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RESEARCH ON THE APPLICATION OF AGRICULTURAL CONSERVATIVE TECHNOLOGIES WITH DEEP LOOSENING WORKS IN ROMANIA AND WORLDWIDE

CROITORU ŞT.[1], BĂDESCU M.[1], UNGUREANU N.[2], BORUZ S.[1], VLĂDUŢ V.[3], USENKO M.[4], MARIN E.[3], MANEA D.[3], CABA I.[5], CUJBESCU D.[3]

[1]University of Craiova; [2]U.P. Bucharest; [3]INMA Bucharest; [4]Lutsk National Technical University / Ukraine; [5]MUNAX SRL Timişoara / Romania

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ABSTRACT

This paper presents the status of research carried out in Romania and worldwide for the development of equipment and agricultural machines that perform superficial or deep loosening of soils, in order to decompact them and to create a layer that allows the movement of water and nutrients towards plants.

INTRODUCTION

Tillage methods in Romania have evolved over the past decades, starting with the "*deep plowing*" system, continuing with the "*optimum depth*" system, "*alternation of working depth of the soil*" and "minimum tillage system" in various types. Each of these methods of tillage had different influences on soil physical-chemical properties and on the production of main crops.

In recent years, the research institutes and universities with agricultural profile have conducted a series of studies in order to determine the efficiency and effectiveness of soil tillage without furrow turning, the limits and conditions of soil and climate in which it can be applied and not least for the necessity to promote it as new technology in production.

MATERIAL AND METHOD

Minimum tillage technology with chisel plow generally consists in two passages, the first being carried out by chisel plow, or by paraplow without furrow turning for primary soil tillage, and the second for sowing.

Often, for soil tillage, one pass is not enough, this being based on preceding compactness condition of the soil and on the previously cultivated plant. The major advantage of such soil loosening technologies is that after sowing, over 30% of the surface remains covered with crop residues, providing favorable conditions for protection against destructive factors and, also, the level of soil processing (i.e loosening and shredding) is reduced. Therefore, this technology is considered a conservative method of long-term beneficial effects. The important limiting factor is generated by the unevenness of the soil surface, which affects the incorporation of pre-emergent herbicides and of seeds during sowing, with negative consequences for germination and emergence.

Tillage with chisel plowing is a basic agro-pedological requirement, that applies to certain soil types, as an agro-ameliorative measure of protection or restoration of the fertility of these soils.

Based on the research done so far, this system of soil tillage is recommended under the following conditions:

- on salty lands, or on lands with salinization tendency, with salt layer near the surface, which in Romania rises to 1 million ha;
- on sloping lands, for soil loosening in order to store water in the soil and to prevent soil runoffs;
- on mobile and semi-mobile sands, to preserve unincorporated stubble for soil conservation;

- for shallow preparation of seedbed on cultivated lands which are compacted by rain.

RESULTS AND DISCUSSIONS

Research conducted by [5] and others aimed to create and promote an TE for decompaction and deep aeration of deficient soils, along with nutrient administration, for high power tractors, in this purpose being developed an experimental model of technical equipment (DECOM-FERTI) with high work productivity on soil tillage in arable sublayer, with requirements related to improving water permeability, rainfall storage capacity, and favoring the development of a deeper root system and the enhance of biological activity in crop soil.

DECOM-FERTI technical equipment was carried by hydraulic lifters of wheel tractors of 190-240 HP wheeled tractors, IIIrd category and could achieve the decompaction and deep aeration of deficient soils, along with the administration of nutrients (fertilizers) and the removal of impermeable layer of soil (hardpan) between the arable layer and sublayer.

This equipment (fig. 1) was composed of two main equipments: DECOM technical equipment (chassis, active bodies with reversible chisel knives, claw rollers, depth adjustment wheel) and FERTI equipment for nutrient administration (crate with the system for nutrient administration, administration tubing, hydraulic system, reduction gear, platform and access ladder).

Fig. 1 *- DECOM-FERTI technical equipment in work/transport position [2]*

DECOM technical equipment (fig. 1) consists of the following main assemblies: chassis, active bodies with reversible chisel knives and special knives for hardpan removal, claw rollers, depth adjustment wheel.

Chassis provides the linkage of equipment in three points to the rods of hydraulic lifter of the tractor and the catch of the 5 active bodies for deep loosening of soil sublayer. The chassis has a four-square frame with large sides made of square tube and short sides of wide steel, one forecarriage and five consoles to bond the active bodies.

