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CHISEL TILLAGE UNDER SPRING BARLEY IN THE FOREST-STEPPE

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The degradation of chernozems and increased soil erosion led to the search for more advanced methods of tillage, taking into account climatic conditions, the quantity and quality of crop residues, and the volume of fertilizer application. The aim of the study was to establish the effect of various methods of basic tillage in the presence of preceding plant's crop residues on the growth and development of spring barley plants. The experiment was carried out in the forest-steppe of Ukraine. During the experiment, the influence of various methods of basic tillage on the agrophysical properties of the soil, its water regime, and weed infestation of spring barley crops was studied. For comparison, the following types of basic tillage were used: dump to a depth of 20–22 cm, chisel tillage to a depth of 14–16 cm, and disc tillage to a depth of 10–12 cm. Dump and chisel processing were characterized by higher grain yield. Chisel tillage provided better moisture accumulation compared to reverse ploughing. In spring, at the time of sowing grain crops in the layer of 0–15 cm, the reserves of productive moisture during chiselling were 145 mm, and during mouldboard processing 122.6 mm. Thus, chisel tillage for spring barley creates the best conditions for moisture supply and guarantees a high level of grain yield and significant profitability of production.

Keywords: tillage; barley; weediness; mineral fertilizers; productivity; economic efficiency

The priorities for the development of agriculture in forest-steppe have changed significantly. The reasons for this were specified by Hanhur et al. (2022) and Romashchenko (2023) as following:

- rise in the price of material and energy resources;
- the placement of spring barley after an atypical preceding plant (sunflower);
- degradation of chernozems and increased soil erosion.

This led to the need to search for more advanced methods of tillage, taking into account soil and climatic conditions (Syromyatnikov et al., 2021; Svechnikov and Troyanovskaya, 2019; Nukeshev et al., 2021; Tarasenko et al., 2022), the quantity and quality of crop residues, the volume of fertilizer application, and the phytosanitary state of crops (Brankatschk and Finkbeiner, 2015; Poliovyy et al., 2021; Çerçioğlu et al., 2019). The efficiency of chisel tillage under spring barley depends on preceding plants characterized by different allelopathic lability (Mamatov et al., 2021; Romanyuk et al., 2023). The amount of residual moisture and nutrients in the soil depends on the right preceding plant (Piazza et al., 2020). The quantity and quality of post-harvest root residues of the preceding plant significantly affect the efficiency of growing spring barley (Acharya et al., 2019; Ergashev et al., 2020; Žák et al., 2012).

When growing spring barley after corn, the quality of chisel aggregates greatly deteriorates if there are more than 5 t·ha^{-1} of plant residues in the field. The specified depth of loosening the soil is not achieved with dehydration or excessive moisture of the arable layer and a blocky relief is formed (Syromyatnikov et al., 2023a; Tarasenko et al., 2023). Post-harvest sunflower residues, unlike corn stalks, are brittle. They are better crushed and wrapped in the soil (Sahoo et al., 2023). The incorporation of plant residues of corn with chisel is 20–25% worse than that of sunflower. Qualitatively mixed with the soil, sunflower residues quickly decompose and saturate the arable layer with macroelements at a lower ratio of carbon to nitrogen (Dong et al., 2022). The warming up of the surface layer of soil in spring after corn accelerates. This creates better conditions

for the vital activity of microbial populations and the release of immobilized nitrogen compounds into the soil solution (Horobets et al., 2021).

The aim of the study is to establish the influence of various methods of basic tillage and its fertilization in the presence of crop residues of the preceding plant on the agrophysical properties and water regime of the soil, weediness of crops, growth and development of plants, and the economic efficiency of growing spring barley in the conditions of the forest-steppe of Ukraine.

The novelty of the research lies in alternative ways of using various methods of basic tillage and its fertilization.

Material and methods

Experimental conditions

Experimental studies were carried out in 2017–2018 at the field training ground of Kharkiv National Agrarian University (Pashchenko et al., 2019; Syromyatnikov et al., 2022). The soil of the experimental plot was heavy loamy ordinary chernozem with the following content in the surface layer of 0–35 cm: 4.4% humus, 13.5% nitrate nitrogen, 146 mg·kg^{-1} mobile phosphorus compounds, and 116 mg·kg^{-1} mobile potassium compounds. Sowed spring barley of the third grade.

