NARDI FUNDULEA, ROMANIA
www.incda-fundulea.ro

ROMANIAN AGRICULTURAL RESEARCH, NO. 27, 2010
Print ISSN 1222-4227; Online ISSN 2067-5720

TILLAGE SYSTEM EFFECTS ON INPUT EFFICIENCY OF WINTER WHEAT, MAIZE AND SOYBEAN IN ROTATION

Alexandru I. Cociu[1]

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

ABSTRACT

Tillage systems for soil conservation (CT) have been extended in the last decades on a large scale all over the world, as an attractive alternative to the conventional practices, mainly due to their reduced cost of production and important contribution to soil and environment protection.This research was carried out at the National Agricultural Research and Development Institute Fundulea (NARDI), in 2008-2009 agricultural year (the second year of these technology testing) on a cambic chernozem soil type. The main objective was the evaluation of economic efficiency of different tillage systems for three crops: winter wheat (*Triticum aestivum* L.), maize (*Zea mays* L.) and soybean [*Glycine max* (L) Merr.], in rotation. The following tillage systems were studied: (I) traditional, with moldboard plough (TS); (II) chisel plough tillage – primary tillage executed with chisel implement type without furrow overthrowing (CS); (III) disk/sweep tillage (DS); (IV) strip till (ST) – a variant of „No till", applied to row crops. (V) No till (NT) – without any tillage work. The results of this research reveal important economical advantages of conservation tillage systems (CT) in comparison with traditional one (TS), for all three crops in rotation, maintaining similar yield levels. Thus, for winter wheat, fuel consumption was reduced with up to 58%, labor cost and time with up to 55%, and the cost per one tone of grain with up to 47%. For maize, fuel consumption was reduced with up to 69%, labor time with up to 61% and the cost per one tone of grain with up to 28%. For soybean, fuel consumption was reduced with up to 66%, labor time with up to 65%, and the cost per one tone of grain with up to 13%. It is considered that, beside enhancing economic efficiency by decreasing inputs for crop production without reducing outputs, the conservative tillage systems have an important contribution to soil preservation against erosion, and overall to the environment protection.

Key words: traditional tillage systems, conservation tillage system, fuel consumption, labor time, cost per one metric ton of grain.

INTRODUCTION

In the last decades, the tillage systems for soil conservation have been extended on a large acreage all over the world, as an attractive alternative to the conventional practices, mainly due to their reduced cost of production and contribution to the environment (Smart et Bradfort, 1999; Bran et al., 2008).

Retention of vegetal residues of the previous crop on 30% of soil surface is considered the lower limit of the classification of tillage systems for soil conservation (conservation tillage: CT). This term is attributed to: no till (direct seeding), minimum till (reduced tillage), and strip till (for row crops), which have the common aim – soil conservation (Baker et al., 2002). CT has also the following advantages: soil erosion reduction, water use efficiency increase, and fuel saving – so lowering CO_2 emission (Grace et al., 2003). Other research shows that CT increases the economic efficiency due to less work for crop implementation (Hobbs and Gupta, 2003).

Vegetal residues on soil surface may slow down plant growth in the first stages of vegetation due to a lower soil temperature, higher moisture, slower root growth, slower nutritive element mobilization, as well as due to some toxicity produced by vegetal residue decomposition (Opoku et al., 1997). The plant growth and development lagging decreases gradually and the differences disappear by blooming stage. It is considered that the slower plant growth in the first stages improves water use efficiency.

We consider that the results and conclusions of this research will help the

Received February 17, 2010; accepted March 15, 2010

Romanian farmers to increase their crops (winter wheat, maize, and soybean) efficiency, which is required by the actual agriculture policy, with no or little governmental subsidies.

MATERIAL AND METHODS

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

I. traditional, with moldboard plough (TS);
II. chisel plough tillage – primary tillage executed with chisel implement type without furrow overthrowing (CS);
III. disk/sweep tillage – it has a combined effect of breaking up the residues, along with the primary tillage performed by sweeps, without furrow over throwing (DS);
IV. strip till (ST) – a variant of „No-till", applied to row crops. It is executed in fall, opening furrows with width of 1/3rd of the distance between the rows, so it agitates less the soil and determines a faster soil warming up in spring;
V. no till (NT) – without any tillage work.

