Comparative assessment of the tillage quality of commercial and combined plow bottoms

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Abstract. The paper presents the results of comparative field studies of the tillage quality of commercial and combined (for the primary layer-by-layer tillage) plow bottoms in terms of plowing quality parameters, in particular, in terms of the completeness of crop residue incorporation and the density of tilled soil layers. The results of the study are directed to a wider introduction of technical means intoproduction that provide conditions for resource saving when performing the primary tillage with the use of mouldboard technology.

1 Introduction

In plant growing technology, tillage occupies a special place; not only the yielding capacity of agricultural crops, but also soil fertility and the ecology of production in general depend on the results of its implementation.

It should also be noted its significant impact on the economic efficiency of crop production, in particular, tillage accounts for up to 40 % of the total energy costs in the technology of cultivating agricultural crops. At present, vast experience has been gained in the use of various tillage systems, without the use of moldboard plowing, in particular, rotary tillage, minimum tillage, no-till, etc. However, practice shows that moldboard plowing has indisputable advantages, and this tillage practice will remain the major one at present and in the foreseeable future. A significant drawback of moldboard plowing is the use of a large number of commercially plows, the working bodies (bottoms) of which have a large traction resistance [1]. In this regard, studies aimed at reducing the traction resistance of plow bottoms turn to be topical, while it is an important condition for them to be suitable for regulated requirements of loosening the soil and incorporating crop residues.

2 Materials and methods

One of the promising areas in solving the problem in terms of the condition of resource saving of plowing is the use of the primary layer-by-layer tillage [2-3]. The peculiarity of this tillage practice lies in the fact that when loosening soil to the entire depth of tillage (α), the top arable layer with crop residues (a1 = 0.10 ...0.16 m)is turned over for the purpose of their incorporation and the lower layer (0.14 ... 0.25 m) is loosened without overturning

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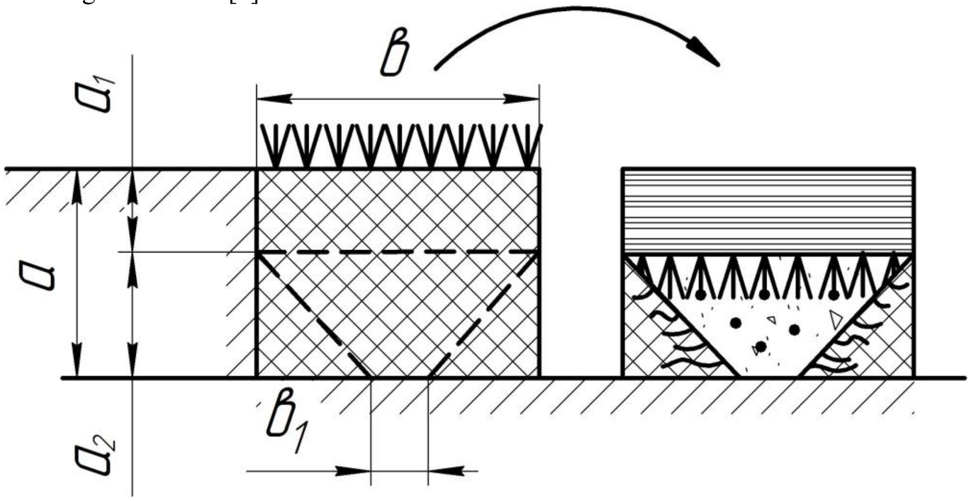
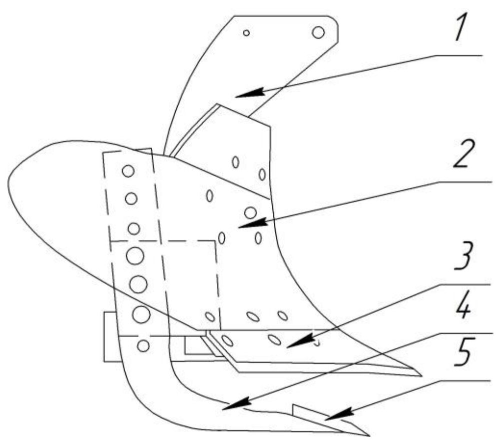
(Figure 1). In the case under consideration, the traction resistance of the plow bottom is reduced in comparison with the commercial one, due to a decrease in the cross-sectional area of the loosened layer and the weight of the soil layer being turned over per linear meter of tillage. To implement this practice, various technical solutions have been proposed [4-6].The commercial bottom "RANCHO" of a chisel plow of the OCHO family manufactured by LLC AgroPromtechmash (Volzhsky, Volgograd region) operates according to a similar technological scheme.[7].



