SECTION «AGRICULTURAL SCIENCES»

ASSESSMENT OF THE ECONOMIC AND BIOLOGICAL POTENTIAL OF SWEET PEPPER HYBRIDS UNDER SPRING–AUTUMN CROP ROTATION IN UNHEATED GLASS GREENHOUSES AND THE ECONOMIC EFFICIENCY OF THEIR CULTIVATION

ОЦІНКА ГОСПОДАРСЬКО-БІОЛОГІЧНОГО ПОТЕНЦІАЛУ ГІБРИДІВ ПЕРЦЮ СОЛОДКОГО В УМОВАХ ВЕСНЯНО-ОСІННЬОЇ КУЛЬТУРОЗМІНИ У СКЛЯНИХ ТЕПЛИЦЯХ БЕЗ ОБІГРІВУ ТА ЕКОНОМІЧНА ЕФЕКТИВНІСТЬ ЇХ ВИРОЩУВАННЯ

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Abstract. The results of a study on the economic and biological potential and economic efficiency of sweet pepper hybrids Vivaldi F_1 (control), Clereni F_1, Bankers F_1, and Almirante F_1 grown under spring–autumn crop rotation in unheated glass greenhouses of the Steppe zone of Ukraine are presented. The relevance of the research is driven by the high energy intensity of greenhouse production and the long growing period of the crop, which necessitates the selection of highly productive and adaptable hybrids. *Purpose.* The study aimed to assess the economic and biological

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potential of sweet pepper hybrids and to determine the economic efficiency of their cultivation under the specified growing conditions. *Methodology.* The research was conducted in 2019–2020 in high-tech greenhouse facilities using low-volume hydroponics on mineral wool substrate. The experimental design included four hybrids: Vivaldi F_1 (control), Clereni F_1, Bankers F_1, and Almirante F_1. Phenological development, biometric traits, yield, marketability, and economic indicators (costs, revenue, profit, profitability) were evaluated. *Results.* Stability of phenological development and uniform plant growth were observed. The studied hybrids demonstrated earliness and high adaptability to unheated greenhouse conditions. Clereni F_1, Bankers F_1, and Almirante F_1 exceeded the control in plant height by 2–6%, number of flowers and fruits by 9–15%, fruit set by 7–10%, and average fruit weight by 4–6%. The average yield of Vivaldi F_1 was 9.5 kg/m², while Clereni F_1 reached 12.3 kg/m² (+29.5%), Bankers F_1 – 12.2 kg/m² (+28.4%), and Almirante F_1 – 11.8 kg/m² (+24.2%). Marketability ranged from 86.8% to 94.0%, with the highest value observed in Almirante F_1. Yield variation between years was minimal (0.1–0.3 kg/m²), indicating high stability. At production costs of 405.7–413.7 UAH/m², revenue reached 681.3–683.3 UAH/m² for the studied hybrids compared to 504.9 UAH/m² for the control. The highest profit (223.2 UAH/m²) and profitability (48.7%) were obtained for Almirante F_1. *Practical implications.* Clereni F_1, Bankers F_1, and Almirante F_1 are recommended as high-yielding and economically efficient hybrids for unheated greenhouse production. *Originality/Value.* The study establishes the relationship between yield, marketability, and economic efficiency under spring–autumn crop rotation, providing a basis for selecting optimal hybrids for energy-efficient greenhouse systems.

Introduction

Sweet pepper (Capsicum annuum L.) is one of the most important vegetable crops in the world and Ukraine, which has a high grub value and a significant supply to the market [5]. In the minds of current climate change, the increased frequency of extreme weather events and the instability of natural factors, the traditional growth of pepper in the fields of open soil is becoming increasingly difficult and will not be guaranteed forever stable yield of high yield [6]. Therefore, growing pepper in closed soil, in cold greenhouses without heating, is of particular relevance, as it allows you to

control the growth and development of plants, optimize the flow of water and nutrients, as well as promote crop productivity throughout the dry season.

Around the world, pepper grows in climatic regions that reflect its biological characteristics. The largest producers of pepper are Italy, Spain, Ugorshchina, Bulgaria, Romania, and Greece. With closed soil in these regions, high productivity is achieved – 24–35 kg/m², while the average world productivity becomes less than 7.8 kg/m² [8,9]. The outdoor area of pepper planting in the world exceeds 3 million hectares, of which only 3.5% is grown in closed soil [4]. For leveling, in Ukraine, the industrial area for the development of intensive technology of pepper in the protected soil is surrounded by 20 hectares (Greenhouse complex "DF Agro" – 9 hectares, POSP "Uman Greenhouse Plant" – 2 hectares, TOV "Barishivsky Greenhouse Plant" – 2 hectares, and others) at the same time as in the Netherlands, from 11 thousand. 1,207 hectares of holy greenhouses under pepper were seen.

