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Adaptation of Hybrid Bell Pepper (*Capsicum annuum* L.) Cultivars to Organic Farming for Yield Improvement

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ABSTRACT

Background: Bell pepper (*Capsicum annuum* L.) is an economically significant crop in both local and international markets. However, low productivity remains a major constraint in organic farming, limiting both sustainability and output. One of the most promising strategies to address this issue is the adoption of hybrid cultivars, which are known for their superior agronomic traits, such as higher yield and enhanced fruit quality. There is a research gap in the comparative performance assessment of hybrid and open-pollinated bell pepper (*Capsicum annuum* L.) cultivars under organic farming conditions, which is essential for evaluating the suitability of hybrids in organic systems.

Methods: This study was conducted to evaluate the agronomic performance of hybrid and standard open-pollinated bell pepper (*Capsicum* annuum L.) cultivars under organic farming conditions. The cultivars were grown in accordance with organic production standards, without the use of synthetic fertilizers or pesticides. Agronomic data were collected throughout the growing season and statistical analyses were performed to determine productivity differences and cultivar responses to organic growing conditions.

Result: The results revealed that hybrid cultivars outperformed open-pollinated cultivars in terms of yield and fruit quality traits. The hybrid cultivar 'Tesla' recorded the highest yield per plant, while 'Aktör' exhibited the greatest average fruit weight, fruit length and fruit width. Although open-pollinated cultivars performed reasonably well under organic conditions, the hybrids demonstrated their capacity to overcome productivity limitations inherent in organic farming systems.

Key words: Agronomic traits, Crop yield enhancement, Hybrid cultivars, Sustainable agriculture.

INTRODUCTION

The projected rise in global population to 9.3 billion by 2050 is expected to intensify food demand (FAO, 2023). However, intensive agriculture has led to environmental problems such as soil degradation, biodiversity loss and water pollution. In response, sustainable farming systems that maintain ecological balance and ensure food security are increasingly prioritized (Reganold and Wachter, 2016; Seufert and Ramankutty, 2017).

Organic farming has emerged as a viable alternative due to its potential to reduce environmental impact, enhance soil fertility and lower the carbon footprint (Willer and Lernoud 2023; Akshay *et al*., 2018; Somdutt *et al*., 2023). By 2022, organic agriculture reached 76.4 million hectares globally with over 3.7 million producers (FiBL, 2023). Post-COVID-19 shifts in consumer awareness have further boosted demand for organic products (Lernoud *et al*., 2022). In Turkey, organic farming has been legally regulated since 1984 and continues to expand with state support, though lower yields remain a key challenge due to input restrictions (TÜİK, 2023; Rahmann *et al*., 2022).

Pepper (*Capsicum* spp.) is among the most economically significant vegetable crops and is widely cultivated under organic systems. Global production increased from 33.6 million tons in 2016 to 36.3 million tons in 2023 (FAOSTAT, 2023). In Turkey, where around 90% of the yield is consumed fresh, varieties such as 'California Wonder' and 'Kandil' are commonly used (TÜİK 2023; Keser *et al*., 2021). Nevertheless, organic pepper production faces challenges like pest pressure, nutrient deficiencies and the limited availability of high-yielding varieties suited to organic systems (Gutiérrez *et al*., 2021).

Hybrid varieties are increasingly considered in organic farming due to their potential for higher yield, disease resistance and improved fruit quality (Menezes *et al*. 2018; Rahmann *et al*., 2022). Yet, their performance can vary significantly depending on environmental conditions and organic system constraints (Mäder *et al*., 2020). While hybrids may outperform standard varieties in some traits, their long-term adaptability under organic management remains uncertain (Boschiero *et al*., 2023).

This study evaluates five hybrid and five standard bell pepper cultivars under organic farming conditions in Turkey. The objective is to compare their growth, yield and fruit quality to assess the feasibility of integrating hybrid varieties

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into organic systems and support sustainable vegetable production strategies.

MATERIALS AND METHODS

The study was conducted on an organic farm in Kuşadası, Aydın, Turkey-an area known for organic fruit, vegetable and livestock production. Kuşadası borders İzmir to the north, the Aegean Sea to the west and Söke to the east and south. The trial site lies at 5/ m elevation (37°45′55.72″N, 27°17′27.28″E) and spans 265/ km^2. The region has a Mediterranean climate with hot, dry summers and mild winters. Annual rainfall ranges between 615.5-672.1/ mm and the average temperature is around 17°C. Soil properties, including texture, pH, organic matter and nutrient levels, are detailed in Table 1.

This experiment was conducted on an organic farming farm located in the Aydın region during the 2022-2023 growing season (Spring and Autumn). The plant material consisted of ten different bell pepper (*Capsicum annuum* L.) cultivars, including five standard cultivars ('Kandil', 'BT Süper', 'BT Doru', 'BT Dik' '11-B-14') (Fig 1) and five hybrid cultivars ('İstek', 'Tesla', 'Doğanay', 'Dut', 'Aktör') (Fig 2). These cultivars are commercial cultivars selected based on their economic significance and extensive regional adaptation.

