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ECONOMIC EFFICIENCY OF GROWING DIFFERENT GROUPS OF TOMATOES IN WINTER GREENHOUSES OF THE STEPPE ZONE OF UKRAINE

Abstract

The article analyzes the economic efficiency of cultivating indeterminate tomato hybrids from various groups in modern winter greenhouses at Dniprovskyi TC LLC. The experimental research was conducted over a period of three years (2021–2023) and involved the indeterminate tomato hybrids Merlis F_1 (as the control), Torero F_1, DRC-564 F_1, Fujimaro F_1, and Biorange F_1. The study assessed the economic efficiency of cultivation, conducted phenological observations, tracked the dynamics of yield formation, and evaluated the marketability of the fruits produced by these hybrids. Additionally, the research explored the adaptation of the hybrids to the growing conditions of winter greenhouses in Ukraine's Steppe zone.

The findings demonstrated an increase in profitability for growing various tomato groups compared to the red-fruited tomato group. Specifically, there was a 17.7% increase in the DRC-564 F_1 cherry group, an 8.7% increase in the Yellow Beef Biorange F_1 group, and a 4.7% increase in the pink-fruited Fujimaro group. By introducing new hybrids into crop rotations, net profits per square meter could reach UAH 1,280.9/m² for DRC-564 hybrids, UAH 802.4/m² for Biorange, and UAH 655.4/m² for Fujimaro.

These results offer valuable insights for greenhouse operations, aiding in the selection of the most economically efficient, high-yield, and well-adapted tomato hybrids for cultivation in winter greenhouses, ultimately boosting overall economic efficiency.

Key words: *group, economic efficiency, cost price, winter greenhouses, net profit, technology, productivity, profitability.*

Introduction. Tomatoes have a long-standing history and are widely cultivated across many countries. Among all vegetable crops, tomatoes stand out due to their significant nutritional value, offering a variety of proteins, sugars, organic acids, vitamins, and minerals that are crucial for human metabolism. They also boost appetite and help maintain overall performance [14]. The extensive distribution of tomatoes is largely due to their excellent taste and high nutritional properties [6].

In 2022, Ukraine produced approximately 2.44 million tons of tomatoes, with 0.23 million tons grown in greenhouse environments. Across the country, tomatoes are cultivated on about 75.8 thousand hectares, with around 3 thousand hectares allocated for greenhouse cultivation [3]. Today, tomatoes are the most widely grown crop in protected soil in Ukraine [12]. Around 400 hectares of industrial greenhouses in Ukraine are dedicated to this crop, producing nearly 1 million tons of tomatoes [7].

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Globally, the leading tomato producers include China, Mexico, Italy, Spain, and the United States. According to 2019 FAO data, tomatoes held the top spot in terms of cultivation area among fruit and vegetable crops worldwide, with about 4 million hectares under cultivation, 60% of which are in protected environments. In 2019, China had the largest tomato-growing area, with over 1 million hectares producing 67.76 million tons. India followed with 520 thousand hectares (19 million tons), Turkey with 225 thousand hectares (12.84 million tons), Egypt with 200 thousand hectares (6.75 million tons), and the United States with 200 thousand hectares (10.86 million tons). Additionally, Italy and Iran produced over 5 million tons each. In total, global tomato production reached 158.4 million tons in 2019, with a yearly growth rate of 3% [9; 10].

Tomato trade within EU countries, encompassing both fresh and frozen products, amounts to roughly 2 billion euros. According to international market data, tomatoes dominate the vegetable market, with fresh tomatoes accounting for over 50% of sales and processed tomatoes comprising the rest. In global tomato production, the Netherlands contributes 1%, Spain 4%, Italy and Egypt 6%, Turkey 8%, and the USA and China 15% each [15].

For successful tomato cultivation in extended greenhouse systems, heterosis hybrids must meet certain criteria. These hybrids should be early-maturing, less reliant on high-intensity light and long daylight hours, exhibit vigorous growth and fruiting, and be resistant to diseases. They must also maintain a high fruit set rate under low light conditions, ensure high productivity (at least 30 kg/m²), and produce high-quality fruit [2; 7]. Furthermore, these hybrids must be adaptable to varying light conditions and higher humidity levels, which improves plant resistance to fungal diseases and positively influences yield [8].

