UDC 635.63.044:631.527.5:631.55]:[338.31:631.544.4"324"]
DOI https://doi.org/10.32782/2226-0099.2026.148.2.2

SELECTION BY YIELD POTENTIAL AND ECONOMIC EFFICIENCY OF PARTHENOCARPIC CUCUMBER HYBRIDS FOR GROWING IN WINTER GREENHOUSES

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The article presents the results of studies on parthenocarpic cucumber hybrids cultivated in winter greenhouses of the IV light zone, evaluating morpho-biometric indicators, fruiting structure, fruit quality, yield level, and economic efficiency. The problem of increasing productivity and commercial feasibility of cucumber cultivation in protected conditions remains relevant for modern horticulture. High-yielding parthenocarpic hybrids provide stable fruiting, improved fruit quality, and efficient use of greenhouse area, which is particularly important for winter intensive cultivation.

The aim of the study was to comprehensively evaluate parthenocarpic cucumber hybrids to determine their suitability for intensive commercial production. Research was conducted during 2023–2025 at LLC TC "Dniprovskiy" (Dnipropetrovsk region) in glass greenhouses of the "Anthracite" type. Cucumbers were grown using low-volume hydroponics on "Begrow" mineral wool substrate. Climate and nutrient control were provided by the automated "Priva Integro" system.

Experimental design included systematic placement with four replicates: plot area – 10 m², plant density – 2.5 plants/m², spacing – 1.6 × 0.25 m, and 4 plants per substrate unit. Seeds were sown in mineral wool cubes, and seedlings were transplanted at 26 days. Pest and disease control followed an integrated system. Harvest was performed every other day throughout the fruiting period (March–June).

Studied hybrids: Spino F_1 (control, Syngenta), Madrilen F_1 (Seminis), Elvinara F_1, and Ilonara F_1 (Rijk Zwaan). Morphometric parameters, number of fruits per plant, average fruit weight, production cost, and economic efficiency were assessed. Spino F_1 showed the highest vegetative growth, while Madrilen F_1 and Elvinara F_1 demonstrated superior generative performance. Number of fruits per plant: Madrilen F_1 – 81.4, Elvinara F_1 – 79.9, Ilonara F_1 – 74.1; average fruit weight – 128.6–130.1 g.

Production costs remained high: energy – 628.1 UAH/m², labor – 311.9–330.5 UAH/m², raw materials – 224.1 UAH/m², packaging/logistics/marketing – 87.4–94.5 UAH/m², fixed and other costs – 35.8 UAH/m². Total costs – 1164.1–1182.7 UAH/m²; full production cost – 1287.3–1313.0 UAH/m².

Economic assessment demonstrated the advantage of Elvinara F_1 and Madrilen F_1: income per m² – 1749.7 and 1712.2 UAH, net profit – 439.8 and 399.2 UAH, profitability – 33.6% and 30.4%. Ilonara F_1 was intermediate; control – lowest.

Conclusions. Elvinara F_1 and Madrilen F_1 possess high potential for generative organ formation, higher fruit weight, and yield realization, ensuring commercial efficiency and profitability in winter greenhouses. Results provide a scientific basis for technological optimization and further research in intensive vegetable production.

Key words: *parthenocarpic hybrids, cucumber, winter greenhouse, economic efficiency, production cost, yield.*

Карачун В.Л., Галагуря А.О., Лебединський І.В. Відбір за потенціалом урожайності та економічною ефективністю партенокарпічних гібридів огірка для вирощування в зимових теплицях

У статті наведено результати досліджень щодо оцінки партенокарпічних гібридів огірка, вирощуваних у зимових теплицях IV світлової зони, за морфо-біометричними показниками, структурою врожаю, товарними якостями плодів, рівнем урожайності та економічною ефективністю. Проблема підвищення продуктивності та комерційної доцільності вирощування огірка в умовах закритого ґрунту залишається актуальною для сучасного овочівництва. Високопродуктивні партенокарпічні гібриди забезпечують стабільне плодоношення, покращені якісні показники плодів і ефективне використання площі теплиць, що особливо важливо для зимового вирощування у інтенсивних технологіях.

Метою дослідження було всебічне оцінювання партенокарпічних гібридів огірка з метою обґрунтування доцільності їх використання в інтенсивному комерційному виробництві. Дослідження виконували протягом 2023–2025 рр. на підприємстві ТОВ ТК «Дніпровський» (Дніпропетровська область) у зимових скляних теплицях типу «Антрацит». Огірки вирощували методом малооб'ємної гідропоніки на мінераловатному субстраті «Begrow», контроль мікроклімату та живлення рослин забезпечувала автоматизована система «Priva Integro».

