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INFLUENCE OF SOIL TILLAGE UPON PRODUCTION AND ENERGY EFFICIENCY IN WHEAT AND MAIZE CROPS

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Abstract

The experiment was placed on the chromic luvisol of the Moara Domnească Teaching Farm belonging to the University of Agronomic Sciences and Veterinary Medicine of Bucharest.
The soil tillage experimental variants were: a_1 - ploughed at 20 cm in depth (control - conventional system); a_2 - chisel ploughed at 20 cm in depth; a_3 - chisel plough at 40 cm in depth; a_4 - disking at 10 cm in depth (minimum tillage system).
The biological material was Dropia in winter wheat (Triticum aestivum L), sown at a density of 450 bg/m^2 and the PO216 hybrid in maize (Zea mays L.) sown at a density of 6 bg/m^2.
Basic tillage was performed during the last decade of September.
In the Ilfov area, the weather conditions for the 2014-2015 agicultural year were less favourable to agricultural crops, particulalry rainfalls. In winter wheat rainfalls recorded 410.7 mm between October 2014 and June 2015; however, during the vegetation time in maize (April-August) they were much under the multi-annual average, i.e. only 153 mm (48.5%), compared with 315.7 mm.
Temperatures were higher than normal in the area, i.e. 1.3^{o}C in winter wheat and 2^{o}C in maize during the vegetation time.
Grain production was highest in the 40 chisel variant (6,378 kg.ha^{-1}) and in ploughed maize (4,521 kg.ha^{-1}).
The calculation of energy efficiency was based on the energy indicators: energy consumed (Ec), energie produced (Ep), net energy (En), energy report (E_R).
Energy indicators Ep and E_R recorded higher values in minimum tillage, compared with the conventional system in winter crop and lower in maize crop.

Key words: *Triticum aestivum L., Zea mays L., soil tillage system, yield, energy efficiency.*

INTRODUCTION

Optimising soil loosening and the number of mechanical works can increase energy and economic efficiency in agricultural production, not only directly through lower fuel consumption (10-40 %), working time (over 50 %) and the necessary equipment, and thus lower production costs, but also indirectly through the favorable effects on soil conservation and the reduced greenhouse gas.
Soil tillage has a significant share in the direct energy consumption per area unit (Stănilă et al., 2011), i.e. about 52% in wheat and 60% in maize.
According to Moraru Paula et al. (2011), in the wheat crop grown on the Transylvanian Plateau fuel consumption decreases to 35% by replacing conventional soil tillage with minimum tillage (paraplough, chisel or disk) while the resulting crop production is close to the ploughed variant (98%).
The results obtained by Raus et al. (2007) on energy consumption and energy efficiency in wheat crop showed that soil mobilization decreased together with the energy consumption per crop, from 5844 kwh.ha^{-1} in plough 30 cm, to 5515 kwh.ha^{-1} for disking, while the energy yield of the main production (grains) varied between 2.9 (plough 30) and 2.2 (disk) in $N_{90}P_{60}$.

Minimum tillage in maize crop results in lower energy consumption; however, production can be lower than in the case of conventional system (Guș et al., 2011; Rusu et al. 2009, 2011; Rusu, 2014; Marin, 2011).

MATERIALS AND METHODS

The test was placed on the reddish preluvisol of the Moara Domnească Teaching Farm, Ilfov County, belonging to the University of Agronomic Sciences and Veterinary Medicine of Bucharest.

The soil tillage experimental variants were: a_1 - ploughed at 20 cm in depth (control); a_2 – chisel ploughed at 20 cm in depth; a_3 – chisel plough at 40 cm in depth; a_4 – disking at 10 cm in depth.

The biological material was the Dropia variety for winter wheat, sown at a density of 450 g.g./m^2 and the PO 216 hybrid in maize, sown at a density of 6 g.g./m^2.

In wheat, fertilization was $N_{120}P_{60}K_{60}$ kg s.a. ha^{-1} + leaf fertilization by Hortifor 2.5kg.ha^{-1}. Plant protection was provided by two treatments based on Bumper 250 EC (*propiconazol 250 g/l*) at a rate of 0.5 l/ha and one treatment based on the insecticide Calypso 480 EC (*tiacloprid 480g/l*) 0.1 l/ha; for weed control we used Ceredin Super (*acid 2.4D 300g/l+dicamba 100 g/l*) at a rate of 1 l/ha.

