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Field Performance Evaluation of a Soil-Leveling Disc Plough

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Field Performance Evaluation of a Soil-Leveling Disc Plough

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Abstract. This study presents the development and performance evaluation of a disc rotary plough designed to achieve uniform field tillage without creating furrows or ridges. The plough features a rotatable diagonal frame activated by a hydraulic cylinder, allowing the working discs to flip alternately to the right and left during operation. Such a mechanism ensures continuous shuttle-type movement and prevents the formation of uneven soil surfaces. The experimental tests were conducted using an MTZ-82 tractor on post-harvest wheat fields in accordance with UzDSt 3355:2018 standards. Key indicators—including travel speed, working width, tillage depth, soil pulverization quality, burial efficiency of plant residues, and surface irregularity parameters—were measured for both right-side and left-side flipping modes. The results demonstrated that the plough maintained stable performance under both operating conditions, achieving a working depth of 25–27 cm, uniform soil pulverization, and high residue burial completeness (over 92%). The support disc installed at the rear ensured consistent depth control and smooth movement. Overall, the developed disc rotary plough reliably fulfilled the required technological process and can contribute to improved field leveling, reduced fuel consumption, and enhanced agronomic efficiency.

INTRODUCTION

Primary soil tillage remains a critical operation in global agriculture, influencing nearly 40–60% of total crop productivity depending on soil type and climatic conditions. In many developing agricultural regions, inefficient tillage practices account for up to 25–30% additional fuel consumption and cause significant field unevenness, which negatively affects seedbed preparation, irrigation efficiency, and crop establishment [1].

Traditional mouldboard ploughs, despite their long-term use, often generate deep furrows and ridges, with surface irregularities reaching 8–12 cm, requiring additional leveling operations. Moreover, their draft resistance is typically 15–20% higher than that of disc-based implements, leading to increased tractor load and fuel usage.

In contrast, disc ploughs equipped with spherical rotating discs have demonstrated greater adaptability to fields containing more than 30–40% plant residues, reducing blockage and improving operational stability. However, most conventional disc ploughs invert soil only in one direction, resulting in alternating ridges and depressions. This reduces field leveling quality and may cause up to 10–15% yield reduction in precision-dependent crops due to uneven moisture distribution.

In Uzbekistan, where more than 1.4 million hectares of land are annually ploughed for cereals, cotton, and repeated crops, the demand for energy-efficient and leveling-capable tillage implements is steadily increasing. According to national agricultural reports, uneven soil surfaces after primary tillage require an additional 1.2–1.5 tractor-hours per hectare for leveling, significantly increasing production costs.

To address these limitations, this study investigates a newly developed disc rotary plough featuring a hydraulically adjustable diagonal frame that allows alternating right- and left-side soil inversion. This design eliminates the formation of furrows and ridges and enables smooth shuttle-type movement across the field. The aim of the research is to evaluate the structural performance, tillage depth accuracy, soil pulverization quality, residue burial efficiency, and field surface leveling achieved by the proposed plough under real operating conditions.

MATERIALS AND METHODS

Disc ploughs equipped with spherical working surfaces have been increasingly utilized in agricultural production due to their ability to operate without clogging in fields containing large amounts of plant residues, their relatively low draft resistance, and the self-sharpening effect of rotating disc edges [2; 3; 4; 5]. Recent research by W.R. Gill, R.J. Godwin, H. Harrison, and Monjurul has focused on determining the forces acting on disc working bodies, their directions, and their magnitudes through analytical and experimental methods. Gill reported that for discs with a diameter of 610 mm, the minimum draft force is achieved at an installation angle of 11–17° relative to the direction of travel. Godwin demonstrated that discs with curvature radii between 700 and 1400 mm perform optimally at working angles of around 20–22°. Harrison's findings further indicated that increasing the tilt angle intensifies lateral soil reaction forces, especially at higher travel speeds [6; 7; 8; 9].