Схема досліду передбачала систематичне розміщення варіантів з чотириразовою повторністю: площа облікової ділянки – 10 м², густота рослин – 2,5 рослин на м², розміщення – 1,6 × 0,25 м, по 4 рослини на субстрат. Насіння висівали в кубики «Begrow», розсаду висаджували на постійне місце у віці 26 діб. Вирощування проводили за рекомендованою технологією для зимових теплиць, захист від хвороб і шкідників здійснювали за інтегрованою системою. Урожай збирали через день протягом всього періоду плодоношення (березень–червень).

Досліджували партенокарпічні гібриди: Спіно F_1 (контроль, Syngenta), Мадрилен F_1 (Seminis), Ельвінара F_1 та Ілонара F_1 (Rijk Zwaan). Оцінювали морфо-біометричні показники рослин, кількість плодів на рослину, середню масу плодів, рівень урожайності та товарності, собівартість та економічну ефективність. Генотипові відмінності рослин проявилися у вегетативному та генеративному розвитку. Рослини гібрида Спіно F_1 відзначався інтенсивним вегетативним ростом, тоді як Мадрилен F_1 та Ельвінара F_1 характеризувалися кращим формуванням генеративних органів. Кількість плодів на рослині: Мадрилен F_1 – 81,4 шт., Ельвінара F_1 – 79,9 шт., Ілонара F_1 – 74,1 шт.; середня маса плодів – 128,6–130,1 г.

Собівартість вирощування залишалася високою: енергоносії – 628,1 грн./м², заробітна плата – 311,9–330,5 грн./м², сировина та матеріали — 224,1 грн./м², упаковка, логістика та маркетинг – 87,4–94,5 грн./м², постійні та інші витрати – 35,8 грн./м². Загальні витрати – 1164,1–1182,7 грн./м², повна собівартість продукції – 1287,3–1313,0 грн./м².

Економічна ефективність показала перевагу гібридів Ельвінара F_1 та Мадрилен F_1: дохід з одиниці площі – 1749,7 і 1712,2 грн./м², умовно чистий прибуток – 439,8 і 399,2 грн./м², рентабельність – 33,6 % та 30,4 %. Гібрид Ілонара F_1 займав проміжне положення, контроль – нижчі показники.

Таким чином, гібриди Ельвінара F_1 та Мадрилен F_1 характеризуються високим потенціалом генеративного розвитку, більшою середньою масою плодів та здатністю реалізувати товарну урожайність, що забезпечує їх високу комерційну ефективність та підвищення рентабельності вирощування огірків у зимових теплицях. Результати створюють наукову базу для оптимізації технологій інтенсивного овочівництва та подальших досліджень.

Ключові слова: *партенокарпічні гібриди, огірок, зимові теплиці, економічна ефективність, собівартість, урожайність.*

Formulation of the problem. In the conditions of modern vegetable growing, the key task is to ensure a stable supply of fresh vegetable products throughout the year, which is especially important for regions with an unstable climate. Cucumber (*Cucumis sativus L.*) occupies a leading position among protected soil crops due to the high nutritional and dietary properties of the fruits, as well as popularity among consumers and the possibility of obtaining several crop rotations during the year [3, 5].

Among modern areas of breeding and agricultural technology, parthenocarpic cucumber hybrids attract special attention. Their ability to form fruits without pollination ensures stable fruiting in closed soil conditions, where the activity of pollinating insects is limited [4]. Parthenocarpic hybrids are characterized by a high percentage of female flowers (58–80%), friendly fruit setting, and uniform fruit morphology, which increases their market value and the efficiency of commercial cultivation [2].

Analysis of statistical data indicates significant structural changes in the cucumber market in Ukraine in recent years. Total cucumber production in 2021 reached a record level of 1.1 million tons, but already in 2022 there was a significant reduction in volumes to 826.1 thousand tons, which is associated with the economic consequences of military operations, disruption of logistics chains, reduction of sown areas, and difficulty in accessing material, technical, and energy resources. However, the protected soil sector continues to play an important role in ensuring the domestic market.

According to official data from the State Statistics Service of Ukraine, in 2024, the area under protected soil was about 4.2 thousand hectares, and the gross harvest of cucumbers exceeded 106 thousand tons, which confirms the strategic importance of greenhouse production in the structure of the industry [10, 13]. At the same time, the decrease in total production led to an increase in dependence on external supplies of cucumbers. In 2025, cucumber imports to Ukraine increased by 46.3% compared to 2024 and reached 70.1 thousand tons, the main suppliers were Turkey, Romania, and Poland. At the same time, there was an increase in exports from Ukraine to Poland, Estonia, and Moldova by 19.7% (3.8 thousand tons), however, its volumes remain significantly lower than imports [8, 9].

