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RESEARCH OF INNOVATIVE RESOURCE-SAVING TECHNOLOGIES FOR SOIL TILLAGE IN CROP PRODUCTION

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At the core of addressing the efficient use of the technical potential of agricultural producers lies the rational design and planning of production processes, as well as the implementation of innovative resource-saving technologies in crop production [1].

The need to improve mechanized technological processes in crop production is driven not only by economic reasons—such as increasing the productivity of machine units and reducing their operating costs per work unit—but also by environmental and ecological considerations. These include improving soil properties, enhancing fertility, protecting soil from water and wind erosion, and establishing rational fertilizer application norms and plant protection systems, including pesticides and herbicides [2]. Research indicates that a significant portion of agricultural enterprises in Ukraine still rely on traditional, resource-intensive production technologies. Given the rapid increase in energy costs, there is a demand for energy-efficient production technologies in agriculture, which can prevent the adverse effects of intense global market competition for agricultural products. Therefore, it is essential to adopt global experience in resource-saving technologies based on new technological, techno-economic, and environmental approaches [3].

In agro-technical practice, various tillage technologies in crop production exist, each optimally suited to certain production conditions, depending on specific soil-climatic and production factors. These technologies include:

1. Classical conventional tillage – plowing with moldboard plows to a depth of 20–50 cm.
2. Mini-Till – shallow tillage to a depth of 10–18 cm.
3. No-Till – zero tillage system with direct seeding through stubble at the seeding depth.

4. Strip-Till – row-based tillage for row crops to a depth of 5–25 cm.
5. Verti-Till – vertical tillage to loosen compacted soil layers at varying depths.

Classical conventional tillage, i.e., plowing, is the most energy-intensive technological operation. Plowing consumes large volumes of diesel fuel and emits significant amounts of carbon oxides into the atmosphere. Moreover, deep tilling introduces air oxygen into the soil's loose fertile layer, leading to the oxidation of organic elements and the release of substantial amounts of carbon dioxide into the atmosphere. Thus, the use of traditional plowing with soil inversion and deep loosening has shown adverse impacts on soil structure, composition, and ecology [3].

Innovative resource-saving soil tillage technologies include minimum tillage (Mini-Till) and zero tillage (No-Till).

Mini-Till refers to a tillage system without plowing for up to three years, focusing only on shallow soil cultivation and mixing. This system involves specific mechanized operations: immediately after harvesting, crop residues are shredded; post-harvest, stubble is tilled to a depth of 6–8 cm; in autumn, disc harrows till the soil to a depth of 15–18 cm, and deep loosening to 35–40 cm is performed once every three years [4].

Shallow mixing tillage minimally reduces soil moisture loss. Plant residues remaining on the field's surface (about 30%) promote microbial activity in the upper soil layers, decreasing soil crust formation from rainfall and reducing wind erosion effects.

In minimum tillage, specialized machinery complexes are used, including high-power tractors, wide cultivators for full-field tillage, and wide stubble seeders. Cultivators feature elevated frames to avoid clogging with crop residues. It is found that the wider the machine's working width, the lower the operating costs per hectare. For example, a machine complex with an 18-meter working width can handle around 10,000 hectares of crops in a season.

Using this technology enhances the economic efficiency of crop cultivation and harvesting by minimizing the technical and technological impact on soil, reducing combined fuel, fertilizer, and plant protection costs, and decreasing machine-tractor complex usage. It also optimizes crop rotations and increases yields. Moreover, it improves the ecological effectiveness of crop production by enhancing soil conditions, maintaining environmental balance, and reducing climate variability impact.

No-Till is a soil tillage system that eliminates conventional plowing with soil inversion. In this system, the soil surface is left undisturbed post-harvest, covered with shredded crop residues. The upper humus layers mineralize naturally under physical, biological, and environmental factors, increasing organic matter. This improves soil structure and fertility. Additionally, soil covered with crop mulch prevents wind and water erosion and preserves moisture.

In the No-Till system, soil is not subjected to traditional methods like cultivation, disking, or harrowing. Instead, only direct seeding is performed using wide stubble seeders, followed by harvesting. Transitioning to this technology is gradual, requiring up to three years of minimum tillage first. For example, continuous cultivation is done in autumn to a depth of 5–7 cm, followed by full-field herbicide application, and another full-field cultivation after two to three weeks. This system evens out field surfaces within two to three years and establishes comprehensive weed and pest control [4].

For No-Till, specific practices include ceasing plowing and burning crop residues, prohibiting organic fertilizer use, direct seeding with simultaneous mineral fertilizer application, and using seeding complexes equipped for direct seeding.

Strip-Till is a strip tillage system that involves minimal soil tillage. This technology combines conventional tillage benefits, like soil warming and drying, with moisture retention by only tilling narrow strips (15–25 cm) for seeding, leaving two-thirds of the field undisturbed, covered with plant residues. Fertilizers are applied under the seed in narrow bands. This approach reduces fuel consumption by approximately 80% and preserves soil moisture.

Strip-Till addresses soil and climatic conditions by extending crop growth periods, increasing soil fertility through gradual organic matter accumulation, reducing weed growth, and decreasing soil erosion. It is recommended for row crops such as beets, sunflowers, corn, and rapeseed, as well as soybeans, and is suitable for regions with adequate rainfall. Verti-Till is a vertical tillage technology used to loosen compacted soils at various depths. Compacted soils hinder capillarity and water penetration, which impedes crop root development. In Verti-Till, crop residues are shredded and accumulated on the soil surface to reduce moisture evaporation and increase organic matter accumulation [5].

This technology employs machinery with wave discs set at slight angles and multiple shanks to loosen various compacted soil layers. A key feature of vertical tillage is avoiding horizontal soil displacement, preventing soil clumping, and avoiding compaction at different depths.

Research into innovative tillage technologies shows that each method has advantages and disadvantages, with their effectiveness influenced by natural-climatic and soil characteristics, production conditions, tractor and machinery availability, crop rotation systems, and crop cultivation technologies.

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EVALUATION OF THE PRODUCTIVITY OF THE MACHINE FOR THE SURFACE TREATMENT OF CEREALS

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In addition to humidity and temperature, the elastic-kinetic properties of grain are significantly influenced by the rate of deformation. During grinding of grain in rolling machines, due to the high relative speeds of the working elements, the time of destruction is very short, and intermolecular bonds in the grain do not have time to break, elastic stress does not relax, and plastic deformation