The application of different technological approaches in tomato cultivation affects production costs, profitability, and overall yield per unit area. The integration of new technological elements in winter greenhouse systems can enhance production efficiency and guarantee the ecological safety of vegetables, which is achievable only in modern greenhouse complexes utilizing small-volume hydroponic methods [11].

The purpose of the research is to determine the economic efficiency of growing different groups of tomatoes in winter greenhouses of the Steppe zone of Ukraine.

After conducting an analysis of literary sources, it became known that growing tomatoes in winter greenhouses is a fairly profitable area of agribusiness, under the conditions of compliance with the technology of intensive cultivation, improvement of the elements of cultivation technology, rational selection of the assortment of hybrids and types of tomatoes, favorable market conditions, it is possible to get the maximum income from area of greenhouses.

An overview of the main material. The research was conducted at the modern enterprise LLC TC "Dniprovskyi," located in the Dnipropetrovsk region, from 2021 to 2023. The winter greenhouses employed automated processes, including computer-controlled microclimate regulation and drip irrigation throughout the study period. The research focused on various heterozygous tomato hybrids from the Dutch manufacturer Monsanto. The hybrids under investigation included: red-fruited Merlis F_1 (control), pink-fruited Fujimaro F_1, yellow beef Biorange F_1, red beef Torero F_1, and red cherry DRC-564 F_1.

The experimental design followed a systematic, regular placement scheme with four replications. The accounting plot covered 10 m², while the total plot area was 14 m², with the overall experiment spanning 224 m². Seedlings were grown using a classical 35-day method and transplanted to a permanent growing location at the 9–11 true leaf stage. Plants were placed on "Hrodan Master" mineral wool substrate (100 x 20 x 7.5 cm), with each plant occupying 3.75 liters of substrate. The initial planting density was 2.5 plants per m², which was later increased to 3.1 stems per m², and eventually to 3.7 stems per m² (for DRC-564 F_1). Each accounting plot housed 25 plants.

Once the seedlings were transplanted into the greenhouse, plant care followed standard greenhouse cultivation technology. Microclimate, irrigation, and fertilization were adjusted to meet the biological needs of the tomato plants. Harvesting took place during the fruiting months (March to November), three times a week. Data collection and observations adhered to established methods as outlined in "Experimental Case in Agronomy" and the "Methodology of Experimental Case in Vegetable and Melon Growing." Economic efficiency was evaluated based on the yield value and additional expenses incurred to increase yield, using actual cost data [1; 4; 10]. An integrated pest and disease management system was also implemented to protect the plants.

Results and discussion. During the phenological observations conducted between 2021 and 2023, several key findings were made. Tomato hybrid seeds were sown in the second decade of December, which is considered the optimal period for winter greenhouse planting, given the climatic zone of the facility. By the third day, individual seedlings of all hybrids began to emerge, and over 75% of mass seedlings were observed by the fifth day, attributed to the ideal microclimate in the seed germination chamber, where the substrate temperature was 25°C, and the relative humidity was 90%.

The third leaf appeared earliest on the tenth day after sowing in the DRC-564 hybrids, while in the Fujimaro hybrid, it appeared on the eleventh day. For the Torero, Merlis, and Biorange hybrids, the third leaf appeared on the twelfth day. All hybrids were transferred to mineral wool cubes 14 days after sowing. Seedlings were relocated to the seedling greenhouse 10 days after diving, and final planting in the permanent greenhouse occurred on the 35th day post-sowing. Seedlings showed uniform growth, with the first panicle distinctly formed on the Biorange and DRC-564 hybrids. In the Merlis, Fujimaro, and Torero hybrids, the panicle emerged from the stem 39 days after germination, and the first fruits appeared 41–43 days after germination in all hybrids.

To increase plant density to 3.1 plants per m², an additional stem was introduced during the second decade of February over the three-year period. For the DRC-564 hybrid, the density was further increased to 3.7 plants per m² in the first decade of April.

Tomato harvesting began earliest with the DRC-564 hybrid, 94 days after germination, in the second decade of March. The Merlis, Fujimaro, Biorange, and Torero hybrids started fruiting in the third decade of March, between 100–105 days after germination. Mass fruiting began at the end of March for the DRC-564 F_1 hybrid, while the other hybrids reached mass fruiting in the first decade of April.

