NARDI FUNDULEA, ROMANIA
www.incda-fundulea.ro

ROMANIAN AGRICULTURAL RESEARCH, NO. 28, 2011
Print ISSN 1222-4227; Online ISSN 2067-5720

YIELD AND SOME QUALITY TRAITS OF WINTER WHEAT, MAIZE AND SOYBEAN, GROWN IN DIFFERENT TILLAGE AND DEEP LOOSENING SYSTEMS AIMED TO SOIL CONSERVATION

Alexandru I. Cociu and Eliana Alionte

National Agricultural Research and Development Institute Fundulea, 915200 Fundulea, Călăraşi County, Romania
E-mail: acociu2000@yahoo.com

ABSTRACT

Previous research revealed that winter wheat (*Triticum aestivum* L.), maize (*Zea mays* L.), and soybean [*Glicine max* (L.) Merill] respond more or less to the soil deep loosening work and different tillage systems, depending on the environment. The few data available showed that these agricultural practices also have a certain influence on nutritive values and physical properties of the harvested products. A three year (2008-2010) winter wheat, maize and soybean field experiment was carried out at Fundulea, Romania, on a cambic chernozem type, with the objective of evaluating the influence of different conservative tillage systems (chisel till, disc till, strip till and no till), with and without deep soil loosening, on yield and some important quality parameters. This research revealed that for winter wheat, the tillage systems and climatic conditions which favored grain yield were unfavorable for protein content. Deep soil loosening and tillage systems had a similar influence on protein and grain yields. 1000 kernels weight and test weight were not influenced significantly by the deep soil loosening and tillage systems. For maize, the application of no till resulted in a significant grain yield increase. Conservation tillage systems may influence negatively grain protein content, depending on the climatic conditions. Protein, fat and starch yields were significantly influenced by tillage systems, year and their interaction. These influences were caused mainly by the magnitude of grain yields differences. 1000 kernels weight and test weight were not significantly influenced by the deep soil loosening and tillage system. For soybean, climatic conditions and tillage systems which influenced the grain yield, affected in a similar way the protein and fat contents. Deep soil loosening had a significant influence only on the grain yield and protein content. Deep soil loosening, tillage system and climatic conditions which influenced the grain yield affected similarly the protein yield. In the case of fat yield, these effects are more or less the same only for deep soil loosening and years, but not for tillage systems.

Key words: conservation tillage systems, grain yield, protein content, fat content, starch content, 1000 kernels weight, test weight.

INTRODUCTION

Conservation tillage systems (CTS) are considered essential in defining a durable and efficient agriculture, due to their influences on soil properties (physical, chemical and biological), yields, input costs and energy requirements. On long term, CTS contribute to soil organic carbon enrichment (West and Post, 2002), soil aggregate establishment (Heard et al., 1988), soil moisture conservation (Hatfield and Stewart, 1994), and its macro-porosity (Lal et al., 1990). The extent of these influences on crop development, yield and quality performances depends very much on soil texture and structure (Dick and Van Doren, 1985), climatic factors – mainly precipitations (Boyer, 1970), and weed control (Kapusta, 1979).

Previous research revealed that the winter wheat (*Triticum aestivum* L.), maize (*Zea mays* L.), and soybean [*Glicine max* (L.) Merill] crops respond to the soil deep loosening and the applied tillage system. The few data available show that these agricultural practices have also a certain influence on nutritive values, as well as on physical properties of the harvested product, such as the seed size and weight, expressed as weight of 1000 kernels and test weight, respectively.

This paper reports the results of our research aimed at determination of the influence of reduced tillage, direct seeding in no tilled soil, seeding in limited tilled soil and seeding in strip tilled soil, in comparison with

Received 14 January 2011; accepted 04 February 2011

the traditional tillage, on yield and some quality traits of these three crops. Concomitantly, the effects of reducing soil tillage and work on the respective yield characteristics are assessed.

MATERIAL AND METHODS

This research was carried out at the National Agricultural Research & Development Institute - Fundulea (NARDI), in agricultural years 2007/2008, 2008/2009, and 2009/2010. The following tillage systems were studied:

1. traditional, with moldboard plough (TS);
2. chisel plough tillage – primary tillage executed with chisel implement type without furrow overthrowing (CS);
3. disc/sweep tillage – it has a combined effect of residues breaking up by the discs along with the primary tillage performed by sweeps, without furrow over throwing (DS);
4. strip till (ST) – a variant of “No Till”, applied to row crops. It is executed in fall, opening furrows with width of 1/3 of the distance between the rows, so it agitates less the soil and determines a faster soil warming up in spring;
5. No Till (NT) – not any tillage work.