Active body of DECOM technical equipment (fig. 2) consists of a base support on which are mounted the reversible chisel blade, the vertical knife and two type "L" knives. Active body performs the tillage of arable layer of soil (without furrow turning) and removes the impermeable layer of soil (hardpan) between arable layer and sublayer.

Fig. 2 *– Active body of DECOM technical equipment [2]*

Claw rollers (fig 3) placed behind the active organs provide a slight grinding and leveling of the processed soil. They consist of two claw rotors rotor, parallel and distant, and four spherical bearings to be mounted in a welded frame. It also has four equal arms (two rigid and two elastic), forming a deformable parallelogram which can be vertically adjusted and another welded frame for mounting on the equipment chassis.

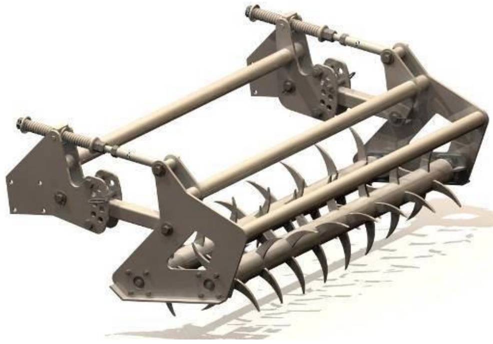

Fig. 3 *– Claw rollers of DECOM technical equipment [2]*

Depth adjustment wheel ensures the adjustment and limitation of working depth of the active bodies.

FERTI equipment for nutrients administration consists of the following main assemblies: crate with the system for nutrient administration, administration tubing, hydraulic system, reduction gear, platform, and ladder.

Crate for nutrients administration (fig. 4) has a fertilizer slot in which are found the devices for nutrients administration through five outlets and five administration tubes.

Fig. 4 *– Crate for nutrients administartion [2]*

The crate for the administration of nutrients is prism-shaped with flow angles for all types of fertilizers. In the crate are mounted some screens against agglomeration of fertilizer and a screen to prevent the entry into the crate, during supply, of lumps or other hard materials that could damage or impair the operation of the equipment. The box is provided, at its lower part, with three apertures for draining-supplying of the fertilizer dispensers that can be blocked by adjustable vane valve. Under these slots are the distributors of fertilizers (fig. 5) mounted on the drive shaft and the gutter for manure collection with mouths and distribution pipes. Nutrient distribution tubes are mounted in the lower rear part of the active bodies for deep loosening of soil.

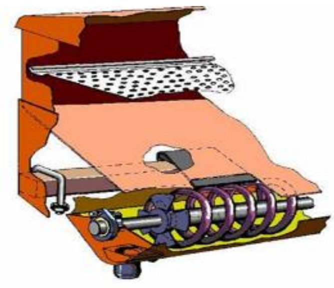

Fig. 5 *- Device* ***/*** *tubes for nutrients administration [2]*

The tubes are connecting the devices for nutrients administration and the rear bottom of the active bodies for deep loosening of the soil (fig. 5).

The hydraulic system and the reduction gear of FERTI equipment for nutrients administration aim the driving of the active bodies for fertilizer distribution in order to achieve and adjust fertilizer norms.

Research conducted by Marin E. et al [4] of INMA Bucharest pursued the development and implementation of an innovative technology and of an technical equipment with driven active bodies for deep loosening and increase of soil fertility, respectively increasing agricultural production by users in farms with lands affected by a strong excess of moisture and aeration deficit in spring season, respectively a moisture deficit in summer moisture, and on compacted soils.

Operation direction of the technical equipment in the plot will be perpendicular to the slope in pedoclimatic conditions with poor water balance and parallel or oblique to the slope in conditions of the surplus water balance and on hollow lands depressions.

The placement of working bodies met the agro-technical requirements that when their number exceeds unity, two of them must be arranged to ensure loosening of the wheel tracks of the tractor, for the annihilation of side effect of soil compaction by them.

Adjustment of soil loosening depth was based on climatic criteria, and the proper indicator for this was given by the amount of rainfall from November to April period (interval without significant quantitative evapotranspiration). Based on this requirement, loosening was carried to a depth at which is obtained the correlation between the amount of rainfall in the mentioned range and the minimum total porosity. Generally, the average working depth is between 50 and 60 cm.

Setting the periodicity of deep soil loosening works has as basic criterion the size of pore deficit, i.e. the difference between the required minimum total porosity and the effective total porosity. The indicator that allows the quantification of these elements is the degree of soil compaction.

By calendar, deep loosening will be executed only during periods when soil moisture is medium or low, which will limit the time of the work during the summer-autumn months and will impose its realization after crops which are harvested in useful time.

