Soil Stratification for Weed Control

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Abstract. The qualitative indicators of a tillage machine for optimizing a ploughed soil layer, modifying the structure and density of a cultivated soil layer in accordance with agronomic requirements, as well as an effective organic weed-control method have been studied. Physical and mechanical properties of the soil have been studied after spring cultivation in the conditions of bare (black) fallow. Soil structure and aggregate composition depending on the type of cultivation, the density of soil layers at different times, and the dynamics of soil moisture changes in the layers for two months after spring cultivation have been analyzed as well. The performance of a soil tillage loosening-separating machine has been studied on a soil layer which was separated after processing into four sublayers: over-seed, seed, under-seed, and subsurface ones. Soil fragments (lumps) of a size larger than 20 mm were completely removed from the over-seed sublayer. The most valuable soil structure in agronomic terms was formed in the seed sublayer where the size of individual components did not exceed three times the size of seeds. The experimental machine for optimizing the agrophysical properties of the ploughed soil layer allowed increasing the structural coefficient about 2.5 times as compared with traditional cultivators. It was found that soil cultivation with a loosening-separating tillage machine allows improving the methods of pre-sowing cultivation to improve its agrotechnical characteristics, skip pre-sowing harrowing and cultivation, prepare the soil for sowing in one run, and control weeds without chemicals.
Key words: structural coefficient, loosening-separating machine, tillage quality, organic weed control, soil.

Introduction

Technological operations of soil cultivation by mechanical action are aimed at making favorable conditions for the accumulation and preservation of moisture, seeding, the growth and development of plants, and weed control (Mechergui et al., 2021; Pavlović et al., 2022). An experimental machine for optimizing the agrophysical properties of a ploughed soil layer is available (Syromyatnikov et al., 2022a). The machine works as follows: when moving along the field, the shares cut the soil layer, and when the cut layer moves along the share surfaces and the rods of the separating grating, it crumbles. Then, the fine crumbled fraction, which size does not exceed three times the size of sown seeds, is split through the grating, thus forming a seed sublayer. Further formation of the seed sublayer occurs when the rotor ripper acts on the layer by crumbling and ripping it, thus moving it along the separating grating. The coarsegrained fraction with fragments of no more than 20 mm goes off the grating, forming an over-seed sublayer with parameters corresponding to the optimum water-air mode. In addition, rotary rippers, in the process of interacting with the soil formation, comb out weeds with roots from it, and transport them to the surface of the above-seed sublayer (Syromyatnikov et al., 2022b). Basing on the germination and development conditions of plants, the structure of the optimally cultivated layer before sowing should meet the following requirements (Fig.): in the seed sublayer, the most agrotechnically valuable structure should be concentrated with the size of individual fragments not exceeding three times the size of seeds (Håkansson et al., 2002). The fulfillment of these requirements will ensure a good contact of seeds with soil, their rapid swelling, germination and unhindered penetration of the roots deep into the soil, the economic consumption of moisture accumulated during the autumn-winter period (due to the layered structure), and effective assimilation of nutrient elements from fertilizers by plants (Osman, 2018). It is known that the content of at least 40–45% of waterproof elements with a size of more than 0.25 mm in the plow layer ensures that the density, hardness, total porosity, and aeration porosity are within optimal limits. The ploughed layer of chernozems contains 55–60% of such elements. Basing on the results of the conducted studies, it can be concluded that the most favorable conditions for plants are made by differentiating the cultivated soil layer according to its structural composition. In that case, the aggregates of 5 to 20 mm in size should prevail in the surface layer of soil, and those from 0.25 to 10 mm should prevail in the seeding zone.

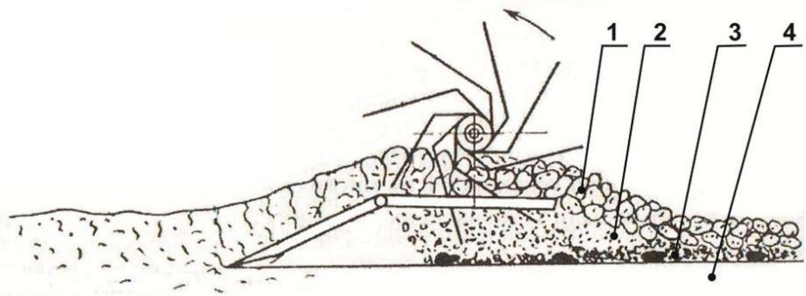

Figure. Structure of the processing layer: 1 – over-seed layer; 2 – seed layer; 3 – under-seed layer; 4 – subsurface layer.