So, the increase in imports in 2025 is a direct consequence of the reduction in domestic production in previous years and the insufficient supply of products, especially in the off-season period. This highlights the need to increase the efficiency of greenhouse production, introduce highly productive parthenocarpic hybrids, and optimize cultivation technologies in order to strengthen food security and reduce import dependence. It should be noted that the scientific assessment of specific commercial hybrids, such as Elvinara F_1, Ilonara F_1, Spino F_1, and Madrilen F_1, in terms of yield, biometric characteristics of plants, and economic efficiency in winter greenhouses, is currently insufficiently covered. The available data are mostly limited to technical characteristics and recommendations of manufacturers, while a systematic analysis is absent in the scientific literature.

Thus, the analysis of scientific sources demonstrates that parthenocarpic hybrids of the medium-fruiting type are promising for cultivation in winter greenhouses. At the same time, there is a need to conduct a comprehensive scientific assessment of hybrids in terms of yield, marketability, biometric characteristics, and economic feasibility of cultivation, which will allow them to be reasonably recommended for industrial implementation.

Analysis of recent research and publications. In Ukraine today, using intensive technology (small-scale hydroponics), industrial greenhouse complexes grow a small amount of medium-fruiting and gherkin-type cucumbers, namely: LLC "Ukraflora-Vinnytsia" – 6.4 hectares; LLC TK "Dniprovsky" – 6.4 hectares; LLC Dniprovsky

greenhouse complex – 6.1 hectares; Greenhouse complex "Dnipro" – 5.1 hectares; LLC "Baryshiv greenhouse complex" – 2.4 hectares; and POSP "Uman greenhouse complex" – 2.1 hectares.

Empirical studies in recent years demonstrate that parthenocarpic cucumber hybrids provide yields within 16–28 kg/m², with a fruiting period of 90–110 days. In particular, the Gunnar F_1 hybrid shows a yield of 23.1–25.8 kg/m² with a fruiting period of 105 days and high marketable fruit quality (87%), which indicates high adaptability to the conditions of winter greenhouses in Ukraine. Other commercial hybrids, such as Director F_1, Madrylen F_1, Spino F_1, SV4097CV F_1, Ilonara F_1, and Kibriya F_1, demonstrate similar, and sometimes higher, yield indicators and a high level of marketability due to the uniformity of the fruits.

According to generalized data on the production activities of greenhouse plants, growing cucumbers in the winter-spring cycle (February-May) is economically feasible provided that intensive technology is introduced and energy resources are used rationally. Under production conditions, the crop yield is 210–250 t/ha, which, at an average selling price of 55–65 UAH/kg, ensures the formation of gross revenue at the level of 11.6–16.3 million UAH/ha. According to practical calculations, the total costs for 1 ha of a winter greenhouse, including heating, electricity, raw materials and materials for cultivation, labor, and depreciation, average 9.5–13.0 million UAH, with the share of energy carriers in the cost structure reaching 30–50%. Under such conditions, net profit is formed within 2.0–3.2 million UAH/ha, which corresponds to the real level of production profitability of 20–25%.

Ukrainian scientists, in particular Sergienko O. V., Shabetya O. M., Ivchenko T. V., and others, carry out systematic research on parthenocarpic cucumber hybrids. In their works, they evaluate new hybrid combinations based on morpho-biometric characteristics, yield level, and variability in protected soil conditions. The results of these studies indicate that heterotic hybrids demonstrate increased yield, stable fruiting, and improved fruit quality compared to the original parental lines, which confirms the effectiveness of using heterosis to create highly productive parthenocarpic forms intended for intensive cultivation in greenhouses [2, 3, 13].

Problem statement. The purpose of the research is a comprehensive assessment of parthenocarpic cucumber hybrids grown in winter greenhouses of the IV light zone, according to the main biometric indicators, yield level, marketable qualities of fruits, and indicators of economic efficiency, in order to substantiate their feasibility for use in conditions of intensive greenhouse production.

Materials and research methods. The research was carried out at the high-tech enterprise LLC TK "Dniprovsky", located in the Dnipropetrovsk region, for three years (2023–2025). The tests were carried out in winter glass greenhouses of the "Anthracite" type with the following parameters: span width – 6.4 m, column height from the foundation to the tray – 3.0 m (total height – 3.6 m), column pitch – 3.0 m, and trellis height – 2.2 m from the substrate surface. Cucumbers were grown using the method of small-volume hydroponics on the mineral wool substrate "Begrow". All indicators of the greenhouse microclimate, including temperature, humidity, ventilation, and carbon dioxide supply, were maintained automatically via a computer system. In addition, the Priva Integro system provided control of the frequency of irrigation, concentration and acidity of the nutrient solution, as well as the time and volume of solution supply for each plant, which allowed maintaining optimal substrate moisture and plant nutrition.

