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Effect of Different Tillage Systems on Soil Properties and Production on Wheat, Maize and Soybean Crop

P. I. Moraru, T. Rusu

***Abstract*—**Soil tillage systems can be able to influence soil compaction, water dynamics, soil temperature and crop yield. These processes can be expressed as changes of soil microbiological activity, soil respiration and sustainability of agriculture. Objectives of this study were: 1 - to assess the effects of tillage systems (Conventional System (CS), Minimum Tillage (MT), No-Tillage (NT)) on soil compaction, soil temperature, soil moisture and soil respiration and 2- to establish the effect of the changes on the production of wheat, maize and soybean. Five treatments were installed: CS-plough; MT-paraplow, chisel, rotary grape; NT-direct sowing. The study was conducted on an Argic-Stagnic Faeoziom. The MT and NT applications reduce or completely eliminate the soil mobilization, due to this; soil is compacted in the first year of application. The degree of compaction is directly related to soil type and its state of degradation. The state of soil compaction diminished over time, tending toward a specific type of soil density. Soil moisture was higher in NT and MT at the time of sowing and in the early stages of vegetation and differences diminished over time. Moisture determinations showed statistically significant differences. The MT and NT applications reduced the thermal amplitude in the first 15cm of soil depth and increased the soil temperature by 0.5-2.2^{0}C. Water dynamics and soil temperature showed no differences on the effect of crop yields. The determinations confirm the effect of soil tillage system on soil respiration; the daily average was lower at NT (315-1914 mmoli $m^{-2}s^{-1}$) and followed by MT (318-2395 mmoli $m^{-2}s^{-1}$) and is higher in the CS (321-2480 mmol $m^{-2}s^{-1}$). Comparing with CS, all the four conservation tillage measures decreased soil respiration, with the best effects of no-tillage. Although wheat production at MT and NT applications, had no significant differences soybean production was significantly affected from MT and NT applications. The differences in crop yields are recorded at maize and can be a direct consequence of loosening, mineralization and intensive mobilization of soil fertility.

***Keywords*—**Soil tillage, soil properties, yield.

I. Introduction

NO-TILLAGE (NT) and Minimum Tillage (MT) have, in recent years, become tillage systems for soil conservation, popular in Romania. Their insertion in agricultural practice reduces soil degradation phenomena, avoids the implementation of an intensive management and reduces production costs.

Implementing the NT and MT systems in Romania are perceived as having effects on soil compaction, namely a higher resistance to penetration than the conventional tillage system (CS) with effects on soil moisture and temperature. Rain water penetration in soil and the increase of the water storage on soil profile depends or is influenced by the amount and intensity of rainfall, water and soil temperature, slope and land form, by hydro-physical properties, by soil texture and compaction. All these soil qualities are closely interdependent and are influenced by the tillage system.

Soil tillage system and its intensity (CS and MT) modify by direct and indirect action soil temperature, moisture, bulk density, porosity, penetration resistance and soil structural condition. Concerning the NT system where the soil is not mobilized, the evolution of these properties is more influenced by intrinsic qualities of soil, by soil profile layering, by weather conditions and history of management. The results obtained by national and international research highly depend on soil type, climatic conditions of the area and the presence of mulch in conservative systems (CT). Many authors have determined a higher bulk density in CT in comparison with CS [11], [7], [10] others have not found significant differences [3], [13], [23] or defined lower values of bulk density in conservative systems with mulch on the soil surface [5], [16].

Penetration resistance has been observed to be more sensitive than bulk density to detect effects of tillage management [2], [11]. Measurements of resistance to penetration can provide a composite image of the effect of compaction and moisture status. Several authors have concluded that high penetration resistance in conservative systems reduced root growth [4], [15], [18], affecting water and nutrient uptake by crops [21].

Low soil-surface temperatures due to accumulation of crop residues [1], [8], [9] can adversely affect emergence and seedling growth under no-tillage in mid-latitudes [20].

