ABSTRACT

The doctoral thesis entitled „**RESEARCH REGARDING THE SYSTEM OF MACHINES USED FOR SOIL TILLAGE IN CONSERVATIVE CONDITION**" was conducted during three years of study, from October 1st, 2008 - October 1st, 2011. The paper is structured in two parts, „**KNOWLEDGE STATUS**" and „**PERSONAL CONTRIBUTIONS**", consisting of nine chapters, containing 248 pages, 130 mathematical relationships, 34 tables and 86 figures.

The first part, „**KNOWLEDGE STATUS**", is divided into four chapters.

In the first chapter, „**The importance of conservative agriculture**", there are presented general aspects of the conservative agriculture importance, conservative soil tillage benefits, as well as conservation agriculture in the detriment of the conventional one.

The conservative agriculture as a form of sustainable agriculture should become part of any strategy and agrarian policy and environmental protection, of any strategies and policies that provide long term assurance of food and water in sufficient quantity, quality and affordable for the entire population.

The second chapter entitled „**Aspects regarding the implementation of soil conservative tillage**" is divided into two subchapters. In the first subchapter there are presented the conditions for implementing conservative tillage, by specifying that the conservative tillage cannot be applied anywhere, anytime and that the assessment of soil and land suitability must be carried out only by specialized units with experience in this field. In this sense, pedological studies must be done at the farm level, which on the basis of suitability (particle size composition, state of compactness, slope, relief, depth of ground water - drainage characteristics) and the range of variation of their numerical values, determine where and what kind of conservative solutions must be applied. In the second subchapter there are presented the main

physical-mechanical characteristics of the soil, such as: the soil texture, it's structure, the soil aparent volumic mass, the compaction degree, the soil porosity, the adhesion and external friction, the specific soil resistance to penetration etc.

The third chapter, „**Technologies and machines systems used in conservative agriculture",** is divided into two subchapters. In the first subchapter there are presented the main technologies of mechanized conservative tillage:

- reduced soil tillage, in which the plowing with furrow reversal is replaced by loosening the soil surface layer (soil tillage perfomed by heavy disc harrows, chisel, paraplow);
- reduced soil tillage performed in strips;
- reduced soil tillage performed in ridges;
- direct drill tillage.

The second subchapter presents the main conservative tillage systems and the equipment used in these systems. The literature cites several versions of soil conservation systems:

- rational tillage system (the agricultural aggregates must be used by knowing the soil conditions, with minimal impact on the arable soil layer)
- minimum tillage system (minimum soil tillage prior to sowing, by keeping at the soil surface the vegetal wastes in proportion of 15-30%);
- mulch minimum tillage system (by keeping at the soil surface the vegetal wastes for more than 30%);
- cover crops system (catch crops);
- ridge-tillage system;
- strip till system (zone till);
- no-tillage system (direct drill).

Agricultural equipments used in soil conservation systems cover a wide range and they are aimed primarily to conservate and to reduce soil erosion.

The most frequently equipments used in the rationalized tillage system are: moldboard plows, combinators, complex aggregates, cultivators and disc harrows. The agricultural tools used in the minimum tillage system or reduced soil tillage system are: heavy disc harrows (by using this agricultural tool, the main work tillage – plowing with furrow reversal is eliminated), chisels, paraplows, complex aggregates etc. The agricultural tools used in mulch minimum tillage system are: disc harrows, chisels, paraplows, complex aggregates etc.

In the case of cover crops system or catch crops system there will be used the soil loosening tools without burying the vegetal wastes protective layer.

The agricultural tools used in the ridge-tillage system are: cultivators with moldboard, special combinators (seedbed preparation, performing the ridges and the seeding are carried out by a single pass).

In the „no-tillage" system or direct drill there are used adequate machines which carried out, on a single shift, directly realise the total or partial soil loosening, the seedbed preparation and the sowing.

The fourth chapter entitled „**The impact of soil compaction on it's structure**" is divided into four subchapters. The first subchapter refers to the soil susceptibility to compaction, provided that the soil property is to become compacted when it is exposed to the risk of compaction factors. This may be low, medium, large and very large, depending on soil properties and on a set of external factors such as climate change, land use etc.

In the second subchapter there are presented the main actions to be taken to reduce the agricultural machines traffic to combat the soil destructuring.

The third subchapter presents aspects related to reducing the impact of the agricultural machines rolling bodies on the soil structure elements.

In the last subchapter there are presented the critical aspects of soil compaction.

The main factors influencing the formation and enhancement of agricultural soil compaction are:

- soil moisture;
- excessive mechanization of soil tillage (harvesting with high capacity harvesters, transporting agricultural production with road vehicles);
- use of inappropriate agricultural tools for soil tillage (use of the agricultural rollers for heavy and wet soils);
- high pressure at the interaction between wheels and soil;
- type, shape and construction of rolling bodies of the agricultural machinery;
- number of passes.

The second part of the thesis, „**PERSONAL CONTRIBUTIONS**", is divided into four chapters.