Table 1. Main soil characteristics at the testing site

Characteristics of arable horizon	
Soil type	Cambic chernozem
Clay content (%)	36.50
Bulk density (g cm^{-3})	1.26
Penetration resistance (kg cm^{-2})	28.00
Hydraulic conductivity (mm h^{-1})	49.20

The mean temperature of 2008/2009 agricultural year at Fundulea was 1.4ºC higher than the normal (Figure 1), positive deviations were recorded each month, ranging between 0.4ºC and 2.8ºC. The warmest months were December (+2.8ºC deviation) and February (+2.7ºC deviation). The highest temperature was recorded in June (24ºC).

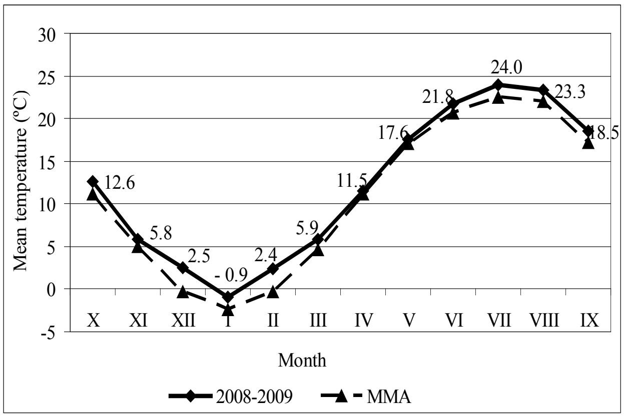

Figure 1. Monthly mean temperatures in 2008/2009 agricultural year, at Fundulea

The total rainfall in 2008/2009 was of 562.4 mm, which was 17.3 mm less than the multi-annual mean (Figure 2). Winter wheat showed a normal growth and development up to yield formation stage, when the lack of water stress started. The adequate soil water reserve in spring assured a good emergence of corn and soybean, and the surplus of rainfall in June and July contributed to a normal crop evolution up to harvest.

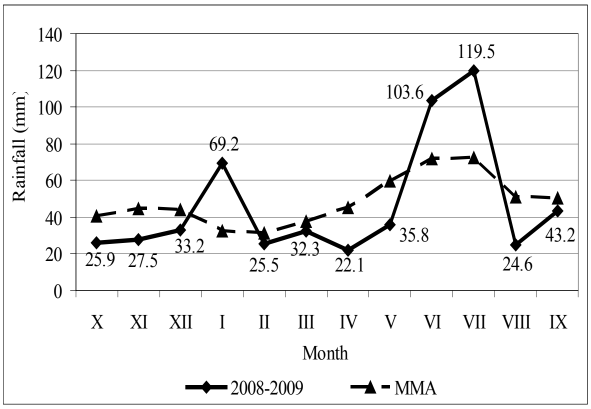

Figure 2. Monthly rainfall in 2008/2009 agricultural year, at Fundulea

Main parameters of the experimented tillage systems are presented for each crop involved in rotation in Tables 2 and 3.

Labor time and diesel fuel consumption were calculated totally for all plots in each treatment. Labor and fuel requirements for tillage, planting, fertilization, herbicide application, and harvest were directly associated with field operations and did not include time spent for equipment repairs and preparations. Fuel consumption was calculated after operation in each plot of each treatment topping up the fuel tank of the tractor with a graduated cylinder. Fuel consumption did not include fuel spent for tractor turning in the alleys between the plots. Labor was measured with a stop watch for each treatment.

The winter wheat and soybean experimental plots were 10 m long and 1.5 wide, and were harvested by combine. The experimental maize plots were comprised of 2 rows, 10 m long, chosen from the middle of a larger plot. Yields were reported on the dry weight basis. The efficiency of the tillage systems under study was estimated only in the second year of testing different technologies (i.e. in 2008/2009), based on the technical-economic parameters of the field equipment utilized and the average yields of the three crops.

