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Technological peculiarities of the mustang and *Triticum dicoccum (Schrank) Schuebl* wheat cultivation according to organic farming standards

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Abstract

The research aim was to determine the technological peculiarities of growing mustard and *Triticum dicoccum* wheat by the organic farming methods on virgin lands in order to obtain agricultural products with the status of "organic". Crop rotation: winter rye – mustard – *Triticum dicoccum* wheat, where winter rye is a green manure, but mustard and *Triticum dicoccum* wheat are organic products was offered. Field experiments were conducted in the experimental field of Poltava State Agrarian University (Ukraine) over the period of three years (2018–2020). It was found that in the first year of the rotation, it is better to grow winter rye as a green manure crop, the residues of which correspond to the organic fertilizer system. For growing mustard in the second year, financial expenses of €81.5 ha^{-1} are required, and if organic products are sold locally, the profit will be €2987.5 ha^{-1}. For the third year, the financial expenses for growing *Triticum dicoccum* wheat will be €182.1 ha^{-1}, and the profit from its sale will be €13200 ha^{-1} under the same conditions. The cultivation of *Triticum dicoccum* wheat according to the organic technology provided a significant yield increase by 21.4% compared to the traditional technology, as evidenced by the analysis of the yield structure elements. It was determined that on virgin lands it is possible to obtain agricultural products with the status of "organic" in the second year after meeting the requirements of organic standards.

Keywords: organic farming, crop rotation, soil fertility, winter rye, mustard, *Triticum dicoccum* wheat

Introduction

At the present stage of human society development, the involvement of natural resources in the economic turnover has become so extensive and comprehensive that the links, relationships and circulation established in the biosphere are damaged, the face of the earth is degraded, i.e. the law of balanced use of natural resources is violated.

Increasingly, the effectiveness of the economic development model in developed countries is being questioned. The degree of contradictions in the society-nature interaction determines the need to restore the balanced use of natural resources. The integration of social production and the natural environment in the ecological production raises the problem of mutual transformation of the economic effect into the ecological one and vice versa.

Recognizing the necessity of introducing new production forms and methods on the principles of natural and anthropogenic balance of resources and environmental conservation, many countries have adopted special laws and developed various concepts. In Ukraine, the concept of agriculture sustainable development or organic farming is the most widespread. In fact, all known concepts indicate the need for ecologization of agriculture. One such area is organic farming. Organic agriculture involves the use of biological factors to increase the natural fertility of soils [1, 2], agroecological methods and biological means of pest and disease control [3, 4], creates conditions for the biodiversity protection [5]. This system is effective only under the balanced activity of all parts and can independently restore the used substances.

Organic agriculture can be defined as a multifunctional agro-ecological model of organic agricultural production with defined objectives, principles and methods, which is based on scientifically proven management of agro-ecosystems [6, 7].

In crop rotations of organic agriculture, built under such conditions, the sustainable ecological equilibrium of agrocenoses is achieved in the long run [8]. However, despite the sufficient advantages of organic agriculture over traditional [9, 10, 11], modern agricultural producers are in no hurry to implement it in practice.

So, scientists are faced with the necessity to assist domestic producers to develop technological solutions and justify their effectiveness (economic, technological, environmental and social), some experience of which has already existed [12, 13, 14].

Today, in Ukraine, the area under organic production is only 411 thousand hectares, on which there are about 200 farms producing organic agricultural products. It should be mentioned that more than 90% of the produced domestic organic products are exported. Domestic sales provide producers with a profitability of about 70%, while sales to EU member states – about 200% [15]. After the introduction of prices for "organic" products, most crops reached an acceptable level of profitability, with the exception of spring wheat, rye, barley and peas [16].

Therefore, in order to achieve a sustainable level of organic production competitiveness, it is necessary to provide the appropriate pricing mechanism for its operation, as it is practiced in other countries. In particular, the association of farmers in Kerala (India) into the trade organization (Fair Trade Alliance Kerala) allowed selling their organic products for export without intermediaries, which increased prices by 20–50% [17]. Research on the example of organic technology in New Zealand has shown that in order to increase profitability to the traditional technology level, prices for organic products must be higher by 27–45% [18].