Thereby, there is an obvious gap between the potential possibilities of growing pepper in closed soil and actual areas in Ukraine. This implies the need for a scientifically supported selection of pepper hybrids, optimization of the technology of spring-autumn cultural change, and assessment of their state-biological potential with immediate analysis of the economic efficiency of production. The relevance of the research is determined not only by the increased yield and quality of products, but also by the possibility of effective resource utilization and adaptation to climate change.

1. Agro-Biological Potential of Sweet Pepper Cultivation

Cultivation of sweet pepper in closed ground is characterized by a high level of intensification and a significant potential for increasing yield and economic efficiency [12]. In greenhouse conditions with prolonged cultivation (over 300 days), the yield is on average 25–30 kg/m², while in high-tech glass greenhouses in the Netherlands it reaches 40 kg/m², and in Israel – up to 45 kg/m². At the same time, in greenhouses of an average technological level, the actual yield is often limited to 12–15 kg/m², which indicates the unrealized biological potential of the crop [13; 14]. The use of modern hybrids and intensive cultivation technologies provides an increase in yield by 15–20% [2]. In the production of Ukraine in closed ground

conditions, highly productive hybrids of sweet pepper are widespread, in particular *Mavera* F_1, *Madonna* F_1, *Claudio* F_1, *Gemini* F_1, *Aristotle* F_1, and *Indalo* F_1, which are characterized by high productivity, marketability of fruits, and suitability for long-term cultivation in greenhouses [4; 5].

The economic efficiency of greenhouse pepper cultivation directly depends on the level of yield. It has been established that when obtaining 20–25 kg/m², a high level of profitability of production and cost recovery is ensured, which is typical for intensive greenhouse farms in the EU countries [7]. At the same time, in Ukraine there is a significant gap between the potential and actual productivity of the crop. Under intensive technology, the potential of pepper is 30 kg/m² and more, but in production conditions only 40–50% of this level is realized. This is due to the insufficient adaptation of hybrids to specific growing conditions, imperfection of technologies, and the high costs of energy carriers.

So, despite the achievement of high yields of sweet pepper in closed ground and significant economic efficiency, in Ukraine the production of this crop in greenhouses is accompanied by high production costs, primarily due to the significant cost of energy. An important factor affecting economic efficiency is the long period of pepper cultivation: from sowing to the beginning of fruiting, it is 100–150 days, depending on the ripeness group and growing conditions (early hybrids – 100–120 days, mid-ripening – 120–140 days, late – up to 150–180 days). Such a duration of the production cycle leads to a slower return on investment compared to other greenhouse crops, in particular cucumber, which begins fruiting already on the 50–55th day, which ensures earlier sales of products and faster capital turnover. In this regard, the search for effective technological solutions and hybrids that ensure a reduction in the growing season, increased yields, and improved economic performance in unheated greenhouses remains relevant [10; 11; 12].

2. Aim, Materials and Research Methods

The aim of the study was to assess the economic and biological potential of sweet pepper hybrids in spring-autumn crop rotation in glass greenhouses without heating and to determine the economic efficiency of their cultivation in the Steppe zone of Ukraine.

The study was conducted during 2019–2020 in a high-tech greenhouse complex located in the Dnipropetrovsk region. The experiments were carried out in winter glass greenhouses of the "Anthracite" type without heating, with a trellis height of 2.2 m from the surface of the mineral wool substrate.

Sweet pepper plants were grown using the method of small-volume hydroponics on the "Begrow" mineral wool substrate. Microclimate parameters (temperature, relative humidity, and ventilation) were maintained automatically using a computer control system. The Priva Integro control system regulated irrigation modes, nutrient solution concentration, acidity, as well as the time and volume of its supply to each plant according to the needs of the crop.

