount of precipitation. This period was followed by a relatively dry three month period. Air temperature mean, recorded for June had much higher value than the average one. In 2012, the total rainfall during the growing season was similar to that of 2011, but precipitation distribution was very different. In 2011, the drought was mainly confined to August and September, while in June and July of 2012 there was an extended very dry period, with rainfall lower than long-term average. Air temperature mean was high, especially in July. In 2013 and 2014, the total rainfall amounts were higher than the long-term average. Their distribution was more favourable to the crops under this study. While in 2013, the only drier month was August; in 2014 the drought installed in July and lasted up to the end of the vegetation season, as it happened in 2011. The precipitations registered in the vegetation period of 2015 were close to the multi-annual value, but distributed very differently. April was rich in precipitations, but the amount registered in May, June and July was well under the multi-annual value. In August and September, the precipitations were in excess. Air temperature mean was very elevated in July.

The main plots (first factor) were represented by sub-soiling (S) or not sub-soiling (NS) and the subplots (second factor) were the tillage systems. Each replication had 6 plots: 2 gradations of sub-soiling / 3 systems of tillage. The following tillage systems were applied: (1) conventional, with mouldboard plough (P); (2) chisel plough tillage (C) – primary tillage executed with chisel implement type without soil inversion, and (3) no tillage (NT) – no tillage work. The effect of different tillage systems was estimated on plots with sub-soiling and plots without sub-soiling, executed in the wheat-maize-soybean crop rotation only after winter wheat crop. Winter wheat and soybean experimental plots were harvested with a plot combine of 2 m work width. Maize ears were hand harvested from the two central rows of each plot, dried and shelled. The yields of all three crops are reported at standardized moistures, as follows: 14% for winter wheat, 15.5% for maize, and 12% for soybean.

Grain chemical traits were evaluated based on the data obtained using the Foss Infratec 1241 Grain Analyzer (Foss Tecator AB, Hóganas, Sweden), which was calibrated based on the results recorded using direct methods, as follows: a) the protein content was determined by Kjeldhal method, which is based on vegetal material mineralization with concentrated sulphuric acid in the presence of catalysers for lifting the boiling point and speeding the mineralization process. The amount of sulphuric acid (N/10) cm^3 consumed is equivalent to the ammonia quantity in the analysed probe. The meal raw (crude, total) protein content (%) was calculated by multiplying the nitrogen percentage of the analysed probe with 6.25; b) the total fat was determined by classical Soxhlet method (fat petrol ether extraction) and reported to dry matter; c) the starch content was estimated following the Ewers-Grossfeld procedure: by hydrolysis under hydrochloric acid influence, a glucose solution is obtained which shows a concentration closely related to the starch content of the probe. As glucose is optically active, its concentration was measured with a refractometer (polarimeter). All these results were reported as percentages. For thousand kernels weight (TKW) evaluation, the mean of three 100 grain probes, randomly chosen, was calculated for each variant.

The quality traits of winter wheat (*Triticum aestivum* L.), maize (*Zea mays* L.) and soybean [*Glycine max* (L.) Merr] grains, under different soil tillage treatments, were investigated by variance analysis and tested using the F-test.

RESULTS AND DISCUSSION

a) Influence of tillage systems and sub-soiling practice on winter wheat yield and main quality traits

The results presented in Table 2 show that the most unfavourable year for this crop was 2011/2012, mainly due to the high precipitation deficit that occurred during March and April. The recorded mean grain yield of 4.73 t ha^{-1} was 63% lower than that registered in 2012/2013, which was the most favourable year for this crop.

The analysis of variance (Table 2) indicates that the grain yield was very significantly affected by year conditions and significantly by tillage systems. Sub-soiling effect was statistically non-significant. Related to this subject, Colecchia et al. (2015) reported that the wheat grain yields were higher practicing P (3.29 t ha^{-1}) than in the case of C (2.67 t ha^{-1}), and in NT (2.54 t ha^{-1}) treatments. In our present study the average grain yield over the 8-year period was non-significantly higher practicing NT (5.96 t ha^{-1}) than in the case of P (5.94 t ha^{-1}), but significantly higher when compared with C (5.81 t ha^{-1}).