The study was carried out with parthenocarpic cucumber hybrids of foreign selection (Netherlands): Spino F_1 (Syngenta) (control), Madrilen F_1 (Seminis), Elvinara F_1 and Ilonara F_1 (Rijk Zwaan) (Fig. 1).

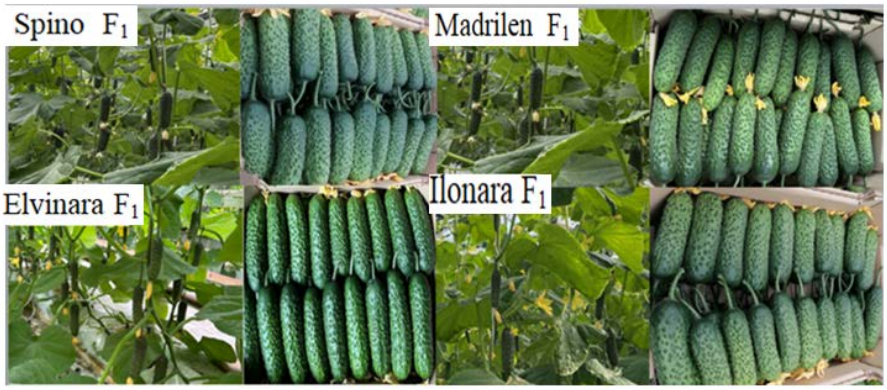

Fig. 1. Visual representation of the studied parthenocarpic cucumber hybrids

All hybrids were selected according to a single classification system taking into account morphological and biometric characteristics, which allows for a correct comparison of their growth, productive, and technological characteristics in studies. General description of hybrids: early parthenocarpic hybrids of gherkin-type cucumber, characterized by a short growing season (38–40 days before the start of fruiting), which allows for stable early harvests in production conditions of greenhouses of various types. Plants have a balanced generative vegetative type of growth with a powerful root system, which ensures active growth and development in changed microclimate conditions, tolerates shading and temperature drops well in the early phases of growth. The fruits of hybrids are uniform, dark green, large-knobbish, and dense, weighing 90–130 g, and 8–14 cm long, without bitterness, with an attractive taste and universal use for fresh consumption, salting, or pickling. High skin density and pulp structure contribute to high transportability and shelf life of products. Hybrids present a substantial reduction in the likelihood of crop losses in greenhouse cultivation due to their enhanced resistance to the primary pathogens of cucumber diseases, including cucumber mosaic virus, powdery mildew, and cladosporiosis. Hybrids are adapted to cultivation on artificial substrates using intensive technologies in winter-spring, spring-summer, and summer-autumn rotations in protected soil.

The layout of the experimental variants was carried out using a systematic method in four replications. The area of the accounting plot is 10 m², the total area of the plot is 14 m², and the total area of the experiment is 224 m². The seeds were sown in mineral wool cubes "Begrow" (100 x 100 mm) previously saturated with a nutrient solution. At the age of 11 days from germination, the seedlings were placed in a scheme of 20 plants per m². At the age of 26 days, the seedlings were planted in a permanent place in the greenhouse. The plant placement scheme was 1.6 x 0.25 m, 4 plants per mineral wool substrate “Begrow” (100 x 20 x 7.5 cm), the volume of the substrate under one plant was 3.75 l. Plant density was 2.5 plants per m². The number of plants in the accounting area was 25 pcs. Cucumber plants were grown according to the recommended technology for winter greenhouses, protection from diseases and pests was carried out using an integrated protection system. Cucumber fruits were collected every other day during all fruiting months (March-June). Accounting and observations in the experiment were carried out according to generally accepted methods according to “Methods of Research in Vegetable and Melon Growing” [1]. Economic efficiency was calculated based on the value of the crop and the costs of obtaining it for each option according to actual data.

Research results. During the three-year research period, systematic phenological observations of the growth and development of cucumber plants were carried out. The results of the analysis showed that no significant differences in the passage of phenological phases between the years of research were detected. Such stability of plant development is explained by the fact that during all years of research, seed sowing was carried out at the same calendar dates, and seedlings were grown under optimal agrotechnical conditions with the use of artificial lighting. This ensured even growth and development of plants and contributed to the stable passage of the main phenological phases during the period of seedling cultivation. Seed sowing was carried out on January 3, while planting of cucumber hybrid seedlings in a permanent place of cultivation in the greenhouse was carried out on the 26th day after the emergence of shoots – January 29.