Experimental design for each crop was randomized complete block, in three replications, and with 5 tillage systems as treatments. The analysis of variance (ANOVA) was applied for all parameters, and Duncan test at $P \leq 0.05$ (multiple comparison method) was calculated to estimate the significance of difference.

*Table 2***.** Estimation of the main technical-economic parameters of the tillage systems experimented for winter wheat at Fundulea, 2008/2009

No.	Technological variant	Fuel consumption l/ha	Work capacity		Costs			
			ha/h	h. mec./ha	Fuel lei	Work hours lei	Materials lei	TOTAL lei
PRIMARY TILLAGE								
1	Moldboard plowing, 18-20 cm	26.9	0.45	2.22	101.4	12.5	0	113.9
2	Chisel plowing, 18-20 cm	10.6	1.04	0.96	40.0	5.4	0	45.4
3	Work with disk/sweep, 10-15 cm	8.2	1.56	0.64	30.9	3.6	0	34.5
SEED BED PREPARATION								
4	Disked + harrowing	6.8	2.2	0.45	25.6	2.5	0	28.1
5	Cultivation – vibro roller	6.7	2.6	0.38	25.3	2.1	0	27.4
SEEDING + CROP CARE								
6	Seeding in prepared seed bed	6.4	2.7	0.37	24.1	2.1	295	321.2
7	Direct seeding	7.96	2.4	0.42	30.0	2.4	295	327.4
8	Phosphor fertilization	1.5	3.5	0.29	5.7	1.6	558	565.3
9	Nitrogen fertilization	1.6	3.6	0.28	6.0	1.6	382	389.6
10	Herbicide application	1.5	1.7	0.59	5.7	3.3	8	17.0
11	Total herbicide application	1.4	1.7	0.59	5.28	3.3	47	55.6
HARVEST								
12	Harvesting + chopping	13.1	2.5	0.4	49.4	2.2	0	51.6
TOTAL TILLAGE SYSTEM								
Traditional (1+4+(5)+6+8+9+10+12)		57.8		4.60	217.9	25.8	1243	1486.7
Chisel (2+4+(5)+6+8+9+10+12)		41.5		3.34	156.5	18.7	1243	1418.2
Disk/sweep (3+4+(5)+6++8+9+10+12)		39.1		3.02	147.4	16.9	1243	1407.3
No till (7+9+10+11+12)		25.6		2.28	96.36	12.8	732	841.2

* Diesel fuel cost: 3.77 lei/l and 5.61 lei/mec.hour

Table 3. Estimation of the main technical-economic parameters of the tillage systems experimented for maize and soybean at Fundulea (2009)