The object of research was sweet pepper hybrids of foreign selection (Netherlands): Vivaldi F_1 (control, (*Hazera*)), Clareni F_1, Bankers F_1, Almirante F_1 (*Enza Zaden*). The hybrids under study belong to the block variety type. Plants are of the generative type, with a powerful root system and intensive growth energy. The bush is compact, of medium height. The leaf apparatus is well developed, with a large leaf surface, which provides high photosynthetic activity and protection of fruits from sunburn. The hybrids are characterized by early maturity: technical ripeness occurs after 60–65 days, and biological – after 85–100 days after planting seedlings (depending on growing conditions). The fruits are cube-shaped, four-chambered, with an average weight of 220–280 g. The thickness of the pericarp is 8.0–10.0 mm, which provides high transportability and keeping quality. The color of the fruits changes from dark green in technical ripeness to intense red in biological ripeness. Hybrids are characterized by high adaptability to abiotic stresses, in particular resistance to elevated temperatures during flowering. They have genetic resistance (HR): Tm:0–3 (tobacco mosaic virus), Xcv:1–3 (bacterial spot), PVY:0.1 (potato virus Y) (Fig. 1).

The experiment was set up according to a systematic scheme with four replications. The area of the registration plot was 10 m², the total area of the plot was 14 m², and the area of the experiment was 224 m². The plant placement scheme was 1.6 × 0.25 m. 4 plants were placed on one substrate mat (100 × 20 × 7.5 cm), the volume of substrate per plant was 3.75 l. Plant density was 2.5 plants/m² with the formation of 7.2 stems/m².

Figure 1. Visual representation of the hybrids under study during the research

The number of plants in the registration plot was 25 pcs. Seeds were sown in cassettes with mineral wool substrate. At the age of 15 days, the seedlings were transplanted (dived) into double mineral wool cubes, and at the age of 40 days, they were planted in a permanent place in the greenhouse. At the time of planting, the plants were in the phase of 9–10 true leaves. Sweet pepper plants were grown using the recommended technology for greenhouses. Protection against diseases and pests was carried out using an integrated protection system. Harvesting was carried out during the fruiting period (June–October) once a week, according to the requirements of the current standard DSTU 3246–95 "Sweet pepper. Technical conditions" [3]. Accounting and observation were carried out in accordance with generally accepted methods according to the "Methodology of Research in Vegetable and Melon Growing" [1]. Economic efficiency was determined based on the cost of the product obtained and production costs separately for each option according to actual data.

3. Technological Aspects of Growing Sweet Pepper

During two years of research, observations were made of the phenological phases of growth and development of sweet pepper plants. It was found that

no significant differences in the duration of the main phases of development were detected between the years of research.

Seeds were sown on March 10, and mass seedlings were obtained on March 16 (on the 6th day after sowing). The energy of seed germination was high, and seedlings were friendly, which was due to optimal germination conditions (substrate temperature – 25 °C). After the emergence of seedlings, artificial lighting was used with sodium lamps with a lighting intensity of 8000 lux, and optimal microclimate parameters were maintained: air temperature during the day – 21 °C, at night – 19 °C, relative humidity – 70%. The mode of supplementary lighting of seedlings was changed depending on the age of the plants: in the first 3 days after emergence – round-the-clock lighting (24 hours), on the 4th–6th day – 20 hours, on the 7th–15th day – 18 hours per day. After picking into mineral wool cubes (16th–26th day), the duration of supplementary lighting was 16 hours per day. During the period of seedling placement (26th–36th day) at a density of 18 plants/m², the duration of lighting was reduced to 14 hours per day. 4 days before planting in a permanent place, it was gradually reduced to 12 hours per day in order to improve the adaptation of plants to greenhouse conditions.

Planting seedlings of sweet pepper hybrids in a permanent place in the greenhouse was carried out on the 40th day after emergence (April 25). Plants were tied up 5 days after planting. During this period, the plants formed a crown flower – the first bud, which is laid in the first fork of the stem.

Further formation of the plants consisted in removing the crown flower and dividing the plants into three stems. On each stem, the ovary was removed in the first three internodes. In order to achieve the best plant load and consistent crop formation, one flower was retained in the subsequent internodes while the side shoots (stepchildren) were removed.