In maize, we used mineral fertilization $N_{120}P_{60}$ kg s.a. ha^{-1}, pre-emergent herbicidation by Dual Gold (*S-metalaclor 960 g/l*) 1.5 l.ha^{-1} and post-emergent by Ceredin Super (*acid2.4D 300g/l+ dicamba 100 g/l*) a rate 1 l.ha^{-1}. Mechanical weeding was applied during vegetation.

The climatic conditions in the Ilfov area in the 2014-2015 agricultural year (Table 1) were satisfactory for cereal crops (winter wheat) and less favourable for hoeing (maize).

Total rainfalls in 2015 was 557.3 mm, i.e. equal with the multi-annual values (556.1 mm); however, their distribution was uneven during plant vegetation.

Between October 2014-June 2015 rainfalls recorded 410.7 mm in winter wheat; nevertheless, during the vegetation period (April-August) of maize they were much under the multi-annual values, i.e. only 153 mm compared to 315.7mm (48.5%). In April rainfalls recorded 2 mm, compared to the multi-annual mean (48.1mm), while in July they recorded 12.2 mm, compared to 63.1mm, which resulted in negative effects on crop production.

Table 1. Climatic conditions at Moara Domnească, Ilfov County

Month	Temperature (^{o}C)		Rainfall (mm)	
	2014-2015	Normal	2014-2015	Normal
October	11.76	11.0	64.2	35.8
November	5.38	5.3	49.1	40.6
December	0.86	0.4	84.6	36.7
January	-1.12	-3.0	33.4	30.0
February	2.03	-0.9	21.4	32.1
March	6.34	4.4	65.6	31.6
April	11.75	11.2	2.0	48.1
May	18.65	16.5	33.6	67.7
June	20.97	20.2	56.8	86.3
July	25.29	22.1	12.2	63.1
August	24.44	21.1	48.4	50.5
September	18.86	17.5	86	33.6
Avg/Sum	**12.1**	**10.5**	**557.3**	**556.1**

Energy balance (kwh.ha^{-1}) was calculated using energy indicators, such as: energy consumption, energy production, net energy, energy efficiency, by using the calculation methodology (Teșu and Bagninschi, 1984).

Energy consumed in kwh.ha^{-1} (Ec) is the energy used for production and includes active energy (E*a*) and passive energy (E*pa*). Active energy is direct (Ea_d), comprising mechanical and human energy, and indirect (Ea_{in}), comprising the energy necessary to produce the materials used in crop technology: seed, fertilizer, pesticide, etc.

Passive energy (E*pa* in kwh.ha^{-1}) is the energy necessary to produce agricultural machinery and equipment, and is distributed according to crop and the depreciation time length of the fixed assets. Produced energy in kwh.ha^{-1} (Ep) results from the energy value of the main (grains – Ep_{pp}) and secondary production (straws, stalks – Ep_{ps}). Net energy En= Ep-Ec.

The energy report E_R= Ep/Ec can be calculated either per total production or only per grain production.

RESULTS AND DISCUSSIONS

Productions achieved in wheat and maize in 2014-2015 (Table 2) recorded differences depending on soil tillage.

In wheat, grain yield varied between 6378 kg.ha^{-1}, in chisel 40 and 6145 kg ha^{-1} in chisel 20, with differences of +1/-2% compared to the control. Secondary production was 1-2% higher in minimum tillage.

In maize, grain yield was low due to the water deficit recorded in the second part of the vegetation period, particularly in July: 4521 kg.ha^{-1} in the control (plough 20) to 4028 kg.ha^{-1} in disking (-11%). Stalk yield was 6137 kg.ha^{-1} in the control and 5795 kg.ha^{-1}, in the chisel 20 cm variant.

Values of energy indicators (Table 3). In wheat crop, energy consumed Ec was 6672 kwh.ha^{-1}, in plough 20 (control) and decreased to 6378 kwh.ha^{-1}in disking (96%). The energy produced for the basic crop varied between 27407 kwh.ha^{-1} in chisel 20cm and 28446 kwh.ha^{-1}. The energy based on straw yield varied between 28612 kwh.ha^{-1} in plough 20cm and 29264 kwh.ha^{-1} in chisel 40. The highest total energy yield (Ep_{PP} + Ep_{PS}) was recorded in the chisel 40 cm variant (57710 kwh.ha^{-1}), i.e. 2% higher than the control.

In maize crop (Table 4), energy consumed (Ec) was 5325 kwh.ha^{-1} in plough 20cm and decreased by 2-6% in minimum tillage. Total energy produced was up to 8% lower in minimum tillage (disk).