Table 1 shows the average duration of phenological phases of growth and development of cucumber hybrids for 2023–2025: Spino F_1 (control), Madrilen F_1, Elvinara F_1, and Ilonara F_1. The analysis covers the timing of the main phases of ontogenesis (emergence of seedlings, beginning of flowering, beginning of fruiting), the duration of interphase periods, and the total duration of the fruiting period.

Table 1

Duration of phenological phases of growth and development of parthenocarpic cucumber hybrids (average for 2023–2025)

Hybrid	Phase entry, date			Duration of the period, days			
	shoots	flowering	fruiting	before plants enter the phase			first–last collection
				flowering	fruiting from		
					shoots	flowering	
Spino F_1 (c)	07.01	22.02	07.03	46	59	15	95
Madrilen F_1	07.01	16.02	01.03	40	53	13	102
Elvinara F_1	07.01	18.02	03.03	42	55	15	99
Ilonara F_1	07.01	18.02	03.03	42	55	15	99

It was found that under the same growing conditions, the emergence of seedlings in all studied hybrids occurred simultaneously – on January 7 (the 4th day from sowing), which indicates a high energy of seed germination. The beginning of the flowering phase was characterized by a certain variability and falls on the period from the 40th to the 46th day from mass germination. The earliest to enter the flowering phase were the Madrilen F_1 hybrid cucumber plants – on the 40th day, while the latest was the Spino F_1 hybrid (control), on the 46th day. The duration of the interphase period from the emergence of seedlings to the beginning of fruiting in the studied parthenocarpic cucumber hybrids ranged from 53 to 59 days. The shortest period of formation of the first fruits was observed in the Madrilen F_1 hybrid plants – 53 days, which is six days less compared to the control variant, Spino F_1. In plants of hybrids Elvinara F_1 and Ilonara F_1, this indicator was 55 days, which was four days less than in the control, which indicates their earlier transition to the generative phase of development. The duration of the interval between the onset of the flowering phase and the beginning of fruiting was characterized by relative stability and varied within 13–15 days depending on the genotype of the hybrid. The lowest value of this indicator was noted in the hybrid Madrilen F_1 – 13 days, while in other studied variants it was 15 days.

The completion of fruiting in all years of the research took place on the same calendar dates – the last fruit harvest was carried out on June 10. The total duration of the

fruiting period, which was determined from the beginning to the end of the harvest in the studied hybrids, was characterized by a significant duration and was 95–102 days. The maximum duration of this period was noted in plants of the hybrid Madrilen F_1 – 102 days. The duration of fruiting in the Elvinar F_1 and Ilonar F_1 hybrids was 99 days, which also indicates their ability to provide a long period of crop formation under conditions of cultivation in winter greenhouses.

Analysis of biometric indicators of plants of parthenocarpic cucumber hybrids (on average for 2023–2025) revealed genotypic differences in the main indicators of plant growth and development. The plants of the Spino F_1 hybrid (control) formed the largest total stem length during the growing season – 341.5 cm. This indicator was smaller in the hybrids under investigation than in the control group, measuring 311.5–321.6 cm. In particular, in the plants of the Madrilen F_1 hybrid, the stem length was 30.0 cm shorter than in the control and amounted to 311.5 cm. For the Elvinara F_1 hybrid, this indicator was 321.6 cm, which is 19.9 cm less than the control. For the Ilonara F_1 hybrid, it was 317.5 cm, which is 24.0 cm less. A similar trend was observed in the number of leaves on the plant during the growing season. The maximum number of leaves was recorded in the control hybrid Spino F_1 – 74.7 pcs. In the studied hybrids, the number of leaves was 5.9–9.6 pcs less. and was 65.1–68.8 pcs. The smallest number of leaves was formed by plants of the Ilonara F_1 hybrid – 65.1 pcs., which is 9.6 pcs. less than the control variant. The advantage of the control hybrid was also observed in the number of lateral shoots. In Spino F_1 plants, 22.2 shoots were formed, which corresponds to a more vegetative type of development, while in the studied hybrids this indicator was less by 4.8–5.6 pcs. and fluctuated within 16.6–17.4 pcs. (Table 2).