The modern means of mechanization for soil tillage in mouldboard, non-mouldboard (subsurface) and minimum (reduced) tillage systems provide the necessary conditions for crop cultivation. However, to bring physical-and-mechanical properties of soil closer to optimal, and also to control weeds, it is necessary to carry out a relatively large number of mechanical operations, often using herbicides. The research goal was to do tests of the experimental tillage machine for soil stratification, and to study the performance quality indicators.

Materials and Methods

The desired structure can be obtained by combining the operation of crumbling soil and its fractional distribution along the depth of cultivation. In the field, the qualitative indices of the machine performance for optimizing the ploughed layer of soil were assessed by the soil structure, density, and moisture. An experimental plot of 1 ha was ploughed in autumn at a depth of 25–27 cm and divided into two parts. According to the agro-soil zoning of Ukraine, the research site is part of the territory of the agro-soil province – the Left-Bank High Forest-Steppe. The soil on the experimental field is represented by typical slightly eroded, low-humus, difficult loamy chernozem on carbonate loess. In the spring, one part of the plot (control) was tilled applying intensive technology at a depth of 10 cm; the second part was tilled with an experimental machine at the same depth. The physical and mechanical properties of the soil during the experiments were determined in accordance with OST 70.2.15-73. Soil absolute moisture was determined. Soil penetration resistance was used as a measuring indicator of soil compaction. Hand-held conical GPS penetrometer "DATAFIELD" designed to measure various indicators of soil density, was used in the studies on soil treatment. To determine the structural-aggregate composition of soil, a sieve method was used. When taking into account the weed contamination of crops, a quantitative-weight method was used. The weeds were counted, and their dry weight was determined in 1 m^2 plots in four repetitions.

Fisher's test was used to determine the significance of a factors' effect, and Student's t-test was used to determine the significance of coefficients in a regression equation.

Results and Discussion

After cultivating the soil with the experimental machine, the amount of soil aggregates larger than 10 mm was four times lower in the 0–5 cm soil layer and almost two times lower in the 5–10 cm soil layer as compared with the control. The number of agrotechnically valuable soil aggregates (10.00–0.25 mm) in the experimental variant was approximately 30% greater if compared with the control treatment. The structural coefficient of the soil layer (0–10 cm) cultivated with the experimental machine was approximately 2.5 times higher compared with the control. Wet sifting of the soil demonstrated that there was practically no difference in the coefficients of water resistance of soil clumps in both variants. The differences between experimental and control plots were smoothed out in the structural-aggregate composition of soil in two months after soil cultivation. The differences in soil densities over the layers at different times did not exceed 3–4%. Compared with the control variant, the moisture content of soil during two months after spring cultivation was 1–2% higher almost in all soil layers at the depth employing the experimental machine.

The most common weeds were *Elytrigia repens*, *Atriplex cana*, *Sinapis arvensis*, *Ambrosia artemisiifolia*, *Setaria pumila*, and *Echinochloa crus-galli*. The total infestation ranged from 55 to 118 specimens m^{-2}. The analysis of obtained data showed that the use of a tillage machine made it possible to reduce the infestation with dicotyledonous and cereal weeds by an average of 63.28% compared to the control, the mass of weeds by an average of 83.9%, and the use of herbicide by 94.7%. Applying a double treatment with a repetition after 35 days (against dicotyledonous weeds), the reduction in the total infestation of crops reached 66.6%, and the death rate of dicotyledonous weeds was 85.5%.

Conclusions

Field studies have shown that the loosening-separating machine provides a 2.5-fold increase in the soil structure coefficient, including a better and 1–2% higher accumulation and preservation of moisture as compared to the control variant. Pre-sowing tillage with the use of the machine allows skipping the pre-sowing harrowing and cultivation, preparing the soil for sowing in one run, and controlling effectively the growth of weeds without the use of herbicides.

Literature

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