Table 2. Influence of soil tillage upon wheat and maize production, 2015

Crop	Production kg.ha^{-1}	Soil tillage							
		Plough 20cm	%	Chisel 20cm	%	Chisel 40cm	%	Disk	%
Wheat	Grains	6292	100	6145	98	6378	101	6305	100
	Straws	6748	100	6825	101	6902	102	6867	102
Maize	Grains	4521	100	4153	92	4310	95	4028	89
	Stalks	6137	100	5795	94	5914	96	5819	95

Table 3. Energy consumption and energy produced depending on soil tillage in wheat crop

Soil tillage	Wheat							
	Energy consumed Ec (kwh.ha^{-1})	%	Energy produced Ep_{pp} (kwh.ha^{-1})	%	Energy produced Ep_{ps} (kwh.ha^{-1})	%	Energy produced $Ep = Ep_{pp} + Ep_{ps}$ (kwh.ha^{-1})	%
Plough 20cm	6672	100	28062	100	28612	100	56674	100
Chisel 20cm	6484	97	27407	98	28938	101	56345	99
Chisel 40cm	6556	98	28446	101	29264	102	57710	102
Disk	6378	96	28120	100	29116	102	57236	101

Table 4. Energy consumption and energy produced depending on soil tillage in maize crop

Soil tillage	Maize							
	Energy consumed Ec (kwh.ha^{-1})	%	Energy produced Ep_{pp} (kwh.ha^{-1})	%	Energy produced Ep_{ps} (kwh.ha^{-1})	%	Energy produced $Ep = Ep_{pp} + Ep_{ps}$ (kwh.ha^{-1})	%
Plough 20cm	5325	100	20616	100	26082	100	46698	100
Chisel 20cm	5137	96	18938	92	24629	94	43567	93
Chisel 40cm	5219	98	19654	95	25135	96	44789	96
Disk	5031	94	18368	89	24731	95	43099	92

The analysis of the net energy amount (En) shows that it was 2% higher in wheat crop (Table 5) in the conservation work variants and up to 6% lower (disk) than the conventional variant. Energy ratio was 8.49 in ploughing and increased to 8.97 in disking in wheat; calculated only for the grain yield, it varied between 4.20 in ploughing and 4.40 in disking.

In maize (Table 6), energy ratio varied between 8.77 (plough) and 8.48 (chisel 20); only for the grain yield, it varied between 3.87 (control) and 3.65 (disk).

Minimum tillage resulted in higher energy indicators in wheat and slightly lower in maize, compared with the conventional variant.

Table 5. Net energy and energy ratio in wheat crop

Soil tillage	Wheat					
	Net energy En ($kwh.ha^{-1}$)	%	Energy ratio E_R	%	Energy ratio E_{Rpp}	%
Plough 20cm	50002	100	8.49	100	4.20	100
Chisel 20cm	49861	100	8.69	102	4.22	100
Chisel 40cm	51154	102	8.80	104	4.33	103
Disk	50858	102	8.97	106	4.40	105

Table 6. Net energy and energy ratio in maize crop

Soil tillage	Maize					
	Net energy En ($kwh.ha^{-1}$)	%	Energy ratio E_R	%	Energy ratio E_{Rpp}	%
Plough 20cm	41373	100	8.77	100	3.87	100
Chisel 20cm	38430	93	8.48	97	3.69	95
Chisel 40cm	39570	96	8.58	98	3.77	97
Disk	38068	92	8.57	98	3.65	94

In wheat, energy consumption for one kg grains (Table 7) was 1.01 $kwh.kg^{-1}$ for disking and 1.06 $kwh.kg^{-1}$ in the plough and chisel 20 variants; in maize, it increased from 1.18 $kwh.kg^{-1}$ (plough) to 1.25 $kwh.kg^{-1}$ (disk).

Table 7. Energy consumption ($kwh.kg^{-1}$) to kg grains in different tillage systems, 2015

Crop	Soil tillage							
	Plough 20cm	%	Chisel 20cm	%	Chisel 40cm	%	Disk	%
Wheat	1.06	100	1.06	100	1.03	97	1.01	95
Maize	1.18	100	1.24	105	1.21	103	1.25	106

CONCLUSIONS

Minimum tillage in winter crop results in equal or slightly higher yields than those resulted from conventional soil tillage; in maize, yield was 5-11% lower, as it was a less favourable year for this crop.
The energy consumed for the crop decreased in minimum tillage, resulting from lower fuel consumption/ha.
For minimum tillage, energy indicators Ep and E_R recorded higher values in weat andlower in maize.

Chiselling 40 cm resulted in best results concerning the crops, as well as the energy indicators for both wheat and maize.

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