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DIFFERENCES IN YIELD AND ECONOMICALLY VALUABLE TRAITS OF SWEET PEPPER VARIETIES AND HYBRIDS GROWN IN OPEN FIELD AND PROTECTED CONDITIONS

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Abstract
The article is devoted to the study of differences in yield and economically valuable traits of sweet pepper varieties and F1 hybrids cultivated under open-field and protected (greenhouse) conditions. The research results provide valuable scientific and practical recommendations for breeders, agronomists, and agricultural producers. It was concluded that cultivation of sweet pepper varieties and F1 hybrids under protected conditions enables effective management of key factors essential for plant growth and development, resulting in higher yields within a shorter period compared to open-field cultivation. Among the varieties and F1 hybrids studied, the Yakut F1 hybrid was identified as the most suitable for cultivation under protected conditions.

Keywords: Sweet pepper, varieties, hybrids, open field, protected cultivation, yield, productivity, average fruit weight, fruit shape, fruit size, wall thickness, fruit color, number of locules.

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Introduction

Ensuring the production of high-quality and high-yield agricultural crops to adequately supply the population with food products is one of the key priorities of the national economy. Sweet pepper (*Capsicum annuum* L.) is currently one of the most important vegetable crops due to its nutritional, economic, and agronomic value. Its fruits are rich in vitamins, mineral elements, and bioactive compounds that are essential for human health. From an economic perspective, sweet pepper cultivation is highly profitable due to its high yield potential and market demand.

In Uzbekistan, sweet pepper is cultivated in various regions under both open-field and protected (greenhouse) conditions. These cultivation systems significantly affect productivity, assortment structure, and economically valuable traits. In particular, varieties and hybrids developed through breeding programs exhibit different levels of adaptability to varying meteorological and agronomic conditions. Therefore, obtaining objective data on yield performance, fruit quality, and productivity parameters is of great scientific and practical importance.

The Decree of the President of the Republic of Uzbekistan No. PF-6059 dated February 3, 2021, “On further development of the knowledge and innovation system and modern service provision in agriculture,” approved the Concept for the Priority Development of the Agricultural Knowledge and Innovation System for 2021–2025. This concept emphasizes efficient use of land and water resources, increasing crop productivity, development of new varieties, advancement of breeding and seed production, implementation of scientific achievements into production, and regional specialization in agricultural and food crop production.

Vegetable crops occupy an important place in the daily diet. Among them, sweet pepper is one of the crops whose cultivated area and production volume have been steadily increasing. Sweet pepper fruits contain high levels of vitamin C, carotene, and mineral substances, making them an essential dietary component. In addition, the fruit contains approximately 25–30 mg% of rutin, which enhances the effectiveness of ascorbic acid. Sweet pepper fruits are consumed fresh, dried, and processed.

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Sweet pepper can be grown in open fields during main and secondary seasons, as well as in greenhouses. Considerable experience has been accumulated in this area in national research and agricultural practice. At present, one of the urgent tasks for the agricultural sector is to replace imported vegetable seeds with locally developed varieties and hybrids and to improve cultivation technologies for obtaining high yields. One of the most effective methods for achieving early and high yields of sweet pepper is cultivation under temporary plastic covers and greenhouse conditions. Sweet pepper is highly responsive to changes in nutrient supply, water availability, and temperature regimes; however, these factors can be effectively controlled under protected cultivation.

The objective of the study was to identify differences in yield and economically valuable traits of sweet pepper hybrids grown under open-field and protected cultivation conditions, and to recommend the most efficient of the two cultivation methods for practical production.

The objects of the study included the local sweet pepper varieties *Tong* and *Shodlik*, the locally developed hybrid *Yakut F1*, and the foreign hybrid *Chelsea F1*. The hybrid *Lotto F1* was used as a standard control.

The subject of the study involved a comparative analysis of sweet pepper grown under open-field and protected conditions, including the duration from sowing to biological maturity, average fruit weight, fruit shape and dimensions, pericarp (wall) thickness, fruit color at the technical maturity stage, number of locules, early yield, early productivity, number of fruits per plant, as well as total yield and overall productivity.