Soil water content is also another factor that is affected by tillage because of changes produced in infiltration, surface runoff, and evaporation [25]. The increase in soil water storage under conservation tillage can be attributed to reduced evaporation, greater infiltration, and soil protection from rainfall impact [24].

Soil respiration leads to CO_2 emissions from soil to the atmosphere, in significant amounts for the global carbon cycle [19]. Soil respiration is one measure of biological activity and decomposition [12]. Soil capacity to produce CO_2 varies depending on soil, season, intensity and quality of agrotechnical tillage, soil water, cultivated plant, fertilizer etc.

The soil conservative systems in different areas have to show specific features according to ecological properties and to cultivated plants characteristics; thus, this system must be

Moraru, P.I. is a Dr. Researcher in the University of Agricultural Sciences and Veterinary Medicine Cluj, 3-5 Manastur Street, Cluj-Napoca, 400372, Romania (phone: 0040741135593; fax: 0040264593792; e-mail: moraru_paulaioana@yahoo.com).

Rusu, T. is a Professor of Agrotechnics in the University of Agricultural Sciences and Veterinary Medicine Cluj, 3-5 Manastur Street, Cluj-Napoca, 400372, Romania (phone: 0040724719774; fax: 0040264593792; e-mail: trusu@usamvcluj.ro).

applied in different ways [6], [14], [17], [22].

Our research follow the effects of the three tillage systems, NT, MT and CS on soil properties (bulk density, penetration resistance, temperature and moisture, soil respiration) and on the production of wheat, maize and soybean, obtained on an Argic Faeoziom from the Somes Plateau.

II. Material and Methods

The data presented in this paper were obtained on Argic-Stagnic Faeoziom [28], at University of Agricultural Sciences and Veterinary Medicine in Cluj-Napoca, within the Research Center for Minimal Systems and Sustainable Agricultural Technologies. The field is a class II quality type, having 78 points for arable use. The soil profile is of type: Amp – Am – A/Btw – Btw – B/C – Cca. The clay content on 0-40cm depth varies between 42.1 and 45.7%. On 0-20cm depth, soil has a reaction at the limit neutral - weak acid, with a value of 6.02. The presence of carbonates in the next horizon, the 120-210 cm depth determines an increase of pH value to 7.88. The base saturation degree of 75% frames this soil type in the eumezobasic soils. As for the humus content, the soil is appreciated as good, namely 4.33% in the first 20cm and 3.27% in the 20-40cm depth. The field is with 8% slope, with the ground water level at 10m depth.

These areas were was our research presents a medium multi annual temperature of 8.2^{0}C medium of multi annual rain drowns: 613mm. The experimental variants chosen were:

A. Conventional system (CS): V_1 – reversible plough (22-25cm) + rotary grape (8-10cm);
B. Minimum tillage system (MT): V_2 – paraplow (18-22cm) + rotary grape (8-10cm); V_3 – chisel (18-22cm) + rotary grape (8-10cm); V_4 – rotary grape (10-12cm);
C. No-Tillage systems (NT): V_5 – direct sowing.

The experimental design was a split-plot design with three replications. In one variant the area of a plot was 300m^2. The experimental variants were studied in the 3 years crop rotation: maize (*Zea mays* L.) - soybean (*Glycine hispida* L. Merr.) – autumn wheat (*Triticum aestivum* L.). The analysis and determinations were done according to acting methodology and standards [26], [28].

The biological material was represented by the LG32 – hybrid maize, Felix – of soya-bean and the Ariesan – species for the wheat. Except for the soil tillage, all the other technological sequences of sowing, fertilizing, are identical in all the variants. Weed control was supplemented each year for the NT version with herbicide before seeding, using Roundup (glifosat 360g/l), 4l/ha.

To quantify the change in soil properties under different tillage practices, determinations were made for each crop in four vegetative stages (spring, 5-6 leaves, bean forming, and harvest). Soil parameters monitored included soil water content (Aquaterr MT300 – Capacitive Sensor), temperature (Aquaterr MT300 – Silicon Junction Sensor), soil bulk density (determined by volumetric ring method using the volume of a ring 100cm^3), penetration resistance (FieldScout SC900 – digital penetrometer) and soil respiration using ACE Automated Soil CO_2 Exchange System. The average result values, obtained in the vegetal phases were statistically processed, taking into consideration the last three cultivation years within the crop rotation. The results were statistically analysed by ANOVA test [27]. A significance level of $P \leq 0.05$ was established a priori.