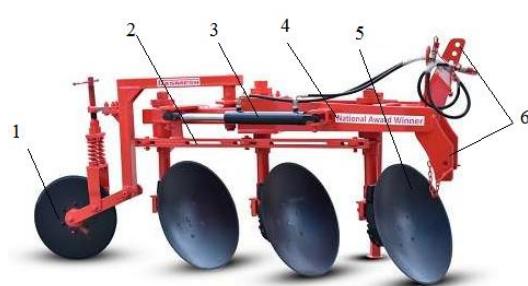
Theoretical investigations into disc parameter optimization have been presented by P.S. Nartov, G.N. Sineokov, S.P. Avakyan, A.Sh. Grigoryan, and F.M. Kanarev. Nartov developed relationships linking disc diameter and inter-disc spacing to the allowable irregularities at the furrow bottom (expression 1.5), while Kanarev proposed determining the disc curvature radius based on working width and permissible unevenness (expression 1.10) [9; 10; 11; 12; 13]. Avakyan and Grigoryan formulated methods for calculating disc curvature radius that incorporate internal and external soil friction coefficients, offering more precise models for soil–disc interaction.

In addition to these developments, several manufacturers have introduced reversible disc ploughs specifically designed to eliminate the formation of ridges, furrows, and surface unevenness during primary tillage(<https://www.landforce.in/lf-disc-plough-4-disc>). The “John Deere” company in the United States has produced a distinctive disc plough equipped with working bodies capable of rotating 180° around their own axes (Fig. 1), allowing the implement to operate across the field without dividing it into planks and preventing the accumulation of irregularities during soil inversion. Similarly, the “Dasmesh-351” series ploughs are characterized by relatively low draft resistance and a hinged connection between the disc posts and the main frame (Fig. 2). This design enables each disc unit to rotate 180° when the travel direction changes, ensuring consistent disc angles during operation and achieving two-directional soil inversion without generating ridges or depressions. Such reversible disc ploughs therefore provide smooth, continuous shuttle-type ploughing and contribute to improved field leveling quality compared to conventional disc ploughs, which typically invert soil in only one direction and create alternating ridges and furrows (<https://kopterinfo.ru/kakoy-vybrat-i-kak-eksploatirovat-plug>).



1 – support disc; 2 – drawbars; 3 – frame;
4 – hitch mechanism; 5 – disc working body;
6 – scraper.

FIGURE 1. Disc reversible plough produced by “John Deere”.



1 – support disc; 2 – drawbars; 3 – hydraulic cylinder;
4 – frame; 5 – disc working body;
6 – hitch mechanism.

FIGURE 2. “Dasmesh 351” four-body disc reversible plough.

Despite notable advancements, studies addressing reversible disc implements suitable for Uzbekistan's agro-climatic conditions remain limited. There is a lack of research considering disc curvature radius, vertical inclination angle, disc spacing, and allowable bottom irregularity in an integrated manner. Thus, the development of an energy-efficient reversible disc plough tailored to local soil conditions and capable of performing stable soil inversion and residue burial forms the scientific basis of this study.

The performance of the newly designed reversible disc rotary plough was evaluated through field experiments carried out at the experimental farm of the Research Institute of Mechanisation and Electrification of Agriculture using an MTZ-82 tractor on post-harvest winter-wheat fields. The plough features a suspended frame equipped with

spherical disc working bodies, a diagonal rotary frame, a hydraulic cylinder, disc posts with self-alignment capability, a rear-mounted support disc, and a central hinge that allows the implement to execute shuttle-type ploughing. During field operation, the tractor moves along alternating forward and return passes; upon reaching the field boundary, the hydraulic cylinder rotates the diagonal frame around the central hinge, repositioning the discs either to the right or to the left. Simultaneously, the disc posts rotate about their own axes, ensuring that the discs retain their original installation and tilt angles relative to the travel direction. The support disc rotates by 180° and stabilizes the ploughing depth during each turning cycle, thereby enabling uniform soil inversion and eliminating the formation of ridges and furrows.

The implement works with tractors of 1.4–2.0 traction class, has a working width of 1.2 m with four disc bodies providing a strip width of 0.30 m each, and operates at a depth of 25–27 cm. The spherical discs have a 650 mm diameter and a 700 mm curvature radius, with installation angles adjustable between 35° and 45°, vertical tilt angles adjustable between 15° and 25°, a longitudinal spacing of 70 cm, a transverse spacing of 30 cm, and a support disc capable of regulating working depth between 20 and 30 cm.