Thus, the producers need to introduce the organic agriculture methods in order to enhance the profitability of agricultural production with a simultaneous reduction of the negative impact on the environment, soil fertility increase and agrobiocenosis restoration, the safety of agricultural products provision. This defines the relevance of our research, its scientific significance and practical value for agricultural producers.

Materials and Methods

The technological peculiarities of growing mustard and two-grained spelt according to organic farming system in the offered crop rotation: winter rye – mustard – *Triticum dicoccum* wheat were conducted during the period of 2018–2020 in the experimental field of Poltava State Agrarian University (Ukraine). The total area of the experimental plot was 25 hectares. This plot corresponds to the criterion "virgin lands". The experimental plot soil was chernozem with low humus content (4.9–5.2%), pH = 6.3. The nutrients content was: P_2O_5 – 100–150 mg kg^{-1}, K_2O – 160–200 mg kg^{-1}. Nitrogen content was quite low – 54.4–81.0 mg kg^{-1}. The stubble was broken with a disc harrow to a depth of 10–12 cm after harvesting winter rye (green manure). The plots shape for sowing seed was rectangular elongated. Mustard and *Triticum dicoccum* wheat seed were sown to a depth of 5–7 cm; width of row spacing was 15–20 cm.

Pre-sowing seed treatment was made by UV irradiation with a ZW20D15W lamp of 20 W [19]. Seeds were placed in a single layer on a grid with a mesh diameter of 2 mm and irradiated simultaneously from the top and bottom. The distance from the lamps to the grid with seeds was 25 cm. By changing the irradiation time and distance to the UV sources, the required irradiation dose was created. Based on the experience of using UV-C irradiation to stimulate carrot and winter wheat seeds [20], the optimal dose was found to be 150 J m^{-2}. The organic fertilizer system included the use of residues of postharvest green manure crop – winter rye. Yields of mustard and *Triticum dicoccum* wheat, as organic products, were determined in the full ripeness phase, recalculated to the standard grain moisture content of 14.0%.

Traditional growing technology provided foliar application of carbamide-ammonium mixture (CAM) in pure form in the tillering phase and in the wheat plants stem elongation phase.

Results and Discussion

In this research, we want to show the advantages of organic farming technologies over traditional ones and perform an economic justification through the example of growing one of the oldest wheat – *Triticum dicoccum (Schrank) Schuebl* wheat. According to the *T. Dicoccum* wheat cultivation technology by the organic farming methods, we offered the following crop rotation: winter rye – mustard – *T. Dicoccum* wheat. In our experiment, winter rye of Syntetyk variety of Ukrainian selection was chosen as a green manure for growing the main crops – mustard and *T. Dicoccum* wheat. This variety is characterized by high tillering, strong root system, and a resistance to the lodging, drought, low temperatures, weediness and disease. The rye root system improves soil properties through the accumulation of nitrogen, sugars, proteins and etc. in the root canal system. The crop residues are as natural mulch, which protects the soil from excessive moisture loss and frost, the fertile layer is not washed away even during heavy autumn rains [21].

T. Dicoccum wheat is of interest because this wheat variety has a higher nutritional value than soft wheat, and it is also a crop with a disease resistance high level, which meets the requirements of organic agriculture [22]. *T. Dicoccum* wheat is rich in proteins, carbohydrates, minerals, poor in fats, and therefore it is recognized as a very healthy cereal crop. The crude fat content of *T. Dicoccum* wheat ranges within 1.14% to 3.80%, the sugar content – from 0.09% to 1%, the protein content – 23.9%, which is one and a half times higher than of huskless wheat varieties [23]. In this regard, the demand for this crop has been increasing rapidly for the past 20 years and is predicted to continue to grow by about 5% annually.

For cultivation according to organic standards, we chose the *T. Dicoccum* wheat Holikovska variety. This variety is characterized by high yields, higher protein content than spelt, a low level of grain hoodness, easier grain threshing, resistance to lodging and diseases, does not require grain treatment [24].

Mustard was included in crop rotation because it leaves about 10 t ha^{-1} of plant residues in the air-dry mass, which can improve the soil organic matter in case of the proper involvement in the soil-absorption complex. A feature of mustard is that in frosts, the plant lies on the ground, thereby protecting its surface from freezing. Blue mustard of Prima variety was chosen among many other mustard varieties. The relatively great popularity of blue mustard among other species is explained, first of all, by its biological and ecological traits – drought tolerance and the ability to form economically effective yields in areas with a harsh hydrothermal coefficient. According to the adaptive cultivation technologies, up to 25.0–27.0 hundredweight ha^{-1} of blue mustard seed can be produced. The field experiments results are given in Table 1 and Table 2.