The effect of different tillage systems was estimated on plots with deep sub-soiling and plots without deep sub-soiling, executed once - only when this research was initiated (summer of 2007). The previous crop residue (so called secondary product) was threshed and uniformly spread on the respective plot during its harvest. The other operations used were those specific to each experimented tillage system (Cociu at al., 2010). The experimental design for each crop in rotation was the split plot in randomized complete blocs design with three replications. The main plots were represented by sub-soiling or not sub-soiling, and the subplots were the tillage systems. Each replication contained 10 plots: 2 variants of sub-soiling*5 of tillage systems. The analysis of variance (ANOVA) was applied, and Duncan’s New Multiple-Range Test at $P \leq 0.05$ (multiple comparison method) was used to estimate the significance of differences between treatment means (Steel and Torrie, 1980). Winter wheat and soybean experimental plots, of 10 m long and 2.0 m wide, were harvested by a Wintersteiger Delta (Wintersteiger AG, Ried, Austria) combine, of 2 m work width. The experimental maize plots were comprised of 2 rows, 10 m long, chosen from the middle of a larger plot. They were hand harvested. The yields and the quality characteristics for all three crops are reported at standardized moistures, as follows: 14% for winter wheat, 15.5% for maize, and 12% for soybean. Correlations between yield means and quality parameters were also estimated.

Grain chemical traits were evaluated based on the data obtained using the Foss Infratec 1225 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 sulfuric acid in the presence of catalysers, for lifting the boiling point and speeding the mineralization process. The amount of sulfuric acid (N/10) cm^3 consumed is equivalent to the ammonia quantity in the analyzed probe. The meal raw (crude, total) protein content (%) was calculated by multiplying the nitrogen percentage of the analyzed probe with 6.25;

(b) the total fat (oil) content of maize and soybean meal 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.

Protein, fat, and starch yield per hectare was calculated for each variant multiplying the grain yield per ha (at standardized moisture) by their content percentages.

For 1000 kernels weight evaluation, the mean of three 100 grain probes, randomly chosen, was calculated for each variant. Test weight was determined with a 1 liter hectoliter scale, performing three replications.

The mean temperature of 2007-2008 agricultural year at this study site (Fundulea), was with 0.8ºC higher than the normal (Table 1). Positive deviations ranged between 0.5ºC and 3.6ºC. The highest deviations were in February (2.7ºC deviation), March (3.6ºC deviation), and August (3.0ºC deviation). The highest temperature was recorded in August (25ºC).

The 2008-2009 year was also warmer, with the annual mean 1.4ºC higher than the multi-annual normal and with positive deviations in all months, between 0.4ºC and 2.8ºC. The highest deviations were in December (2.8ºC deviation) and February (2.7ºC deviation). The highest temperature was recorded in July (24ºC).

Table 1. Monthly mean temperatures and precipitation amounts in 2007/2008, 2008/2009 and 2009/2010 agricultural years at Fundulea

Month	2007/2008	Dev.*	2008/2009	Dev.*	2009/2010	Dev.*
Air temperature (°C)						
October	11.7	0.5	12.6	1.4	12.1	0.9
November	3.3	-1.7	5.8	0.8	7.5	2.4
December	-0.6	-0.3	2.5	2.8	0.5	0.7
January	-3.1	-0.7	-0.9	1.5	-3.9	-1.5
February	2.4	2.7	2.4	2.7	-0.8	-0.5
March	8.2	3.6	5.9	1.3	5.0	0.3
April	12.7	1.6	11.5	0.4	11.9	0.8
May	16.6	-0.4	17.6	0.6	17.4	0.4
June	21.9	1.3	21.8	1.2	21.7	1.1
July	23.3	0.8	24.0	1.5	23.5	0.9
August	25.0	3.1	23.3	1.3	25.4	3.3
September	16.6	-0.6	18.5	1.3	18.2	1.0
Mean	11.5	0.8	12.1	1.4	11.5	0.8
Precipitations (mm)						
October	46.2	5.8	25.9	-14.5	60.1	19.6
November	52.7	8.0	27.5	-17.2	19.1	-24.7
December	62.4	18.3	33.2	-10.9	54.9	10.8
January	15.0	-17.1	69.2	36.9	45.4	12.1
February	2.3	-29.1	25.5	-5.7	69.8	38.0
March	21.4	-16.8	32.3	-5.3	38.3	0.8
April	61.6	16.3	22.1	-22.9	41.8	-2.7
May	59.9	1.0	35.8	-23.6	31.2	-27.2
June	30.6	-40.4	103.6	32.1	104.5	31.7
July	57.5	-14.2	119.5	47.2	95.0	22.2
August	1.6	-51.1	24.6	-26.5	34.4	-16.4
September	59.2	9.1	43.2	-6.9	28.6	-21.1
Total	470.4	-110.2	562.4	-17.3	623.1	43.1

*Dev. = deviation from 50-years average

In 2009-2010, the annual mean temperature was with 0.8ºC over normal, the positive deviations ranging between 0.5ºC and 3.6ºC. The highest deviations were in November and August, with positive deviations of 2.4ºC and 3.3ºC, respectively. The highest temperatures were recorded in August 2007/2008 (25ºC), July 2008/2009 (24ºC), and August 2009/2020 (25.4ºC).