In the fifth chapter, "**Scope and objectives of the doctoral thesis**", the following structureis presented:

A. Modeling the interaction between the agricultural aggregates active bodies and the soil, namely:

1. modeling and simulating the interaction between a rigid wheel and soil, by determining the depth of compaction and the sinkage of the wheel, and the normal tensions in the soil, at the interaction between a rigid wheel and soil;
2. three-dimensional modeling and simulating of the interaction between an arrow type active body with a clay – loamy soil representative in the North-Eastern area of Moldova.

B. Conducting experimental research in the field to determine the impact of agricultural aggregates active bodies with the soil:

1. the impact of tillage mechanization on the soil, for the crops: winter wheat, corn and sunflower;
2. determining the working quality indices, energy indices and exploitation indices of the agricultural machinery depending on the mechanization technologies;
3. determining the influence of various soil compaction degrees caused by agricultural machinery traffic on some indicators of soil physical degradation;
4. determining the influence exercised by different degrees of soil compaction induced by farm machinery traffic, on work quality indices, energy indices and exploitation indices of the machines that perform the soil tillage;
5. determining the influence of different tillage mechanization technologies, correlated with the influence of various degrees of soil compaction on tested agricultural crops production (winter wheat, sunflower and corn grain).

In the sixth chapter there is presented the „**Modeling of interaction between the agricultural aggregates active bodies and soil**” and it is divided in two subchapters. In the first subchapter it is pursued the modeling by numerical simulation of the wheel – soil interaction by finite element method FEM. Modeling and simulating results were focused on soil, by determining the depth of compaction and the wheel sinkage and the normal tensions in the soil. 3D dynamic simulation of a rigid wheel on a moving anisotropic and nonlinear soil leads to reasonable results in the deformation of soil and the normal state of tension in the soil at various depths, by highlighting the residual tensions in the soil that have as effect the soil compaction, leading to soil destructuring in the contact area with the wheel.

The second subchapter presents the modeling of the interaction between the agricultural machines working bodies and soil through finite volume method (FVM). In this method, the main steps for solving a problem of working body-soil interaction are:

- discretization of calculation domain (eg: soil model) in the control volumes (finite volume), based on a network discretization;

- integration of equations on each control volume to determine algebraic equations characteristic to the unknowns of the problem;
- solving such discretized equations.

The results of simulations were performed for a soil considered stationary and for a type arrow working body, moving with a constant speed. The surface pressure distribution on the arrow working body surface varies depending on the arrow cutting surfaces position and on the soil type parameters. The maximum pressure was observed on the cutting edges of the arrow. Average of the normal pressure varies between 4.5 and 53.5 kPa on the edges of the arrow, for the type of soil used in the simulation (clay-loam soil: 38% clay, 30% sand, 32% dust).

In the seventh chapter entitled "**Research material and method**" there are presented:

The natural environment in which the researches were conducted. The experience was located at the experimental field within Ezăreni Farm from U.S.A.M.V. ”Ion Ionescu de la Brad”, Iaşi, in the agricultural years 2008-2009, 2009-2010, 2010-2011, on a cambic chernozem, with a clay-loamy texture and a medium level of fertilization.

Experimental research organization. The research was conducted in three experiments (winter wheat, sunflower and corn grain), the surface of a experimental parcel was 300 m^2 at winter wheat crop and 150 m^2 at hoes crops. It was followed the influence of compaction and the various mechanization technologies on soil characteristics, production, quality indices, energy indices and exploitation indices.

Method of research. On winter wheat crop there were used fifteen experimental variants concerning the soil compaction degree, in three graduations and the agricultural machines used for soil tillage and sowing, in five graduations. At the two hoes crops there were used nine experimental variant concerning the soil compaction degree, in three graduations and agricultural machines used for soil tillage and sowing, also in three graduations. During performance of soil tillage there were determined the quality index (crumbling degree of soil), the energy indices and the exploitation indices (the working real speed of agricultural aggregates, the strength resistance, the tractor driving wheels slip, the rate of using the shift time, the working capacity in an hour during the shift and fuel consumption per hectare). Ten days after sowing, soil samples were taken to determine the soil structure elements distribution, the hydro stability of these elements and the apparent volumic mass. Then, it was also determined the soil resistance to penetration. There were also determined the fuel consumption per hectare and the obtained production of seeds.

The statistical interpretation of the research results was carried out with the method of variation analysis and it included the following stages: the determination of the degrees of freedom (DF), the calculation of the sum of deviation squares, the making of the variation table, the calculation of the limit differences (LD) for transgression probabilities of 5%, 1% and 0.1%, the calculation of the differences towards the sample test and the determination of its significance.

In the last part of the chapter there were presented *the apparatus, the devices and accessories* used to determine the indices followed in the experimental research.