The main technical requirements that the technical equipment with driven active bodies had to meet were:

- ✓ to work in all types of soil, at optimum or low moisture content at which will produce a maximum degree of its loosening.

- ✓ to ensure the largest possible reduction in tensile strength at traction, compared to the same non-oscillating body, such that by the use of power available from the tractor power takeoff shaft to achieve fullest use of engine power.
- ✓ to easily penetrate the soil, up to the maximum designed depth, and the space covered by the aggregate during this time must be minimized.
- ✓ to have a good stability in the working position, both vertically and horizontally, for the whole range of the working depths carried out.
- ✓ to ensure good soil aeration without turning, reversing or mixing soil horizons.
- ✓ to work in aggregate with 220...240 HP wheeled tractors existing in our country, corresponding to this requirement, both from the point of view of traction characteristics, and of design and functional parameters of the PTO.
- ✓ to have a maximum of constructive simplicity, and must be done exclusively with currently existing materials in the enterprises manufacturing agricultural machinery.

Thus, according to these requirements, within the conducted research were studied several variants of work and were conducted theoretical and experimental research on active bodies involved for an experimental model of technical equipment for deep soil loosening. This will allow a change in wide limits of the functional parameters of active bodies, such as oscillation frequency, whose value can be adjusted between 3.2 and 21.5 Hz. Vibratory mechanism adopted on the experimental model, of type crank and balancer, ensures the maintaining of functional parameters of the coulter to set values, correlated with working conditions, and the chosen driving scheme allows their modification during experiments in order to determine the optimum working regime. In order to avoid water evaporation, the technical equipment was fitted with the rear roller to carry out grinding, arrangement and further leveling of the soil.

Fig. 6 *– Experimental model of technical equipment with driven active bodies for deep soil loosening [4]*

The main components of this equipment are: active working bodies, transmission, flexible coupling bolts, depth adjustment wheel, support leg and roller assembly.

In his doctoral thesis Epure (Totolici) I.C. [3] conducted theoretical and experimental research to the better knowledge of work processes performed by soil loosening bodies, an important requirement for the design, construction and use of soil loosening machines with optimal technological and economic parameters.

Experiments were performed using equipment with one EA1 working body, respectively on equipment with 7 working bodies EA7 (PC7 chisel plow).

Equipment with one EA1 loosening body (fig. 7) was achieved from the device for measuring the tensile strengths (DMRT), this equipment being used in the carried version, by shutting down the support wheel 2.

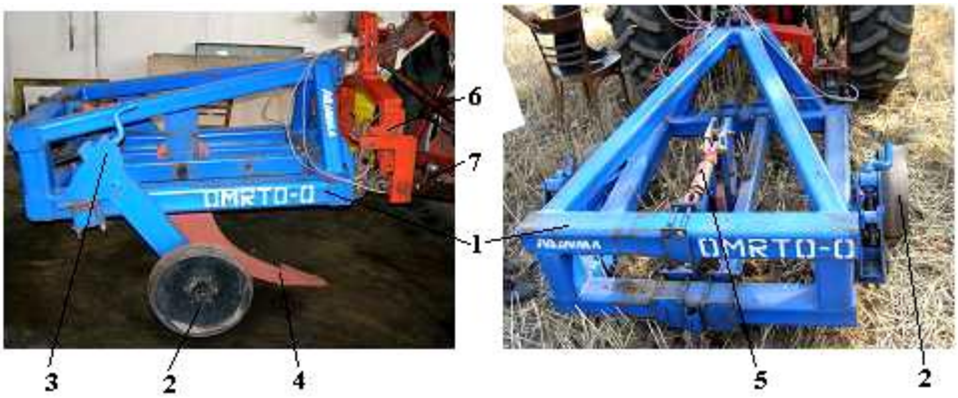

***Fig. 7** – Equipment with one EA1 loosening body (frame for determination fo tensile strenght of DMRT loosening bodies) [3]*

1 - frame; 2 – support wheel (for the variant with copying wheel); 3 - mechanism for position adjustment of the support wheel relative too the frame (working depth adjustment for the operation of hydraulic system of suspension mechanism in floating regime); 4 – working body (knife); 5 – rod for sloping adjustment of working body

Equipment with 7 loosening bodies EA7 is represented by the PC7 machine for soil loosening (fig. 8), in the version carried on the suspension mechanism of 65...80 HP, and catching is in three-point at the coupling device. The machine is made from a frame on which are mounted the 7 working bodies (knives) for soil loosening, type chisel tip and a support wheel that provides working depth adjustment when the suspension mechanism of the tractor works in „floating" regime. The machine can be fitted with a toothed roller (which allows the obtaining of a well-prepared seedbed), which was dismantled during testing.

