EFFECT OF DIFFERENT DESIGN COULTERS ON SEEDBED HARDNESS

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Abstract: Soil tillage and sowing machinery construction, and work technological processes have strong influence on the soil physical and mechanical properties. In order to estimate this influence the research was carried out in the laboratory soil bin. The aim of the experiment – to estimate the effect of different design coulters on seedbed hardness. Shoe and combined coulters and disc narrow pressure rollers were mounted on one section of the sugar beet direct driller frame. The coulters were pulled by a self-propelled chassis at speed 1.39 $m \cdot s^{-1}$. The experiments were carried out in the soil of three different hardnesses: 0.02, 0.40 and 0.88 MPa. To determine soil hardness at the seedbed area a multipenetrometer was used, which consisted of 11 two mm diameter steel pins, set out in a row at 13 mm distances. If was found in the studies that in soils compacted with a combined sowing coulter comprised of two dissected blade disc coulters and a shoe coulter roll most of all the walls of the seedbed are compacted, while in soil loosened with a vertical rotary cultivator, the furrow bottom is compacted most of all. The furrow bottom is compacted with a shoe coulter and narrow pressure roller, and walls are compacted with disc coulters set at an angle of 15°. When forming the seedbed with a combined coulter, 0.9 to 2.6 % more of moisture can be preserved in all depths ranging from 10 to 50 mm compared to the case of forming the seedbed with a shoe coulter.

Keywords: design coulters, seedbed, soil hardness, soil moisture, tillage technologies.

Introduction

The most important purpose of tillage is to form favourable conditions for the growth of plants. Regular deep ploughing affects many properties of soil and promotes densification of the subsoil layer [1]. The selection of the proper tillage method depends on various properties of the soil and agrotechnological conditions. The most influential factors include the soil cultivation level, organic matter content, weediness, moisture conditions, soil pedality level, tillage technological expertise, etc. The organic matter content of soil and its decomposition processes [2; 3] are interpreted differently in scientific literature; however, it is acknowledged that it is one of the key indicators of the soil quality in organic biosphere equilibrium as well as a stability indicator of significance for the climate change [4; 5]. In search of alternative options of reducing intensive tillage, soil-saving, minimum-tillage technologies are applied more and more broadly. They allow reducing the impact of the tillage machines on wind and water erosion and soil properties, easing compaction of soil layers and, consequently, preserving natural water filtration and plant root penetration into various soil layers [6-8]. Minimum tillage and plant residue insertion in the upper soil layer are beneficial to the soil structure and its quality from the ecological and environmental point of view [9]. Ploughless minimum tillage can be applied in soils with different properties and under various climatic conditions. The application of this technology also allows expecting sufficiently good farming results in heavy soils under arid climatic conditions [10]. Direct seeding is a no-tillage farming technology, in which the top layer of the soil is touched only once and is worked by seeding-machine coulters only to a minimum extent so that to insert plant seeds. Direct seeding machines should be designed so that sowing coulters, irrespective of changing the soil properties and plant residues on the soil surface, could evenly draw a furrow in the soil at the set depth and insert seeds at required intervals [11].

The main task of the application of ploughless minimum tillage or direct seeding technologies is to prevent deterioration of physical, chemical and microbiological properties of soil and to better preserve natural development of soil, conserve soil fauna and reduce environmental pollution compared to conventional ploughing tillage [12; 13]. Of course, the crop productivity and quality should not be ignored and it should be sought that the crop yield and its quality in ploughless tillage technologies would be similar to those achieved when applying conventional tillage [5]. When considering the benefit of ploughless tillage technologies in economic (reduced working time and fuel consumption) and environmental (lower environmental pollution) aspects, a certain reduction in crop yield by 3-10 % compared to conventional tillage technology can be justified [14; 15].