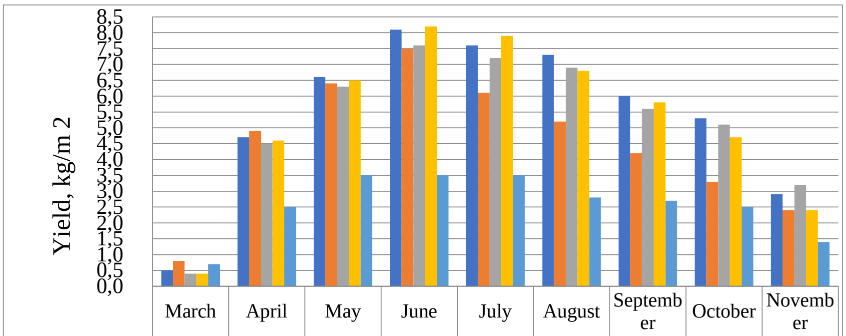
Table 1 shows the biometric data for tomato fruits during the mass fruiting phase (April – May). The average fruit weight for the hybrids was as follows: DRC-564 F_1 – 23.9 g, Merlis F_1 – 158.5 g, Fujimaro F_1 – 196.1 g, Torero F_1 – 207.6 g, and Biorange F_1 – 221.2 g. The average number of fruits per bunch was: Biorange F_1 – 3.7, Fujimaro F_1 and Torero F_1 – 23.9, and Merlis F_1 – 4.9.

Table 1. Indicators of biometric measurements of tomato fruits in the phase of the beginning of mass fruiting (April–May), 2022–2023

Hybrid	Weight of the fruit, g	Fruit diameter, cm	The number of fruits in a bunch, pcs.	Fruit height, cm	Index fetus	Chamberiness, %
Merlis	158,5	6,9	4,9	5,7	0,85	3 camera – 0% 4 camera – 25% 5 camera – 75%
Fujimaro	196,1	7,7	3,9	7,1	0,92	5 camera – 0% 6 cameras – 50% 7 cameras – 50%
Biorange	221,2	7,8	3,7	7,4	0,95	5 camera – 0% 6 camera – 75% 7 cameras – 25%
Torero	207,6	7,9	3,9	7,2	0,90	4 camera – 0% 5 camera – 25% 6 cameras – 75%
DRC-564	23,9	6,5	12,0	2,8	1,03	2 camera – 100% 3 camera – 0% 4 cameras – 0%

The removal of tops and growth points across all tomato hybrids was conducted simultaneously on September 15, approximately eight weeks (55 days) before the final fruit collection. The plants of all hybrids reached senescence simultaneously on November 15. Over the years of the study, the total vegetation period was 335 days.

On average, tomato plants bore fruit for a period ranging from 227 to 230 days during the 2021–2023 studies. Figure 1 provides a detailed representation of the yield dynamics across all the months of fruiting, including March, April, May, June, July, August, September, October, and November.



	March	April	May	June	July	August	Septemb er	October	Novemb er
Merlis F1	0,5	4,7	6,6	8,1	7,6	7,3	6,0	5,3	2,9
Fujimaro F1	0,8	4,9	6,4	7,5	6,1	5,2	4,2	3,3	2,4
Biorange F1	0,4	4,5	6,3	7,6	7,2	6,9	5,6	5,1	3,2
Torero F1	0,4	4,6	6,5	8,2	7,9	6,8	5,8	4,7	2,4
DRC-564 F1	0,7	2,5	3,5	3,5	3,5	2,8	2,7	2,5	1,4

Fig. 1. Yield dynamics of different groups of tomatoes per month, kg/m²

The total yield on average for 2021–2023 on different tomato groups was as follows: hybrid DRC-564 produced the lowest yield and it was 23.1 kg/m², Fujimaro F_1 produced yield at the level of 40.8 kg/m², in Biorange F_1 the productivity indicator was at the level of 47.0 kg/m², the Torero F_1 hybrid achieved a productivity of 47.3 kg/m². The highest yield in the group of medium-fruitful tomato Merlis F_1 (Table 2).