***Fig. 8** – Equipment with 7 loosening bodies EA7 (PC7 chisel plow), fitted with toothed harrow [3]*

Studies on the optimization of active bodies of equipment used for deep loosening of soil were also made by other researchers [1], for the study and completion of structural and functional parameters of the active body for soil loosening, oscillating coulter type, being designed and built an experimental model of the machine for the deep loosening of soil (fig. 9).

***Fig. 11** – View of experimental model [1]*

The model was designed as a mobile stand, incorporating a three-point linkage of the tractor on 47.8 kW (65 HP), with possibilities to modify the structural and functional parameters.

Changing the angle α formed by the active surface of the coulter with the support plan (bottom of the furrow) was performed using a hydraulic cylinder mounted in place of the central rod of the suspension mechanism.

Changing of other structural and functional parameters characterizing the working process of the active body was performed as follows:

- width and shape of coulter cutting edge, by fitting on the model of some coulters with corresponding sizes and shapes;
- amplitude of oscillations, by fitting on the model of some cranks with proper eccentricity;
- frequency of oscillations, by setting on the model of some pairs of gears;

The model was designed to work in aggregate with tractors without automatic control device of traction force, for which purpose it was provided with two pneumatic copying wheels of the soil surface. Providing the transport position of the machine (fig. 10) is made primarily by means of hydraulic lifter of the tractor, and the subsoiler could be coupled to a lifting device in three-points.

Fig. 10 *– Side view of the experimental model [1]*

Other researchers have pursued the development of optimized classic equipment (reversible performing plow with 5 plough bodies), which ensures a qualitative work, corresponding to the requirements of agricultural practice. For this purpose were achieved, through careful scientific analysis, studies and research on the kinematics and dynamics of reversible plow, primarily on the inversion system of the reversible plow.

WORLDWIDE APPLICATION OF AGRICULTURAL CONSERVATION TECHNOLOGIES WITH DEEP LOOSENING

Vertical tillage technology refers to soil loosening and mobilizing on 20÷30 cm soil depth, or even deeper without furrow turning. After sowing, soil surface remains covered with plant debris in a suitable proportion (over 30%), while soil compaction is reduced on short term. The most used agricultural equipment consists of different types of chisels, cultivators and vibrocultors.

This "vertical tillage" is different from that achieved by scarification, which is applied from time to time in order to improve naturally or anthropically compacted layers of soil that are located below 30 cm deep. In figure 11 are presented some aspects during the application of vertical tillage technology with chisel in Easton, Maryland, USA.

Fig. 11 – *Soil tillage with chisel in soybean stubble, before maize sowing in Easton, Maryland [5]*

In 2008, at the University of Minnesota in the USA, was launched a research project on the evaluation of maize crops, set with chisel in six farms located in Minnesota. Compared to the easily measurable benefits, farms, that have a history of using vertical tillage technology, have obtained many benefits such as: soil organic matter has increased resulting in increased levels of fertility, water retention was better and also was achieved an improved soil structure.

In figure 12 are presented issues during application of vertical tillage technology with a chisel and of maize crop established with this technology. The residue conservation is observed when they were left on the surface of soil.

Fig. 12 – *Aspects during the application of vertical tillage technology and maize crop established by chisel [6]*

Figure 13 presents an aspect during the application of vertical tillage technology with Case IH Flex chisel that can handle virtually any type of soil which has a solid construction and a wide range of working depth adjustment.

Fig. 13 – *Aspects during the application of vertical tillage technology with Case IH Flex Chisel [7]*

Research conducted by the CASE company, on sorghum crops, using chisels for soil tillage showed that their use reduced soil compaction, increased water infiltration capacity in the soil and resulted in better plant growth and increased yields on some soils. Figure 14 presents some aspects during the application of vertical tillage technology with

CMP chisel, manufactured by ÖZDÖKEN in Turkey, which by the action of soil penetration and tillage without furrow turning facilitates the decomposition of weeds. The existence of a layer of plant debris at soil surface reduces the phenomenon of crusting the as the impact energy of raindrops is reduced.

Fig. 14 – *Application of vertical tillage technology with CMP chisel [8]*

Minimum tillage technology of soil consists in processing or loosening of the entire surface of the soil, but by decreasing the intensity and frequency of work, mainly by elimination of some mechanical works applied in the conventional system.