Processing technologies

The following crop rotation was used: bare fallow – winter wheat – sunflower – barley – corn. The experiment included three different backgrounds:

– crop residues without soil fertilizers;
– crop residues with mineral fertilizer $N_{30}P_{30}K_{30}$;
– crop residues with mineral fertilizer $N_{60}P_{30}K_{30}$.

Fertilizers were applied in spring for pre-sowing cultivation in a scattered way. Crops in the tillering phase were treated with the Tur 20 herbicide at a dosage of 0.8 l·ha^{-1} for the complete destruction of sunflower carrion.

Working tools used

Soil cultivation was carried out using the tillage units of the Iozovamachinery company. The main tillage for spring barley was carried out with the Imperial plough to a depth of 20–22 cm. It is an eight-furrow reversible semi-mounted plough with a working width of 2.64 m (Fig. 1a). Chisel tillage was carried out by the Gulden subsoiler to a depth of 14–16 cm. The Gulden subsoiler is designed for two-level tillage using no-mouldboard technology. It has two rows of racks. The first row provides soil cultivation. The second row is designed for mulching the top layer of soil (Fig. 1b). Disk processing was carried out using Ducatgold-6 heavy disc harrows to a depth of 10–12 cm (Syromyatnikov et al., 2023b). The working width of the Ducatgold-6 disc harrow is 6 m. The diameters of the discs are 724 mm (Fig. 1c).

Experimental technique

During the experiment, the study focused on the influence of different methods of primary tillage (mouldboard, chisel, and disc) on:

– reserves of productive moisture;
– weediness of crops;
– yield of spring barley.

Results and discussion

The agrophysical parameters of the soil were within the optimal limits for all the methods of cultivation. Density in the cultivated layer was 1.27–1.29 g·cm^{-3}, which is less than the limit value for spring barley (1.35 g·cm^{-3}). Soil hardness in the surface layer (0–30 cm) was 10.9 kg·cm^{-2} for mouldboard tillage, 12.9 kg·cm^{-2} for chisel tillage, and 15.1 kg·cm^{-2} for disc tillage, which is less than the limit value for spring barley (21 kg·cm^{-2}). With fine disc tillage, the differentiation of the arable layer was traced in terms of density (Syromyatnikov et al., 2021).

When determining the structural condition of the soil in spring, the greatest value in the surface layer of 0–30 cm is formed by small agronomic aggregates 10–0.25 mm in size. Their number in spring barley crops for all the methods of processing was 73.1–75.8%. The growth of the most valuable aggregates was recorded against the background of chisel and disc tillage (Syromyatnikov et al., 2023a). A similar result is observed by Kiryushin (2019).

In spring, at the time of sowing a grain crop in the layer of 0–150 cm, the reserves of productive moisture were 122.6 mm with mouldboard cultivation, 145 mm with fine tillage, and 136.5 mm with disc tillage. Soil moisture was measured using a SOIL MC-7828 electronic moisture meter with a 320 mm long probe. Its measurement range is 0–80% with an error of ±0.5% (Syromyatnikov et al., 2023a). At least 5 measurements were taken on each experimental field.

Chisel tillage was more favourable in terms of moisture accumulation compared to reverse ploughing. This phenomenon is explained by the presence of plant residues on the surface of the field and the wavy relief, which contributed to a significant accumulation of snow with a shortage of precipitation in December–February and the absence of snow cover during the years of research. The water regime changed depending on soil surface condition, growth rate, and the development of plants in various agro-backgrounds and hydrothermal conditions.



Fig. 1 The working tools used in the experimental studies: (a) Imperial plough; (b) Gulden subsoiler; (c) Ducatgold-6 disc harrows

During the vegetative mass formation, plants intensively used the water against the background of a shortage of precipitation. In the heading phase, soil moisture reserves decreased to 21.5–38.5 mm. For two years, the highest use of moisture (118–134.7 mm) was observed in chisel tillage. The lowest use of moisture (98–112.3 mm) was observed during disc tillage. The use of fertilizers contributed to an increase in the use of water reserves (Table 1).