Table 2

Biometric indicators of parthenocarpic cucumber hybrids (average for 2023–2025)

Hybrid	Hybrid				$NIR_{0,05}$
	Spino F_1 (c)	Madrilen F_1	Elvinara F_1	Ilonara F_1	
Total stem length for the entire growing season, cm	341,5	311,5	321,6	317,5	4,6-15,2
Number of leaves on the plant during the entire growing season, pcs	74,7	66,9	68,8	65,1	1,8-4,4
Number of lateral shoots, pcs	22,2	16,6	17,4	17,2	0,6-0,8
Number of fruits per plant for the entire fruiting period, pcs .	73,8	81,4	79,9	74,1	1,8-2,3
Average fruit weight for the entire fruiting period, g	121,9	129,3	130,1	128,6	2,8-3,5

At the same time, the studied hybrids were superior to the control variant in terms of the number of fruits formed from one plant. The plants of the Madrilen F_1 hybrid formed the largest number of fruits – 81.4 pcs., which is 7.6 fruits more compared to the control. In the Elvinara F_1 hybrid, this figure was 79.9 pcs., which is 6.1 fruits more, while in the Ilonara F_1 hybrid – 74.1 pcs., which practically corresponded to the control level. The

average fruit weight also varied depending on the genotype. The smallest fruit weight was observed in the control hybrid Spino F_1 – 121.9 g. In the studied hybrids, this figure was higher by 6.7–8.2 g and amounted to 128.6–130.1 g. The largest average fruit weight was formed by the plants of the Elvinara F_1 hybrid – 130.1 g, which was 8.2 g more than the control.

The results of the research show that despite the somewhat lower biometric parameters of vegetative growth, the studied parthenocarpic hybrids Madrilen F_1, Elvinara F_1 and Ilonara F_1 were characterized by higher indicators of fruit formation and their average weight, which is important for the realization of the yield potential in winter greenhouses. Table 3 shows the results of research on the yield of parthenocarpic cucumber hybrids for the entire fruiting period on average for 2023–2025. Analysis of the data obtained indicates a significant influence of the genetic characteristics of hybrids on the formation of the level of plant yield in the studied growing conditions.

Table 3

Yield of parthenocarpic cucumber hybrids for the entire fruiting period (average for 2023–2025)

Hybrid	Yield, kg/m²				Yield increase	
	2023	2024	2025	average yield	kg/m²	%
Spino F_1 (c)	21,7	22,4	23,3	22,5	–	–
Madrilen F_1	25,7	26,6	26,8	26,3	3,8	16,9
Elvinara F_1	25,6	26,1	26,3	26,0	3,5	15,6
Ilonara F_1	22,0	24,6	24,7	23,8	1,3	5,8
NIR $_{0,05}$ kg/m²	0,66	0,68	0,56			

It was found that the plants of the hybrid Spino F_1 (control) provided an average yield of 22.5 kg/m². During the years of research, a gradual increase in yield was observed from 21.7 kg/m² in 2023 to 23.3 kg/m² in 2025, which may be due to the variability of growing conditions and the biological characteristics of the hybrid. The highest yield indicators among the studied samples were formed by the hybrid Madrilen F_1, the average level of which over three years was 26.3 kg/m². The excess over the control variant was 3.8 kg/m² or 16.9%. A high level of yield of this hybrid was observed in all years of research, which indicates the stability of crop formation under experimental conditions. Similar values were obtained for plants of the Elvinara F_1 hybrid, the average yield of which was 26.0 kg/m², which exceeded the control by 3.5 kg/m² or 15.6%. Over the years of research, the yield of this hybrid varied within 25.6–26.3 kg/m². The Ilonara F_1 hybrid formed an average yield of 23.8 kg/m², which is 1.3 kg/m² or 5.8% more than the control variant. In the dynamics of the years, an increase in the yield indicator was noted, which may indicate good adaptability of the Ilonara F_1 hybrid to growing conditions.

Consequently, according to the results of the conducted research, it was established that the studied cucumber hybrids differed significantly in the level of yield formation. The highest indicators were obtained from the Madrilen F_1 and Elvinara F_1 hybrids, the average yield of which for 2023–2025 was 26.3 and 26.0 kg/m², respectively, which exceeded the control hybrid Spino F_1 by 3.8 and 3.5 kg/m² or by 16.9 and 15.6%. High yield values of these hybrids were observed in all years of research, which indicates the stability of crop formation. The Ilonara F_1 hybrid also exceeded the control variant in yield, but the difference was smaller and amounted to 1.3 kg/m² or 5.8%.