α – tillage depth; α_1 - depth of the top root-inhabited soil layer; α_2 - depth of the lower tilled soil layer, *в*- width of the plow bottom; $в_1$ - width of the mouldboardless ripper

Fig. 1. Scheme of the primary layer-by-layer tillage.

If there are design features, these combined working bodies of the plow are made according to the general technological scheme and include a mouldboard 2 (Figure 2) with a share 3 and a chisel point 5.



1 – standard of bottom;
2 – mouldboard;
3 – share;
4 – shank;
5 –chisel point

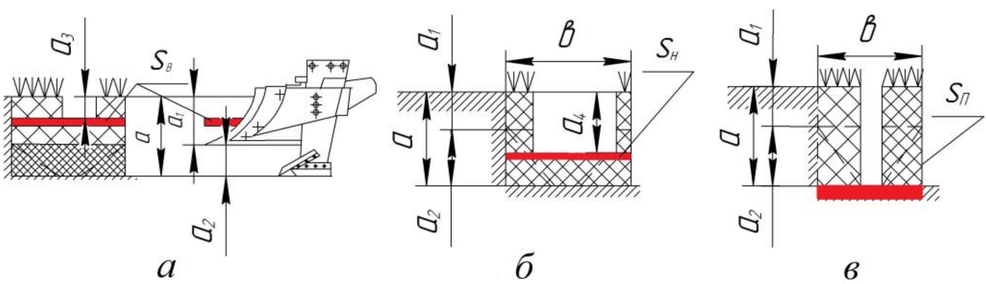
Fig. 2. Scheme of the combined plow bottom for the primary layer-by-layer tillage.

In this option, the plow bottom provides loosening of the soil to the entire tillage depth, while the share and mouldboard surface provides the overturning of the top arable layer, and the underlying layer is loosened without overturning. The conducted field studies show that for various conditions, the use of a combined plow bottom for the primary layer-by-layer tillage, compared to a commercial one, provides a decrease in traction resistance from

15 to 27% [2-3]. In this case, the question of the tillage quality of a combined plow bottom remains open, in particular, in terms of such parameters as the completeness of incorporating crop residues and the degree of loosening various soil layers of the tilled arable horizon. For this purpose, using general and individual methods, comparative studies were carried out in the field to assess the tillage quality of combined and commercial plow bottoms [8-16].

Comparative field studies were carried out in the Staromainsky district of the Ulyanovsk region, at LLC Agrofirma "Privolzhye". The land use conditions of this enterprise are typical for most farms of the Ulyanovsk region. Comparative studies were carried out in the field, the main type of soil of which is grey soil; in terms of mechanical composition, it belongs to light loamy soils.

Based on an individual technique, samples for assessing soil moisture and density before and after tillage with commercial and combined bottoms were taken from three levels - in the middle of the top layer tilled with soil overturning (Figure 3.a), in the middle of the lower layer tilled with a combined bottom without overturning the soil layer (Figure 3.b) and at the level of the subsurface horizon (Figure 3, c).



S_B, S_H,$S_П$ - sampling levels, respectively, the top, lower tilled and subsurface layer

Fig. 3. Sampling levels for assessing soil parameters before and after tillage with commercial and combined plow bottoms: a) sampling level for the analysis of the toptilledlayer; b) sampling level of the lower tilled layer; c) the level of sampling for the analysis of the state of the subsurface layer.

3 Results

The study aimed to assess the tillage quality of plow units together with tractors "BELARUS 82.1"and plows PLN-3-35 with bottoms of the standard option (Figure 4, a) and PLN-3-35 equipped with combined bottoms (Figure 4, b).

a b

1 – share and mouldboard surface, 2–ripper

Fig. 4. Option of plow units while conducting field studies: a –commercially produced plow unit; b – unit with a plow equipped with combined bottoms.

The results of field studies to assess the quality of crop residue incorporation are presented in Figure 5.