Total precipitation in 2007/2008 was of 470.4 mm, which was with 109.3 mm lower than the multi-annual average (Table 1). In 2008/2009, the total precipitation was of 662.4 mm, with 17.3 mm less than normal. In

2009/2010, the total precipitation was of 623.1 mm, with 43.1 mm over normal.

RESULTS

Influence of tillage systems and deep soil loosening on winter wheat yield and some quality traits

The results presented in Table 2 show that the most unfavorable year for this crop was 2008/2009, mainly due to the high precipitation deficit that occurred during the yield formation period (April - May). The recorded mean grain yield of 4513 kg ha^{-1} was 19% and 43% lower than those registered in 2007/2008 and 2009/2010, respectively.

The analysis of variance indicates that the grain yield was significantly affected only by the year conditions. Deep soil loosening and tillage systems, as well as their interactions with the other factors were non-significant.

Table 2. Tillage systems and deep soil loosening influence on grain yield, protein content, protein yield, thousand kernels weight and test weight of winter wheat, at Fundulea, in three agricultural years

Variability cause	Grain yield (kg ha^{-1})	Protein content (%)	Protein yield (kg ha^{-1})	Thousand kernels weight (g)	Test weight (kg hl^{-1})
A. Year:					
2007/2008	5368 b	13.2 a	717 b	46 a	-
2008/2009	4513 c	15.1 a	678 b	38 c	69.6 a
2009/2010	6470 a	14.0 a	907 a	42 b	71.7 a
B. Deep soil loosening:					
Scarified	5508 a	14.2 a	780 a	42 a	70.6 a
Non scarified	5393 a	14.0 a	755 a	42 a	70.7 a
C. Tillage system					
TS	5442 a	14.9 a	804 a	42 a	70.8 a
CS	5282 a	14.1 bc	747 a	42 a	72.6 a
DS	5473 a	14.2 b	776 a	42 a	70.2 a
NT	5642 a	13.6 c	766 a	42 a	69.3 a
ANOVA					
A	**	ns	**	***	ns
B	ns	ns	ns	ns	ns
C	ns	***	ns	ns	ns
A x B	ns	ns	ns	ns	ns
A x C	ns	**	**	*	ns
B x C	ns	ns	ns	ns	ns

Protein content was not statistically influenced by the year (varying between 13.2 to 15.1%) nor by deep soil loosening, but it was very significantly affected by the tillage system, and significantly by the year*tillage system interaction. The highest protein content was reached with the traditional system (TS): 14.9%, and the lowest with no tillage system (NT): 13.6%.

In the case of traditional tillage (TS), the protein content varied largely with the years: 14.0% in 2008, 15.7% in 2009, and 14.9% in 2010 (Table 3). A similar tendency can be seen when the other tillage systems were applied.

Protein yield per hectare was significantly influenced by year and year*tillage system interaction ($P<0.01$). The highest values were recorded in 2010 (907 kg ha^{-1}), higher with 26% and 34% than in 2008 and 2009, respectively.

The most interesting results presented in Table 3 are in the case of protein yield per hectare achieved by applying the chisel tillage system (CS): the highest in 2010 (964 kg ha^{-1}) and the lowest of all in 2008 (589 kg ha^{-1}), demonstrating how much the climatic conditions of the year affect this trait.

TKW was influenced very significantly by years and significantly by year*tillage system interaction (Table 2). The highest mean value was recorded in 2008, with chisel tillage system (CT): 46 g, which is higher with 9.5% and 21% than those of 2010 and 2009, respectively. These results point out that the climatic conditions also play a great role in the expression of this trait. Data presented in Table 3 shows that the highest value was obtained in 2008 with the chisel tillage (CS): 48 g and the lowest values were in 2009 with the traditional system (TS) and chisel tillage (CT).

In this study, test weight was not significantly affected by any treatment or conditions, the values varying between 69.3 and 72.6 kg hl^{-1} (Table 2).

Table 3. Details on influence of Year*Tillage System interaction in winter wheat

Tillage system / Year	TS	CS	DS	NT
	Protein content (%)			
2008	14.0 cd	12.1 e	13.6 d	13.0 d
2009	15.7 a	15.7 a	14.7 bc	14.8 abc
2010	14.9 ab	14.5 bcd	14.3 bcd	13.0 d
	Protein yield (kg ha^{-1})			
2008	762 b	589 c	736 b	706 b
2009	701 b	688 bc	676 bc	699 b
2010	948 a	964 a	918 a	894 a
	TKW (g)			
2008	46 ab	48 a	45 b	47 ab
2009	37 d	37 d	39 d	38 d
2010	43 c	42 c	43 c	42 c

Means within the same analysed trait, followed by different letters are significantly different at P<0.05.

