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TECHNOLOGIES FOR GROWING MAIZE IN REPEATED AND CONTINUOUS CROPS UNDER IRRIGATION

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Abstract

The use of chemical ameliorant allows maintaining agrophysical soil parameters in dark chestnut medium loam soil with constant corn cultivation under drip irrigation at the initial baseline level. Without the use of ameliorant, the stocking density increased by 1.5...4.8% compared to the base year. The soil was most compacted in the 10-20 cm horizon. The use of ameliorant allowed to maintain the initial soil density during the constant cultivation of corn for 5 years 2020…2024. Soil porosity decreased by 1.5...1.8%, and in relative values by 2.5...3.3% under constant corn crops without the use of chemical ameliorants. The use of a soil improver allowed to slow down the decrease in porosity by almost an order of magnitude – to 0.2…0.3 relative percent. The humus content when using chemical ameliorant was half as low compared to the options without ameliorant. Fluctuations in humus content and a possible downward trend were at a low level - the percentage of fluctuation of the indicator to the base year 2020 was 0.7-1.4% without the use of ameliorant and 0.3% with the use of ameliorant.

Key words: *maize, humus content, soil bulk density, soil porosity, chemical ameliorant.*

INTRODUCTION

In the southern regions of Ukraine, maize is predominantly cultivated under irrigation, ensuring high profitability. A critical issue for researchers studying the cultivation of agricultural crops under irrigation in the Southern Steppe is the trend toward the degradation of the soil's agrophysical and physico-chemical properties due to prolonged irrigation with highly mineralized water (classified as Class II water quality) and long-term continuous maize cropping. Intensive cultivation technologies for profitable grain crops (maize, soybeans) require increased irrigation rates (up to 6,000–8,000 m³/ha) and impose greater technical pressure on the soil, leading to secondary salinization and the destruction of the agrophysical structure of the arable layer. The issue of soil fertility preservation and regeneration has become a matter of national significance. Regenerative agriculture should primarily be based on the use of chemical and phytomeliorants, as well as monitoring the agrophysical indicators of soil fertility.

Analysis of Recent Research and Publications. Even though some positive examples of crop tolerance to continuous cropping exist, they do not eliminate certain problems associated with this cultivation system. Maize serves as a prime example. Extensive practical experience with high crop concentration and continuous cropping of maize demonstrates that its cultivation should not exceed a period of 4-6 years. After this period, it becomes necessary to introduce a break of at least two years and cultivate crops from different botanical families that do not share common pests and pathogens (Bocsa et al., 2000).

Continuous cropping of any crop, including maize, requires specific environmental conditions for successful growth and development, particularly in terms of soil fertility. These conditions are also necessary for maize cultivation within classical crop rotation systems (Klymchuk, 2005; Cherney & Small, 2016). At first glance, there appears to be no significant difference. However, detailed analysis reveals otherwise. Specifically, in areas where continuous maize cropping occurs, there is an increasing presence of crop-specific insect pests and disease pathogens. In the early stages of concentration, these changes may be insignificant, but as the duration of continuous cropping increases, the trend toward the accumulation of harmful organisms intensifies (Fedorenko et al., 2016).

A significant challenge in continuous cropping systems is the activity of plant root systems, particularly the biochemical nature of their root exudates - colloquially referred to as allelochemicals - which contribute to soil fatigue. The allelopathic activity of rhizosphere soil and extracts from aerial plant organs can act as strong inhibitors of monoculture growth (Jalgaonwala & Mahajan, 2014).

The accumulation of such biologically active substances in the arable layer over the years can induce unfavorable changes in plant growing conditions. Numerous examples of soil fatigue under long-term monoculture cultivation have been documented, including in fruit orchards, flax, sugar beet, and sunflower (Skrypchenko et al., 2020; Grodzinsky, 1991).

At the same time, it is well known that maize, winter rye, potatoes, and certain other crops can withstand continuous cropping for decades without significant yield reduction (Fedotov & Shoba, 2019).