Table 1: The effect of cultivation technology and fertilizers on the field germination of winter wheat seeds

Technology	Plant residues, t ha^{-1}	Number of seedlings, pcs m^{-2}	Field germination, %	$N\text{-}NO_3$	P_2O_5	K_2O
Traditional	0.16	362	80.5	21.3	21.4	228
	0.19	374	83.1	19.7	22.2	223
	0.21	367	84.7	20.2	21.6	224
	average 0,19	368	82.8	20.4	21.7	225
Organic	1.01	410	86.7	23.5	27.3	262
	1.08	398	88.5	22.9	24.4	258
	1.12	413	91.8	24.7	26.2	261
	average 1,07	407	89.0	23.7	26.0	260

Note: $N\text{-}NO_3$, P_2O_5, K_2O – nitrate nitrogen content, mobile phosphorus, exchangeable potassium, mg kg of soil

As we can see from the data in Table 1, the mineral fertilizers application according to the traditional technology contributed to the accumulation of the main nutrients in the soil and at the *T. Dicoccum* wheat sowing, their content in the arable layer was on averaged: $N\text{-}NO_3$ – 20.4 mg kg^{-1}, P_2O_5 – 21.7 mg kg^{-1}, K_2O – 225 mg kg^{-1} of soil. As a result, field germination of wheat seed was 82.8%.

In the organic cultivation technology, the main plant nutrients are accumulated in the root system of winter rye, which is a green manure in the offered crop rotation. In addition, a significant amount of plant residues are accumulated in the soil after the mustard cultivation which are involved in the soil adsorption complex and improve the soil organic matter indicators. The increase of nitrate nitrogen $N\text{-}NO_3$ by 16.2%, mobile phosphorus P_2O_5 by 19.8% and exchangeable potassium K_2O by 15.5% is the result of the offered technology compared with the traditional one (Table 2).

Table 2: The effect of the cultivation technologies on the structure yield elements of *T. dicoccum* wheat

Technology	Number			1000-grain weight, g	Yield, t ha^{-1}
	Plant, pcs m^{-2}	Productive stems, pcs m^{-2}	Grains per spike, pcs		
Traditional	328	339	39	31.4	4.26
	321	344	37	32.2	
	317	327	39	31.7	
	average 322	337	38	31.8	
Organic	346	356	30	39.3	5.17
	355	368	32	38.9	
	361	371	34	37.8	
	average 354	365	32	38.7	

Sowing in this soil resulted in germination of 89.0 % of the number of seeds sown, which is 7.5% higher than the germination according to traditional technology.

The main elements of the *T. Dicoccum* wheat yield structure are the productive stem density, the number grains per spike, and the 1000-grain weight. Our research did not reveal the advantage of one of the factors on the grain yield – there is a direct correlation between all three elements of the yield structure and the wheat yield.

At the same time, higher indicators of productive stem density, the number grains per spike and grain weight were formed during the winter wheat cultivation according to organic technology, which predetermined a higher grain yield compared to traditional technology.

So, on average, the traditional technology received 337 pcs m^{-2} of productive stems, 38 grains per spike and 1000 grains weight was 31.8 g. The number of productive stems using organic technology was 8.3% more 1000 grains weight was also 21.7% more. It should be noted that the number grains per spike of wheat grown by traditional technology is 15.8% higher than of wheat grown by organic technology, however, based on the 1000 grains weight, we can conclude that grain can be characterized as small.

Thus, as the data in Table 2 show, the *T. Dicoccum* wheat cultivation according to organic technology is able to provide a reliable yield increase by 21.4% compared to the traditional technology. This is confirmed by the analysis of the elements yield structure.

The growing winter rye technology for green manure, taking into account the requirements of organic production involves the operations given in Table 3. The seeding rate of winter rye was 250 kg ha^{-1}. These prices are valid for October 2021: diesel cost is €0.9 per liter; winter rye seed Syntetyk variety is €273.45 per ton.