Influence of tillage systems and deep soil loosening on maize yield and some quality traits

The droughty June-August period of 2008, with a 107 mm deficit compared to normal, along with 1.7ºC higher mean temperature, diminished drastically the maize grain yield at 5964 kg ha^{-1}, which represented 52% and 57% from the mean yields obtained in 2009 and 2010, respectively (Table 4). The analysis of variance shows that the yield was very significantly influenced by year, tillage system applied, and the interaction of these two factors. The effect of deep soil loosening and year*deep soil loosening, as well as deep soil loosening*tillage system interactions were non-significant. The highest three year mean yield was with no till system (NT): 9928 kg ha^{-1}, which was significantly higher than from those obtained with the other systems: 9488 kg ha^{-1} with CS, 9150 kg ha^{-1} with DS, and 8664 kg ha^{-1} with DS. The highest mean maize yield was recorded in 2010 with non tillage system (12012 kg ha^{-1}) and the lowest was of 5117 kg ha^{-1} obtained in 2008 with strip till (ST) system (Table 5).

Protein content was significantly influenced by year (P<0.001), by tillage system (P<0.01) and by year*tillage interaction (P<0.05) (Table 4). The highest average value (9.4%) was recorded in 2008, with 1.5% and 1.8% higher than in 2009 and 2010, respectively. With regards to tillage system influence, the highest value (8.6%) was obtained with the traditional tillage (TS). All the other values were almost similar (8.2% and 8.3%).

During the three experimental years, protein content varied between 7.8% (with chisel system, in 2008) and 9.7% (with traditional system, in 2010): Table 5.

The fat and starch content were affected very significantly by the year and not by the other factors (Table 4). The highest fat content value (3.8%) was registered in 2010 and the lowest in 2008 (3.6%).

This trait looks quite constant in different conditions of cropping. Starch content expressed more or less a similar variation, between 62.6% in 2008 and 58.4% in 2009.

Table 4. Tillage systems and deep soil loosening influence on grain yield, protein, fat and starch content, protein, fat, and starch yield, thousand kernels weight and test weight of maize, at Fundulea, in three agricultural years (2008-2010)

Variability cause	Grain yield (kg ha⁻¹)	Protein content (%)	Fat content (%)	Starch content (%)	Protein yield (kg ha⁻¹)	Fat yield (kg ha⁻¹)	Starch yield (kg ha⁻¹)	Thousand kernels weight (g)	Test weight (kg hl⁻¹)
A.Year									
2008	5964 b	9.4 a	3.6 c	62.6 a	558 c	214 b	3732 b	262 b	-
2009	11430 a	7.9 b	3.7 b	58.4 b	902 a	428 a	6674 a	356 a	72.7 b
2010	10411 a	7.6 c	3.8 a	58.7 b	789 b	393 a	6105 a	336 a	76.6 a
B. Deep soil loosening									
With sub-soiling	9317 a	8.2 a	3.7 a	60.1 a	750 a	347 a	5552 a	319 a	74.8 a
Without sub-soiling	9219 a	8.3 a	3.7 a	59.6 a	749 a	343 a	5455 a	317 a	74.5 a
C. Tillage system									
CS	9151 bc	8.6 a	3.7 a	60.2 a	768 ab	343 b	5487 b	322 a	75.5 a
CT	9488 b	8.3 b	3.7 a	59.6 a	763 ab	356 ab	5607 ab	326 a	74.8 ab
DT	9110 c	8.3 b	3.7 a	60.5 a	739 b	336 bc	5487 b	320 a	75.1 a
ST	8664 d	8.2 b	3.7 a	59.7 a	693 c	324 c	5118 c	310 a	74.4 ab
NT	9928 a	8.2 b	3.7 a	59.3 a	786 a	366 a	5820 a	313 a	73.5 b
ANOVA									
A	***	***	***	***	**	***	***	***	**
B	ns	ns	ns	ns	ns	ns	ns	ns	ns
C	***	**	ns	ns	***	***	***	ns	*
A x B	ns	ns	ns	ns	ns	ns	ns	ns	ns
A x C	***	*	ns	ns	**	**	*	ns	ns
B x C	ns	ns	ns	ns	ns	ns	ns	ns	ns