4. Phenological Development of Pepper Hybrid Plants

The results of the research presented in Table 1 suggest that the phenological phases of growth and development of sweet pepper hybrids are unique under the conditions of a spring-autumn crop rotation in glass unheated greenhouses (average for 2019–2020). All sweet pepper hybrids (Vivaldi F_1, Clareni F_1, Bankers F_1, and Almirante F_1) showed mass

germination on March 16 at the same time, demonstrating excellent seed quality and ideal germination conditions. The plants entered the flowering phase between May 7–11, with the fastest development rates being observed for the Clareni F_1 and Bankers F_1 hybrids (52 days from germination), while the Vivaldi F_1 hybrid (control) entered this phase later – on the 56th day. The Almirante F_1 hybrid plants occupied an intermediate position (54 days). The beginning of fruiting in all studied hybrids was noted simultaneously – on June 30 (106th day from germination), which indicates the close biological characteristics of the studied genetic material in growing conditions. The duration of the period from flowering to the beginning of fruiting was 50–54 days, which characterizes the hybrids as early-ripening and adapted to the conditions of extended cultivation. The last harvest of pepper fruits was carried out on all hybrids simultaneously on October 10. The duration of the fruiting period (from the first to the last harvest) was the same in all variants and was 104 days, which indicates their suitability for long-term use in closed soil conditions and ensuring a stable supply of products.

Table 1

Duration of phenological phases of growth and development of sweet pepper hybrid plants (average for 2019–2020)

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	
Vivaldi F_1 (c)	16.03	11.05	30.06	56	106	50	104
Clareni F_1	16.03	07.05	30.06	52	106	54	104
Bankers F_1	16.03	07.05	30.06	52	106	54	104
Almirante F_1	16.03	9.05	30.06	54	106	52	104

5. Assessment of Biometric Parameters of Pepper Hybrids

According to the results of studies of biometric indicators of sweet pepper hybrid plants, conducted on average in 2019–2020, certain differences were found between the Vivaldi F_1 variant (control) and the studied hybrids (Table 2). The height of the plants in the Vivaldi F_1 variant (control) was 153.9 cm. In the studied hybrids, this indicator was slightly higher:

in Almirante F_1 – by 3.7 cm (157.6 cm), in Claren F_1 – by 7.4 cm (161.3 cm), and in Bankers F_1 – by 8.4 cm (162.3 cm). In terms of plant height, a tendency for vegetative plant development was observed in the Claren F_1 and Bankers F_1 hybrids. The number of leaves per plant in the control variant was 39.2 pcs. In the Almirante F_1, Claren F_1 and Bankers F_1 hybrids, this indicator exceeded the control by 3.7, respectively; 5.7 and 5.9 pcs., reaching 42.9–45.1 pcs., which indicates a more intensive formation of generative organs.

Table 2

Biometric indicators of sweet pepper hybrid plants, average for 2019-2020

Biometric plant measurement indicators	Hybrid				NIR $_{0,05}$
	Vivaldi F_1 (c)	Clareni F_1	Bankers F_1	Almirante F_1	
Total stem length for the entire growing season, cm	153,9	161,3	162,3	157,6	2,04-3,18
Number of leaves on the plant during the entire growing season, pcs	39,2	44,9	45,1	42,9	0,59-0,65
Number of flowers for the entire period, pcs.	29,5	32,5	33,1	31,1	0,58-1,56
Number of fruits per plant for the entire fruiting period, pcs.	21,7	26,4	26,7	25,1	0,37-0,56
Fruit set rate, %	73,5	81,2	80,7	80,1	-
Average fruit weight for the entire fruiting period, g	181,6	190,1	189,6	192,2	0,78- 1,88

The number of leaves on a plant in the control variant was 39.2 pcs. In the hybrids Almirante F_1, Claren F_1, and Bankers F_1 this indicator exceeded the control by 3.7; 5.7 and 5.9 pcs., reaching 42.9–45.1 pcs., which indicates a more intensive formation of generative organs.

By the number of flowers during the growing season, Vivaldi F_1 (control) was noted at 29.5 pcs., while Almirante F_1 was at 31.1 pcs. (+1.6 pcs. to the control), in Claren F_1 – 32.5 pcs. (+3.0 pcs.), in Bankers

F_1 – 33.1 pcs. (+3.6 pcs.). The obtained data confirm the general tendency to increase generative activity in the studied hybrids compared to the Vivaldi F_1 (control). The number of formed fruits from one plant in the control variant was 21.7 pcs. In the studied hybrids, this indicator was within 25.1–26.7 pcs., which is 3.4–5.0 pcs. more compared to Vivaldi F_1. The hybrid Bankers F_1 produced the most fruits (26.7 pieces), followed by Kleren F_1 (26.4 pieces) and Almirante F_1 (25.1 pieces).

Analysis of biometric indicators of sweet pepper fruits indicates the presence of interhybrid variability in the main morphometric characteristics (Fig. 2).