One of the key factors in mitigating the negative effects of continuous cropping is maintaining high nutrient availability. However, the rational application of organic and mineral fertilizers in production conditions can only be assessed by considering numerous factors that influence their efficiency. The dependence of crop yield on increased application rates of specific types of mineral fertilizers and their combinations can only be determined experimentally through vegetation and field trials (Werf et al., 1996).

Specialization in agriculture has been a key factor in increasing farmers' profitability. Production systems have become increasingly simplified as farmers cultivate only a small number of crops that command favorable market prices. However, monoculture systems require increased agrochemical inputs, leading to unsustainable environmental costs (Arrobas et al., 2015).

Corn is one of the agricultural crops increasingly grown in no-till systems. This approach enhances the efficient use of agricultural land, which, in addition to enabling high yields, improves overall farm management and economic efficiency. In Poland, studies have shown that the lowest average corn yield was recorded in monoculture under direct seeding. The yield obtained in monoculture was 17-27% lower than in a crop rotation system. The humus content in soil under monoculture corn grown with direct seeding or conventional tillage remained unchanged, whereas it increased in soil where corn was grown in rotation with other cereals (Księżak et al., 2018).

The reduction in yield under continuous maize cultivation can range from 0% to 30%, but typically falls between 5% and 15%. This decline is associated with nitrogen (N) immobilization, increased disease risk, and allelopathy. The elevated volume of corn residues exacerbates these negative effects. Continuous maize requires more nitrogen than maize grown after soybeans. Hybrid selection plays a crucial role in adapting to continuous maize cultivation (Licht, 2019).

A study on the impact of long-term monoculture and crop rotation on soil biological activity revealed a statistically significant increase in soil enzymatic activity and the total number of bacteria and actinomycetes in monoculture (Gałązka et al., 2017).

Intensive agroecosystem management may lead to soil degradation, negatively affecting the relationship between agricultural production and climate change. To increase soil organic carbon (SOC) and total nitrogen (STN) reserves, conservation tillage (i.e., zero and minimal tillage) is recommended. This practice positively impacts food security, biodiversity, water quality, and the environment. An eight-year comparison of tillage systems in irrigated monoculture maize showed that minimum tillage (MT) is a valuable alternative for increasing maize yield and biomass return compared to conventional tillage (CT). However, this does not apply to no-till (NT), which resulted in lower maize yields and biomass return during the initial five-year transition period. Implementing conservation tillage in intensive maize monoculture systems should be recommended to support maize yields (Fiorini et al., 2020).

In Ukraine's southern regions, maize is primarily grown under irrigation, ensuring high profitability. A key issue for researchers studying irrigated agriculture in the Southern Steppe is the degradation trend in agro-physical and physico-chemical soil properties due to prolonged irrigation with highly mineralized water (classified as Class II water quality) (Vozhehova et al., 2014).

Intensive technologies for growing high-profit grain crops (such as maize and soybeans) require increased irrigation rates (up to 6,000-8,000 m^3/ha) and higher mechanical loads on the soil, leading to secondary salinization and the destruction of the agro-physical structure of the plow layer. Preserving and regenerating soil fertility has become a matter of national importance. Regenerative agriculture should be based primarily on the use of chemical and phytomeliorants (Vozhehova et al., 2020).

The economics of crop production in Ukraine dictate a specific structure of sown areas. High-profit crops dominate crop rotations, sometimes disrupting traditional (archaic) scientifically based crop rotation systems. The share of crops such as maize, soybeans, and sunflower in crop rotations has significantly increased. Scientists recommend and actively promote tripartite crop rotation with two maize fields, two-field rotation (maize-soybean), and four-field rotation with three maize fields (Zubets, 2010).

Research on continuous maize cultivation for grain on typical chernozem in the Left-Bank Forest-Steppe of Ukraine has shown varying impacts of anthropogenic and natural factors on yield levels and soil fertility. Maize yield depends more on weather conditions than on the duration of cultivation in the same location. A mathematical analysis of maize yield data and its correlation with fertilization systems, temperature, and water regimes demonstrated a broad spectrum of correlations, ranging from direct to inverse relationships. Weed surveys indicated that over four years, the average weed density in continuous maize fields was 84.9 plants/m^2, whereas in crop rotation systems, it was 59.1 plants/m^2 - a 30% reduction (Kohan et al., 2019).