The biometric indicators of spring barley plants in the tillering phase are highly dependent on the methods of basic processing and applied mineral fertilizers (Garmashov et al., 2019). Under mouldboard and chisel tillage, plant height was almost the same. The same result was found by Blednykh et al. (2017) and Hanhur et al. (2022). Plant height was 22.5 cm for the $N_{30}P_{30}K_{30}$ fertilizer and 35.5 cm for the $N_{60}P_{30}K_{30}$ fertilizer.

Plants under disc treatment were lower in height by 3.5–9.6 cm. The application of mineral fertilizers contributed to an increase in biometric indicators (the number of nodal roots and stems per plant) by 1.32 times, which subsequently had a positive effect on crop yields.

Treatment methods had a different effect on crop weed infestation. This is confirmed by Bielashov et al. (2022) and Kuts et al. (2021). For example, in the tillering phase of barley during ploughing, the number of weeds was 9.8 pcs·m^{-2} when the $N_{30}P_{30}K_{30}$ fertilizer was applied and 11.1 pcs·m^{-2} when the $N_{60}P_{30}K_{30}$ fertilizer was applied. During the chisel tillage, the average number of weeds, depending on the fertilizer background, was 11.2 pcs·m^{-2} and 13.5 pcs·m^{-2}. During discing, the number of weeds was 15.3 pcs·m^{-2} when the $N_{30}P_{30}K_{30}$ fertilizer was used and 17.6 pcs·m^{-2} when the $N_{60}P_{30}K_{30}$ fertilizer was used. The lowest quantitative indicators for ploughing are explained by the ploughing of weed seeds into a deeper layer of soil, which makes it difficult for them to germinate. The application of mineral nitrogen fertilizers stimulated the emergence of weeds. The application of $N_{30}P_{30}K_{30}$ and $N_{60}P_{30}K_{30}$ fertilizers increased the infestation of spring barley crops by 1.1 and 1.2 times. A similar result was published in the article by Fan et al. (2016).

In the early stages of development of spring barley under mouldboard and chisel tillage (Rozhkov et al., 2021) carrion sunflower dominated (44.1–76.6%) in agro-phytocenosis. During disc tillage, the amount of sunflower carrion and ragweed was approximately the same (45.5–50.5%) in the structure of weed groups. The introduction of an increased dose of nitrogen (N_{60}) as part of a complete mineral fertilizer stimulated the germination of white quinoa.

At the time of harvesting the grain crop, weeds were 4.1–6.5 pcs·m^{-2} (1.4–3.1 g·m^{-2}) with mouldboard tillage. In terms of the number of weeds, this is 1.6–1.7 times less compared to chisel tillage and 1.2–2.0 times less in weight. Plots with disc tillage turned out to be the most infested both at the beginning of the growing season and during harvesting. Depending on the agrochemical background, the number of weeds was:

– without fertilizer: 6–18 pcs·m^{-2};
– with fertilizer $N_{30}P_{30}K_{30}$: 5–12 pcs·m^{-2};
– with fertilizer $N_{60}P_{30}K_{30}$: 4–9 pcs·m^{-2}.

The yield of spring barley with mouldboard and chisel treatments was almost the same (Table 2). With disc tillage, yield decreased by 0.45–1.9 t·ha^{-1}.

The probable reason for the decrease in yield during disc tillage is the growth of weed infestation and a large amount of sunflower leaf-stem mass on the soil surface. Better mixing of plant residues of the preceding plant with the soil and rapid heating of the surface layer provide better conditions for the vital activity of microbial populations and the release of immobilized mineral compounds into the soil solution.

Mouldboard and chisel tillage were characterized by a higher and almost identical grain yield (Fig. 2).

However, disc tillage (10–12 cm) was characterized by fuel savings of 13.2–12.0 l·ha^{-1} compared to ploughing and chisel tillage. Similar results were obtained by Katayama et al. (2018), and Tomer and Liebman (2014). This had a positive

Table 1 Reserves of productive moisture (mm) under spring barley depending on the methods of tillage and fertilization (layer 0–15 cm)