Table 5. Details on influence of Year*Tillage System interaction in maize

Tillage system / Year	TS	CS	DS	ST	NT
	Yield (kg ha⁻¹)				
2008	6398 e	6097 e	6112 e	5117 f	6095 e
2009	11087 b	11810 a	11472 ab	10772 bc	12012 a
2010	9969 cd	10556 c	9748 d	10105 cd	11678 ab
	Protein content (%)				
2008	9.7 a	9.5 ab	9.4 ab	8.95 c	9.3 bc
2009	8.2 d	7.9 def	7.9 def	8.0 de	7.7 fg
2010	7.8 ef	7.4 g	7.6 fg	7.5 fg	7.6 fg
	Protein Yield (kg ha⁻¹)				
2008	618 d	579 d	574 d	456 e	563 d
2009	908 ab	930 a	900 ab	864 b	910 ab
2010	777 c	781 c	741 c	760 c	885 ab
	Fat yield (kg ha⁻¹)				
2008	230 e	224 e	219 e	180 f	217 e
2009	422 bc	445 ab	423 abc	403 c	447 a
2010	377 cd	398 c	367 d	389 cd	434 ab
	Starch yield (kg ha⁻¹)				
2008	3970 d	3810 d	3828 d	3215 e	3839 d
2009	6544 ab	6800 a	6872 a	6268 b	6888 a
2010	5948 bc	6211 b	5760 c	5870 bc	6735 a

Means within the same analysed trait, followed by different letters are significantly different at P<0.05.

Protein yield per hectare was significantly influenced by year and year*tillage system ($P<0.01$) and very significantly by the tillage system ($P<0.001$) (Table 4). The lowest protein yield level was recorded in 2008 (588 kg ha^{-1}), 62% and 41% less than in 2009 and 2010, respectively. These differences are significant and quantitatively important. As the influence of tillage system is concerned, the highest value of 786 kg ha, was obtained with no tillage system, statistically similar to those recorded for traditional tillage and chisel tillage, but significantly higher than with the disc till and strip till.

Analysis of variance reveals that the fat yield per hectare had an almost similar pattern to the protein yield: significant influence of year and tillage ($P<0.001$), and of year*tillage ($P<0.01$) (Table 4). Year 2008 was also the most unfavorable for the fat yield, with 214 kg ha^{-1}, significantly lower than the values recorded in 2009 and 2010. The highest fat yields were obtained with no till (366 kg ha^{-1}) and chisel tillage (356 kg ha^{-1}), significantly higher than with the other tillage systems.

Like the protein and fat yields, the starch yield was only affected by year and tillage system ($P<0.001$) and by their interaction ($P<0.05$) (Table 4). The other factors and their interactions had no important impact. The highest starch yields were obtained in 2009 (6674 kg ha^{-1}) and 2010 (6105 kg ha^{-1}), significantly higher than in 2008 (3732 kg ha^{-1}). Like in the case of fat yield, no till and chisel tillage determined the highest starch yields, 5820 kg ha^{-1} and 5607 kg ha^{-1}, respectively. The lowest starch yield was registered again with the strip till.

Thousand kernels weight (g) was influenced significantly only by years. The highest value was recorded in 2009 (356 g), being 5.9% and 35.9% higher than in 2010 and 2008, respectively. All the other factors did not affect significantly this trait

Test weight (kg hl^{-1}) of maize grains was also influenced by year ($P<0.01$): the average value of 72.7 kg hl^{-1} obtained in 2009 was quite different from 76.6 kg hl^{-1}, recorded in 2010. Tillage system affected less this trait: the lowest value (73.5 kg hl^{-1}) was registered with no till and the highest (75.5 kg hl^{-1}) with traditional tillage system.

Influence of tillage systems and deep soil loosening on soybean yield and some quality traits

In 2008, the severe drought during the vegetation period caused important soybean yield losses. The mean grain yield, of 1145 kg ha^{-1}, was with 123% and respectively 194% lower than in 2009 and 2010 (Table 6). Analysis of variance over three experimental years shows that years had a very significant effect, and deep soil loosening and tillage system also affected significantly the yield performance. Deep loosening by sub-soiling brought a significant yield advantage of 150 kg ha^{-1}. The yields obtained with different tillage systems were quite close to each other, a little higher levels being achieved with traditional and no till systems.

Protein content, which is the principal component of soybean crop quality, was influenced significantly by year and tillage system, as well as by their interaction (at $P<0.01$), and by the deep soil loosening (at $P<0.05$), (Table 6). During the three experimental years, protein content varied significantly between 40.5% (with chisel system and strip till, in 2010) and 41.5% (with no-till, in 2008), (Table 7).

Fat content was also very significantly influenced by the effect of year and in a less extent by tillage system. The lowest mean value was registered in 2008 (21.2%), which was 1.7% and 1.3% lower than those recorded in 2009 and 2010, respectively. The other cropping conditions had much less influence on this component of quality.