The purpose of the technological processes of tillage and seeding machines is to form a seedbed with suitable properties because it preconditions a proper contact between seed and soil aggregates. If a proper seedbed is prepared, seeds and, later on, plant roots can be optimally provided with soil water, nutrients and oxygen. It is greatly influenced by the physical and mechanical properties of the seedbed such as the soil density, hardness and moisture content [16]. If the topsoil is loosened excessively, the soil in the seedbed area becomes very loose; therefore, excessively big soil pores may disturb the capillary water equilibrium. In addition, a compacted layer, the so-called crust, may form on the soil surface as a result of heavier precipitation. In such cases, water filtration and soil respiration processes are disturbed. Excessively strong seedbed compaction has exactly opposite effect – soil pores are contracted and their efficiency in providing the plant roots with moisture and oxygen decreases remarkably.

In ploughless tillage and sowing technologies, the design of seeding-machine coulters has the greatest impact on seedbed compaction. Some coulters are able to form furrows of proper depth but fail to ensure a good contact between seeds and soil aggregates. Other coulters form seedbeds insufficiently uniformly under difficult conditions of untilled soil. This is why minimum-tillage and direct-seeding technologies often involve the application of combined seeding coulters that are able to evenly draw sowing furrows in soil and to form a seedbed of the required hardness.

The objective of this study is to determine the impact of the operation of coulters of different designs on the hardness of seedbeds in soils prepared by various methods.

Materials and methods

Experimental studies were conducted in a soil channel with a length of 46 m, width of 5 m and soil layer thickness of 1.2 m. The composition of soil: 72 % of sand, 16 % of loam and 12 % of clay. The tillage and seeding machines and research equipment were hauled by a self-propelled 6 m wide bridge-structure, hydraulic-drive truck GANTRY. The truck was fitted with measurement equipment in three different options:

Option I – the topsoil (100 mm thick layer) was loosened by a vertical-rotary cultivator Howard HK10 150S with a working width of 1.5 m;

Option II – the topsoil was loosened by a vertical-rotary cultivator and compacted with a 1000 kg plain roller twice. The soil was rolled with a 1.3 m wide Bertschi – FORBO roller. The weight of the roller is 245 kg when unloaded and 1000 kg when filled with water.

Option III – the topsoil was loosened by a vertical-rotary cultivator and compacted with a 1000 kg plain roller six times.

In all the options, the hardness, shear stress and moisture content of the soil prepared for the studies was measured in nine points of the soil channel. The hardness of the soil was measured with a manual penetrometer with a clock-type indicator; shear stress was measured with a device impeller-type head. The moisture content was determined with the volumetric moisture meter TRIME-FM.

Two coulters were used for the studies: combined and shoe ones. The combined coulter was formed by two 380 mm diameter dissected blade disc coulters placed at an angle of 15º. The disc coulters dented soil to a depth of 25 mm. A shoe coulter which dented into the soil at an angle of 105º was mounted between the disc coulters. It drew a 30 mm deep furrow. A 15 mm thick rubbered disc pressure roller with a diameter of 220 mm rolled behind the coulters over the furrow bottom (Fig. 1). In case when a furrow only with the shoe coulter was drawn, the disc coulters were dismantled. In all cases, the coulter moving speed was $1.39\ m \cdot s^{-1}$.

After drawing the research furrows on the soil surface along the soil channel with the coulters of different designs, the hardness and moisture of the seedbeds were measured.

The hardness of the furrow bottom and walls was determined with a manual multipenetrometer (Fig. 2). It consists of eleven 2 mm diameter steel needles arranged with intervals of 13 mm. The needles are based on rings that bear two pairs of sensors. The rings are fastened to the frame which is pushed with a handle. The needles are pushed into the soil with the handle, their penetration depth was recorded by the sensor (4) and the hardness of the soil was recorded with the sensors (3). Amplified pulses of all the sensors were accumulated in the computer memory.