No.	Technology variant	Fuel consumption l/ha	Work capacity		Costs			
			ha/h	h.mec./ha	Fuel lei	Work hours lei	Materials lei	TOTAL lei
MAIZE								
PRIMARY TILLAGE								
1	Moldboard plowing, 25-30 cm	31.3	0.31	3.23	118	18		136
2	Chisel plowing, 20-22 cm	10.6	1.04	0.96	40	5		45
3	Work with disk/sweep, 15-17 cm	8.2	1.6	0.63	31	4		35
4	Strip initiation	5.2	1.45	0.69	20	4		24
SEED BED PREPARATION								
5	Disked + harrowing	6.9	2.21	0.45	26	3		29
6	Cultivation – vibro roller	6.7	2.61	0.38	25	2		27
SEEDING + CROP CARE								
7	Seeding in prepared seed bed	4.5	1.97	0.51	17	3	308	328
8	Direct seeding	8.8	1.96	0.51	33	3	640	676
9	Phosphor fertilization	1.6	3.58	0.28	6	2	564	572
10	Nitrogen fertilization	1.6	3.58	0.28	6	2	579	587
11	Herbicide application	2 x 1.45	3.30	1.22	11	7	101	119
12	Total herbicide application	1.4	1.70	0.59	5	3	36	44
13	Hoeing	2 x 1.85	4.30	0.94	14	5		19
HARVEST								
12	Harvesting + chopping	8.50	1.17	0.85	32	5		37
TOTAL TILLAGE SYSTEM								
Traditional (1+5+6+7+9+10+11+13+14)		67.7		8.14	255	47	1552	1854
Chisel (2+5+6+7+9+10+11+13+14)		47.0		5.87	177	34	1552	1763
Disk/sweep (3+5+6+7+9+10+11+13+14)		44.6		5.54	168	33	1552	1753
Strip till (4+8+10+11+12+14)		28.4		4.14	107	24	1356	1487
No till (8+10+11+12+14)		23.2		3.45	87	20	1356	1463
SOYBEAN								
PRIMARY TILLAGE								
1	Moldboard plowing, 25-30 cm	31.3	0.31	3.23	118	18		136
2	Chisel plowing, 20-22 cm	10.6	1.04	0.96	40	5		45
3	Work with disk/sweep, 15-17 cm	8.2	1.6	0.63	31	4		35
4	Strip initiation	5.2	1.45	0.69	20	4		24
SEED BED PREPARATION								
5	Disked + harrowing	6.9	2.21	0.45	26	3		29
6	Cultivation – vibro roller	6.7	2.61	0.38	25	2		27
SEEDING + CROP CARE								
7	Seeding in prepared seed bed	4.5	1.97	0.51	17	3	236	256
8	Direct seeding	8.8	1.96	0.51	33	3	551	587
9	Phosphor fertilization	1.6	3.58	0.28	6	2	564	572
10	Herbicide application	2x1.45	3.30	1.22	11	7	540	558
11	Total herbicide application	1.4	1.7	0.5	5	3	52	60
12	Hoeing	2x1.85	4.30	0.94	14	5		19
HARVEST								
13	Harvesting + chopping	8.70	3.7	0,27	33	2		35
TOTAL TILLAGE SYSTEM								
Traditional (1+5+6+7+9+10+12+13)		66.3		7.28	250	42	1340	1632
Chisel (2+5+6+7+9+10+12+13)		45.6		5.01	172	29	1340	1541
Disk/sweep (3+5+6+7+9+10+12+13)		43.2		4.68	163	28	1340	1531
Strip till (4+8+10+11+13)		27.0		3.19	102	19	1143	1264
No till (8+10+11+13)		21.8		2.50	82	15	1143	1240

* Disel fuel cost: 3.77 lei/l and 5.61 lei/mec.hour

RESULTS

Effect of tillage systems on grain yields

The average yields were: 4.55 t ha^{-1} for winter wheat, 11.55 t ha^{-1} for maize, and 2.55 t ha^{-1} for soybean. The differences of yields obtained with different tillage systems were not statistically significant for any of the three crops (Figure 3).

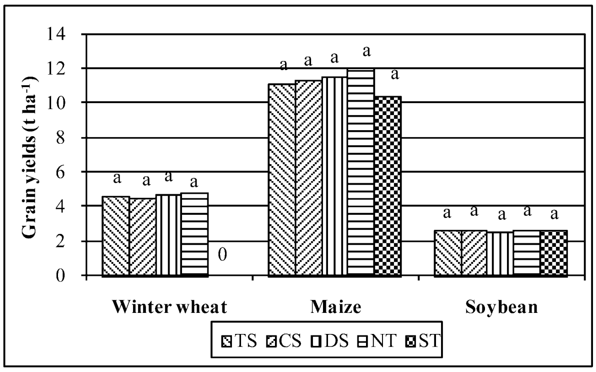

Figure 3. Winter wheat, maize and soybean grain yields when different tillage systems were applied, t ha^{-1}. Fundulea, 2009

Effect of tillage systems on fuel consumption

For winter wheat, fuel consumption for TS was 57.8 l ha^{-1}. It was reduced to 41.5 l ha^{-1} with CS, to 39.1 l ha^{-1} with DS, and to 25.6 l ha^{-1} with NT (Table 2). For maize, the fuel consumption for TS was 67.7 l ha^{-1}and it was reduced to 47.0 l ha^{-1} with CS, to 44.6 l ha^{-1} with DS, to 28.4 l ha^{-1} with ST, and to 23.2 l ha^{-1} with NT (Table 3). For soybean, the fuel consumption for TS was 66.3 l ha^{-1}, and it was reduced to 45.6 l ha^{-1} with CS, to 43.2 l ha^{-1} with DS, to 27.0 l ha^{-1} with ST, and to 21.8 l ha^{-1} with NT (Table 3).

