PRODUCTIVITY AND PROFITABILITY OF SHORT GRAIN CROP ROTATION DEPENDING ON TILLAGE SYSTEMS

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Abstract

Tillage systems have significant impact not only on soil properties, but also on general productivity of cultivated crops and, consequently, on the economic efficiency of agriculture. This study's primary goal was to assess the effects of various tillage techniques used in short-grain crop rotation"grain corn – winter rapeseed – winter wheat – soybeans", on the resulting yields and profitability of crop production. The study was conducted at the Institute of Climate-Smart Agricultureon the irrigated trial fields in Ukraine between 2021 and 2023. Tillage systems, embraced in the study, were represented by differentiated moldboard plowing, differentiated chiseling and differentiated disking with soil slitting. Crop yields were accounted after harvesting at technical ripeness of grain. Economic efficiency was assessed by calculating the figures of gross product value, expenditures, profits, production costs, profitability and recompensating terms. As a result, it was established that the best economic output is provided by differentiated disking with soil slitting, where general profitability reached 73.5% owing to the highest average yields of the crops studied and general yields of grain (7.66 t/ha) and forage (8.31 t/ha) units. The shortest recompensating term of 1.4years was also recorded for the disc tillage system.

Key words: *corn, economic efficiency, production cost, rapeseed, recompensating term, soybeans, wheat*

INTRODUCTION

Nowadays, mankind is facing the challenge of the global food crisis, which is aggravated by dramatic climate change. Global warming has led to increased frequence of adverse meteorological events worldwide, including hurricanes, extensive drought, hailstorms, extreme heating, instability in water income, etc., which in turn have detrimental effects on agriculture in general and crop production in particular [6]. Adverse meteorological phenomena are resulting in crop losses and deterioration of crop products quality [20]. The latter contributes to food distribution inequality, as well as inequality in access to high-quality products because of increasing prices. Ongoing military activities in Ukraine and the Middle East, as well as ongoing COVID-19 pandemic, just add fuel to the fire of global food crisis and malnourishment, making crop products prices even higher than expected because of destruction of powerful crop production systems and disturbed logistics [14,19]. If earlier mainly African countries were considered to be vulnerable to food crisis, today even the developed countries with powerful economy such as, for example, Germany and the United States, suffer food insecurity [1, 13]. Therefore, a major task of modern agriculture is to provide solutions for achieving the highest economic efficiency of crop production at the expense of minimizing expenditures, in addition to satisfying the sustainable development of agro-ecosystems on the basis of climate-smart and environmentally friendly technologies.

In this regard, an important role is played by tillage systems, which have significant effects on both soil fertility preservation, soil physical and chemical properties, climate resilience, growth and development of agricultural plants and, as a result, shaped general economic efficiency of crop production [8, 11, 16]. It has been proved that optimal tillage technology is decisive for proper water resources management in agriculture, as well as proper plant residues management and general efficiency of natural resources usage [7]. This is especially true for the cultivation of crops in semi-arid and arid climates [17], to which almost all the South of Ukraine belongs.

Therefore, the main goal of this study was to establish the best tillage system for economically efficient grain production on the irrigated lands of the South of Ukraine in short crop rotations to facilitate qualitative crop products at the minimal costs.

MATERIALS AND METHODS

The study was conducted on the irrigated experimental fields of the Institute of Climate-Smart Agriculture of NAAS, located in the Kherson region of Ukraine, close to the village of Naddniprianske. The experimental area's soil-climate conditions are typical of Ukraine's Southern Steppe region. The weather conditionscan be classified as semi-arid [9], the soil is represented by dark-chestnut middle-loamy soil with slightly increased salinity and sodium contents.Generally, the zone of the experiment conduction belongs to the zone of so-called risky agriculture [15]. The research was performed during the period 2021-2023 with strict accordance to common standards and procedures of the experimental work in irrigated agriculture.

Table 1. The Scheme of the Stationary Field Experiment on Tillage Systems in Short Grain Crop Rotation and Their Effects on the Crops Productivity and Economic Efficiency

No	Tillage system	Crops of the crop rotation, depth of tillage			
		corn	wnter rapeseed	wnter wheat	soybeans
1	Differentiated plowing	28-30	14-16	20-22	23-25
2	Differentiated chiseling	28-30	14-16	20-22	23-25
3	Differentiated disking with soil slitting	10-12 + 38-40	12-14	14-16	10-12

Source: Own study.

The scheme of the stationary field experiment on tillage systems in the short grain crop rotation is presented in Table 1.