Table 4

Commodity yield of cucumber fruits of parthenocarpic hybrids for the entire fruiting period (average for 2023–2025)

Hybrid	Marketability, %				The difference in marketability, %
	2023 p.	2024 p.	2025 p.	average marketability	
Spino F_1 (c)	91,6	91,1	91,8	91,5	–
Madrilen F_1	93,2	92,7	93,4	93,1	1,6
Elvinara F_1	96,3	95,8	96,7	96,3	4,8
Ilonara F_1	93,8	93,1	94,3	93,7	2,2

Among the studied variants, an increased level of fruit marketability was observed in the Madrilen F_1 hybrid, the average value of which was 93.1%, which exceeded the control variant by 1.6%. The highest indicators of fruit marketability were formed by the Elvinara F_1 hybrid, the average value of which over the years of research was 96.3%, compared to the control, the increase was

4.8%. The Ilonara F_1 hybrid was also characterized by a high proportion of marketable fruits. The average marketability indicator was 93.7%, which exceeded the control by 2.2%.

Therefore, the results of the research indicate that the highest level of fruit marketability under the studied conditions was provided by the Elvinara F_1 hybrid, which significantly exceeded the control variant. High indicators were also observed in the Ilonara F_1 and Madrilen F_1 hybrids, which indicates their ability to form a significant proportion of marketable products.

Analysis of the economic efficiency indicators of growing parthenocarpic cucumber hybrids on average for 2023–2025 indicates a significant differentiation of the experimental variants in terms of yield, income, and profitability of production. The average sales price of products for the studied period varied within 67.4–69.9 UAH/kg on average over three years. The sales price is affected by the marketability of cucumber fruits. The highest price level was recorded for the Elvinara F_1 hybrid – 69.9 UAH/kg, while for the Madrilen F_1 hybrid this indicator was 69.8 UAH/kg. For the Ilonara F_1 and Spino F_1 hybrids, the sales price was slightly lower and was 68.1 and 67.4 UAH/kg, respectively (Table 5).

The combination of yield and favorable selling price provided significant differences in the level of income per unit area. The maximum income indicator was formed by the Elvinara F_1 hybrid – 1749.7 UAH/m², which exceeds the control by 364.4 UAH/m² (26.3%). A high level of income was also obtained in the variant with the Madrilen F_1 hybrid – 1712.2 UAH/m². In the Ilonara F_1 hybrid, this indicator was 1517.3 UAH/m², which is 132.0 UAH/m² more compared to the control.

The structure of production costs in the studied variants was relatively stable. The largest share of costs was formed by energy sources – 628.1 UAH/m². Labor costs amounted to 311.9–330.5 UAH/m², with the highest value noted in the variant with the Madrylen F_1 hybrid, but this is explained by higher costs due to higher yield. Raw material costs amounted to 224.1 UAH/m², while packaging, logistics, and marketing costs ranged from 87.4 to 94.5 UAH/m². Fixed costs and other production costs remained unchanged for all variants and amounted to 14.2 and 21.6 UAH/m², respectively. Total production costs amounted to 1164.1–1182.7 UAH/m². The lowest costs were recorded in the control variant – 1164.1 UAH/m², while in the variants with the Madrylen F_1 and

Table 5

Economic efficiency of growing parthenocarpic cucumber hybrids on average for 2023–2025

Economic efficiency indicator of production	Hybrid			
	Spino F_1 (c)	Madrilen F_1	Elvinara F_1	Ilonara F_1
Yield, kg/m^2	22,5	26,3	26,0	23,8
Average price (2023-2025), UAH	67,4	69,8	69,9	68,1
Yield on area, UAH/m^2	1385,3	1712,2	1749,7	1517,3
Energy costs, UAH/m^2	628,1	628,1	628,1	628,1
Salary costs, UAH/m^2	311,9	330,5	329,6	321,1
Costs for raw materials and supplies, UAH/m^2	224,1	224,1	224,1	224,1
Packaging, logistics, marketing costs, UAH/m^2	87,4	94,5	92,3	90,5
Fixed costs, UAH/m^2	14,2	14,2	14,2	14,2
Other costs, UAH/m^2	21,6	21,6	21,6	21,6
Total production costs, UAH/m^2	1164,1	1182,7	1181,8	1173,3
Full cost, UAH/m^2	1287,3	1313,0	1309,9	1299,6
Conditional net profit, UAH/m^2	98,0	399,2	439,8	217,7
Net profit growth, UAH/m^2	0,0	301,2	341,8	119,7
Profitability level, %	7,6	30,4	33,6	16,8

Elvinara F_1 hybrids, they were slightly higher – 1182.7 and 1181.8 UAH/m², respectively. The total cost of production varied within 1287.3–1313.0 UAH/m².