Grain protein content depended greatly on year conditions and tillage systems (very significantly), and significantly on sub-soiling treatment (Table 2). The highest average protein content was recorded in 2009 (14.35%), and the lowest in 2015 (11.38%). The mean protein content over the 8 experimental years was significantly higher in P (13.85%) than in C (13.27%) and NT (12.89%). However, other studies found that the tillage system had no effect on wheat grain protein content (Carr et al., 2003; Gürsoy et al., 2010). Rice et al. (1986) suggested that low availability of N frequently observed in NT soils, can sometimes be a transient effect. This was also observed in other long-term experiments (Amato et al., 2013; Ruisi et al., 2014). For these reasons, Ferreira et al. (2009) recommended a supplemental N (10-20%) application within the NT system during the conversion (2-3 years) period from conventional tillage to NT systems. Grain protein content was significantly higher in NS than in S (13.40% vs. 13.28%, respectively). From data presented in Table 2 we can see that the environmental conditions and tillage systems, which influenced positively the winter wheat grain yield, had a negative influence on the protein content. On the other hand, unfavorable conditions for grain yield, such as drought and high temperatures, determined higher levels of protein content (Table 2). This assertion is not new, that wheat yield and protein content are negatively and linearly related: the most frequently quoted reasons for this are energy constraints and dilution effects.

Table 2. Analysis of variance and means of winter wheat examined parameters and grain yield, recorded at Fundulea, when practicing different tillage methods during 2008-2015

Variable	Grain protein (%)	TKW (g)	Grain yield (t ha^{-1})
A. Year			
2007/2008	13.16 bc	46.50 b	5.11 de
2008/2009	14.35 a	42.30 cd	5.19 de
2009/2010	13.76 ab	42.32 cd	6.64 b
2010/2011	13.53 b	45.80 b	5.97 c
2011/2012	13.55 b	46.93 b	4.73 e
2012/2013	12.68 c	44.33 bc	7.70 a
2013/2014	14.29 a	39.94 d	5.60 cd
2014/2015	11.38 d	49.45 a	6.30 bc
B. Sub-soiling			
NS	13.40 a	44.65 a	5.85 a
S	13.28 b	44.74 a	5.96 a
C.Tillage system			
P	13.85 a	44.16 c	5.94 a
C	13.27 b	45.12 a	5.81 b
NT	12.89 c	44.81 b	5.96 a
F-values			
A. Year	19.53***	11.231***	31.276***
B. Sub-soiling	4.52*	ns	ns
C. Tillage	208.99***	27.806***	3.988*
A x B	ns	ns	ns
A x C	14.19***	9.884***	6.981***
B x C	ns	ns	ns

***Significant at the 0.001 level; ** Significant at the 0.01 level; * Significant at the 0.05 level, ns – Not significant.
Means with the same lower case letters are not significantly different at p<0.05 level.

TKW was influenced very significantly by years and tillage systems (Table 2). The highest mean value was recorded in 2015 (49.45 g) and the lowest in 2014 (39.94 g). It is known that within unfavourable habitat and agro-technical conditions, wheat grain is characterized by a reduced grain size (TKW) and by a higher proportion of small grains (Convertini et al., 1996; López-Bellido et al., 1998; Vita et al., 2007). The highest mean TKW was registered with C (45.12 g), which was significantly higher, with 0.66% and 2.0% than those of NT and P, respectively. Sub-soiling effect was statistically non-significant.

Year x tillage system interaction was very significant for grain yield, protein content and TKW (Table 2). These parameters were not influenced by year x sub-soiling and sub-soiling x tillage system interaction.

b) Influence of tillage systems and sub-soiling on maize yield and some quality traits

The very dry June − August period of 2012, with a 123.9 mm deficit compared to the normal amount, along with 3.3 °C higher mean temperature, diminished drastically the maize grain yield, at 4.42 t ha^{-1}, which represent 36% from the mean yield obtained in 2013, which was the most favorable year of the experimental period for this crop (Table 3). The analysis of variance shows that the yield was influenced very significantly by year and tillage system applied. Sub-soiling (S) brought a significant yield advantage, of 190 kg ha^{-1}. In the Wilhelm and Wortmann (2004) study the significant tillage effect on maize occurred because the yield obtained with NT treatment was significantly lower (6.20 t ha^{-1}) than applying C (6.34 t ha^{-1}) and P (6.75 t ha^{-1}). In the present research, the grain yields were statistically similar for NT and C (9.24 and 9.05 t ha^{-1}, respectively) but significantly lower in the case of P treatment (8.82 t ha^{-1}).

Protein content of maize grains was very significantly influenced by year and tillage system, and significantly by sub-soiling (Table 3). The highest average value (10.05%) was recorded in 2012 and the lowest in 2010 (7.86%). The difference in maize seed protein content across years corroborates the findings by Sebetha et al. (2015) who emphasized that protein content in grain is influenced by changes in weather condition during the vegetation period of maize. Their study showed that highest protein content in maize grain was obtained in dry and warm years, while in years with abundant precipitation high yields of grain were obtained but with lower protein content levels. In our research, during the eight experimental years, protein content varied between 9.19% and 9.04%, in S and NS respectively. With regards to tillage system influence, the highest value (9.36%) was obtained with P, being significantly higher than with the other tillage systems (9.05% and 8.93%, in C respectively NT).