Within the eighth chapter entitled "**Experimental research regarding the impact of agricultural aggregates active bodies on soil**" there are systematicly presented the influences exerted by the soil compaction and the agricultural technologies used for each crop in part, as follows:

In the winter wheat crop, the optimal variant which reflects the best conservative soil conditions for the tillage system is the direct sowing in stubble, respectively the V7 variant (Valtra T 190 + MCR-2.5). The soil tillage quality indices, the energy indices and the exploitation indices obtained for the agricultural aggregate formed by Valtra T 190 tractor and MCR-2.5 combined machine for soil tillage performed in strips and sowing, in this variant (V7) were very good: the crumbling degree of soil at FU-2.5 grassland rotor cutter – 94.6 % (very good); the slap of agricultural aggregate formed by Valtra T 190 + MCR-2.5 – 3.4 % (very good), the fuel consumption per hectare of agricultural aggregate formed by Valtra T 190 + MCR-2.5 – 21.135 l/ha (very good);

Concerning the experience with mechanized soil tillage technologies, at the corn grain crop, the optimal variant which reflects the best conservative soil conditions for the soil tillage system is the V4 experimental variant (Valtra T 190 + Opal 140; Valtra T-190 + BS 400 A Combinator; U-650 + SPC-8). The soil tillage quality indices, the energy indices and the exploitation indices for the tools and agricultural aggregates machines used in this experimental variant were very good: crumbling degree of soil at reversible plow Opal 140 – 81.2 % (very good), BS 400 A Combinator – 97.8 % (very good); the slap of agricultural aggregate formed by Valtra T 190 + OPAL 140 – 11.3 % (very good), of agricultural aggregate formed by Valtra T 190+BS 400 A – 4.2 % (very good); the fuel consumption per hectare of agricultural aggregate formed by Valtra T 190 + OPAL 140 – 16.92 l/ha (very good), of agricultural aggregate formed by Valtra T 190 + BS 400 A – 16.35 l/ha (very good);

Regarding the experience with mechanized soil tillage technologies, at the sunflower crop, there were obtained the same result as in the case of the corn grain crop, respectively V4 (Valtra T 190 + Opal 140; Valtra T-190 + BS 400 A Combinator; U-650 + SPC-8).

In the last part of this chapter there is rendered the influence of different soil tillage mechanization technologies, correlated with the influence of various degrees of soil compaction on agricultural production in all crops tested.

In the last chapter there are presented the “**Conclusions and recommendations**”.

In all experiments performed, the soil compaction made by a tractor Valtra T-190 before plowing, through one passing and respectively two passes “trail by trail”, to get different graduations of soil compaction, had a negative impact on all indices followed in the experimental researches and thus on the production capacity of the soil.

Whithin the tests performed, the specific resistance of soil to penetration has corresponding values. It was not notified an increase in the specific resistance of soil to penetration due to the use of machines. On the contrary, due to their use it was realised that the specific soil penetration resistance is reduced. In exchange, there were registered increases in soil resistance to penetration due to the soil compaction.

In the experimental measurements it was found that the soil apparent volumic mass values of the variants has corresponding values in the case of the uncompacted variants. It was not notified an increase in soil apparent volumic mass due to the use of machines. On the contrary, due to their use there was registered a decrease in soil apparent volumic mass. In exchange, there were registered increases in soil apparent volumic mass due to the soil compaction, in the case of the variants with degree of compaction „compacted once” and „compacted twice”, in some cases, the soil apparent volumic mass values was classified in the range of 1.40 to 1.58 g/cm^3, part of the class of soils with “very high” soil apparent volumic mass.

It is estimated that the hydrostability of the soil structure elements had corresponding values only for uncompacted variants. The I_1 index value of the hydrostability of the soil structure elements has been changed, due to the number of passes performed by agricultural machines, by the soil tillage intensity and it’s value was classified within the limits set by the agrotechnical requirements only for the uncompacted variants. Therefore, the I_1 index had values ranging from 3 to 5, making part of the class of soils with „soil structure is very good” (uncompacted variants), only in a few cases (variants compacted twice) the I_1 index value has values between 0.61 to 3, making part of the class of soils with „soil structure is good”.

In the tested variants, the mean weight diameter values of the soil structural elements are part of the class „very good” in the range 2 to 5 mm.

The inappropriate use of the machines leads in some years, to a degradation of the soil, by tamping it, fragmenting its structure elements, and producing a strong mineralization of the organic matter, the humus, etc. For these facts there should be used the mechanized technologies in soil preparation that ensure its highest possible conservation.

The alteration of the soil tillage concept seems to be an economic, agro-technical and organizational necessity. The future evolution in the field of soil tillage tends towards a decrease in tillage depth, the replacement of plowing with the tilling done by disc harrow or machines that do no overturn the furrow (chisel, paraplow) as well as the direct sowing on the untilled land.

By implementing the concept of conservative agriculture and by establishing some appropriate technologies there will be achieved the conservation of the soil structure and even its improvement, the reduction of hydric and wind erosion, the production surpluses or a production equal to the one realized in the conventional system, a significant reduction of fuel consumption, work time, and also a reduction of the number of passing of the agricultural machines.

In order to apply the different soil tillage systems it is necessary to know its advantages and the disadvantages, the variation of certain economic and agrotechnical indicators, the imposed requirements for the unconventional soil tillage systems, the performance indicators on productivity, costs, profit, etc. established during the research. The obtained results contribute to a better understanding of the conservative technologies than those applied up to present.