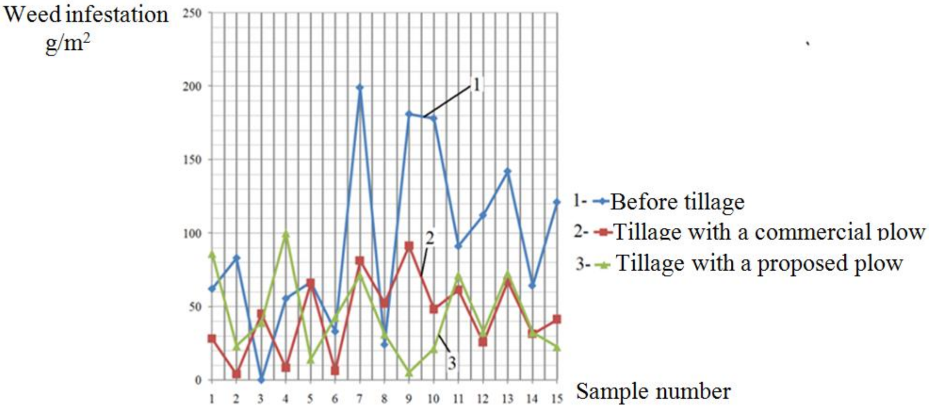


Fig. 5. The presence of crop residues before and after tillage with plow units of various options.

When assessing the quality of crop residue incorporation, it was found that the average weight of unincorporated residues after a pass with commercial bottoms is 43.7 g/m^2. This indicator after a pass of a plow with combined bottoms is 44.28 g/m^3. The diagram of the ranked experimental weight values of unincorporated crop residues left behind the bottoms in the mass-produced and proposed options is shown in Figure 6.

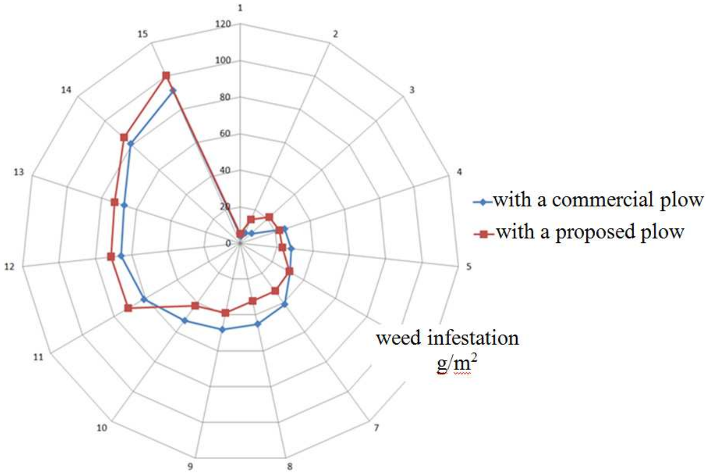


Fig. 6. Diagram of ranked experimental data of the weight of unincorporated crop residues.

It should be noted that the combined bottoms are slightly inferior in terms of the quality of incorporating crop residues compared to commercial ones. The difference in the average deviation of this parameter obtained during the operation of the plow unit in various options was 0.6 g/m^2.

Taking account of the features of the primary layer-by-layer tillage and the operation of the combined plow bottom, the field experiment method provided for the collection of experimental soil samples from three tiers. As a result of field studies, it was found that the soil density of the top arable horizon (Figure 3, a) obtained after tillage with plows with commercial and combined bottoms corresponds to the optimal value for the cultivation of the main types of agricultural crops (Figure 7). In particular, the average value of the density of the top (turned over) arable layer of soil after tillage with commercial plows was 0.9 g/cm^3, with combined bottoms it was 1.1 g/cm^3. For this type of soil, the optimal density value for grain crops is 1.2 g/cm^3, for row crops is 1.1 g/cm^3 [17].

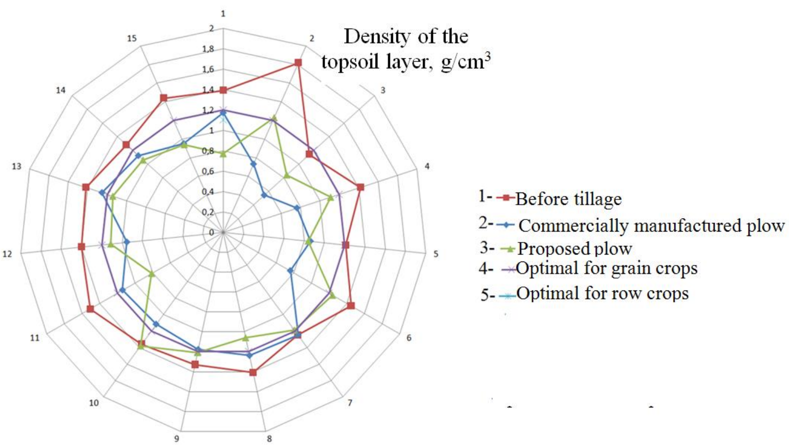


Fig. 7. Diagram of the density of the top (turned over)arable layer of soil before and after tillage.