The analysis of variance, presented in Table 3, reveals that the fat and starch content were affected very significantly by the year and not by the other factors. This seems to be in contradiction with the results of the study conducted by Riedell et al. (2009), which indicated that year had no significant effect on kernel fat concentration, so the whole environmental conditions made a big difference in this particular case too. Coming back to our research, the highest fat content value (4.55%) was registered in 2013 and the lowest in 2008 (3.52%). Starch content of maize grains expressed more or less a similar variation, between 72.43% in 2012 and 59.45% in 2009. This finding corroborates with Buresova et al. (2010), who reported that starch content was significantly affected by weather during growing season. They indicated that warm weather during the growing season had a significant positive effect on starch content. Generally, protein concentration is negatively and positively correlated with the other two grains components, starch and fat concentration, respectively (Dudley and Lambert, 2004).

Table 3. Analysis of variance and means of maize examined parameters and grain yield, recorded when practicing different tillage methods at Fundulea, during 2008-2015

Variable	Grain protein (%)	Grain fat (%)	Grain starch (%)	TKW (g)	Grain yield (t ha^{-1})
A. Year					
2008	9.28 c	3.52 e	61.33 e	222.50 f	6.20 d
2009	8.08 e	3.86 d	59.45 g	355.19 b	11.64 ab
2010	7.86 f	3.86 d	60.29 f	342.37 b	10.73 b
2011	9.47 c	4.35 b	71.69 c	313.28 c	8.72 c
2012	10.05 a	4.00 c	72.43 a	245.50 e	4.42 e
2013	9.73 b	4.55 a	70.67 d	386.78 a	12.25 a
2014	9.07 d	4.30 b	71.90 b	295.28 d	9.27 c
2015	9.40 c	4.10 c	71.99 b	284.39 d	9.06 c
B. Sub-soiling					
NS	9.04 b	4.08 a	67.52 a	306.90 a	8.94 b
S	9.19 a	4.05 a	67.42 a	304.42 a	9.13 a
C. Tillage system					
P	9.36 a	4.07 a	67.42 a	301.99 a	8.82 b
C	9.06 b	4.06 a	67.52 a	309.23 a	9.05 a
NT	8.93 b	4.07 a	67.48 a	305.76 a	9.24 a
F-values					
A. Year	179.732***	93.816***	1126.075***	113.957***	94.385***
B. Sub soiling	8.656**	ns	ns	ns	5.886*
C. Tillage	22.163***	ns	ns	ns	7.887***
A x B	ns	ns	4.571**	2.932*	2.265*
A x C	2.366*	ns	3.216***	ns	3.616***
B x C	3.231*	ns	ns	ns	ns

***Significant at the 0.001 level; ** Significant at the 0.01 level; * Significant at the 0.05 level, ns – Not significant.
Means with the same lower case letters are not significantly different at p<0.05 level.

TKW was influenced very significantly by years (Table 3). The highest mean value was recorded in 2013 (386.78 g) and the lowest in 2014 (by 57.5%). The sub-soiling and tillage systems effects were statistically non-significant.

Year x sub-soiling interaction was significant for grain yield, starch content and TKW (Table 3). Year x tillage system interaction was very significant for grain yield and starch content and significant for protein content. Sub-soiling x tillage system interaction was significant only for the protein content.

c) Influence of tillage systems and sub-soiling on soybean yield and main quality traits

In 2012, the severe drought stress during the vegetation period was the main factor responsible for the important soybean yield losses (Table 4). The mean grain yield, of 0.81 t ha^{-1}, was with 76% lower than in 2010, which was the most favourable experimental year for this crop. Analysis of variance over the eight year indicated that the soybean yield was greatly influenced by the year, sub-soiling and tillage system (Table 4).

Sub-soiling brought a significant yield advantage, of 50 kg ha^{-1}. In Yusuf et al. (1999) study, the grain yield was similar for P and NT treatments. In the present research, the yield of soybean was lower applying C and NT than with the P treatment (Table 4). NT is detrimental to early-season plant growth, but usually does not decrease substantially the grain yields of soybean (Kladivko et al., 1986). Norwood (1999) stated that among four tested crops (soybean, sunflower, corn, grain sorghum) soybean seemed the least likely to show a yield increase with NT, and that soybean responded least often to NT, contrary to corn. In our research, NT and C resulted with 5.9% lower yield compared to P.