Protein yield per hectare was very significantly influenced by years, and significantly by deep soil loosening, tillage system, and year*tillage system interaction. The climatic conditions of 2008 were also unfavorable for protein production, mainly due to the very low grain yield level: 472 kg ha^{-1} was 123% and 191% lower than the protein yields registered in 2009 and 2010. These differences were not only significant, but also very important quantitatively. Sub-soiling resulted in a significant increase of protein yield, of 61 kg ha^{-1}. Regarding the tillage system influence, the highest and significantly different yield levels, over 980 kg ha^{-1}, were obtained with the traditional and no till systems.

Table 6. Tillage systems and deep soil loosening influence on soybean grain yield, protein and fat content and yield, thousand kernels weight and test weight, at Fundulea, in three agricultural years (2008-2010)

Variability cause	Grain yield (kg ha^{-1})	Protein content (%)	Fat content (%)	Protein yield (kg ha^{-1})	Fat yield (kg ha^{-1})	Thousand kernels weight (g)	Test weight (kg hl^{-1})
A. Year:							
2008	1145 c	41.2 a	21.2 c	472 c	243 c	125 c	-
2009	2552 b	41.3 a	22.9 a	1053 b	585 b	140 b	69.5 b
2010	3368 a	40.7 b	22.5 b	1372 a	758 a	153 a	73.7 a
B. Deep soil loosening:							
With sub-soiling	2434 a	41.0 b	22.2 a	996 a	547 a	141 a	71.4 a
Without sub-soiling	2275 b	41.2 a	22.2 a	935 b	511 b	139 b	71.2 b
C. Tillage system:							
TS	2497 a	41.3 a	22.0 c	1033 a	554 a	146 a	71.0 c
CS	2253 b	41.0 b	22.2 b	921 b	508 a	139 b	71.3 bc
DS	2337 b	40.9 b	22.4 a	955 b	529 a	140 b	71.8 ab
ST	2295 b	41.0 b	22.3 ab	939 b	517 a	141 b	71.7 ab
NT	2393 ab	41.0 b	22.1 bc	981 ab	536 a	132 c	71.9 a
ANOVA							
A	***	**	***	***	***	***	***
B	*	*	ns	*	**	*	*
C	*	**	**	*	ns	***	**
A x B	ns	ns	ns	ns	ns	ns	ns
A x C	ns	**	ns	*	ns	***	ns
B x C	ns	ns	ns	ns	ns	*	ns

Protein yield per hectare varied greatly and very significantly from year to year, between 361 kg ha^{-1} in 2008, with strip till, to 1466 kg ha^{-1} in 2010, with traditional tillage (Table 7).

Fat yield per hectare was also significantly influenced by years (at P<0.001) and by the deep soil loosening (P<0.01) (Table 6). The lowest fat yield was also recorded in 2008 (243 kg ha^{-1}), with 342 kg ha^{-1} and 515 kg ha^{-1} less than those obtain in 2009 and 2010. Sub-soiling resulted in a significant increase of fat yield of 7%.

Thousand kernels weight (g) was very significantly affected by years, tillage systems, and year*tillage system interaction, and significantly by deep soil loosening and deep soil loosening*tillage system interaction (Table 6). The mean values of this trait recorded each year were all significantly different, varying from 125 g in 2008 to 153 g in 2010. The deep soil loosening had a much smaller influence. The traditional tillage produced the highest TKW (146 g), significantly different from all the other experimented systems. The lowest value was recorded with no till. Overall, the lowest value, of 120 g, was obtained in 2008 with no till, and the highest in 2010 (168 g) with traditional tillage system.

Sub-soiling affected TKW most positively and significantly, only in the case of traditional tillage (149 g versus 143 g) and no till (135 g versus 128 g) variant (Table 8).

Table 7. Details on influence of Year*Tillage System interaction in soybean

Tillage system / Year	TS	CS	DS	ST	NT
	Protein content (%)				
2008	41.2 abc	41.2 abc	40.9 c	41.1 bc	41.5 a
2009	41.4 ab	41.2 abc	41.2 abc	41.3 ab	41.3 ab
2010	41.4 ab	40.5 d	40.6 cd	40.5 d	40.6 cd
Protein yield (kg ha^{-1})					
2008	550 d	411 f	523 d	361 f	512 de
2009	1082 c	1064 c	995 c	1074 c	1053 c
2010	1466 a	1287 b	1346 b	1381 ab	1377 ab
TKW (g)					
2008	129 de	121 f	126 ef	130 de	120 f
2009	142 c	144 c	144 c	139 c	131d
2010	168 a	151 b	152 b	155 b	144 c

Means within the same analysed trait, followed by different letters are significantly different at $P<0.05$.