The lower layer of soil tilled with combined bottoms, in contrast to commercial ones, is loosened without overturning. As a result of field studies, it was found that the average density of this layer after tillage with plows in the proposed option is 11.1 g/cm^3, after a pass with commercial bottoms, this parameter was 0.88 g/cm^3. It should be noted that before tillage, the average density of this arable layer is 1.62 g/cm^3, which significantly exceeds the optimal value for most crops and determines the need for loosening this arable layer in pre-sowing soil preparation. As a result of field studies, it was found that commercial bottoms provide more intensive loosening of this layer, compared to combined ones, but in both cases the resulting density corresponds to the optimal one for the cultivation of grain and row crops (Figure 8).

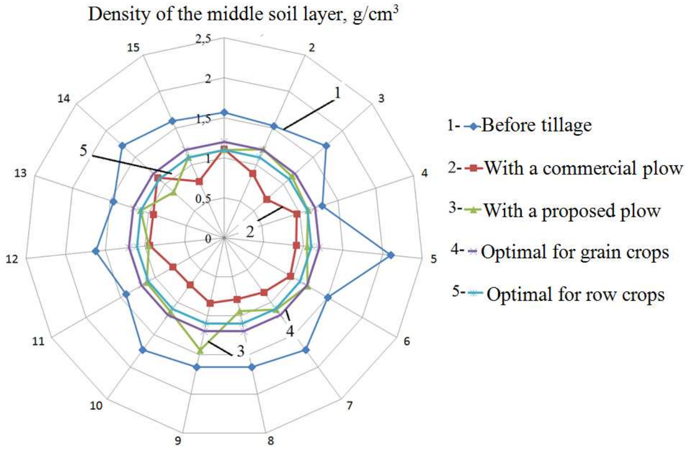


Fig. 8. Density of the lower cultivated arable soil layer before and after tillage.

The obtained results of assessing the compaction of the subsurface soil horizon with plow bottoms of various options did not establish significant differences. After tillage with the plow unit equipped with commercial bottoms, the average density of the subsurface layer was 1.39 g/cm^3, after a pass with combined bottoms - 1.38 g/cm^3 (Figure 9).

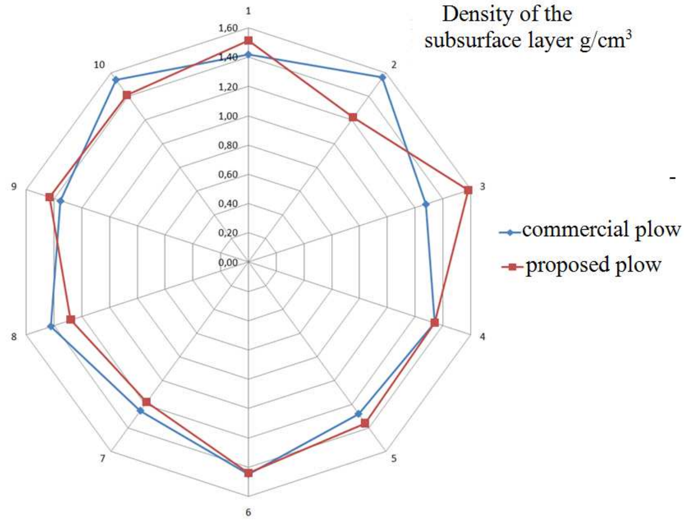


Fig. 9. Density of the subsurface horizon of the soil.

The ridgeness of plowing determined according to the generally accepted method, by the difference in the lengths of a straight line (one meter) and a line profiled along the plowing surface, was 11.7 cm after tillage with commercial bottoms, and 9 cm with combined bottoms. This parameter of ridgeness corresponds to the agrotechnical requirements for both types of options of the plow unit [17].