Tillage (depth)	Sowing		Heading		Cleaning		Average value		
	2017	2018	2017	2018	2017	2018	sowing	heading	cleaning
Without fertilizer									
Dump (20–22 cm)	163.1	82.1	26.5	16.5	45.2	0	122.6	21.5	22.6
Chisel (14–16 cm)	172.9	117.1	43.9	10.1	51.3	0	145.0	27.0	25.6
Disc (10–12 cm)	174.7	98.3	60.3	16.7	60.6	0	136.5	38.5	30.3
Fertilizer $N_{30}P_{30}K_{30}$									
Dump (20–22 cm)	163.1	82.1	13.1	10.8	48.8	0	122.6	11.9	24.4
Chisel (14–16 cm)	172.9	117.1	23.2	7.2	56.2	0	145.0	15.2	28.1
Disc (10–12 cm)	174.7	98.3	47.8	0.6	69.1	0	136.5	24.2	34.5
Fertilizer $N_{60}P_{30}K_{30}$									
Dump (20–22 cm)	163.1	82.1	9.3	4.5	48.1	0	122.6	6.9	24.0
Chisel (14–16 cm)	172.9	117.1	20.3	0.4	58.7	0	145.0	10.3	29.3
Disc (10–12 cm)	174.7	98.3	43.3	0.3	66.9	0	136.5	21.8	33.4

Table 2 Yield (t·ha^{-1}) of spring barley depending on the methods of basic tillage and fertilizer

Tillage (depth)	Fertilizers	2017	2018	Average
Dump (20–22 cm)	without fertilizer	3.66	1.55	2.61
	fertilizer $N_{30}P_{30}K_{30}$	3.78	1.75	2.76
	fertilizer $N_{60}P_{30}K_{30}$	3.90	1.93	2.92
	average	3.78	1.74	2.75
Chisel (14–16 cm)	without fertilizer	3.47	1.51	2.49
	fertilizer $N_{30}P_{30}K_{30}$	3.69	1.80	2.75
	fertilizer $N_{60}P_{30}K_{30}$	3.84	2.02	2.93
	average	3.67	1.78	2,73
Disc (10–12 cm)	without fertilizer	2.82	1.48	2.15
	fertilizer $N_{30}P_{30}K_{30}$	3.27	1.71	2.49
	fertilizer $N_{60}P_{30}K_{30}$	3.56	1.90	2.73
	average	3.22	1.70	2.46

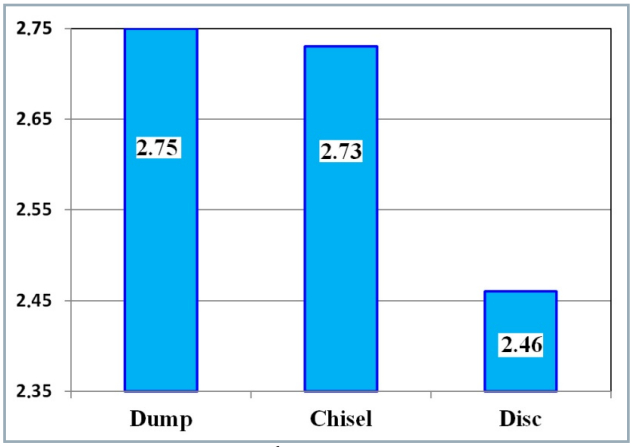


Fig. 2 Average yield (t·ha^{-1}) of spring barley depending on the methods of basic tillage (2017–2018)

effect on the profitability of production and made it possible to reduce labour costs by 0.91–0.62 man hours·ha^{-1}.

Conclusion

Chisel tillage provided the highest level of profitability (48.6%). The indicators during ploughing were the lowest (44.6%). The profitability of disc tillage was 41.1%. The application of mineral fertilizers contributed to an increase in the yield of spring barley by 0.32–0.59 t·ha^{-1}. However, economic indicators did not improve with the use of fertilizers due to the high cost of fertilizers.

Chisel tillage provided a higher level of moisture accumulation in the cold season and large reserves of productive moisture in spring, which affects the grain crop, especially in dry years. With chisel tillage, the cost of main products turned out to be the lowest.