Table 8. Details on influence of Deep Soil Loosening*Tillage System interaction in soybean

Tillage system	TS	CS	DS	ST	NT
Deep soil loosening	TKW (g)				
With sub-soiling	149 a	139 c	141 bc	140 bc	135 d
Without sub-soiling	143 b	138 cd	140 bc	143 bc	128 e

Means within the same analysed trait, followed by different letters are significantly different at $P<0.05$.

Test weight (kg hl^{-1}) was also significantly influenced by years ($P<0.001$), by deep soil loosening, ($P<0.05$) and by tillage system ($P<0.01$) (Table 6). The highest average value of this trait was recorded in 2010 (73.7 kg hl^{-1}), significantly higher than in 2009 (69.5 kg hl^{-1}). With regards to deep soil loosening and tillage system influence, there were some significant but relatively small differences.

DISCUSSIONS

Environmental conditions and tillage systems, which influenced positively the winter wheat grain yield, reduced correspondently the grain 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). Year*tillage system interaction (significant at $P<0.01$) indicates that lower protein content levels are obtained with tillage systems which favors the grain yield (Table 3). This inverse relationship between winter wheat grain production and protein content is well known and quite common. The relationship depends more on N availability for plant than on water supply (Marinciu and Saulescu, 2009). The influences of deep soil loosening and tillage system on winter wheat protein yield per hectare look similar to their influences on grain yields. Year*tillage system interaction was significant ($P<0.01$) for protein yield per hectare. This interaction can be explained mainly by the important differences among the conditions of years of experimentation (Table 3). Winter wheat protein yield correlated positively and very significantly with the grain yield ($r = 0.919$, $P<0.001$). The thousand kernels weight of winter wheat was not significantly influenced by the experimented deep soil loosening and tillage systems. The influence of year*tillage system interaction on protein yield was significant ($P<0.05$), mainly due to the great climatic conditions differences during yield formation period (Table 3). The winter wheat weight of thousand kernels was quite stable, not being significantly influenced by any factor under study.

Year*tillage system interaction influence on maize grain yield was very significant (P<0.001), the no till system realizing a significant yield increase in each experimental year (Table 5). The significance of this interaction can be explained by the magnitude of differences of grain yields, as response to different tillage systems within specific climatic conditions of each experimental year. Regarding the protein content of maize grains, the influence of year*tillage system interaction, significant at the level P<0.05, indicates that the conservation tillage systems determine lower protein content levels, depending on the specific conditions of the year (Table 5). Protein content of maize grains showed a very strong negative correlation (P<0.001) with the grain yield. The calculated coefficient of correlation was of r = -0.885. Fat content, being generally in competition with protein content for most crops, showed a very significant positive correlation with the grain yield (r = 0.784). Starch content proved to be in a very significant correlation with the grain yield (r = 0.951). Year*tillage system interaction influenced significantly the maize protein and fat yields per hectare (P<0.01), and the starch production (P<0.05). In all three cases, the strong interaction can be explained by the magnitude of differences of grain yields as response to different tillage systems within specific climatic conditions of each experimental year (Table 5). Maize grain yield correlated positively and very significantly (P<0,001) with the protein yield per hectare (r = 0.979), with the fat yield (r = 0.979), and with starch yield (r = 0.882). TKW was influenced significantly only by years, especially by the different climatic conditions during yield formation period (Table 4). Test weight (kg hl^{-1}) appeared to be affected less by years and by the tillage systems. TKW was correlated very strongly (P<0.001) with the grain yield (r = 0.965). In contrast, test weight (kg hl^{-1}) showed a negative, significant (P<0.01) correlation with grain yield (r = -0.799).

Specific climatic conditions of each experimental year and of tillage systems, which influenced the soybean grain yield, affected correspondingly the protein and fat contents. The deep soil loosening had a significant influence only on the grain yield and protein content. Year*tillage interaction affected significantly (P<0.01) the protein content (Table 7). The results of this research suggest that when the same soybean variety is used in different tillage systems, grain yield may correlate negatively or not significantly with the protein content. In most cases, lower fat content values corresponded to higher protein content (Table 6). This inverse relationship between protein and fat contents in soybean grains is well known and was clearly underlined by Scott and Aldrich (1983). The results of this study suggest that the variation of protein and fat content across years, are mainly due to temperature during the seed formation period. Similar conclusion was drown by Calvin (1965), who showed that a lower temperature during this period lowers the protein content and increases the fat content. As we can see in Table 1, the air temperature in August – September (seed formation period) was lower in 2008 than in 2009 and 2010. Year*tillage system interaction influence on soybean protein yield was significant (P<0.05). It was mainly determined by the different climatic conditions of each experimental year (Table 7). Year, deep soil loosening and tillage system variants which influenced soybean grain yield affected in a similar way the protein yield per hectare. For the fat yield per hectare, these effects were similar only in the case of years and deep soil loosening, but not in the case of tillage systems. Soybean grain yield was correlated positively, and very significantly (P<0.001) with protein and fat yields, the calculated coefficients of correlation being of r = 0.999 and r = 0.943, respectively. Grain yield had a much greater weight in the calculation of protein and fat yields per hectare than the protein and fat content. TKW and test weight (kg hl^{-1}) were correlated very strongly (P<0.001) with the grain yield: r = 0.965 and r = 0.892, respectively.