In this category is assigned soil work with milling machine or other rotary milling, followed by sowing, similar to the technology of reduced soil tillage (fig. 15), performed with the Maxima GT drill, manufactured by Kuhn.

Fig. 15 – *Minimum soil tillage performed with Maxima GT seeder [9]*

Soil compaction is a form of physical degradation resulting in densification and distortion of soil, in which the biological activity, porosity and permeability are reduced, strength is increased and soil structure is partially destroyed. Compaction can reduce water infiltration capacity and increases the risk of soil erosion by accelerating soil movement. Compaction process can be initiated by the wheels, tracks, rollers or animal tramping.

Some soils are naturally compacted, strongly cemented or they have a thin layer of topsoil on basement rock. Soils may vary from very strong which withstand all applied loads to very shallow which are compacted by small loads.

In arable land with classic plowing, both the topsoil and the subsoil compaction is possible. A characteristic of compacted soil is the forming of a hard pan (highly compacted soil), caused by the tires of tractor directly driven on the soil during plowing (fig. 16) or at the bottom of the furrow, under the coulter.

Fig. 16 – *Formation of hardpan at the passage of heavy tractors on the soil [10]*

Hardpan layer is less permeable to roots, water and oxygen than normal soil and is a impediment to subsoil function. Unlike topsoil, subsoil is not annually loosened and compaction becomes cumulative and in time it creates a uniform compacted layer.

Driving heavy tractors on soil during plowing and harvesting is a major cause of subsoil compaction.

Research on soil compaction in agriculture and forestry were conducted by Matthias Lebert and Holger Boken [11]. They observed that large frontal loads have the potential to affect soil health by compacting it. In order to maintain soil functions on a sustainable basis, strategies to combat compaction are still needed, and for this purpose technical solutions are developed for the best management practices in agriculture and the reduction of soil compaction. But they may not be sufficient to protect the damage of soil structure, as they cannot compare to the compressive forces of agricultural tools with the soils physical resistance against compaction. Efficacy of practical means against soil compaction must be validated by physical methods of evaluation. Mechanical research of soil led to the development of models to predict stress propagation in the soil at the passing of a tire. Using a bearing capacity model, it is possible to evaluate, for certain loading conditions, if deep soil compaction will occur. If soil compaction is likely to occur, indicators are needed for the assessment of harmful changes in soil structure. Soil physical research identified soil parameters which indicate that soil compaction is harmful and proposed an indicator set to protect soils against compaction and integrating practical, mechanical, physical and soil aspects into a single strategy.

The level of soil compaction in different locations has been studied by researchers in the USA [12] and [13] using various methods and instruments, and they observed that soil structure has a great influence on the following factors: leakage, water retention, food, compaction and the rate of infiltration.

CONCLUSIONS

• The large number of works that are executed by applying conventional technologies that result in soil compaction, damage to its structure, loss of fertility, etc. and which are carried out with a major energy consumption, as well as the need of farming in optimal periods, has led to the *extension of reduced (minimum) tillage technologies* in which the *chisel system*, which requires that tillage must be done without furrow turning and crop residues to be incorporated only partially, is *one of the most used*.

• Worldwide it is developed a wide variety of loosening equipment, depending on soil conditions, which are different from each other in width, number and shape of active bodies, type of surface of the active bodies, etc., with large working widths (up to 6 m), generally destined for medium and high power tractors.

• Research conducted by now in Romania on soil tillage without furrow turning aimed at substantiating the work in agro-technical terms and less at the development of advanced production equipment.
• So far, in Romania, tillage technology without furrow turning was not practiced on large areas, being recommended by experts only on certain types of soil, such as the salty, sandy soils exposed to erosion, the ones in sloping lands (to accumulate water in the soil and prevent soil runoff) etc. where soil tillage should be mandatory without furrow turning in order to conserve soil structure and maintain its fertility.
• Tillage without furrow turning with chisel is an alternative to plow tillage and the basis for cultivation technology in an alternative and sustainable agriculture.
• Analysis of research conducted in Romania shows that although *the expansion of soil tillage without furrow turning* is supported by most experts as by comparison with the conventional work (plow tillage) leads to similar production, reduction of energy consumption, restoring and maintaining soil fertility, being favorable to its vital activities, and yet until now is not finalized at national level for wheat crop an application technology of tillage without furrow turning.
• The complex working process of equipment which carry out soil loosening by mechanical disintegration and shredding, as opposed to the conventional plows which cut the soil by required surfaces, allow that the separation surface coincides with the natural fracture surface of minimum strength, which has beneficial effects on soil structure and leads to the achievement of tillage with less energy consumption.

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