Field tests were conducted on irrigated meadow–alluvial soils characterized by 7.3–14.2% moisture and 2.03–3.27 MPa hardness within the 0–30 cm layer, with the surface covered by an average of 0.670 kg/m² of plant residues and stubble height averaging 21.2 cm. The evaluation procedure followed the requirements of O'zDSt 3355:2018, where travelling speed, working width and depth, soil pulverization, completeness and depth of residue burial, surface irregularity height, and furrow-bottom unevenness were measured using standard methodologies. Speed was determined by timing marked distances, while soil depth and residue incorporation were measured across three transverse profiles per pass. Soil pulverization was assessed by sieving into fractions larger than 100 mm, between 100–50 mm, and smaller than 50 mm. Surface irregularities were recorded using a three-point profilometer in accordance with national standards. The plough was tested in two operating modes—right-side inversion and left-side inversion—and for each mode, three repetitions of 100-meter ploughing were performed. After each turn at the field edge, the plough frame was hydraulically rotated, the support disc was repositioned, and performance indicators were recorded to assess symmetry, operational stability, and the overall effectiveness of the reversible disc mechanism.

RESULTS AND DISCUSSION

Field experiments showed that the reversible disc rotary plough ensured stable operation and uniform soil inversion under the given agro-technical conditions. The soil moisture ranged from 7.3% to 14.2% within the 0–30 cm layer, while soil hardness varied from 2.03 MPa in the upper layers to 3.27 MPa at deeper horizons, indicating moderately compact post-harvest meadow–alluvial soils. Under these conditions, the plough maintained a working depth of 25–27 cm across all passes, confirming the effectiveness of the rear support disc in stabilizing immersion depth during right- and left-side tipping. The surface residue load of 0.670 kg/m² with an average stubble height of 21.2 cm did not cause clogging of the working bodies, demonstrating the suitability of spherical discs for residue-rich fields. The implement operated at a forward speed of 6–9 km/h, and throughout the shuttle-type movement, no formation of ridges or depressions was observed, confirming that the 180° rotation of both the diagonal frame and support disc effectively prevented accumulation of soil at turning points.

TABLE 1. Field performance indicators of the reversible disc rotary plough

Indicator	Unit	Left-side inversion	Right-side inversion
Working depth (Mean ± SD)	cm	27.4 ± 2.04	26.7 ± 1.87
Forward speed	km/h	7.8	7.3
Soil fractions <50 mm	%	84.7	82.3
Plant residue burial depth	cm	12.8	13.7
Soil fractions 100–50 mm	%	11.5	10.7
Soil fractions >100 mm	%	3.8	7.0
Working width (Mean ± SD)	cm	119.4 ± 2.36	121.2 ± 2.74
Surface irregularity	cm	4.7	5.6
Furrow-bottom unevenness	cm	4.2	3.8
Residue burial completeness	%	92.8	93.6

Visual inspection and field measurements indicated that the soil surface remained level across the working width, and the furrow-bottom plane met the agro-technical requirements for post-harvest ploughing. The symmetry of soil inversion between right and left tipping modes suggests that the disc-post self-alignment mechanism reliably maintained the disc setting and tilt angles. The overall results indicate that the reversible disc rotary plough performs

stable, uniform, and ridge-free tillage in soils with moderate hardness and medium residue loads, confirming its suitability for field conditions typical of irrigated farming systems.

CONCLUSIONS

The field experiments demonstrated that the newly developed reversible disc rotary plough provides stable and ridge-free tillage under post-harvest irrigated-field conditions. The implement consistently maintained a working depth of 25–27 cm in both right- and left-side inversion modes, confirming the effectiveness of the rear support disc and the self-aligning disc-post mechanism. Despite the presence of 0.670 kg/m² surface residues and 21.2 cm stubble height, the plough operated at 6–9 km/h without clogging. Soil pulverization remained within acceptable agro-technical limits, with more than 80% of aggregates smaller than 50 mm, and surface irregularity did not exceed 5.6 cm. These results indicate that the plough ensures uniform soil inversion and produces a smooth tilled surface suitable for subsequent operations.

Overall, the reversible disc rotary plough showed reliable two-directional soil inversion, enabling shuttle-type operation without ridge formation and reducing the need for additional leveling. Its stable performance in moderately compact soils with medium residue load suggests suitability for tractors of 1.4–2.0 traction class in irrigated agriculture. The findings also indicate that further refinement of disc geometry and support mechanisms may enhance residue burial, soil pulverization, and depth stability under varying soil conditions.

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