CONCLUSIONS

For winter wheat crop:

Tillage systems and climatic conditions which favored the grain yield were unfavorable for protein content.

Deep soil loosening and tillage systems had a similar influence on protein and grain yields. Protein yield correlated positively and very significantly with the grain yield.

1000 kernel weight was not significantly influenced by the deep soil loosening and tillage systems. This trait was correlated very strongly with the grain yield.

Test weight (kg hl^{-1}) was not affected significantly by the tillage system and climatic conditions. It showed a strong negative correlation with grain yield.

For maize crop:

No till system application resulted in a significant grain yield increase each experimental year.

Conservation tillage systems may influence negatively grain protein content, depending on the specific climatic conditions of the year. This trait showed a very strong negative correlation with the grain yield, while fat content and grain yield proved to be in a very significant positive correlation.

Protein, fat and starch yields were significantly influenced by tillage systems, year and their interaction. These influences were caused mainly by the magnitude of grain yields differences.

Protein, fat and starch yields correlated positively and very significantly with grain yield.

Thousand kernels weight was influenced significantly only by year, especially by the conditions during the period of yield formation. It was correlated very strongly with the grain yield.

Test weight (kg hl^{-1}) appears to be less affected by years and by the tillage system. It showed a negative, significant correlation with grain yield.

For soybean crop:

Climatic conditions and tillage systems, which influenced the grain yield, affected similarly the protein and fat contents.

Deep soil loosening had a significant influence on the grain yield and protein content.

In most cases, lower fat content values corresponded to higher protein content, as a lower temperature during seed formation period decreases the protein content and increases fat content.

Years, deep soil loosening, and tillage system which influence the grain yield affects in a similar way the protein yield. For the fat yield, these effects are similar only in the cases of years and deep soil loosening, but not in the case of tillage systems.

Grain yield was correlated positively and very significantly with protein and fat yields, grain yield having a much greater weight in the calculation of protein and fat yields per hectare than the protein and fat contents.

Thousand kernels weight and test weight (kg hl^{-1}) were correlated very strongly with the grain yield.

REFERENCES

Boyer, J.S., 1970. *Leaf enlargement and metabolic rates in corn, soybean and sunflower at various leaf water potentials*. Plant Physiol., 46: 233-235.

Calvin, D.T., 1965. *The effect of temperature on the oil content of fatty acid composition of the oils from several oil seed crops*. Can. J. Bot., 43: 63-69.

Cociu, A.I., Zaharia, G.V. and Constantin, N., 2010. *Tillage system effects on water use and grain yield of winter wheat, maize and soybean in rotation*. Romanian Agricultural Research, 27: 69-81.

Dick, W.A., and Van Doren, Jr D.M., 1985. *Continuous tillage and rotation combinations effects on corn, soybean and oat yields*. Agron. J. 77: 459-465.

Hatfield, J.L., and Stewart B.A., 1994. *Crop residue management*. Adv. Soil Sci. Lewis Publ., Boca Raton, FL.

Heard, J.R., Kladivko, E.J., and Mannering, J.R., 1988. *Soil macroporosity, hydraulic conductivity, and air permeability of silty soils under long-term conservation tillage in Indiana.* Soil Tillage Res., 11: 1-8.

Kapusta, G., 1979. *Seedbed tillage and herbicide influence on soybean (Glycine max) weed control and yield*. Weed Sci., 27: 520-526.

Lal, R., Vleeschauwer, D. de, and Ngaje, R.M., 1990. *Changes in properties of a newly cleared tropical Alfisol as affected by mulching*. Soil Sci. Soc. Am. J., 44: 823-827.

Marinciu, C., Saulescu, N.N., 2009. *Grain yield and protein concentration in winter wheat cultivars tested with and without nitrogen fertilizer*. Rom. Agr. Res., 27: 69-81.

Scott, W.O., Aldrich, S.R., 1983. *Modern soybean production*. 2nd ed. S&A Publications, Champaign, IL.

Steel, R.G.D., Torrie, J.H., 1980. *Principles and procedure of statistics: A biometrical approach*. 2nd ed. McGraww - Hill. New York.

West, T.O., and Post, W.M., 2002. *Soil organic carbon sequestration rates by tillage and crop rotation: A global data analysis*. Soil Sci. Am. J., 66: 1930-1946.