Research methods

For greenhouse cultivation, seeds were sown in boxes measuring 60 × 40 × 10 cm on February 2, 2023, and for open-field cultivation on March 10. The seeds were soaked in clean water for one day and then kept for two days in a 0.1% solution of

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succinic acid. Seeds placed in a specially heated nursery began to germinate after 7–10 days, and complete germination was observed after 9–12 days. When the seedlings formed two true leaves, they were pricked out into 45-cell trays and transferred to a larger greenhouse. At the stage of 4–5 true leaves, the seedlings were fertilized with a 0.5% working solution of Novoorganic organo-mineral fertilizer containing microelements.

To maintain air humidity in the nursery at 70–75% and to prevent condensation droplets from accumulating on the inner surface of the plastic cover, warm air was supplied as needed using heaters. At the stage of five true leaves, in order to promote the formation of a strong root system, seedlings were fertilized with a 0.2% working solution of monoammonium phosphate fertilizer (NPK 12:61:0).

Due to anomalously cold weather conditions in 2023, it was not possible to transplant seedlings into unheated protected areas on time. Seedlings were transplanted into the greenhouse on April 2 at a spacing of 90 × 25 cm, and into the open field on May 10 at a spacing of 70 × 30 cm. Irrigation in both cultivation methods was carried out using a drip irrigation system.

The first fertilization was applied 10 days after transplanting, using FORTE fertilizer with an NPK ratio of 20:10:20 at a rate of 1 kg per 1000 L of water. The second fertilization was carried out at the beginning of mass flowering and fruit set, using FORTE fertilizer with an NPK ratio of 10:5:40 at a rate of 1 kg per 1000 L of water.

To control fungal diseases, treatments were applied twice during the growing season with a 0.05% suspension of Quadris fungicide and once with a 0.2% working solution of HOM preparation. In addition, to control pests such as thrips, aphids, and whiteflies, treatments were carried out using a 0.05% working solution of the contact insecticide Mospilan and a 0.1% working solution of the systemic insecticide Gaucho.

From the beginning of mass fruiting, foliar feeding with Energen+7 microelement fertilizer was applied every 5–7 days. To increase the efficiency of fertilizer application, treatments were mainly carried out during the cooler times of the day.

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Phenological observations were conducted on seedlings grown in both greenhouse and open-field conditions, including flowering, formation of the first fruits, and the stages of technical and biological maturity of fruits. During harvest, complex traits such as total fruit mass per sample, number of fruits per plant, fruit wall thickness, fruit color, and shape were recorded. Calculations were also performed to determine the proportion of the first six harvests relative to total yield, as well as overall yield indicators.

Research Results

The studies were conducted in 2023 in the greenhouses and open fields of the private seed production enterprise Green Valley Seeds, located in Andijan Region, Oltinkol District.

The comparison of sweet pepper cultivars and hybrids grown under open-field and greenhouse conditions showed that, under greenhouse conditions, it was possible to obtain a harvest 3–4 weeks earlier than in the open field. Seedlings for both greenhouse and open-field cultivation were raised under identical nursery conditions. Seeds of all samples germinated almost simultaneously, with only minor differences among them (see Table 1). The difference in the period required

Table 1. Results of phenological observations of sweet pepper samples grown under open-field and protected (greenhouse) conditions (2023).

Cultivars and F1 hybrids	From sowing to biological maturity						
	Germination (emergence)		Three-true-leaf stage.	Flowering		Technical maturity stage	Biological maturity stage
	10 %	75 %		10 %	75 %		
Under protected conditions							
Tong	6	9	45	50	62	115	120
Shodlik	5	8	35	45	56	105	110
Chelsea F1	5	8	40	52	63	103	120
Yoqut F1	4	7	30	43	55	98	107
Lotto F1-St.	5	8	40	50	60	110	115
In open-field conditions							
Tong	6	9	44	55	67	120	138
Shodlik	5	7	35	57	63	115	135
Chelsea F1	5	7	40	60	67	120	136
Yoqut F1	4	7	30	45	60	115	120
Lotto F1-St.	6	8	40	55	68	125	130

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To reach 0–75% germination was 2–3 days. Among the tested samples, the Yoqut F1 hybrid exhibited the earliest emergence, completing full germination within 7 days. The seeds of this hybrid germinated 1 day earlier than those of the standard Lotto F1 hybrid.