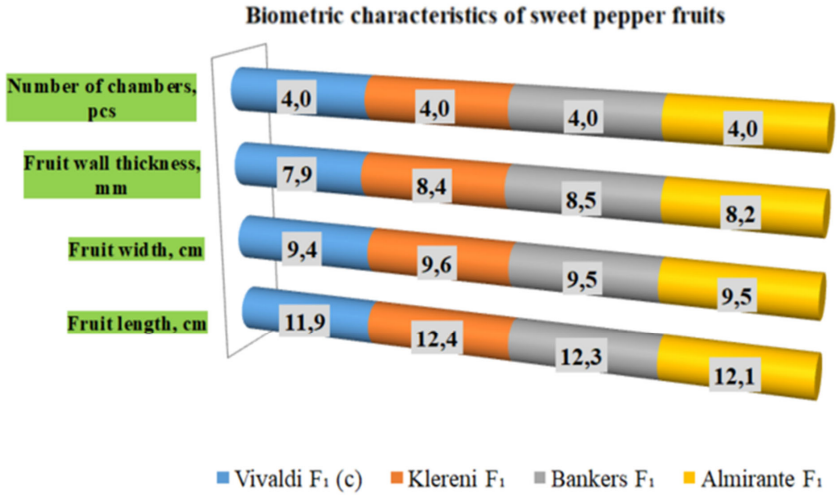

Figure 2. Biometric indicators of sweet pepper fruits depending on the hybrid, on average for 2019-2020

Significantly higher fruit length indicators were observed in the hybrids Clareni F_1 (12.4 cm) and Bankers F_1 (12.3 cm) compared to the Vivaldi F_1 (control) (11.9 cm). In terms of fruit width, the hybrid Clareni F_1 (9.6 cm) also had an advantage, while other variants formed indicators close in value (9.4–9.5 cm). The maximum fruit wall thickness was recorded in the hybrid Clareni F_1 (8.5 mm), which exceeded the control by 0.6 mm, while

Almirante F_1 and Clareni F_1 occupied an intermediate position. The number of fruit chambers in all studied hybrids remained stable (4.0 pcs.) and did not depend on the genotype. In general, the hybrids Clareni F_1 and Bankers F_1 were characterized by the most balanced combination of biometric fruit indicators, which indicates their potential advantage for commercial production.

The degree of fruit setting in the control variant was 73.5%. In the hybrids Almirante F_1, Bankers F_1, and Claren F_1, this indicator was higher, with values of 80.1% (+6.6%), 80.7% (+7.2%), and 81.2% (+7.7%), respectively. This indicates a more effective realization of the generative potential.

The average fruit weight in the hybrid Vivaldi F_1 (control) was 181.6 g. In the studied hybrids it was higher: in Bankers F_1 – by 8.0 g (189.6 g), in Claren F_1 – by 8.5 g (190.1 g), and in Almirante F_1 – by 10.6 g (192.2 g). The largest fruit weight was observed in the hybrid Almirante F_1.

Summarizing the results obtained, it should be noted that the hybrid Vivaldi F_1 (control) provided stable growth and productivity indicators, while the hybrids Claren F_1, Bankers F_1, and Almirante F_1 were characterized by a tendency to increase both vegetative and generative indicators. The most pronounced advantages in terms of the number of flowers and fruits were noted in the hybrid Bankers F_1, in terms of the level of setting – in Claren F_1, while Almirante F_1 was noted for the largest average fruit weight.

6. Yield and Marketability of Sweet Pepper Hybrids

Analysis of the dynamics of the formation of the yield of sweet pepper hybrids (2019–2020) shows a gradual increase in yield during the fruiting period (Fig. 3). In June, the yield of the Clereni F_1 and Bankers F_1 hybrids (0.5 kg/m²) exceeded the Vivaldi F_1 control (0.3 kg/m²) by 66.7%, while Almirante F_1 (0.4 kg/m²) exceeded it by 33.3%. In July, the excess yield was 17.6–23.5% (2.0–2.1 versus 1.7 kg/m²). The difference between the types became slightly smaller in August. The yield of the hybrids Clareni F_1, Bankers F_1, and Almirante F_1 (2.5–2.8 kg/m²) was 8.7–21.7% higher than the Vivaldi F_1 control (2.3 kg/m²), with Clareni F_1 and Bankers F_1 having the highest value. In September, the excess level was 22.7–31.8% (2.7–2.9 versus 2.2 kg/m²). In October, the tendency towards more

intensive crop formation in the studied hybrids persisted: their indicators (4.0–4.2 kg/m²) exceeded the Vivaldi F_1 control (3.2 kg/m²) by 25.0–31.3%, with the maximum value noted in the hybrid Clareni F_1.