The **objective** of this research is to determine the impact of soil ameliorants on the agro-physical properties of the arable layer of dark chestnut soil under drip irrigation in continuous maize fields in the Southern Steppe of Ukraine.

MATERIALS AND METHODS

The research was conducted using methodological approaches employed in international practice and compliant with the state standards of Ukraine.

The response of corn hybrids to different cultivation conditions was studied at the Institute of Climate-Smart Agriculture, National Academy of Agrarian Sciences of Ukraine, located in Kherson, Ukraine (46°44'33" N; 32°42'28" E; 50 m above sea level) (location A) during the period of 2020-2024. Agricultural cultivation techniques and research methods were consistent with generally accepted practices for irrigation conditions, in addition to the factors under investigation. Surface drip irrigation was applied, maintaining the pre-irrigation soil moisture level at 80% of the lowest moisture capacity in the 0-50 cm soil layer (Vozhehova et al., 2014). The mathematical processing of research results was performed using the dispersion analysis method with the Agrostat computer software package (Ushkarenko et al., 2013).

The cultivation practices were standard for irrigated conditions and aligned with the requirements of grain corn production technologies (Vozhehova et al., 2023). Plowing was carried out after the harvest of the preceding crop (grain corn) to a depth of 26-28 cm. Spring soil tillage included early spring harrowing at the stage of soil physical maturity. Pre-sowing cultivation was conducted to a depth of 6-8 cm, corresponding to the seeding depth. Gypsum was applied as a chemical ameliorant at a rate of 5 t/ha. Agronomic indicators of the arable soil layer were assessed after the corn harvest.

RESULTS AND DISCUSSIONS

The analysis of humus content dynamics in different soil layers over a five-year rotation revealed that the highest losses occurred in the 0-10 cm soil layer when no chemical ameliorant (gypsum at a rate of 5 t/ha) was applied (Table 1). In the 10-20 cm and 20-30 cm layers, the negative indicators were half as significant. The loss of humus was reduced by half when a chemical ameliorant was applied compared to the non-ameliorant variants. However, fluctuations in humus content and a potential decreasing trend were minimal - ranging from 0.7-1.4% without the ameliorant and 0.3% with the ameliorant, relative to the baseline year of 2020. Thus, the application of the chemical ameliorant reduced humus loss in the 0-30 cm soil layer by 0.01%. The greatest humus loss was observed in the 0-10 cm layer (up to 0.04%), likely due to increased moisture availability in this layer under drip irrigation and enhanced root system activity. Over the five-year period, humus content fluctuations were minor in the non-ameliorant variant (0.7-1.4%) and even smaller with the ameliorant (0.3%), indicating the feasibility of continuous corn cultivation under irrigation without significant humus loss in the arable soil layer.

Table 1. Dynamics of Humus Content in Dark Chestnut Medium Loamy Soil on Carbonate Loess Under Continuous Corn Cultivation with Drip Irrigation, %

Experiment Variant	Soil Layer, cm	Study Years					Changes in 2024 vs. 2020	
		2020	2021	2022	2023	2024	Absolute Values	%
Without Ameliorant	0–10	2.75	2.75	2.74	2.74	2.71	–0.04	1.4
	10–20	2.70	2.70	2.69	2.69	2.68	–0.02	0.7
	20–30	2.37	2.36	2.35	2.35	2.35	–0.02	0.7
	0–30	2.61	2.60	2.59	2.59	2.58	–0.03	1.1
With Ameliorant	0–10	2.75	2.75	2.73	2.74	2.74	–0.01	0.3
	10–20	2.70	2.70	2.71	2.70	2.71	+0.01	0.3
	20–30	2.37	2.36	2.36	2.36	2.36	–0.01	0.3
	0–30	2.61	2.60	2.60	2.60	2.60	–0.01	0.3
CV_{05}		0.11	0.12	0.09	0.10	0.09		

The dynamics of humus reserves followed a similar pattern. Without the ameliorant, humus reserves in the 0-30 cm soil layer were 24.4 t/ha in 2024, compared to 24.7 t/ha in 2020 (Table 2).