Table 2. Total yield of indeterminate tomato hybrids of different groups on average for the research period 2021–2023

Version	Yield, kg/m2			
	2021	2022	2023	average yield
Merlis F1	47,7	48,6	50,6	49,0
Fujimaro F1	41,3	40,9	40,2	40,8
Biorange F1	46,4	47,2	47,5	47,0
Torero F1	48,1	46,8	47,0	47,3
DRC-564 F1	23,1	22,6	23,7	23,1
NIR, 05 kg/m2				

The cherry DRC-564 hybrid demonstrated the highest marketability, reaching 97.1%. The yellow beef hybrid Biorange F1 had the lowest marketability at 90.2%. The pink-fruited Fujimaro F1 achieved a marketability of 91.9%, while the red beef Torero F1 and Merlis F1 hybrids showed marketability levels of 92.7% and 94.8%, respectively (Table 3).

From the analysis of marketability for the indeterminate tomato hybrids of various groups over the study period, it can be concluded that these hybrids, when cultivated in winter greenhouses under extended culture, achieve high marketability levels ranging from 90.2% to 97.1%.

Table 3. Marketability of tomato hybrids of different groups for 2021–2023

Hybrid	Marketability, %			
	2021	2022	2023	average marketability
Merlis F1	94,7	94,8	94,8	94,8
Fujimaro F1	91,9	91,8	92,1	91,9
Biorange F1	90,9	90,9	88,9	90,2
Torero F1	92,4	93,1	92,7	92,7
DRC-564 F1	96,4	97,6	97,3	97,1
NIR, 05 kg/m2				

The assessment of the economic efficiency of cultivating indeterminate tomato hybrids of various groups in winter greenhouses revealed that the total cost of cultivation is relatively high, ranging from UAH 1,740.1/m² to UAH 1,904.7/m² (Table 4). For the Merlis F_1 control, the total cost was UAH 1,753.9/m². The lowest cost was observed in the Torero F_1 hybrid, amounting to UAH 1,740.1/m², which is UAH 13.8/m² lower than the control. On the other hand, the highest cost was recorded for DRC-564 F1 at UAH 1,904.7/m², exceeding the control by UAH 150.8/m². The cost for Biorange F_1 was UAH 1,769.3/m², which is UAH 15.4/m² higher than the control. Torero F_1 had a cost of UAH 1,750.3/m², which is UAH 3.6/m² below the control (Table 4, Fig. 2). These costs include major expenses such as energy, labor, raw materials, packaging, logistics, marketing, fixed costs, and other associated expenses.

Table 4. Economic efficiency of tomato cultivation of different groups for 2021–2023

Indicator	Version				
	Merlis F1 (control)	Fujimaro F1	Biorange F1	Torero F1	DRC-564 F1
Yield, kg/m2	49,0	40,8	47,0	47,3	23,1
Marketability, %	94,8	91,9	90,2	92,7	97,1
Yield increase, kg/m2	0,0	-8,2	-2,0	-1,7	-25,9
Increase in marketability, %	0,0	-2,9	-4,6	-2,1	2,3
Profitability from UAH /m2	2264,0	2405,7	2571,7	2078,9	3185,6
Base costs for energy carriers, UAH /m2	641,2	641,2	641,2	641,2	641,2
Base salary costs, UAH /m2	604,1	576,2	589,7	591,1	619,5
Basic costs of raw materials, UAH /m2	250,1	289,4	292,1	261,2	308,4
Costs for packaging, logistics, marketing, UAH /m2	97,1	82,1	84,9	85,2	174,2
Fixed costs, UAH /m2	64,5	64,5	64,5	64,5	64,5
Other expenses, UAH /m2	96,9	96,9	96,9	96,9	96,9
Total production costs, UAH /m2	1495,4	1588,9	1523,0	1493,5	1569,1
Full cost, UAH /m2	1753,9	1750,3	1769,3	1740,1	1904,7
Notional net profit, UAH /m2	510,1	655,4	802,4	338,8	1280,9
The level of profitability, %	22,5	27,2	31,2	16,3	40,2
Increase in the level of profitability, %	0,0	4,7	8,7	-6,2	17,7

The basic costs for energy carriers (natural gas, biofuel, electricity) were UAH 641.2/m², accounting for 36.6% of the total cultivation cost. This figure remained constant across all hybrids since the same microclimate was maintained in the winter greenhouse for all tomato groups (Table 4).