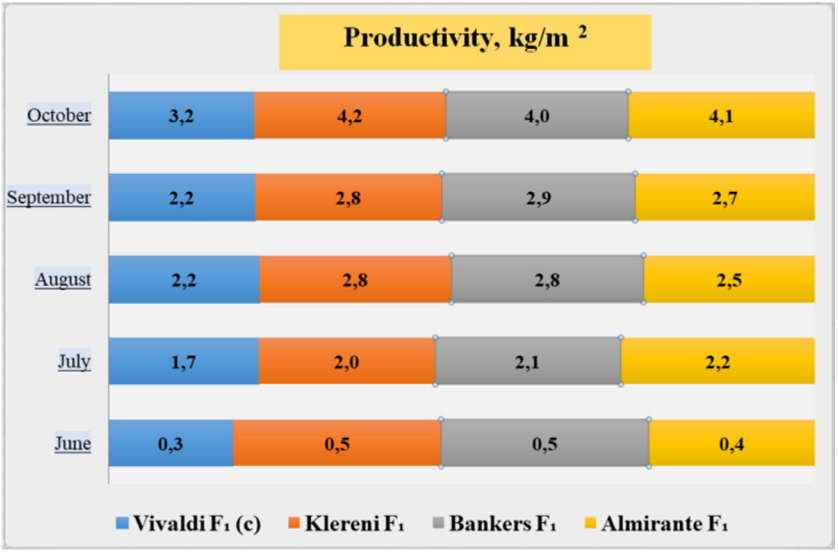

Figure 3. Dynamics of the harvest of sweet pepper hybrids on average for 2019-2020

Accordingly, throughout the entire growing season, the sweet pepper hybrids Clareni F_1, Bankers F_1 and Almirante F_1 provided a consistently higher level of yield compared to the Vivaldi F_1 control, with the greatest relative advantage being evident at the initial stages of growth and during the period of mass fruiting.

Analysis of the total yield of sweet pepper hybrids over the entire fruiting period showed a clear differentiation of variants depending on the genotype. Plants of the Vivaldi F_1 hybrid (control) formed a yield at the level of – 9.5 kg/m². The highest indicators were obtained in the Clareni F_1 hybrid – 12.3 kg/m², which provided an increase in yield by 2.8 kg/m², or 29.5% compared to the control. The yield of the Bankers F_1 hybrid was practically at the same level – 12.2 kg/m², exceeding the control by

2.7 kg/m² (28.4%). Slightly lower but consistently high results were demonstrated by the Almirante F_1 hybrid – 11.8 kg/m², which is 2.3 kg/m² (24.2%) more than the hybrid Vivaldi F_1 (control). It is important to note that the variation in yield between the years of research was insignificant (within 0.1–0.3 kg/m²), which indicates the stability of the realization of productive potential and the high adaptability of hybrids to growing conditions in unheated greenhouses. Thus, all the studied hybrids significantly exceeded the control in terms of yield, with Clareni F_1 being the most productive. The results obtained indicate the feasibility of using the Clareni F_1 and Bankers F_1 hybrids as high-yielding, while Almirante F_1 combines a sufficiently high level of productivity with stability of indicators (Table 3).

Table 3

Yield of sweet pepper hybrids over the entire fruiting period

Hybrid	Yield, kg/m²			Yield increase	
	2023	2024	average yield	kg/m²	%
Vivaldi F_1 (c)	9,4	9,5	9,5	-	-
Clareni F_1	12,1	12,4	12,3	2,8	29,5
Bankers F_1	12,1	12,2	12,2	2,7	28,4
Almirante F_1	11,6	11,9	11,8	2,3	24,2
NIR, $_{05}$ kg/m²	0,34	0,63			

As a result of studies of the marketability of sweet pepper hybrids during the fruiting period (2019–2020), it was found that the level of marketability depended on the genotype and varied within 86.8–94.0%. The hybrid Vivaldi F_1 (control) was characterized by stable fruit marketability indicators: 86.5% in 2019 and 87.1% in 2020, with an average value of 86.8%. The studied hybrids exceeded the control in this indicator. In particular, in the Clareni F_1 hybrid, the average marketability of fruits was 90.0%, which is 3.2% more compared to the control. The Bankers F_1 hybrid provided an average marketability level of 90.7% (+3.9% to the control), demonstrating consistently high indicators in both years of research. The highest level of marketability was observed in the Almirante F_1 hybrid – 94.0%, which exceeded the control by 7.2%. At the same time, the variability of the indicator by year was insignificant (94.1% in 2019 and 93.9% in 2020), which indicates a high stability of the trait (Table 4).