During observations of the three-true-leaf stage, this phase occurred within 35–45 days depending on the genotype. In the Yoqut F1 hybrid, the three-true-leaf stage was recorded at 30 days, whereas in the remaining hybrids it occurred within 35–45 days. Seedlings of the standard Lotto F1 hybrid formed the third true leaf on the 40th day. The developmental processes up to the flowering stage were observed to occur at nearly the same time in seedlings prepared for both open-field and greenhouse cultivation. When the flowering stage of greenhouse-transplanted seedlings was recorded, flower formation was observed earlier compared with open-field conditions.

When observing the flowering phase of seedlings planted in the greenhouse, the opening of 10% of flowers occurred between 43–52 days among the samples. The 75% flowering phase lasted 55–62 days, with the shortest duration observed in the Yakut F1 hybrid, ranging from 43–55 days. Seedlings of the Lotto F1 hybrid flowered later, between 50–60 days. The difference in flowering phases between seedlings grown in open fields and protected areas ranged from 5 to 8 days, depending on the variety and hybrid.

The conducted observations showed that growing sweet pepper in open fields versus protected areas significantly affected the early productivity and yield indicators of the plants. In this experiment, early productivity was recorded as the yield from the first six harvests (see Table 2).

Table 2 Early yield and productivity indicators of sweet pepper samples grown in open fields and protected areas (2023)

Varieties and F1 Hybrids	Early yield (first 6 harvests), t/ha		Early productivity (first 6 harvests), kg/plant		Number of fruits per plant	
	Greenhouse	Open field	Greenhouse	Open field	Greenhouse	Open field
Tong	34,3	17,2	0,85	0,38	18	9
Shodlik	37,8	18,3	0,9	0,4	14,7	7,6
Chelsea F1	40,7	18,5	1	0,41	6,8	3
Yoqut F1	57.8	24,3	1,4	0,54	10,7	4,5
Lotto F1-St.	54,3	21,2	1,3	0,47	10,8	4,2

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The results indicated that cultivating sweet pepper in protected areas allowed not only earlier but also approximately twice the yield compared to open-field cultivation. In the greenhouse, early yields ranged from 34.3 to 57.8 tons per hectare, while in open fields, yields varied between 17.2–24.3 tons per hectare depending on
the variety and F1 hybrids. The yield per seedling in protected areas ranged from 0.85 to 1.4 kg, whereas in open fields it was 0.38–0.54 kg.

Another important indicator for determining the early productivity of sweet pepper is the number of fruits per plant. In greenhouse-grown samples, the number of fruits per plant ranged on average from 6.8 to 18. In open-field crops, the number of early fruits per plant varied between 3 and 9, depending on the variety and F1 hybrids.

When assessing yield, the average weight of a single fruit also plays a significant role. Due to the relatively favorable growing conditions in protected areas, larger fruits were obtained compared to open-field cultivation. The average fruit weight in protected areas ranged from 47 to 146.3 g across varieties and F1 hybrids, while in open-field conditions, the average fruit weight was 42.3–136.4 g (see Table 3). The largest fruits were observed in the Chelsea F1 and Yakut F1 hybrids.

Regarding fruit shape, all samples were conical, except for the Chelsea F1 hybrid, which had a prismatic shape. At the technical ripening stage, the fruit color was recorded as follows: Lotto F1, Yakut F1, and Tong varieties – light green; Chelsea F1 hybrid – dark green; Shodlik variety – green.

Table 3 Description of fruits of the studied varieties and hybrid samples

Varieties and F1 Hybrids	Average fruit weight, g		Fruit shape	Fruit dimensions H×D, cm		Fruit wall thickness, mm	Fruit color at technical ripening	Number of locules
	Greenhouse	Open field		Greenhouse	Open field			
Tong	47	42,3	Elongated conical	7,2x4,7	6,5x4,3	3-4	Light green	2-3
Shodlik	60-62	50-55	Conical-like	7,5-5,4	6,3x4,7	4	Green	3-4
Chelsea F1	146,3	136,4	Prism	8,7x5,8	6,7x4,8	4	Dark greenл	4
Yoqut F1	130	122	Conical-like	12,5x6,3	10,3x5,2	5-6	Light green	3
Lotto F1-St.	120	111	Conical-like	11,5x5,7	10,2x4,8	5-6	Light green	3