Fuel consumption for obtaining one ton of wheat grain was between 13.0 l t^{-1} with ST and 5.4 l t^{-1} with NT (Figure 4). It was 8.5 l t^{-1} with DS, and 1.0 l t^{-1} less than with CS. Fuel consumption for one ton of maize was between 6.2 l t^{-1} with ST and 1.9 l t^{-1} with NT. With ST it was 2.7 l t^{-1}, rising to 3.9 l t^{-1} with DS and to 4.0 l t^{-1} with CS. In the case of soybean, fuel consumption for one ton was between 25.4 l t^{-1} with ST and 8.6 l t^{-1} with NT. With SD variant it was 18.0 l t^{-1}, lowering to 17.7.9 l t^{-1} with CS, and to 10.4 l t^{-1} with ST. All these differences were statistically significant.

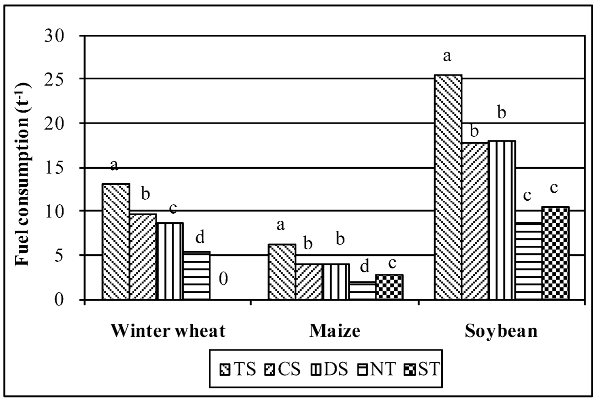

Figure 4. Effect of tillage systems on fuel consumption for one metric ton of winter wheat, maize and soybean yield. Fundulea, 2009

Effect of tillage systems on labor expenditure

Labor expenditure for winter wheat with TS was 4.60 hour ha^{-1}. It was reduced to 3.34 hour ha^{-1} with CS, to 3.02 hour ha^{-1} with DS, and the smallest one was of 2.28 hour ha^{-1} with NT (Table 2). For maize, the labor for TS was 8.14 hour ha^{-1} and it was reduced to 5.87 hour ha^{-1} with CS, to 5.54 hour ha^{-1} with DS, to 4.14 hour ha^{-1} with ST, and to 3.45 hour ha^{-1} with NT (Table 3). For soybean, the labor for TS was 7.28 hour ha^{-1}. It was reduced to 5.01 hour ha^{-1} with CS, to 4.68 hour ha^{-1} with DS, to 3.19 hour ha^{-1} with ST, and to 2.50 hours ha^{-1} with NT (Table 3).

Labor spent for one ton of wheat grain was between 1.0 hour t^{-1} with ST and 0.5 hour t^{-1} with NT. It was 0.8 hour t^{-1} with CS, and 0.1 hour t^{-1} less than with DS (Figure 5).

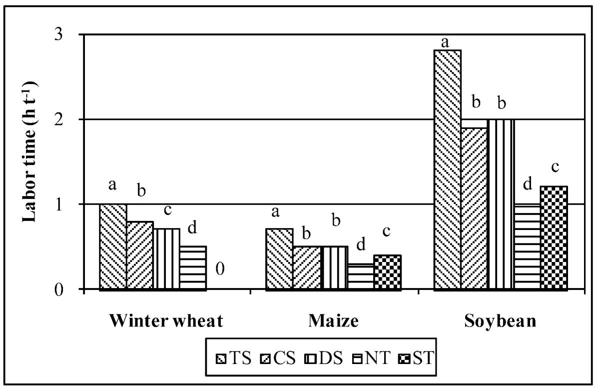

Figure 5. Effect of tillage systems on labor expenditure for one ton winter wheat, maize and soybean yield Fundulea, 2009

For one ton of maize, labor was between 0.7 hour t^{-1} with ST and 0.3 hour t^{-1} with NT.