Standard agricultural machines and tillage means of the national Ukrainian manufacturer were used in the experiment. Cropcultivars, cultivated in the experiment, were as follows: corn variety Skadovskyi,soybeans variety Diona,winter wheat varietyKonkaand ChornyiVeletenvariety of winter rapeseed. Irrigation was carried outby the means of sprinkler overhead machine DDA-100-MA when soil moisture level decreased to 70% of the field water-holding capacity. Crop yields were established after direct harvesting with a self-propelled combine harvester at the full technical ripeness of grain, and then recalculated to the standard moisture content in the kernels (14% for corn, wheat and soybeans, and 15% for rapeseed). General grain and forage unit yields were also evaluated. The economic efficiency of the used agro-technologies was estimated using common economic indices, namely: production costs, expenditures, profit, profitability, and recompensating term [18]. All the calculations were performed in EUR/ha considering current currency exchange rates (dated October 2024, 1 EUR = 45.0 UAH).

RESULTS AND DISCUSSIONS

According to the study's findings, the chisel tillage system produced the worst results among the options examined, even falling short of the traditional moldboard plowing system. In contrast, the highest yield of each crop in the short grain crop rotation was harvested under differentiated disking with soil slitting (Table 2).

The highest yield of the studied crops was 6.31 t/ha for winter wheat, 12.79 t/ha for grain corn, 2.53 t/ha for winter rapeseed, and 3.60 t/ha for soybeans, respectively. The difference with the lowest yields was 6.1% for winter wheat, 11.7% for corn, 6.3% for winter rapeseed, and 13.2% for soybeans, respectively. Thus, it could be concluded that among the studied crops winter wheat and winter rapeseed had the least susceptibility to tillage options, while soybeans provided the strongest reaction on tillage changes within the crop rotation.

As for the profits and general profitability rates, it was established that winter wheat was, surprisingly, the most profitable crop among the studied, while soybeans are the least commercially attractive crop. This is mainly because of higher production costs for soybeans, compared to other crops, which is strongly related to more frequent irrigation and higher expenditures for plant care.

The same is also true for recompensating terms, which were the shortest for winter wheat, and the longest for soybeans, respectively. As for comparison between the studied tillage systems, the best average profitability rate of the crop rotation was recorded for differentiated disking tillage, as well as the shortest period of recompensation. As for chiseling and plowing, profitability rates were close enough (the difference of just 1.6%), as well as recompensating term duration (the difference of just about 0.2 years).

Table 2. The economic efficiency of the irrigated short grain crop rotation depending on the tillage system (averaged data for the period 2021-2023, prices dated October 2024)

Economic indices and parameters	Crops				Average per 1 ha of the crop rotation
	Winter wheat	Corn	Winter rapeseed	Soybeans	
Differentiated plowing					
1. Yield. t/ha	6.08	11.85	2.45	3.32	-
2. Yield of forage units. t/ha	7.78	15.76	2.86	4.81	7.80
3. Yield of grain units. t/ha	6.08	11.85	4.90	5.97	7.20
4. Gross value. EUR	803.9	1,540.5	680.6	1,010.8	1,008.9
5. Expenditures. EUR	470.2	969.2	407.9	778.1	656.3
6. Profit. EUR/ha	333.8	571.3	272.7	232.6	352.6
7. Profitability rate. %	70.9	58.9	66.8	29.9	56.6
8.Production cost. EUR/t	77.3	81.8	166.5	234.4	140.0
9. Recompensating terms	1.4	1.7	1.5	3.4	2.0
Differentiated chiseling					
1. Yield. t/ha	5.95	11.45	2.38	3.18	-
2. Yield of forage units. t/ha	7.61	15.23	2.78	4.61	7.55
3. Yield of grain units. t/ha	5.95	11.45	4.76	5.72	6.97
4. Gross value. EUR	786.7	1,488.5	661.1	968.1	976.1
5. Expenditures. EUR	454.8	961.2	395.2	774.3	646.4
6. Profit. EUR/ha	332.0	527.3	265.9	193.8	329.8
7. Profitability rate. %	73.0	54.8	67.3	25.0	55.0
8.Production cost. EUR/t	76.4	84.0	166.0	243.5	142.5
9. Recompensating terms	1.4	1.8	1.5	4.0	2.2
Differentiated disking with soil slitting					
1. Yield. t/ha	6.31	12.79	2.53	3.60	-
2. Yield of forage units. t/ha	8.07	17.01	2.96	5.22	8.31
3. Yield of grain units. t/ha	6.31	12.79	5.06	6.48	7.66
4. Gross value. EUR	834.3	1,662.7	702.8	1,096.0	1,074.0
5. Expenditures. EUR	441.7	948.3	379.5	757.2	631.7
6. Profit. EUR/ha	392.6	714.4	323.3	338.8	442.2
7. Profitability rate. %	88.8	75.3	85.2	44.7	73.5
8.Production cost. EUR/t	70.0	74.2	150.0	210.4	126.1
9. Recompensating terms	1.1	1.3	1.2	2.2	1.4

Source: Own results.

In addition to being a sign of sensible resource management in agriculture, fuel consumption is one of the most important factors influencing production costs under various tillage schemes.

It was determined that the plowing system had the highest energy costs of all the tillage systems, followed by the disking and chiseling systems (Table 3). It has to do with the crop rotation's highest average fuel costs per hectare of arable land. Remarkably, in all tillage scenarios, grain corn was found to have the greatest average fuel expenditures, rather than soybeans, the commodity with the highest production cost.