The highest level of conditional net profit was provided by the Elvinara F_1 hybrid – 439.8 UAH/m², which is 341.8 UAH/m² higher than the control variant. A high economic effect was also obtained in the variant with the Madrilen F_1 hybrid – 399.2 UAH/m², which is 301.2 UAH/m² higher than the control. A significantly lower level of profit was noted in the Ilonara F_1 hybrid – 217.7 UAH/m². According to the results obtained, the level of profitability of production varied within 7.6–33.6%. The highest indicator was recorded in the variant with the Elvinara F_1 hybrid – 33.6%, which is 4.4 times higher than the control. A high level of profitability is also characteristic of the Madrilen F_1 hybrid – 30.4%. For the Ilonara F_1 hybrid, this indicator was 16.8%, which indicates an average level of economic efficiency compared to other studied variants.

Conclusions and suggestions

1. The obtained research results indicate the presence of genotypic features of the formation of biometric indicators of plants and elements of the yield structure in the studied parthenocarpic cucumber hybrids. It was established that the control hybrid Spino F_1 was characterized by more intensive vegetative growth, which was manifested in the formation of the greatest stem length (341.5 cm), a greater number of leaves (74.7 pcs.) and lateral shoots (22.2 pcs.) compared to other hybrids. At the same time, the studied hybrids Madrilen F_1, Elvinara F_1, and Ilonara F_1 had slightly lower rates of vegetative mass development and were characterized by better rates of formation of generative organs. In particular, the number of fruits per plant in the Madrilen F_1 hybrid was 81.4 pcs., which exceeded the control by 7.6 fruits, and in the Elvinara F_1 hybrid it was 79.9 pcs., which was 6.1 fruits more compared to the Spino F1 hybrid. In the Ilonara F_1 hybrid, this indicator was 74.1 pcs., which was 0.3 fruits more than the control. The superiority of the studied hybrids was also noted in terms of average fruit

weight. Thus, in the Madrilen F_1 hybrid, it was 128.6 g (6.7 g more than the control), in the Elvinara F_1 hybrid – 130.1 g (8.2 g more), while in the Ilonara F_1 hybrid – 129.5 g (7.6 g more than the control).

2. According to the results of three-year studies, it was established that the studied hybrids formed different levels of yield, which fluctuated within 22.5–26.3 kg/m². The highest indicator was obtained in the Madrilen F_1 hybrid – 26.3 kg/m², which exceeds the control (Spino F_1) by 3.8 kg/m², or 16.9%. A somewhat lower, but close to the maximum yield was provided by the Elvinara F_1 hybrid – 26.0 kg/m², which is 15.6% more compared to the control. The yield of the Ilonara F_1 hybrid was 23.8 kg/m², exceeding the control variant by 1.3 kg/m² (5.8%). Thus, the results of the studies indicate that the intensity of vegetative growth does not always directly correlate with the level of formation of crop elements. The studied parthenocarpic cucumber hybrids, in particular Madrilen F_1 and Elvinara F_1, showed a higher ability to form fruits and were characterized by a greater average fruit weight, which indicates their high potential for yield formation and the prospects for use in crop cultivation technologies in winter greenhouses.

3. Analysis of the cost of growing parthenocarpic cucumber hybrids showed that production costs in all variants were similar in structure but remained relatively high. The main share of costs was energy – 628.1 UAH/m², significant costs were on wages (311.9–330.5 UAH/m²), followed by raw materials and supplies – 224.1 UAH/m², packaging, logistics, and marketing – 87.4–94.5 UAH/m², and fixed and other costs – 35.8 UAH/m². Total production costs ranged from 1164.1 UAH/m² in the control variant (Spino F_1) to 1182.7 UAH/m² in the variant with the Madrylen F_1 hybrid, which causes a high total cost of production – 1287.3–1313.0 UAH/m².

The economic efficiency of growing hybrids shows that the most expedient is the use of Elvinara F_1, which generates the highest income per unit area (1749.7 UAH/m²), conditional net profit (439.8 UAH/m²) and profitability (33.6%). High efficiency indicators were also noted in Madrylen F_1 (income 1712.2 UAH/m², profit 399.2 UAH/m², profitability 30.4%). The Ilonara F_1 hybrid occupies an intermediate position, while the control variant Spino F_1 is characterized by the lowest economic indicators.

4. Based on the conducted research, it can be stated that the Elvinara F_1 and Madrylen F_1 hybrids are characterized by the highest economic efficiency, in particular in terms of profitability and the structure of production costs. Their introduction into production is advisable to optimize economic indicators and increase the profitability of commercial cucumber cultivation.

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Дата першого надходження статті до видання: 02.04.2026
Дата прийняття статті до друку після рецензування: 01.05.2026
Дата публікації (оприлюднення) статті: 22.05.2026