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References

ACHARYA, B. S. – DODLA, S. – GASTON, L. A. – DARAPUNENI, M. – WANG, J. J. – SEPAT, S. – BOHARA, H. 2019. Winter cover crops effect on soil moisture and soybean growth and yield under different tillage systems. In Soil and Tillage Research, vol. 195, article no. 104430. DOI: https://doi.org/10.1016/j.still.2019.104430

BIELASHOV, O. – ROZHKOV, A. – KALENSKA, S. – KARPUK, L. – MARENYCH, M. – KUTS, O. – ZAITSEVA, I. – ROMANOV, O. – MUZAFAROV, N. 2022 Influence of pre-sowing application of mineral fertilizers, root and foliar nutrition on productivity of winter tritical plants. In Ecological Engineering & Environmental Technology, vol. 23, no. 6, pp. 1–14. DOI: https://doi.org/10.12912/27197050/152118

BLEDNYKH, V. V. – SVECHNIKOV, P. G. – TROYANOVSKAYA, I. P. 2017 Tractor plough with repeated cutting angle on working elements. In Procedia Engineering, vol. 206, pp. 1577–1582. DOI: https://doi.org/10.1016/j.proeng.2017.10.680

BRANKATSCHK, G. – FINKBEINER, M. 2015. Modeling crop rotation in agricultural LCAs –Challenges and potential solutions. In Agricultural Systems, vol. 138, pp. 66–76. DOI: https://doi.org/10.1016/j.agsy.2015.05.008

DONG, L. – ZHANG, W. – XIONG, Y. – ZOU, J. – HUANG, Q. – XU, X. – REN, P. – HUANG, G. 2022. Impact of short-term organic amendments incorporation on soil structure and hydrology in semiarid agricultural lands. In International Soil and Water Conservation Research, vol. 10, no. 3, pp. 457–469. DOI: https://doi.org/10.1016/j.iswcr.2021.10.003

ERGASHEV, I. T. – YSLOMV, Y. – PARDAEV, K. K. – TOSHTEMIROV, B. R. – ISMATOV, A. –ABDULLAEV, B. 2020. Results of comparative studies of tillage technologies when sowing repeated crops. In International Journal on Integrated Education, vol. 3, no. 7, pp. 128–131. DOI: https://doi.org/10.31149/ijie.v3i7.510

FAN, J.-W. – DU, Y.-L. – WANG, B.-R. – TURNER, N. C. – WANG, T. – ABBOTT, L. K. – STEFANOVA, K. –SIDDIQUE, K. H. M. – LI, F.-M. 2016. Forage yield, soil water depletion, shoot nitrogen and phosphorus uptake and concentration, of young and old stands of alfalfa in response to nitrogen and phosphorus fertilisation in a semiarid environment. In Field Crops Research, vol. 198, pp. 247–257. DOI: https://doi.org/10.1016/j.fcr.2016.08.014

GARMASHOV, V. M. – KORNILOV, I. M. – NUZHNAYA, N. A. – KRYACHKOVA, M. P. – GOVOROV, V. N. 2019. Agrophysical properties of soil and yield of spring barley on the background of the main

processing. In International Journal of the Humanities and Natural Sciences, vol. 10, no. 37, pp. 124–127.
DOI: https://doi.org/10.24411/2500-1000-2019-11619 (In Russian)

ÇERÇIOĞLU, M. – ANDERSON, S. H. – UDAWATTA, R. P. – ALAGELE, S. 2019. Effect of cover crop management on soil hydraulic properties. In Geoderma, vol. 343, pp. 247–253.
DOI: https://doi.org/10.1016/j.geoderma.2019.02.027

HANHUR, V. V. – LEN, O. I. – HANHUR, N. V. 2022. Impact of different tillage systems on soil nutrient regime in the field of winter wheat and spring barley in the left-bank forest-steppe zone of Ukraine. In Bulletin of the Poltava State Agrarian Academy, vol. 1, pp. 38–44.
DOI: https://doi.org/10.31210/visnyk2022.01.04 (In Ukrainian)

HOROBETS, M. – CHAIKA, T. – KOROTKOVA, I. – PYSARENKO, P. – MISHCHENKO, O. – SHEVNIKOV, M. – LOTYSH, I. 2021. Influence of growth stimulants on photosynthetic activity of spring barley (*Hordeum vulgare* L.) crops. In International Journal of Botany Studies, vol. 6, no. 2, pp. 340–345.