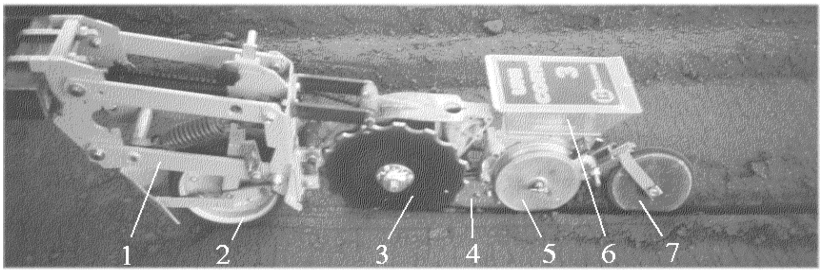


Fig. 1. **Experimental research unit: 1 – frame; 2 – support wheel; 3 – two disc coulters with dissected blades; 4 – shoe coulter; 5 – sowing assembly; 6 – seedbox; 7 – pressure roller**

The multipenetrometer was installed so that the central needle would be located against the axial line of the furrow. Prior to measuring, soil clots were removed from the edges of the furrow. The needles were pressed into the soil with the handle and the sensors recorded the hardness of the soil.

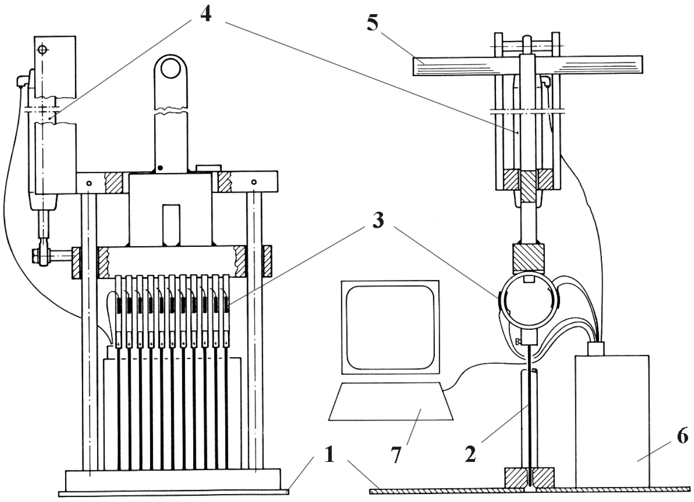


Fig. 2. **Multipenetrometer:** 1 – support; 2 – steel needles; 3 – sensors; 4 – depth sensor; 5 – handle; 6 – amplifier; 7 – computer

Ten measurements were recorded each second. The measurements were performed with three repetitions. The hardness of the soil in terms of MPa was calculated according to the following formula:

$$K = \frac{x_m g}{1000 \pi R_a^{\ 2}}, \tag{1}$$

where K – soil hardness, MPa;
x_m – multipenetrometer readings, g;
g – free-fall acceleration, m·s^{-2};
R_a – needle head radius, mm.

The moisture content of the seedbeds was studied 24 hours after drawing the furrows. The moisture content was determined for samples taken from different seedbed depths: 10 mm, 20 mm, 30 mm, 40 mm and 50 mm. The samples taken were dried in a cabinet and the moisture content of the soil was calculated by the weighing method.

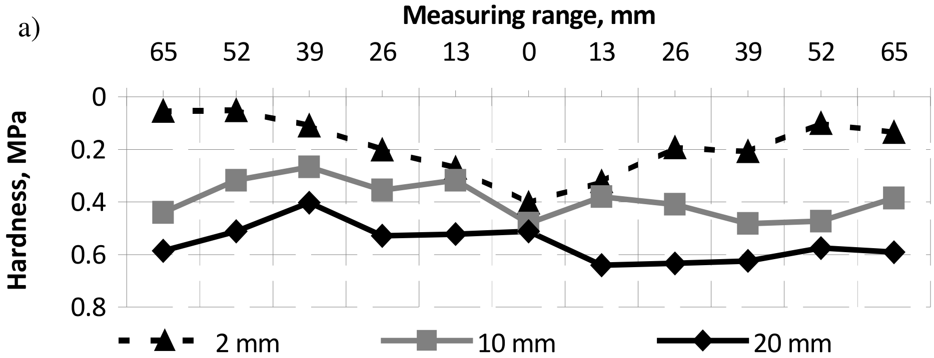
The obtained research data were statistically processed by program ANOVA [17].