Table 3: Technological cad of winter rye cultivation by the organic farming standards (first year)

Operations type	Agricultural machinery	Agricultural machinery type	Wages, €	Diesel consumption, *l*	Cost biologics, €	Total cost, €
Soil harrowing	15-27 HP tractor	Disc Harrow KDN-3.1	7.3	75		74.9
Soil cultivation	15-27 HP tractor	Soil cultivator	26.6	300		296.8
Sowing operations + seeds at the rate 250 kg ha^{-1}	15-27 HP tractor	Roto Seed Drill	33.8	200		1923.0
Biological treatment	15-27 HP tractor	GreenSystem Fertilizer Broadcaster	4.6	75	321.7	393.9
Green manure treatment	15-27 HP tractor	Normandie 60 disc shelling machine	23.9	350		339.1
Production costs						3027.7
Unforeseen costs (20 %)						586.3
Total production costs						3614.0

The data show that the highest expenses in the production costs are the expenses for the seed purchase (€1709) and diesel cost (€901). In total, the financial expenses in the first year will be €3614 (€144.6 ha^{-1}), taking into consideration the unforeseen costs of 20%. No profit is expected in the first year, as winter rye will function as a green manure to improve soil structure and properties, which will reduce the expenses for tillage in the following year. In the second year of crop rotation, it was planned to grow mustard to improve the field phytosanitary condition. Mustard seeding rate was 1.5 million pcs ha^{-1} (16 kg ha^{-1}). The cost of seed was €836.43 per ton. Technology of blue mustard cultivation Prima variety taking into account the organic farming requirements in our experiments is shown in Table 4.

Table 4: Technological cad of blue mustard Prima variety cultivation by the organic farming standards (second year)

Operations type	Agricultural machinery	Agricultural machinery type	Wages, €	Diesel consumption, *l*	Cost biologics, €	Total cost, €
Soil cultivation	15-27 HP tractor	Soil cultivator	26.6	250	-	6.2
Rolling crops	15-27 HP tractor	Tractor Operated Land Leveler	7.3	75	-	8.1
Sowing operations + seeds at the rate 16 kg ha^{-1}	15-27 HP tractor	Green System Roto Seeder	33.8	125	-	480.9
Pre-emergence weed harrowing	15-27 HP tractor	Disc Harrow KDN-3.1		100	-	97.4
Post-emergence weed harrowing	15-27 HP tractor	Disc Harrow KDN-3.1	7.3	100	-	97.4
Biological treatment	15-27 HP tractor	Cima Blitz 45 Trailed Low Volume Sprayer	7.3	125	321.7	438.9
Harvesting	harvester "SAMPO-500"		4.6	250	-	281.5
Production costs						53552.0
Unforeseen costs (20 %)						9820.0
Total production costs						63372.0

In accordance with the calculations, the largest part of expenses is the expenses for diesel cost – €923.3. The share of seed costs in total production costs is 19.4% (€334.6), which is significantly lower than the cost of winter rye due to the reduced seeding rate. This will result in production expenses of €1722.8 and, taking into account unforeseen costs, total cost of €2038.7 or €81.5 per hectare.

So, at the second year summary, the yield of blue mustard Prima variety with "organic" status will be up to 2.0 t ha^{-1}. It is necessary to admit that the organic mustard seed cost on the domestic market is in the range of €3.1 kg^{-1}. Producers can directly sell their products at least at a price of €1.54 kg^{-1}. Therefore, the revenue from the sale of a 50 t yield of organic mustard is approximately €77200.

T. Dicoccum wheat was planned for crop rotation in the third year. Seeding rate of *T. Dicoccum* wheat Holikovska variety was 4.5 million pcs ha^{-1} (200 kg ha^{-1}). The cost of seed was €482.5 per ton. Considering the organic farming requirements, the technology of the *T. Dicoccum* wheat growing is shown in Table 5.