KATAYAMA, K. – KAWASAKI, Y. – YAMAZAKI, R. – KAMEI, M. 2018. Chisel plough cultivation enhanced soybean growth and yield due to improvement of soil water drainage in upland field converted from paddy field in mountainous areas. In Japanese Journal of Crop Science, vol. 87, no. 4, pp. 312–318.
DOI: https://doi.org/10.1626/jcs.87.312 (In Japanese)

KIRYUSHIN, V. I. 2019. The management of soil fertility and productivity of agrocenoses in adaptive-landscape farming systems. In Eurasian Soil Science, vol. 52, no. 9, pp. 1137–1145.
DOI: https://doi.org/10.1134/S1064229319070068

KUTS, O. – SHEVCHENKO, S. – SEMENENKO, I. – DUKHIN, E. – YAKOVCHENKO, A. – YAKOVCHENKO, O. 2021. Study of the efficiency of sweet potato growing in the Forest-Steppe of Ukraine by different methods of soil mulching. In EUREKA: Life Sciences, vol. 6, pp. 17–24. DOI: https://doi.org/10.21303/2504-5695.2021.002156

MAMATOV, F. – TEMIROV, I. – OCHILOV, S. – CHORIEVA, D. – RAKHMATOV, D. –MURTAZAEVA, G. 2021. Substantiation the technology and parameters of the "paraplau" type soil dredger for a two-tier plow. In E3S Web of Conferences, vol. 304, article no. 03014. DOI: https://doi.org/10.1051/e3sconf/202130403014

NUKESHEV, S. O. – KAKABAEV, N. A. – ROMANYUK, N. N. – TROYANOVSKAYA, I. P. –SMELIK, V. A. – VOINASH, S. A. 2021. Design and rationale for parameters of the seed-fertilizer seeder coulter for subsoil broadcast seeding. In IOP Conference Series: Earth and Environmental Science, vol. 677, no. 5, article no. 052010.
DOI: https://doi.org/10.1088/1755-1315/677/5/052010

PASHCHENKO, V. F. – SYROMIATNIKOV, Y. N. – KHRAMOV, N. S. 2019. Qualitative performance indicators of a ripping-and-separating machine for soil cultivation in the growth of sugar beet. In Vegetable and Melon Growing, vol. 65, pp. 39–49.
DOI: https://doi.org/10.32717/0131-0062-2019-65-39-49 (In Russian)

PIAZZA, G. – PELLEGRINO, E. – MOSCATELLI, M. C. – ERCOLI, L. 2020. Long-term conservation tillage and nitrogen fertilization effects on soil aggregate distribution, nutrient stocks and enzymatic activities in bulk soil and occluded microaggregates. In Soil and Tillage Research, vol. 196, article no. 104482.
DOI: https://doi.org/10.1016/j.still.2019.104482

POLIOVYY, V. – SNITYNSKYY, V. – HNATIV, P. – SZULC, W. – LAHUSH, N. – IVANIUK, V. –FURMANETS, M. – KULYK, S. – BALKOVSKYY, V. – POLIUKHOVYCH, M. – RUTKOWSKA, B. 2021. Agro-ecological efficiency of a crop fertilization system with the use of phytomass residues in the forest steppe of western Ukraine. In Journal of Elementology, vol. 26, no. 2, pp. 433–445.
DOI: https://doi.org/10.5601/jelem.2021.26.1.2120

ROMANYUK, N. – EDNACH, V. – NUKESHEV, S. – TROYANOVSKAYA, I. – VOINASH, S. – KALIMULLIN, M. – SOKOLOVA, V. 2023. Improvement of the design of the plow-subsoiler-fertilizer to increase soil fertility. In Journal of Terramechanics, vol. 106, pp. 89–93.
DOI: https://doi.org/10.1016/j.jterra.2023.01.001

ROMASHCHENKO, M. – BOHAIENKO, V. – SHATKOVSKYI, A. – SAIDAK, R. – MATIASH, T. – KOVALCHUK, V. 2023. Optimisation of crop rotations: A case study for corn growing practices in forest-steppe of Ukraine. In Journal of Water and Land Development, vol. 2023, no. 56(I-III), pp. 194–202.
DOI: https://doi.org/10.24425/jwld.2023.143760

ROZHKOV, A. O. – SUKHOVA, H. I. – STANKEVICH, S. V. – VITANOV, O. D. – SEMENENKO, I. I. – KUTS, O. V. – GEPENKO, O. V. – POTASHOV, Y. M. – POTASHOVA, L. M. – HERMAN, L.V. 2021. Effect of pre-sowing seed treatment and foliar nutrition on productivity and yield of chickpea grain in the eastern forest-steppe of Ukraine. In Ukrainian Journal of Ecology, vol. 11, no. 9, pp. 74–81.
DOI: https://doi.org/10.15421/2021_298