III. Results and Discussion

Minimum Tillage (MT) and No-Tillage (NT) application reduce or completely eliminate the soil mobilization, due to this; soil is compacted in the first years of application. The degree of compaction is directly related to soil type and its state of degradation. Significant differences are recorded up to 18cm depth. Determinations made on Faeoziomul Argic (Table I) shows a bulk density greater in case of the direct sowing at maize crop (1.35 g/cm^3) and soybean (1.38 g/cm^3), respectively at rotary harrow and direct sowing, in case of wheat (1.32-1.38 g/cm^3). The state of soil compaction diminishes over time, tending toward a specific type of soil density.

Soil tillage system influences more significantly the penetration resistance. This is because the resistance to penetration is a more complex determination that depends on the condition of soil settlement and its humidity. The differences were mainly determined in the first 20cm and there were no differences in the depth.

All determined values were higher in NT and MT compared with CS, the differences being significant distinct positive or significant positive at NT. Differences are also depending on the crop (Table II): wheat – CS: 1524 kPa, CT: 1621-1735 kPa; maize – CS: 1421 kPa, CT: 1523-1624 kPa; soybean: CS: 1643 kPa, CT: 1755-1799 kPa.

Moisture determinations (Table III) shows significant differences, statistically insured, at NT (wheat: 76%; soya-bean: 86%), although high values were recorded at MT, too. Soil moisture was higher in NT and MT at the time of sowing and in the early stages of vegetation, then the differences diminishes over time.

Soil temperature increases in all variants with MT and NT, with differences insured statistically, at wheat crop (Table IV). The differences are recorded especially in the first 15cm, where the NT recorded lower thermal amplitude compared with MT and CS.

Soil respiration (Table V) varies throughout the year for all three crops of rotation, with a maximum in late spring (1383 to 2480 mmoli $m^{-2}s^{-1}$) and another in fall (2141 to 2350 mmoli $m^{-2}s^{-1}$). The determinations confirm the effect of soil tillage system on soil respiration; the daily average is lower at NT (315-1914 mmoli $m^{-2}s^{-1}$), followed by MT (318-2395 mmoli $m^{-2}s^{-1}$) and is higher in the CS (321-2480 mmol $m^{-2}s^{-1}$).

Wheat has ensured equal productions between 3745-3856kg/ha (Table VI), with no significant differences between tillage systems. Maize responded better at the soil loosening, at the mobilization of soil fertility and nutrient mineralization, providing a production of 6310 kg/ha. The production was between 5890-6145 kg/ha at MT, being significant negative at rotary harrow, respectively 5774 kg/ha at NT, being distinct significant negative. The soybean crop productions are between 2112-2341 kg/ ha, being significant positive at MT and NT.

TABLE I
INFLUENCE SOIL TILLAGE SYSTEMS ON SOIL BULK DENSITY (G/CM^3), 0-50 CM DEPTH

Variants	Wheat	Maize	Soya-bean
Plough	1.24^{ws}	1.20^{ws}	1.22^{ws}
Paraplow	1.28^{ns}	1.22^{ns}	1.26^{ns}
Chisel	1.29^{ns}	1.22^{ns}	1.25^{ns}
Rotary grape	1.32*	1.31^{ns}	1.32^{ns}
Direct sowing	1.38*	1.35*	1.38*

Note: wt – witness, ns – not significant, *positive significance, ^{0}negative significance.