Tillage minimization resulted in a great economy of financial resources, which reached 19.4% in case of chiseling and plowing comparison, and 75.5% in case of plowing and disking comparison, respectively.

Table 3. Fuel costs in the irrigated short grain crop rotation vary according to the tillage regimes (averaged data for 2021-2023, prices dated October 2024)

Indices and parameters	Crops				Average by the crop rotation
	Corn	Winter rapeseed	Winter wheat	Soybeans	
Differentiated plowing					
Tillage depth.cm	28-30	14-16	20-22	23-25	-
Fuel expenditures.L/ha	25.4	20.6	23.8	24.7	23.6
Fuel costs. EUR/ha	31.33	25.40	29.36	30.47	29.13
Energy of fuel. MJ/ha	1,211.6	982.6	1,135.3	1,178.2	1,126.9
Differentiated chiseling					
Tillage depth. cm	28-30	14-16	20-22	23-25	-
Fuel expenditures. L/ha	21.2	18.2	19.4	20.3	19.8
Fuel costs. EUR/ha	26.16	22.44	23.93	25.04	24.40
Energy of fuel. MJ/ha	1,011.2	868.1	925.4	968.3	943.3
Differentiated disking with soil slitting (on 38-40 cm once per the crop roatation)					
Tillage depth. cm	10-12	12-14	14-16	10-12	-
Fuel expenditures. L/ha	18.0	12.0	12.4	11.4	13.5
Fuel costs. EUR/ha	22.20	14.82	15.29	14.07	16.60
Energy of fuel. MJ/ha	858.6	572.4	591.5	543.8	641.6

Source: Own results.

Energy efficiency of fuel usage was also almost twice better in the variant of discing tillage than moldboard plowing. Thus, tillage minimization resulted in all-round improvement of economic efficiency of crop production, manifested in decreased production costs, increased profitability, fuel economy and better management of energy resources in general.

Our results find sufficient support in other studies. For instance, less tillage significantly lowered the energy expenses of growing sugar beets in Pannonia, improving crop production's economic and energetic efficiency [12]. Our findings are consistent with those of Romanian researchers who investigated the effects of various tillage strategies on winter wheat yields, soil characteristics, and the financial viability of agricultural production. Cociu (2011) claimed that all the conservation tillage options, namely, chisel tillage, disc tillage and zero tillage, provided more benefits for soil health (especially mechanical and physical properties), winter wheat yields and increased economic efficiency of crop cultivation. The greatest income and the least production costs among the tillage options were attributed to disking tillage, as in our study, while the highest costs and expenditures were recorded for traditional plowing tillage [5].

An extremely valuable improvement in economic efficiency of winter wheat production was registered in the study, devoted to the comparison of no-till and conventional tillage systems. Yield difference was insignificant (just about 35 kg/ha of wheat grain), while technological expenditures reduction, owing to cutting fuel costs down, reached 19.2% [3]. Apart from economic benefits, no-till system provided environmental benefits because of facilitating soil structure, properties and fertility preservation, and better water regime formation.

As for corn crops, it was also established that minimal tillage is not significantly inferior in yields compared to moldboard plowing, but provides great fuel economy and therefore, results in the best economic efficiency of corn grain production. The only drawback of tillage minimization was observed in higher weediness of crops [4]. However, rational use of selective herbicides can be suggested as a solution for this issue.

The study, devoted to sweet corn cultivation economic efficiency determination in the irrigated conditions of the Southern Steppe zone of Ukraine revealed that decreased tillage depth even under traditional moldboard tillage system provides better yields and increases crop profitability. The only condition when deep plowing is superior to minimized tillage is nutritional stress [10].

However, some studies claim different results. For example, Zhichkinaet al. (2021) stated that the best yields of soybeans were obtained under conventional plowing tillage in comparison to minimized tillage options. The authors admitted higher fuel and general costs for soybeans production in the variant of moldboard plowing, however, the total income because of significantly higher crop yield was better in this variant than in the variants with minimal tillage [21]. But another study provided evidence for better economic efficiency in minimal strip tillage system for soybeans cultivation, which provided higher profitability under the lower production costs [2]. Thus, it could be concluded that most scientific evidence favors tillage minimization to achieve the highest possible economic efficiency of crop production at the expense of cutting down fuel costs and labor expenditures.

CONCLUSIONS

The study's findings, which were recorded in 2021–2023, on dark-chestnut soil in the semi-arid environment of southern Ukraine, showed that the most cost-effective crop rotation strategy in the conditions of irrigation with average profit of 442.2 EUR/ha, and profitability rate of 73.5% under the highest yield of grain (7.66 t/ha) and forage (8.31 t/ha) units were provided by the differentiated disc tillage system with one soil slitting on the depth 38-40 cm per the crop rotation. Moldboard plowing and chiseling provided close economic outcomes, but chisel tillage saved more energy and fuel. Further investigations will be directed on no-till systems research.

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