Table 4

Marketability of sweet pepper hybrid fruits during the entire fruiting period

Hybrid	Marketability, %			The difference in marketability, %
	2019	2020	average marketability	
Vivaldi F_1 (c)	86,5	87,1	86,8	-
Clareni F_1	89,9	90,1	90,0	3,2
Bankers F_1	90,4	90,9	90,7	3,9
Almirante F_1	94,1	93,9	94,0	7,2

In this way, all the studied hybrids were characterized by a high level of fruit marketability, with the Almirante F_1 hybrid providing the maximum values of the indicator, while Clareni F_1 and Bankers F_1 were also characterized by consistently high product quality compared to the control variant Vivaldi F_1.

7. Economic Efficiency of Growing Sweet Pepper Hybrids

The results of the analysis of the economic efficiency of growing sweet pepper hybrids indicate that the key determinants of the formation of the market value of products are the level of yield and marketability, which function as interrelated indicators of a single production and economic system. Yield within 9.5–12.3 kg/m² determines the total potential yield of products per unit area, while marketability (86.8–94.0%) characterizes the share of standard products suitable for sale, which directly transforms the biological harvest into marketable mass. It was established that these two indicators have a coordinated effect on the average sales price of products. In particular, with the highest marketability of the Almirante F_1 hybrid (94.0%), a higher-quality product batch is formed, which is reflected in a relatively stable and slightly higher average sales price (60.1 UAH). In contrast, with lower marketability in Vivaldi F_1 (86.8%), the minimum value of the average price (59.6 UAH) is observed, which indicates a negative impact of the decrease in the share of standard products on the market valuation of the product.

Yield and marketability should be considered in an inextricable relationship: the first determines the volume of production, while the second

determines the quality and marketability of products, and their coordinated action forms the price parameters of sales (Table 5).

Table 5

Economic efficiency of growing sweet pepper hybrids under spring-autumn crop rotation in unheated glass greenhouses (average for 2019–2020)

Indicator	Hybrid			
	Vivaldi F_1 (c)	Clareni F_1	Bankers F_1	Almirante F_1
Yield, kg/m²	9,5	12,3	12,2	11,8
Marketability, %	86,8	90,0	90,7	94,0
Average sales price, UAH	59,6	60,6	60,7	60,1
Revenue from UAH/m²	504,9	681,6	683,3	681,3
Energy costs (including growing seedlings), UAH/m²	87,1	87,1	87,1	87,1
Salary costs, UAH/m²	184,1	192,1	189,7	184,5
Costs for raw materials and supplies, UAH/m²	134,5	134,5	134,5	134,5
Packaging, logistics, marketing costs, UAH/m²	41,1	44,2	43,5	42,9
Fixed and other costs, UAH/m²	9,1	9,1	9,1	9,1
Total production costs, UAH/m²	405,7	413,7	411,3	406,1
Full cost, UAH/m²	455,9	467,0	463,9	458,1
Conditional net profit, UAH/m²	49,0	214,6	219,4	223,2
Net profit growth, UAH/m²	0,0	165,6	170,4	174,2
Profitability level, %	10,7	46,0	47,3	48,7

The yield of the Vivaldi F_1 hybrid (control) was 504.9 UAH/m². The Bankers F_1 hybrid had the highest level of this indicator among the experimental variants, measuring 683.3 UAH/m². Clareni F_1 and Almirante F_1 are characterized by similar values, measuring 681.6 and 681.3 UAH/m², respectively. In comparison to the control, the experimental hybrids exhibit a higher yield and marketability indicator, which guarantees a higher yield of sold products and a more favorable market valuation.

The analysis of costs showed their relative stability for all experimental variants. The costs for energy carriers were 87.1 UAH/m², for raw materials

and materials – 134.5 UAH/m², and for fixed costs – 9.1 UAH/m². The main variation in total costs was formed by labor costs (184.1–192.1 UAH/m²) and costs for packaging, logistics, and marketing (41.1–44.2 UAH/m²). Total production costs were within 405.7–413.7 UAH/m², and the total cost price was 455.9–467.0 UAH/m². The lowest costs were recorded in the variant with the Vivaldi F_1 hybrid, but this did not provide high economic efficiency due to the low level of income.