Table 2. Dynamics of Humus Reserves in Dark Chestnut Medium Loamy Soil Under Continuous Corn Cultivation with Drip Irrigation, t/ha

Experiment Variant	Soil Layer, cm	Study Years					Changes in 2024 vs. 2020	
		2020	2021	2022	2023	2024	Absolute Values	%
Without Ameliorant	0–10	26.1	26.1	25.9	25.9	25.7	–0.4	1.5
	10–20	25.6	25.6	25.5	25.5	25.4	–0.2	0.7
	20–30	22.4	22.2	22.2	22.2	22.2	–0.2	0.7
	0–30	24.7	24.6	24.5	24.5	24.4	–0.3	1.2
With Ameliorant	0–10	26.1	26.1	25.9	25.9	26.0	–0.1	0.3
	10–20	25.6	25.6	25.7	25.6	25.7	+0.1	0.3
	20–30	22.4	22.4	22.3	22.3	22.3	–0.1	0.3
	0–30	24.7	24.7	24.7	24.6	24.6	–0.1	0.3
CV_{05}		1.22	1.13	1.15	1.06	1.14		

Changes in humus reserves from 2020 to 2024 ranged from –0.2 to –0.4 t/ha in absolute terms, or 0.7-1.5%. The application of the ameliorant reduced humus reserve losses in the 0-30 cm layer. Humus reserves decreased from the 0-10 cm to the 20-30 cm layer, likely due to increased organic stem residues after grain harvest in the upper layers. This trend of decreasing humus reserves in lower layers was observed in all study years, both with and without the ameliorant.

The bulk density of dark chestnut medium loamy soil under continuous corn cultivation with drip irrigation was more pronounced for analysis (Table 3). Without the ameliorant, bulk density increased by 1.5-4.8% compared to the baseline year of 2020. The greatest compaction occurred in the 10-20 cm layer. The application of the ameliorant mitigated soil compaction during continuous corn cultivation. Bulk density increased from 1.340 to 1.405 g/cm³ over the five-year period without the ameliorant, while with the ameliorant, it increased from 1.270 to 1.281 g/cm³, six times less than the non-ameliorant variant. Soil bulk density was higher in the lower layers (10-20 cm and 20-30 cm) across all study years, regardless of ameliorant use. The ameliorant reduced soil bulk density in all layers by 1.1-4.0%, with the most significant effect observed in the 10-20 cm layer.

Table 3. Dynamics of Bulk Density in Dark Chestnut Medium Loamy Soil Under Continuous Corn Cultivation with Drip Irrigation, g/cm³

Experiment Variant	Soil Layer, cm	Study Years					Changes in 2024 vs. 2020	
		2020	2021	2022	2023	2024	Absolute Values	%
Without Ameliorant	0-10	1.298	1.303	1.301	1.342	1.350	+0.052	4.0
	10-20	1.340	1.351	1.374	1.386	1.405	+0.065	4.8
	20-30	1.371	1.376	1.380	1.391	1.392	+0.021	1.5
	0-30	1.336	1.343	1.351	1.373	1.382	+0.046	3.34
With Ameliorant	0-10	1.199	1.201	1.203	1.198	1.205	+0.006	0.5
	10-20	1.270	1.273	1.274	1.279	1.281	+0.011	0.8
	20-30	1.307	1.315	1.310	1.304	1.302	–0.005	0.4
	0-30	1.259	1.262	1.262	1.260	1.262	+0.003	0.2
CV_{05}		0.045	0.039	0.042	0.053	0.048		

The porosity of dark chestnut medium loamy soil under continuous corn cultivation tended to decrease without the ameliorant (Table 4). In absolute terms, porosity decreased by 1.5-1.8%, and in relative terms, by 2.5-3.3%. The application of the ameliorant slowed the reduction in porosity by nearly an order of magnitude to 0.2-0.3%. Soil compaction increased with depth, reaching 20-30 cm. Porosity in all soil layers was significantly higher with the ameliorant, indicating improved soil aeration under drip irrigation.