TABLE II
INFLUENCE SOIL TILLAGE SYSTEMS ON SOIL PENETRATION RESISTANCE (KPA), 0-45 CM DEPTH

Variants	Wheat	Maize	Soya-bean
Plough	1524^{ws}	1421^{ws}	1643^{ws}
Paraplow	1626*	1523*	1762*
Chisel	1627*	1523*	1755*
Rotary grape	1621*	1621**	1774*
Direct sowing	1735**	1624**	1799*

TABLE III
INFLUENCE SOIL TILLAGE SYSTEMS ON SOIL MOISTURE (% V/V), 0-50 CM DEPTH

Variants	Wheat	Maize	Soya-bean
Plough	61^{ws}	83^{ws}	75^{ws}
Paraplow	65^{ns}	88^{ns}	77^{ns}
Chisel	64^{ns}	85^{ns}	76^{ns}
Rotary grape	64^{ns}	86^{ns}	86*
Direct sowing	76**	89^{ns}	86*

TABLE IV
INFLUENCE SOIL TILLAGE SYSTEMS ON SOIL TEMPERATURE (°C), 0-50 CM DEPTH

Variants	Wheat	Maize	Soya-bean
Plough	17.3^{ws}	23.2^{ws}	22.2^{ws}
Paraplow	19.3*	23.5^{ns}	22.5^{ns}
Chisel	18.9^{ns}	23.4^{ns}	22.5^{ns}
Rotary grape	19.4*	23.9^{ns}	22.3^{ns}
Direct sowing	19.5*	23.9^{ns}	22.6^{ns}

TABLE V
THE INFLUENCE OF SOIL TILLAGE SYSTEMS UPON SOIL RESPIRATION (MMMOLI, M^{-2}S^{-1})

Culture	Soil tillage systems	Plough	Paraplow	Chisel	Rotary grape	Direct sowing
Wheat	Spring	721	714	708	641	532
	5-6 leaves	321	320	321	318	315
	Bean forming	1531	1460	1414	1408	1383
	Harvest	2114	2111	2070	1942	1914
Maize	Spring	1014	1010	1010	982	914
	5-6 leaves	1580	1523	1541	1512	1510
	Bean forming	2340	2308	2312	2252	2218
	Harvest	2250	2242	2221	2208	2141
Soy-bean	Spring	1140	1140	1129	1092	1042
	5-6 leaves	1620	1615	1612	1580	1550
	Bean forming	2480	2395	2382	2350	2320
	Harvest	2350	2314	2318	2270	2183

TABLE VI
INFLUENCE SOIL TILLAGE SYSTEMS ON YIELD OF WHEAT, MAIZE AND SOYABEAN (KG/HA)

Variants	Wheat	Maize	Soya-bean
Plough	3812^{ws}	6310^{ws}	2112
Paraplow	3856^{ns}	6120^{ns}	2251*
Chisel	3795^{ns}	6145^{ns}	2198^{ns}
Rotary grape	3745^{ns}	5890^{0}	2241*
Direct sowing	3786^{ns}	5774^{00}	2341*

IV. CONCLUSION

The state of soil settlement is changed through the tillage, which increases bulk density and penetration resistance in MT and NT, but does not modify soil moisture and temperature.

MT and NT systems reduce the thermal amplitude in the first 15cm of soil and increase soil temperature by 0.5-2.2^{0}C.

Tillage appeared to affect the timing rather than the total amount of CO_2 production: the daily average is lower at NT (315-1914 mmoli m^{-2}s^{-1}), followed by MT (318-2395 mmoli m^{-2}s^{-1}) and is higher in the CS (321-2480 mmol m^{-2}s^{-1}). An exceeding amount of CO_2 produced in the soil and released into the atmosphere, resulting from aerobic processes of mineralization of organic matter (excessive loosening) is considered to be not only a way of increasing the CO_2 in the atmosphere, but also a loss of long-term soil fertility.

Water dynamics and soil temperature showed no differences that could affect crop yields. Productions obtained at MT and NT don’t have significant differences at wheat and are higher at soybean. The differences in crop yields are recorded at maize and can be a direct consequence of loosening, mineralization and intensive mobilization of soil fertility.

Application of MT and NT systems can lead to soil conservation in the Somes Plateau, without affecting crop yields, especially on soils with high initial fertility.

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