As for wage costs, the control hybrid Merlis F_1 had basic wage expenses of UAH 604.1/m². The lowest wage costs were recorded for Fujimaro F_1 at UAH 576.2/m², which is UAH 27.9/m² less than the control. The highest wage costs were found in DRC-564 F_1, reaching UAH 619.5/m², which is UAH 15.4/m² more than the control. The Biorange F_1 and Torero F_1 hybrids had wage costs ranging from UAH 589.7 to UAH 591.1/m², which is UAH 13.0–14.4/m² lower than the control.

The variation in basic wage costs is primarily attributed to differences in yield between the tomato groups. In particular, hybrids in the cherry tomato group required the highest wage expenses due to the intensive labor demands of their cultivation. Overall, wage costs accounted for 32.1% to 34.1% of the total cost structure (Table 4).

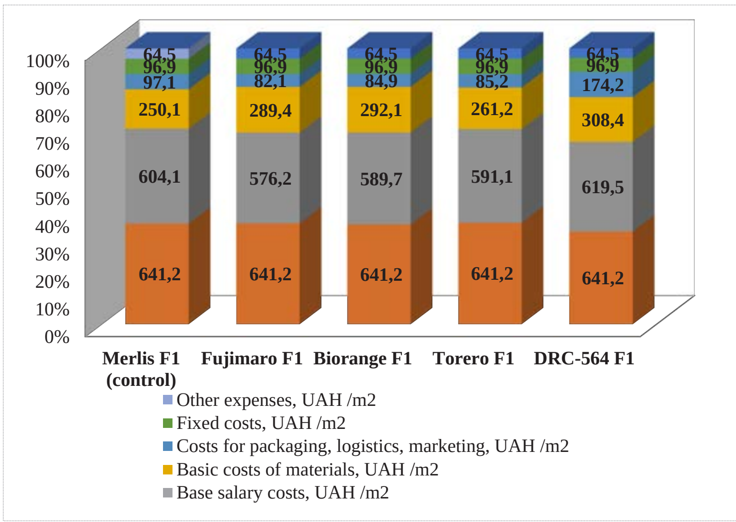


Fig. 2. The full cost of growing different groups of tomatoes on average in 2021–2023

The basic costs for materials in tomato cultivation encompass various categories, including mineral fertilizers, seeds, substrates, plant protection products, pollination materials, and agrotechnical materials. For all hybrids, these costs were managed uniformly, with identical planting densities, irrigation schedules, plant nutrition, substrates, microclimate control, and pest management. The variance in basic costs for materials across different hybrids was primarily due to the differing costs of seeds, ranging from UAH 250.1 to UAH 308.4 per m², which represents 14.1% to 16.2% of the total cultivation cost.

Costs associated with packaging, logistics, and marketing were UAH 97.1/m² for the control hybrid, Merlis F_1. The highest costs were observed for DRC-564 F_1 at UAH 174.2/m², which is UAH 77.1/m² more than the control, attributed to additional packaging expenses. Conversely, Fujimaro F_1 had the lowest costs in this category at UAH 82.1/m², UAH 15.1/m² less than the control. Biorange F_1 and Torero F_1 had packaging, logistics, and marketing costs ranging from UAH 84.9 to UAH 85.2/m², which is 11.2–12.1/m² lower than the control. These costs constituted 4.7% to 9.1% of the total cost (Table 5).

Fixed costs, including fuel, lubricants, and repairs, were consistent across all tomato groups, at UAH 64.5/m², accounting for 5.1% to 5.6% of the total cost. Other expenses, such as depreciation, rent taxes, dividends, and social contributions, amounted to 3.4% to 3.7% of the total cost, or UAH 96.9/m² (Table 4).