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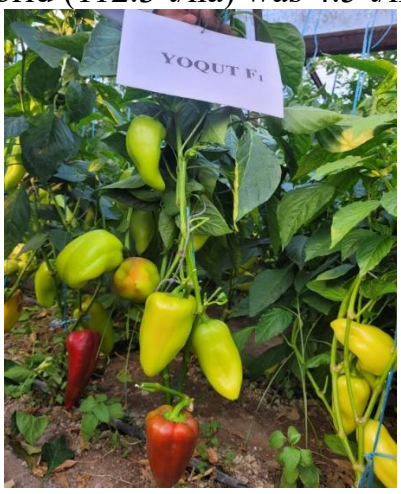
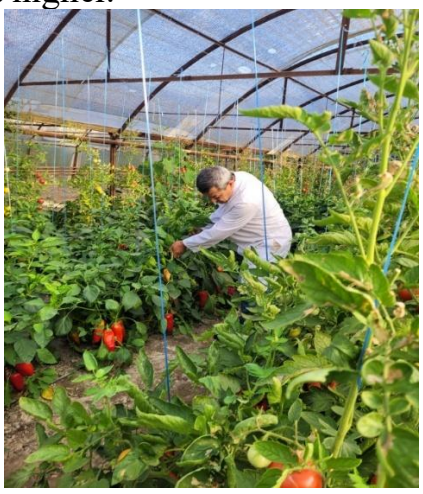
The shape and color of the fruit are considered varietal or hybrid-specific traits, and these characteristics are determined by its genetic potential rather than the growing conditions. At the same time, while the shape of the fruit is related to its size, the color of the fruit indicates its degree of transportability and suitability for long-term storage. During the study, the total yield and productivity of sweet pepper samples grown under protected and open-field conditions were compared (see Table 4). Under open-field conditions, the total yield of sweet pepper samples ranged from 44.8 to 55.7 t/ha. The highest value was recorded in the Yakut F1 hybrid (55.7 t/ha), which exceeded the total yield of the standard Lotto F1 hybrid (54.3 t/ha) by 1.4 t/ha.

Table 4 Total yield and productivity indicators of sweet pepper samples grown under open-field and protected conditions (2023).

Varieties and F1 Hybrids	Total Yield, t/ha		Productivity, kg/plant	
	Protected Field	Open Field	Protected Field	Open Field
Tong	89,4	44,8	2,23	0,99
Shodlik	96,7	45,8	2,4	1,0
Chelsea F1	100,2	51,6	2,5	1,1
Yoqut F1	112,3	55.7	2,8	1.2
Lotto F1-St.	107,8	54,3	2,6	1,2

The yield of samples grown under protected conditions ranged from 89.4 to 112.3 t/ha. Compared to the standard Lotto F1 hybrid (107.8 t/ha), the total yield of the Yakut F1 hybrid (112.3 t/ha) was 4.5 t/ha higher.





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The productivity of varieties and F1 hybrids grown under protected conditions was found to be almost twice as high as that in the open field. The inter-varietal and F1 hybrid productivity indicators were 2.2–2.8 kg/ha under protected conditions, compared to 0.9–1.2 kg/ha in the open field.

Conclusions

Based on the results of the study, it can be concluded that when sweet pepper varieties and F1 hybrids are grown under protected conditions, it is possible to manage a number of factors important for plant growth and development. As a result, a higher yield can be achieved in a shorter period compared to open-field conditions. Despite the favorable conditions created for plant growth in the protected environment, the variety-specific quality characteristics of the fruit were found to be almost the same under both open-field and protected conditions. Among the varieties and F1 hybrids studied, the Yakut F1 hybrid was identified as the most suitable for cultivation under protected conditions. This Yakut F1 hybrid has been registered in the State Register of Plant Varieties of the Republic of Uzbekistan under registration number NAP 587 by the Ministry of Justice of the Republic of Uzbekistan on October 11, 2025.

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