The key criterion for assessing the economic efficiency of cultivation is the conditional net profit, which varied significantly depending on the hybrid. Its highest level was provided by Almirante F_1 – 223.2 UAH/m², which is 3.8 UAH/m² higher than Bankers F_1 and 8.6 UAH/m² higher than Clareni F_1. Compared to the control (Vivaldi F_1), the profit increase was 174.2 UAH/m². The cultivation of the Vivaldi F_1 hybrid was characterized by a profitability of 10.7%. The profitability level confirms the indicated trend: higher values were established for the cultivation of the Almirante F_1 hybrid (48.7%), and somewhat lower values for Bankers F_1 (47.3%) and Clareni F_1 (46.0%).

Conclusions and suggestions

1. The studies found that the phenological stages of the sweet pepper hybrids Vivaldi F_1, Clareni F_1, Bankers F_1, and Almirante F_1 were stable, with no big differences between years. The hybrids are characterized by balanced development, early maturity, and high adaptability to the conditions of unheated glass greenhouses.

2. According to the results of the studies (2019–2020), it was found that the biometric indicators of sweet pepper hybrids varied depending on the genotype. The hybrid Vivaldi F_1 (control) was characterized by stable values of plant height (153.9 cm), number of flowers (39.2 pcs.), fruits (21.7 pcs.), degree of setting (73.5%), and average fruit weight (181.6 g). The studied hybrids Claren F_1, Bankers F_1, and Almirante F_1 had a tendency to increase these indicators: plant height – up to 157.6–162.3 cm, number of flowers – up to 42.9–45.1 pcs., fruits – up to 25.1–26.7 pcs., degree of setting – up to 80.1–81.2%, average fruit weight – up to 189.6–192.2 g.

3. Analysis of the total yield of sweet pepper hybrids showed a significant advantage of the studied variants over the control. Plants of the Vivaldi F_1 hybrid produced a yield of 9.5 kg/m², while Clareni F_1 produced

12.3 kg/m² (+2.8 kg/m², or 29.5%), Bankers F_1 produced 12.2 kg/m² (+2.7 kg/m², or 28.4%), and Almirante F_1 produced 11.8 kg/m² (+2.3 kg/m², or 24.2%). The fluctuations in yield indicators over the years were insignificant (0.1–0.3 kg/m²). The marketability of the fruits of sweet pepper hybrids depended on the genotype and varied within the range of 86.8–94.0%. The hybrid Vivaldi F_1 (control) provided an average level of marketability of fruits of 86.8% with a slight variation over the years. The studied hybrids were characterized by higher indicators compared to the control: Claren F_1 – 90.0% (+3.2%), Bankers F_1 – 90.7% (+3.9%), and Almirante F_1 – 94.0% (+7.2%).

4. Yield within 9.5–12.3 kg/m² forms the potential volume of production, while marketability (86.8–94.0%) determines the share of standard products that are directly transformed into marketable mass. It was established that the coordinated action of these indicators affects not only the volume of sales but also the average price of products, which varied within 59.6–60.7 UAH/m². The Vivaldi F_1 variant (control) had a yield level of 504.9 UAH/m², while this indicator was significantly higher in the experimental hybrids and amounted to 681.3–683.3 UAH/m². Analysis of costs showed their relative stability within the experiment, which allows us to consider them as a conditionally constant factor. The main fluctuations were associated with labor costs and logistics and marketing operations, while total production costs remained within the range of 405.7–413.7 UAH/m², and total cost price was 455.9–467.0 UAH/m². The key integral indicator of economic efficiency was conditional net profit, the maximum value of which was established in the Almirante F_1 hybrid – 223.2 UAH/m². The Bankers F_1 and Claren F_1 hybrids were characterized by slightly lower but close values of this indicator, while the variant control (Vivaldi F_1) provided a minimum level of profit. A similar trend was observed in terms of profitability: the Almirante F_1 hybrid provided the highest level of profitability – 48.7%, which exceeds the indicators of Bankers F_1 (47.3%) and Clareni F_1 (46.0%), while the control variant (Vivaldi F_1) was characterized by the lowest profitability – 10.7%.

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