In terms of profitability, the financial returns per m² ranged from UAH 2,078.9 to UAH 3,185.6. For Merlis F_1, the control hybrid, profitability was UAH 2,264.0/m². The highest profitability was achieved by DRC-564 F_1, with UAH 3,186.5/m², which is UAH 921.6/m² or 40.7% higher than the control. Torero F_1 had the lowest profitability at UAH 2,078.9/m², UAH 185.1/m² or 8.2% less than the control. Fujimaro F_1 recorded a profitability of UAH 2,405.7/m², UAH 141.7/m² or 6.3% more than the control. Biorange F_1 achieved a profitability of UAH 2,571.7/m², which is UAH 307.7/m² or 16.6% higher than the control (Table 4).

The net profit per m² for the control hybrid, Merlis F_1, was UAH 510.1. DRC-564 F_1 had the highest net profit at UAH 1,280.9/m², UAH 770.8/m² or 151.1% higher than the control. Torero F_1 recorded the lowest net profit at UAH 338.8/m², UAH 171.3/m² or 33.6% less than the control. Biorange F_1 netted UAH 802.4/m², which is UAH 292.3/m² or 57.3% more than the control. Fujimaro F_1 generated a net profit of UAH 655.4/m², UAH 145.3/m² or 28.5% higher than the control (Table 4).

The profitability of growing different tomato groups in winter greenhouses from 2021 to 2023 varied from 16.3% for Torero F_1 to 40.2% for DRC-564 F_1. Biorange F_1 had a profitability of 31.2%, while Fujimaro F_1 achieved 27.2%. The control hybrid Merlis F_1 had a profitability level of 22.5% (Table 4).

Conclusions. The following conclusions can be made in the process of research on promising indeterminate tomato hybrids of various groups, conducted in 2021–2023.

1. The adherence to technological maps in winter greenhouses was confirmed, with no deviations observed in plant growth timelines. The biometric characteristics of the tomato fruits aligned with those specified by the Dutch manufacturer, Monsanto.

2. The total cost of cultivating indeterminate tomato hybrids varied between UAH 1,740.1 and UAH 1,904.7 per square meter. Productivity and marketability of tomatoes significantly impact these costs, particularly through wages and packaging, logistics, and marketing expenses. Additionally, the cost of seeds affects the overall cost price.

Introducing new, promising hybrids into crop rotation can lead to increased profitability compared to the red-fruited Merlis F1 hybrid. Specifically, the cherry group DRC-564 F_1 showed a 17.7% increase, the yellow beef Biorange F_1 a 8.7% increase, and the pink-fruited Fujimaro F_1 a 4.7% increase.

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ЕКОНОМІЧНА ЕФЕКТИВНІСТЬ ВИРОЩУВАННЯ РІЗНИХ ГРУП ПОМІДОРА В ЗИМОВИХ ТЕПЛИЦЯХ СТЕПОВОЇ ЗОНИ УКРАЇНИ

Анотація

У статті розглянуто економічну ефективність вирощування індетермінантних гібридів помідора різних груп, вирощених у зимових теплицях в сучасному тепличному комплексі ТОВ ТК «Дніпровський». Експериментальні дослідження проводили протягом трьох років (2021–2023 рр.). Дослідження виконували з індетермінантними гібридами помідора: Мерліс F_1 (контроль), Тореро F_1 DRC-564 F_1, Фуджимаро F_1, Біоранж F_1. Дослідження визначає економічну ефективність вирощування, фенологічні спостереження, динаміку формування врожайності та товарність плодів індетермінантних гібридів. Одночасно представлено пристосування гібридів до умов вирощування в зимових теплицях Степової зони України.

Дослідження показали приріст рентабельності вирощування різних груп помідора порівняно з групою червоно плідного помідора, а саме: в групи чері на DRC-564 F_1 приріст 17,7%, група жовтий біф Біоранж F_1 приріст 8,7%, група рожево плідний помідор Фуджимаро F_1 приріст 4,7%. При впровадженні в культурозміну нових гібридів різних груп можна отримати показник чистого прибутку з м² на гібридах DRC-564 1280,9 грн. /м², Біоранж 802,4 грн. /м², Фуджимаро 655,4 грн. /м².

Отримані результати надають цінну інформацію для тепличних комбінатів щодо вибору найбільш продуктивних економічно вигідних та пристосованих гібридів помідора для вирощування в зимових теплицях, сприяючи підвищенню економічної ефективності.

Ключові слова: *група, економічна ефективність, собівартість, зимові теплиці, чистий прибуток, технологія, урожайність, рентабельність.*

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