With CS and DS it was 0.5 hour t^{-1}, and came down to 0.4 hour t^{-1} with ST. For one ton of soybean, labor expenditure was between 2.8 hours t^{-1} with ST and 1.0 hour t^{-1} with NT. With SD it was 2.0 hours t^{-1}, getting lower, to 1.9 hours t^{-1} with CS, and to 1.2 hours t^{-1} with ST. All these differences were statistically significant.

Effect of tillage systems on material cost

Material cost for winter wheat decreased from 1243 lei ha^{-1} with TS, CS, and DS variants to 732 lei ha^{-1} with NT (Table 2). For maize and soybean (Table 3), material cost decreased from 1552 lei ha^{-1} with TS, CS, and DS to 1356 lei ha^{-1} with ST and NT.

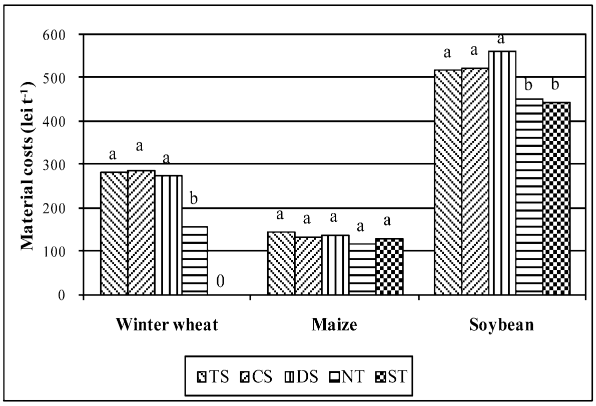

Figure 6. Effect of tillage systems on material cost for one ton winter wheat, maize and soybean yield
Fundulea, 2009

Material costs for one ton of wheat grain was between 283 lei t^{-1} with CS and 155 lei t^{-1} with NT, the difference being statistically significant (Figure 6). It was 279 lei t^{-1} with TS and 270 lei t^{-1} with DS. For one ton of maize, material costs was between 141 lei t^{-1} with ST and 113 lei t^{-1} with NT, but all differences were not statistically significant. For one ton of soybean, material costs was between 557 lei t^{-1} with DS and 440 lei t^{-1} with ST and all differences were statistically significant.

Effect of tillage systems on total cost

Total cost for winter wheat production decreased from 1487 lei ha^{-1} with TS variant to 1418 lei ha^{-1} with CS, to 1407 lei ha^{-1} with CS, and to 841 lei ha^{-1} with NT (Table 2). For maize, the total cost decreased from 1854 lei ha^{-1} with TS to 1763 lei ha^{-1} with CS, to 1753 lei ha^{-1} with DS, to 1487 lei ha^{-1} with ST, and to 1463 lei ha^{-1} with NT (Table 3). For soybean, the total cost decreased from 1632 lei ha^{-1} with TS to 1541 lei ha^{-1} with CS, to 1531 lei ha^{-1} with DS, to 1264 lei ha^{-1} with ST, and to 1240 lei ha^{-1} with NT (Table 3).

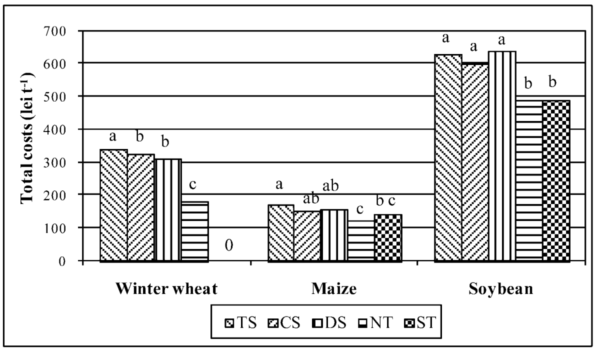

Figure 7. Effect of tillage systems on total cost for one ton winter wheat, maize and soybean yield
Fundulea, 2009

Total cost for one ton of wheat grain was between 334 lei t^{-1} with TS and 178 lei t^{-1} with NT, the difference being statistically significant (Figure 7). For one ton of maize, the total cost was between 168 lei t^{-1} with ST and 122 lei t^{-1} with NT. For one ton of soybean, total cost was between 637 lei t^{-1} with SD and 487 lei t^{-1} with ST and NT, and all differences were statistically significant.