Results and discussion

On the basis of the conducted experimental studies of the hardness, shear stress and moisture content of the prepared soil, it was established that at the depth of 25 mm, in Option I the hardness of the soil was 0.02 MPa and the shear stress was 0.002 MPa; in Option II the hardness of the soil was 0.40 MPa and the shear stress was 0.017 MPa; in Option III the hardness of the soil was 0.90 MPa and the shear stress was 0.044 MPa. In Option I, the moisture content of the soil was 4.5 %, and in Options II and III it was similar at 11.0 %. Taking into account the hardness of the soil in the topsoil, it can be conventionally assumed that in Option II the hardness of the soil was similar to that of light loam in untilled soil, and that in Option III was as that of moderate-heavy untilled soil.

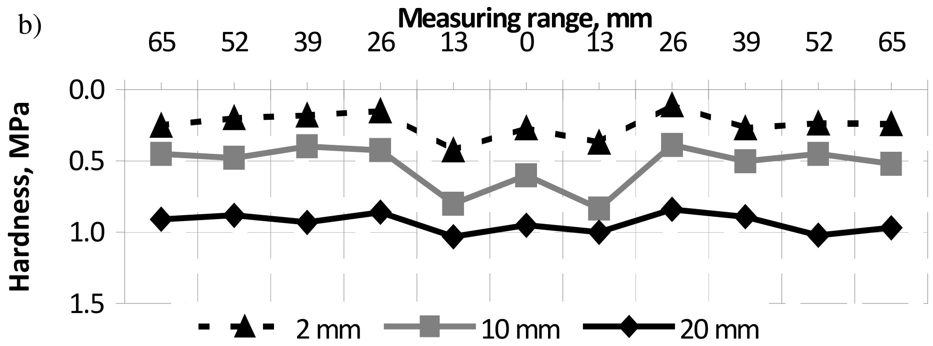
Seedbed soil hardness studies. The studies of the hardness of the topsoil furrow drawn with a combined coulter (at the depths of 2 mm, 10 mm and 20 mm) allowed establishing that in Option I the hardness of the topsoil of the furrow bottom (2 mm and 10 mm) was the highest – approximately 0.4-0.5 MPa (Fig. 3, a). At the depth of 20 mm, the maximum hardness was recorded at the furrow wall at a distance of 13 mm away from the furrow axial line.

a)



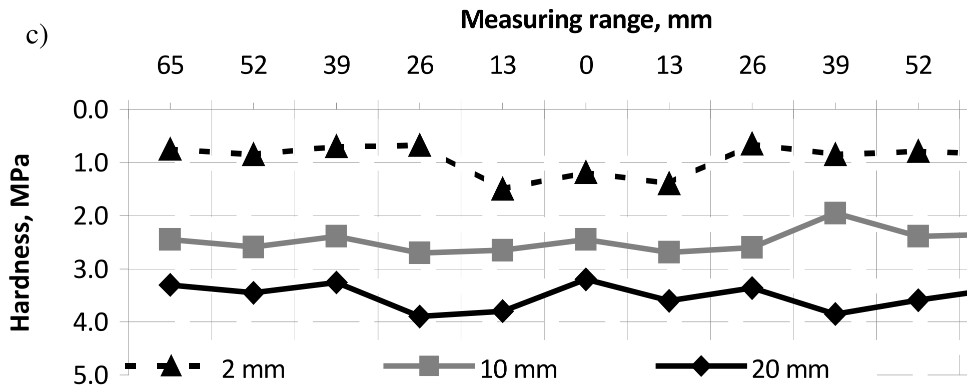
Option I. $LSD_{05} = 0.066$

b)