Table 5: Technological cad of *T. dicoccum* wheat Holikovska variety cultivation by the organic farming standards (third year)

Operations type	Agricultural machinery	Agricultural Machinery type	Wages, €	Diesel consumption, *l*	Cost biologics, €	Total cost, €
Crop residue treatment	15-27 HP tractor	Cima Blitz 45 Trailed Low Volume Sprayer	17.7	125	-	130.3
Disking stubble	15-27 HP tractor	Normandie 60 disc shelling machine	17.7	225	-	220.4
Sowing operations + seeds at the rate 200 kg ha^{-1}	15-27 HP tractor	Green System Roto Seeder	7.3	100	-	2510.2
Autumn harrowing in the tillering phase	15-27 HP tractor	Disc Harrow KDN-3.1		125	-	117.1
Autumn biological treatment	15-27 HP tractor	Cima Blitz 45 Trailed Low Volume Sprayer	4.5	125	321.7	441.6
Spring harrowing	15-27 HP tractor	Disc Harrow KDN-3.1	7.3	125	-	117.1
Spring biological treatment in the phase of going into the tube	15-27 HP tractor	Cima Blitz 45 Trailed Low Volume Sprayer	4.5	125	321.7	438.9
Harvesting	harvester "SAMPO-500"		4.6	200	-	236.5
Production costs						4212.0
Unforeseen costs (20 %)						339.4
Total production costs						4551.4

The total production costs for the third year will be €4551.4 (€182.1 ha^{-1}), including unforeseen costs (20%). In the expenses structure, the largest part of 57.3% (€2412.8) is for seed, which is determined by the seeding rate, as in the case of winter rye. The diesel expenses are 1150 liters, which according to Table 3 and 4 is slightly higher than the expenses for growing winter rye (1000 liters) and mustard (1025 liters).

The potential yield of *T. Dicoccum* wheat Holikovska variety is 5.0 t ha^{-1}, while the real yield is 4.0 t ha^{-1}. The real yield was used in the calculations. According to our research, the cost of organic *T. Dicoccum* wheat on the domestic market fluctuates in the range of €8.4 kg^{-1}.

Therefore, a producer will be able to sell it at a price of €3.3 kg^{-1} and get revenue from the sale of 100 tons of organic wheat in the sum of €330000. Thus, it is reasonable to assess the growing organic products effectiveness according to the all three years data in order to prove the transition efficiency from traditional farming to organic farming from an economic point of view (Table 6). The total production costs have not included tax payments, depreciation and rent, as they are individual and not averaged.

Table 6: Indicators of economic performance for growing mustard and *T. Dicoccum* wheat using organic farming methods for three years, €

Income and expenditure forms	**Indicators**		
	Firs year - winter rye (green manure)	**Second year - organic mustard**	**Third year - *T. Dicoccum* wheat organic**
Full production cost, €	3614.0	2038.7	4551.4
Payment for inspection and certification by the organic standards, €	482.6	482.6	482.6
Product price, € t^{-1}	-	1544.2	3345.7
Product Sales Revenues, €	-	77208.6	334570.8
Income / loss, €	-4096.5	74687.4	329536.9

These calculations show that in the first year, a producer will have only financial expenses of €4096.5, while the profit for the next two years will be €404200, which fully covers the expenses for all years. Furthermore, the net profit in the second year exceeds the expenses by 29.6 times and in the third year by 65.5 times, which indicates the high effectiveness of growing mustard and *T. Dicoccum* wheat according to organic standards even in case of no profit in the first year.

The financial safety margin of €400100 makes it possible to fully cover the fixed costs which we did not take into account (land and fixed asset rent, taxes, etc.).

It is worth noting that *T. Dicoccum* wheat is in considerable demand on the European market, due to its magnesium content, eight essential amino acids and low gluten content. Organic *T. Dicoccum* wheat production is priced approximately from €10 kg^{-1}, which raises the prospect of selling organic raw materials for export.

Conclusions

Research results found that introduction of organic farming on virgin lands allows obtaining farm products with “organic” status in the second year. The use of winter rye as a green manure crop increases soil fertility and improves its structure, positively affects the soil microorganism’s development, improves the crops phytosanitary condition and provides effective weed control, etc. This crop is an effective preceding crop, which provides the conditions for the potential yield of organic mustard and *T. Dicoccum* wheat, especially given the seed treatment with UV-C rays.

Growing mustard and *T. Dicoccum* wheat according to organic standards on the area of 25 hectares needs financing in the amount of €2038.7 (€81.5 per hectare) and €4551.4 (€182.1 per hectare), respectively. Revenue from their sale with status of “organic products” on domestic market may be €77200 and €334600, respectively.

Conflict of interest statement

We declare that we have no conflict of interest

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