Table 4. Dynamics of Porosity in Dark Chestnut Medium Loamy Soil Under Continuous Corn Cultivation with Drip Irrigation, %

Experiment Variant	Soil Layer, cm	Study Years					Changes in 2024 vs. 2020	
		2020	2021	2022	2023	2024	Absolute Values	%
Without Ameliorant	0–10	58.3	58.0	57.4	56.9	56.8	–1.5	2.5
	10–20	54.5	54.2	53.2	52.9	52.7	–1.8	3.3
	20–30	50.6	50.3	49.7	49.5	48.8	–1.8	3.3
	0–30	54.4	54.2	53.4	52.8	52.7	–1.7	3.1
With Ameliorant	0–10	61.2	61.0	60.9	60.9	61.0	–0.2	0.3
	10–20	55.4	55.3	55.0	55.2	55.2	–0.2	0.3
	20–30	51.1	51.2	51.3	51.2	51.0	–0.1	0.2
	0–30	55.9	55.8	55.7	55.7	55.7	–0.1	0.2
CV_{05}		2.31	1.87	2.14	2.40	2.15		

Nitrate content in dark chestnut medium loamy soil under continuous corn cultivation was highly variable across study years (Table 5). Without the ameliorant, nitrate content decreased from 2020 to 2024 by 0.4-2.2 mg/kg soil, or 2.6-13.3%. However, in 2022, nitrate levels exceeded those of the previous year. Similar fluctuations were observed with the ameliorant. In 2024, nitrate content increased by 5.5-17.2% compared to 2020, indicating significant dependence on preceding weather conditions.

Table 5. Dynamics of Nitrate Content in Dark Chestnut Medium Loamy Soil Under Continuous Corn Cultivation with Drip Irrigation, mg/kg

Experiment Variant	Soil Layer, cm	Study Years					Changes in 2024 vs. 2020	
		2020	2021	2022	2023	2024	Absolute Values	%
Without Ameliorant	0-10	16.5	16.7	17.6	16.6	14.3	–2.2	13.3
	10-20	18.9	18.5	19.2	18.9	17.8	–1.1	5.8
	20-30	15.4	15.0	13.8	14.8	15.0	–0.4	2.6
	0-30	16.9	16.7	16.9	16.8	15.7	–1.2	6.1
With Ameliorant	0-10	16.2	16.0	18.4	17.2	15.3	–0.9	5.5
	10-20	18.1	18.7	19.5	19.3	20.0	+1.9	10.4
	20-30	15.7	16.2	17.8	18.1	18.4	+2.7	17.2
	0-30	16.6	17.0	18.5	18.2	17.9	+1.3	7.8
CV_{05}		0.66	0.58	0.71	0.69	0.57		

CONCLUSIONS

The application of a chemical ameliorant helps maintain the agro-physical properties of dark chestnut medium loamy soil under continuous corn cultivation with drip irrigation at a sufficiently high fertility level.

Variability in humus content was halved with the ameliorant compared to non-ameliorant variants. Fluctuations in humus content and a potential decreasing trend were minimal - 0.7-1.4% without the ameliorant and 0.3% with the ameliorant, relative to the 2020 baseline.

Without the ameliorant, soil bulk density increased by 1.5-4.8% compared to 2020, with the greatest compaction in the 10-20 cm layer. The ameliorant preserved initial bulk density levels during continuous corn cultivation.

Porosity decreased by 1.5-1.8% in absolute terms and 2.5-3.3% in relative terms under continuous corn cultivation. The ameliorant slowed porosity reduction to 0.2-0.3%.

Nitrate content in dark chestnut medium loamy soil under continuous corn cultivation was highly variable, depending on preceding weather conditions and years of continuous cropping.

REFERENCES

Arrobas, M., Aguiar, P., & Rodrigues, M.Â. (2015). A comparison of a pasture ley with a maize monoculture on the soil fertility and nutrient release in the succeeding crop. *Archives of Agronomy and Soil Science*, *62*(6), 829–839.

Bocsa, I., Karus, M., & Gohmeyer D. (2000). *Der Hanfanbau*. Munster: Gandevirtschaftsverlag GmbH.

Cherney, J.H. & Small, E. (2016). Industrial hemp in North America: production, politics and potential. *Agronomy, 6*(4), 58.