Option II. $LSD_{05} = 0.056$

c)



Option III. $LSD_{05} = 0.207$

Fig. 3. **Soil hardness dynamics in the seedbed area when the furrow is drawn with a combined coulter (shoe coulter + 2 disc coulters)**

In Option II (rolled twice), it was established in all the soil depths under research that the combined coulter compacted most of all the soil at the furrow walls (Fig. 3, b). This trend is especially obvious at the depth of 10 mm. The hardness of the soil at the furrow walls was by approximately

0.3 MPa greater than that at the furrow bottom and by 0.4 to 0.5 MPa greater than that at the topsoil near the furrow. The topsoil near the furrow was cracky.

The dynamics of the hardness of soil in the seedbed area is important in that respect that if the furrow bottom is compacted excessively, the contact of seeds with the soils may be affected and provision of seeds with nutrients may be deteriorated. Excessively loose topsoil at the seedbed bottom is not desired either because in this case a certain period of time is required for the soil to settle and to enable provision of seeds with nutrients available in the soil.

In Option III (rolled for six times), the hardness of the soil at the wall surface (2 mm) was by approximately 0.3-0.40 MPa greater than at the furrow bottom and by 0.59-0.84 MPa greater than at the topsoil near the furrow (Fig. 3, c). The topsoil near the furrow was not cracky, and the furrow walls were smooth.

By comparing the hardness of soil in different soil depths, the greatest impact of the combined coulter on the hardness of soil was found in the upper depth of 2 mm. In deeper-laying soil layers (10 mm and 20 mm), the impact of the coulter on the hardness of soil was remarkably lower because the hardness of soil in all the three seedbed areas was quite similar.

The studies showed that the furrow bottom is pressed by the shoe furrow and narrow pressure roller, while the furrow walls are pressed by the two disc furrows.

Soil moisture content in seedbeds. The impact of coulters of different designs on the moisture content of the soil in seedbed areas was studied. It was found that under the same soil and climatic conditions, after 24 hours the amount of moisture preserved in the adjacent area (10 mm) of furrows drawn with the combined furrow was 2.0 to 2.6 % greater compared to those in the case of the shoe coulter. At the depth of 20 mm, the difference in moisture content was approximately 1.7 %, and in deeper-laying soil layers (30-50 mm) it was approximately 0.9 % (Table 1). The difference in the moisture content of the soil could be attributed to the fact that the combined coulter causes more moderate agitation of the topsoil compared to the shoe coulter. Disc coulters precisely cut the topsoil and form a furrow.

Table 1

Dependency of the moisture content of seedbed soil from the coulter design

Depth, mm	Shoe coulter			Combined coulter		
	Soil moisture content, %					
	I	II	III	I	II	III
10	3.7	6.0	4.2	3.8	8.0	6.8
20	4.0	6.4	6.0	4.3	8.1	7.7
30	4.1	7.2	7.1	4.5	8.1	8.0
40	4.2	7.4	7.3	4.5	8.2	8.2
50	4.2	7.4	7.3	4.6	8.2	8.3

The obtained results of the studies show that when a combined coulter comprised of disc coulters and a shoe coulter is used in untilled soils, more moisture can be preserved in the soil. It is especially important in spring, when precipitation is often scarce, while sufficient moisture content of soil must be ensured for seed sprouting.

Conclusions

1. A combined sowing coulter made of two dissected blade disc coulters and a shoe coulter, in soils rolled twice and 6 times, most of all compacts the walls of the seedbed. In soil loosened with a vertical rotary cultivator, the furrow bottom is compacted most of all.
2. The furrow bottom is compacted with a shoe coulter and narrow pressure roller, and the walls are compacted with disc coulters set at an angle of 15º.
3. When forming the seedbed with a combined coulter, 0.9 to 2.6 % more of moisture can be preserved in all depths ranging from 10 to 50 mm compared to the case of forming the seedbed with a shoe coulter.

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