Soybean protein content and fat content were influenced very significantly by the main effects of all year and all tillage systems (Table 4). Fat content was the highest in 2013 and the lowest was in dry 2012 year. Soybean grain contained more protein in 2012 than in other investigated years. The inverse relationship between grain fat and grain protein is well known (Scott and Aldrich, 1983). Years affected significantly soybean fat and protein content in the research carried out by Yusuf et al. (1999), who stated that differences in grain oil and protein response between years was probably due to temperature.

Regarding tillage, the highest protein content was obtained in P case and the lowest with NT. The highest fat content was obtained with NT, and the lowest with P. The differences between P and NT were significant (Table 4).

Thousand kernels weight was very significantly affected by years and tillage systems and significantly by sub-soiling (Table 4). The highest mean value was recorded in 2010 (153.96 g) and the lowest in 2014 (by 29.3%). The sub-soiling had much smaller influence. The conventional tillage determined the highest TKW (129.33 g) significantly different from all the other experimented systems.

Year x sub-soiling interaction was significant for grain fat and TKW (Table 4). Year x tillage system interaction was very significant for grain yield, protein content, fat content and TKW. On the contrary, in Yusuf et al. (1999) research, soybean yield was not influenced by either the main effects of tillage and year or by the year x tillage interaction. All studied parameters were not affected by sub-soiling x tillage system interaction.

Table 4. Analysis of variance and means of soybean examined parameters and grain yield by tillage methods, at Fundulea during the 8-year period (2008-2015)

Variable	Grain protein (%)	Grain fat (%)	TKW (g)	Grain yield (t ha^{-1})
A. Year				
2008	39.83 de	20.35 d	123.22 d	1.32 d
2009	41.15 b	22.79 a	139.22 c	2.58 b
2010	39.58 e	21.76 c	153.96 a	3.37 a
2011	39.58 e	22.61 ab	148.61 b	2.59 b
2012	42.52 a	18.67 e	81.96 f	0.81 e
2013	40.03 d	22.80 a	138.56 c	3.21 a
2014	40.02 d	22.49 b	108.91 e	1.42 cd
2015	40.50 c	22.44 b	109.37 e	1.61 c
B. Sub-soiling				
NS	40.50 a	21.74 a	126.21 a	2.09 b
S	40.55 a	21.74 a	124.75 b	2.14 a
C.Tillage system				
P	40.69 a	21.61 b	129.33 a	2.20 a
C	40.49 b	21.77 b	124.56 b	2.07 b
NT	40.40 b	21.84 a	122.54 c	2.07 b
F-values				
A. Year	190.232***	303.180***	765.074***	158.235***
B. Sub soiling	ns	ns	10.745**	5.396*
C. Tillage	15.320***	10.317***	31.855***	7.517**
A x B	ns	3.484*	4.654**	ns
A x C	22.838***	11.129***	16.855***	4.912***
B x C	ns	ns	ns	ns

***Significant at the 0.001 level; ** Significant at the 0.01 level; * Significant at the 0.05 level, ns – Not significant.
Means with the same lower case letters are not significantly different at P<0.05 level.

CONCLUSIONS

The quality of winter wheat grain was affected greatly by agro climatic conditions and by tillage systems. The 8-year average yield of winter wheat was significantly lower in the case of chisel plough tillage (C) treatment than no-tillage (NT) and conventional tillage (P). The winter wheat protein content varied significantly in all investigated tillage systems and was also affected by the main effect of sub-soiling. TKW significantly varied significantly in and among all investigated tillage treatments.

The quality of maize seeds was influenced to a greater extent by climatic conditions than by tillage systems and sub-soiling treatment. The 8-year average yield of maize was significantly lower in the conditions of conventional tillage (P) than in no-tillage (NT) and chisel plough tillage (C). The maize protein content varied significantly in all and among investigated tillage systems, and it was also affected by the main effect of sub-soiling. Fat and starch levels varied too, but not significantly, in the investigated sub-soiling and tillage practices. TKW varied not significantly in all investigated tillage systems over the 8 experimental years.

The quality of soybean grain was affected to a greater extent by agro climatic conditions and by tillage systems. The 8-year average yield of soybean was significantly lower under chisel plough tillage (C) and no-tillage (NT) than in conventional tillage (P) and was also affected by the main effect of sub-soiling. The soybean fat and protein contents varied significantly in all of investigated tillage systems over the 8-year average. Soybean TKW varied significantly in all of investigated tillage and sub-soiling practices.

Conventional tillage has been the most common agricultural practices in most areas of Eastern Danube Plain of Romania. This tillage system requires a high energy input and may cause water loss and also long-term soil physical degradation. The results of our research prove that adopting conservation tillage practices more or less similar winter wheat, maize and soybean yield with similar quality levels can be obtained.

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