SAHOO, T. R. – BEHERA, B. – PAIKARAY, R. K. – GARNAYAK, L. M. – SETHI, D. – JENA, S. –RAZA, M. B. – PANDA, R. K. – SONG, B. – LAL, M. K. – KUMAR, A. 2023. Effects of sunflower residue management options on productivity and profitability of succeeding rice under different crop establishment methods. In Field Crops Research, vol. 290, article no. 108763.
DOI: https://doi.org/10.1016/j.fcr.2022.108763

SVECHNIKOV, P. G. – TROYANOVSKAYA, I. P. 2019. Tractor plough designing with specified tillage quality. In IOP Conference Series: Earth and Environmental Science, vol. 341, article no. 012119.
DOI: https://doi.org/10.1088/1755-1315/341/1/012119

SYROMYATNIKOV, Y. – KUTS, A. – TROYANOVSKAYA, I. – OREKHOVSKAYA, A. –TIKHONOV, E. – SOKOLOVA, V. 2022. Transporting ability calculation of the rotor of soil-cultivating loosening and separating vehicle. In Acta Technologica Agriculturae, vol. 25, no. 2, pp. 73–78.
DOI: https://doi.org/10.2478/ata-2022-0012

TOMER, M. D. – LIEBMAN, M. 2014. Nutrients in soil water under three rotational cropping systems, Iowa, USA. In Agriculture, Ecosystems and Environment, vol. 186, pp. 105–114.
DOI: https://doi.org/10.1016/j.agee.2014.01.025

SYROMYATNIKOV, Y. – SEMENENKO, I. – MAKSIMOVICH, K. – TROYANOVSKAYA, I. –KARNAUKHOV, A. – OREKHOVSKAYA, A. – VOINASH, S. 2023a. Influence of agrotechnical practices and sowing time in various weather on soybean yield. In Acta Technologica Agriculturae, vol. 26, no. 1, pp. 9–16.
DOI: https://doi.org/10.2478/ata-2023-0002

SYROMYATNIKOV, Y. – TROYANOVSKAYA, I. – VOINASH, S. – OREKHOVSKAYA, A. –SOKOLOVA, V. – MAKSIMOVICH, K. – GALIMOV, R. – LOPAREVA, S. 2021. Productivity of tillage loosening and separating machines in an aggregate with tractors of various capacities. In Journal of Terramechanics, vol. 98, pp. 1–6.
DOI: https://doi.org/10.1016/j.jterra.2021.09.002

SYROMYATNIKOV, Y. – VOINASH, S. – TROYANOVSKAYA, I. – TIKHONOV, E. – PARTKO, S. – SOKOLOVA, V. 2023b. Selection of parameters of the disc working bodies of the ripping-separating machine for soil treatment. In Journal of Terramechanics, vol. 108, pp. 1–5. DOI: https://doi.org/10.1016/j.jterra.2023.03.005

TARASENKO, B. – DROBOT, V. – TROYANOVSKAYA, I. – OREKHOVSKAYA, A. – VOINASH, S. – SOKOLOVA, V. – MAKSIMOVICH, K. – GALIMOV, R. – LOPAREVA, S. 2022. Research and development of a combined unit for tillage with a layer turnover. In Journal of Terramechanics, vol. 99, pp. 29–33. DOI: https://doi.org/10.1016/j.jterra.2021.11.002

TARASENKO, B. F. – KUZMIN, V. V. – TROYANOVSKAYA, I. P. – PARTKO, S. A. – VOINASH, S. A. 2023. Harrow with turning disc section. In Engineering Technologies and Systems, vol. 33, no. 1, pp. 10–20.
DOI: https://doi.org/10.15507/2658-4123.033.202301.010-020

ŽÁK, Š. – MACÁK, M. – HAŠANA, R. 2012. Influence of soil cultivation technologies and fertilisation on productivity and energy production of arable crops. In Agriculture (Poľnohospodárstvo), vol. 58, no. 1, pp. 25–33. DOI: https://doi.org/10.2478/v10207-012-0004-9