DISCUSSION

The results of this research reveal important economical advantages of conservation tillage systems (CT) in comparison with traditional one (TS), for all three crops in rotation. When the cost of the final product (grain yield) is considered, the main benefits are as follows:

- For producing one ton of winter wheat:
  - fuel consumption was reduced by 58% with NT, 35% with DS, and 27% with CS;
  - labor expenditure was reduced by 55% with NT, 36% with DS, and 26% with CS;
  - material costs were reduced by 45% with NT, 3% with DS, but were 1% higher with CS;
  - total cost was reduced by 47% with NT, 8% with DS, and 3% with CS.

- For producing one ton of maize:
  - fuel consumption was reduced by 69% with NT, 57% with ST, 37% with DS, and 36% with CS;
  - labor expenditure was reduced by 61% with NT, 47% with ST, 34% with DS, and 32% with CS;
  - material costs were reduced by 20% with NT, 10% with ST, 4% with DS, and 7% with CS;
  - total cost was reduced by 28% with NT, 17% with ST, 9% with DS, and 11% with CS.
- For producing one ton of soybean:
  - fuel consumption was reduced by 66% with NT, 59% with ST, 29% with DS, and 30% with CS;
  - labor expenditure was reduced by 65% with NT, 56% with ST, and 30% with DS and CS;
  - material costs were reduced by 14% with ST, 13% with NT, 8% with DS, and 8% with CS;
  - total cost was reduced by 22% with NT and ST, 17% with ST, and 4% with CS, but with DS the total cost was 2% higher.

CONCLUSIONS

Four main economical benefits can be achieved adopting conservation tillage systems (CT), in comparison with traditional one (TS):

- labor expenditure and time reduction;
- reduction of fuel consumption and field operation activity;
- economic efficiency improving by decreasing inputs and parallel increasing outputs;
- enhancing soil and overall environment protection.

REFERENCES

Baker, C.J., Saxton, K.E. & Ritchie, W.R., 2002. *No-tillage seeding science and practice*. 2nd edn. Oxford, UK, CAB International.

Bran, M., Dobre, I., Ştefan, M., Boboc, D. and Papuc, C.M., 2008. *Long-term development of agriculture in micro-area „Dobrotfor-Pojorâta”.* Romanian Agricultural Research, 25: 97-105.

Grace, P.R., Harrington, L., Jain, M.C. and Robertson, G.P., 2003. *Long-term sustainability of the tropical and subtropical rice-wheat system: an environmental perspective.* Improving the productivity and sustainability of rice-wheat system: issues and impact, vol.65 (eds.: J.K. Ladha, J. Hill, R.K. Gupta, J. Duxbury & R.J. Buresh), paper 7, ASA special publications: 27-43, Madison, WI: ASA.

Hobbs, P.R. & Gupta, R.K., 2003. *Resource conserving technologies for wheat in rice-wheat systems*. Improving the productivity and sustainability of rice-wheat system: issues and impact, vol. 65 (eds. J.K. Ladha, J. Hill, R.K. Gupta, J. Duxbury & R.J. Buresh), paper 7, ASA special publications: 149-171, Madison, WI: ASA.

Opoku, G., Vyn, T.J. and Swanton, C.J., 1997. *Modified no-tillage systems for corn following wheat on clay soils*. Agron. J., 89: 549-556.

Smart, J.R., and Bradford, J.M., 1999. *Conservation tillage corn production for a semiarid, subtropical environment*. Agron. J., 91: 116-121.