Fedorenko, V.P., Kabanets, V.V., & Kabanets, V.M. (2016). *Pests of hemp crops*. Kyiv: Agrarna nauka.

Fedotov, G.N., Shoba, S.A., Fedotova, M.F., & Gorepekin, I.V. (2019). The impact of soil allelotoxicity on germination of grain seeds. *Eurasian Soil Science, 52*(4), 448–454.

Fiorini, A., Boselli, R., Maris, S.C., Santelli, S., Ardenti, F., Capra, F., & Tabaglio, V. (2020). May conservation tillage enhance soil C and N accumulation without decreasing yield in intensive irrigated croplands? Results from an eight-year maize monoculture. *Agriculture, Ecosystems and Environment, 296*, 106926.

Gałązka, A., Gawryjołek, K., Perzyński, A., Gałązka, R., & Księżak, J. (2017). Changes in enzymatic activities and microbial communities in soil under long-term maize monoculture and crop rotation. *Polish Journal of Environmental Studies*, *26*(1), 39–46.

Grodzinsky, A.M. (1991). *Allelopathy of plants and soil fatigue*. Kyiv: Scientific opinion.

Jalgaonwala, R., & Mahajan, R. (2014). A review on microbial endophytes from pl ants: A treasure search for biologically active metabolites. *Global Journal of Research on Medicinal Plants & Indigenous Medicine, 3*(6), 263–277.

Klymchuk, O.V. (2005). Phenotypic response of corn starting material to monoculture. *Collection of scientific works of VDAU*, *23,* 9–13.

Kohan, A.V., Gluschenko, L.D., Len, O.I., Olepir, R.V., & Samojlenko, O.A. (2019). Productivity of grades and hybrids of corn at different fertilizer systems and their permanent growing. *Bulletin of Agricultural Science, 10*(799), 18–23.

Księżak, J., Bojarszczuk, J., & Staniak, M. (2018). Comparison of maize yield and soil chemical properties under maize (*Zea mays* L.) grown in monoculture and crop rotation. *Journal of Elementology, 23*(2), 531–543.

Mark, L. (2019). Considerations for Continuous Corn. *Integrated Crop Management News, and Iowa State University Extension and Outreach.* November 18. URL: https://crops.extension.iastate.edu/cropnews/2019/11/considerations-continuous-corn

Skrypchenko, N.V., Dziuba, O.I., & Horbenko, N.Y. (2020). The estimation of soil fatigue in condition of long-term cultivation of woody fruit lianes. *Scientific Bulletin of UNFU*, *30*(3), 36–40.

Ushkarenko, V.O., Vozhegova, R.A., Holoborodko, S.P., & Kokovikhin, S.V. (2013). *Statistical analysis of the results of field experiments in agriculture*. Kherson: Ailant.

Vozhegova, R.A., Lavrynenko, Yu.O., & Malyarchuk, M.P., (2014). *Methodology of field and laboratory research on irrigated lands*. Kherson: Grin D.S.

Vozhegova, R.A., Stashuk, V.A., Zaryshnyak, A.S., & Romashchenko, M.I., (2014). *Farming systems on irrigated lands of Ukraine*. Kyiv: Agrarna nauka.

Vozhegova, R.A., Kokovikhin, S.V., & Stashuk, V.A. (2020). *Development of intensive farming systems on irrigated lands of Ukraine: scientific and technological support*. Kherson: OLDI-PLUS.

Vozhehova, R., Marchenko, T., Lavrynenko, Y., Piliarska, O., Sharii, V., & Borovik, V. (2023). Models of quantitative assessment of the influence of elements of technology on seed yield of parental components of maize hybrids under irrigation conditions. *Scientific Papers. Series A. Agronomy*, *66*(1), 623–630.

Werf, H.V.D., Mathussen, E.W., & Haverkort, A.J. (1996). The potential of hemp (*Cannabis sativa* L.) for sustainable fibre production: a crop physiological appraisal. *Annals of Applied biology, 129*(1), 109–123.

Zubets, M.V., & Melnyk, Y.F., et al. (2010). *Scientific foundations of agro-industrial production in the Steppe zone of Ukraine*. Kyiv: Agrarna nauka.