4 Discussion

The analysis of the results of comparative field studies indicates that the combined plow bottom for the primary layer-by-layer tillage provides regulated plowing parameters, in particular, for loosening the arable horizon, estimated by density, and the formed profile of the tilled surface (ridgedness). Taking account of the reduction in traction resistance compared to commercial bottoms, these combined plow bottoms are promising working bodies that provide resource-saving conditions with regulated quality parameters of plowing.

5 Conclusion

Upon the completion of the field studies at the enterprise of LLC Agrofirma "Privolzhye", it was found that the use of plow units consisting of tractors BELARUS 82.1 and plows PLN-3-35 equipped with combined bottoms for the primary layer-by-layer tillage, in comparison with plow units equipped with commercial bottoms, after tilling 210 hectares made it possible to obtain annual savings in the amount of 60.757,4 roubles due to a decrease in operating costs. In this regard, it is considered economically feasible to substitute traditional plowing with the primary layer-by-layer tillage using combined plow bottoms.

References

1. Tillage (energy-saving technologies and technical means): recommendations (Rosinformagrotekh, Moscow, 2004)
2. E.V. Boikova, Improving the energy-saving technological process of the main tillage and a general-purpose plow: dis. cand. those, Sciences, 165 (2010)
3. A.V. Pavlushin, S.V. Streltsov, V.P. Zaitsev, Primary tillage with plows equipped with experimental working bodies, *Agrarian science and education at the present stage of development: experience, problems and ways to solve them*, Materials of the VI International Scientific and Practical Conference, Ulyanovsk, 90-92 (2015)
4. A.V. Pavlushin, V.A. Bogatov, A.V. Fedotov, V.I. Kurdumov, Patent No. 2273119. RF. Combined soil-cultivating working body, Published. 04/10/2006; Bull. **10** (2006)
5. A.V. Pavlushin, V.A. Bogatov, V.I. Kurdyumov, Patent No. 229745. RF. Combined soil-cultivating working body, Published. 04/27/2007, Bull. 12 (2007)
6. I.T. Kovrov, I.V. Popov, A.A. Mitin, Patent No. 2131653. RF. Method of primary tillage and plow-ripper for its implementation, Published 05/20/1999 (1999)
7. I. B. Borisenko, Resource-saving "anti-zero" chisel body "RANCHO" - a universal assistant to farmers, New technologies of the agro-industrial complex, **11**, 15 (2009)
8. GOST 20915-2011, Testing of agricultural machinery, Methods for determining test conditions (Standartinform, Moscow, 2013)
9. GOST 33687 - 2015, Machines and tools for surface tillage, Test methods (Standartinform, Moscow, 2016)
10. GOST 33736-2016, Machines for deep tillage, Test methods (Standartinform, Moscow, 2020)
11. GOST 52778-2007, Testing of agricultural machinery, Methods of operational and technological assessment (Standartinform, Moscow, 2008)
12. GOST 54784-2011, Testing of agricultural machinery, Methods of evaluation of technical parameters (Standartinform, Moscow, 2012)

13. OST 10.4.1-2001, Testing of agricultural machinery, Cars and tools for deep tillage. Methods for assessing functional indicators (Ministry of Agriculture of Russia, Moscow, 2001)
14. V.I. Kurdyumov,, V.E. Proshkin,, E.S. Zykin,, E.N. Proshkin,, I.A. Sharonov, *Analysis of the structural composition of the soil during field studies of a soil-cultivating vibratory roller*: IOP Conference Series: Earth and Environmental-mental Science. II International scientific and practical conference "Ensuring sustainable development in the context of agriculture, green energy, ecology and earth science", 012106 (2022)
15. V.I. Kurdyumov,, V.E. Proshkin,, E.S. Zykin,, E.N. Proshkin,, V.V. Kurushin, *Studies of the vibratory roller from the standpoint of compliance with the agrotechnical requirements of soil density and structure*: IOP Conference Series: Earth and Environmental Science. II International scientific and practical conference "Ensuring sustainable development in the context of agriculture, green energy, ecology and earth science", 012030 (2022)
16. OST 10.2.2 - 2002, Testing of agricultural machinery, Methods of energy assessment, Ministry of Agriculture of Russia, Moscow (2002)
17. V.I. Aniskin, Initial requirements for basic machine technological operations in crop production, Ministry of Agriculture of the Russian Federation, Moscow (2005)