Seedlings of all cultivars were grown under controlled greenhouse conditions and sown on March 11, 2022. After adaptation, they were transplanted into the field on May 9, 2022, at the optimal physiological stage with 2-4 true leaves and a well-developed root system. Before planting, seedlings were hardened and care was taken to preserve root integrity. Light irrigation was applied immediately after transplanting to reduce stress and ensure root establishment. All cultivars were sown and transplanted simultaneously. The trial site in Aydın has a Mediterranean climate with a long, warm growing season, no frost risk and ample sunlight-ideal for pepper cultivation. The region's soil structure and irrigation capacity support sustainable organic farming. Prior to transplanting, the soil was plowed and tilled twice using a rotary tiller to ensure fine preparation for flat bed planting. During the trial, irrigation was managed *via* a drip system with 30 cm emitter spacing and 2L/h discharge rate. Water was applied when 25% of the available moisture in the 60 cm root zone was depleted. Fertilizers and crop protection products used during the trial are listed in Table 2. Plant growth parameters, including plant height, stem diameter and biomass, were measured during the vegetative-to-generative transition (50-60 days after sowing). The first harvest began around

Table 1: Trial area soil analysis results and evaluation.

Soil properties	Analysis results	Analysis evaluation
Lime (%)	22.29	Too much lime
Organic material (%)	1.24	Little
pH	7.79	Alkali
EC (dS/m) (Salinity)	0.015	Salt free
Total nitrogen (N)	0.06	medium
Phosphorus (P_2O_5) (kg/da)	11.14	Medium
Potassium (K_2O_5) (kg/da)	62.49	Too much



Fig 1: Standard cultivars.

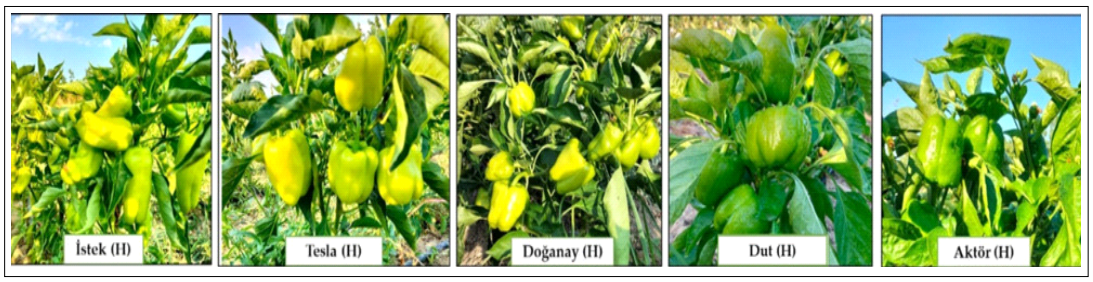


Fig 2: Hybrid cultivars.

July 10, approximately 68 days after sowing, varying by cultivar. Yield data were collected starting from the first harvest and fruit characteristics were measured from 10 randomly selected fruits per harvest.

The field trial used a randomized complete block design (RCBD) with three replications (Mäder *et al*., 2020; Boschiero *et al*., 2023). This design suits homogeneous fields, allowing statistically reliable comparisons of cultivars. Each replication had 2 m × 5 m plots with 30 plants, spaced 1 m between rows and 0.4 m within rows to optimize growth and resource access. This layout minimized plant competition and accurately reflected cultivar differences. It is also suitable for organic farming studies, limiting environmental effects and revealing genetic potential (Acar, 2020; Rahmann *et al*., 2017; Pimenta *et al*., 2018).

Measured Parameters, to evaluate plant growth, yield and fruit quality, the following parameters were assessed

Observations recorded

Plant growth parameters, like plant height was measured from stem base to the highest point (cm). Plant diameter was determined by measuring the widest crown span (cm). Root fresh weight was recorded immediately after harvest (g) and root dry weight after oven-drying at 65°C to constant weight (g). Shoot fresh weight included stems and leaves weighed fresh (g), while shoot dry weight was measured after oven-drying (g). Leaf fresh weight was measured by weighing detached leaves (g) and leaf dry weight after drying to constant weight (g).

Yield parameters

Total yield (g/plant); fruits harvested from each plant were weighed and the total yield per plant was calculated, number of fruits per plant (units/plant); the fruits on each plant were counted and the total number of fruits per plant was determined, fruit fresh weight (g); fresh fruits were weighed immediately after harvest and their fresh weights were recorded and fruit dry weight (g); the fruits were dried to remove moisture and their dry weights were measured.

Fruit quality parameters

Average fruit weight (g); the total fruit weight was divided by the number of fruits and the average weight per fruit was calculated, fruit length (mm); the length of each fruit from the stem to the tip was measured with a caliper and recorded, fruit width (mm); the widest horizontal part of the fruit was measured using a caliper and determined, fruit flesh thickness (mm); after the fruit was cut crosswise, the thickness of the edible flesh, excluding the skin and core, was measured.

Chemical quality parameters, water-soluble solids (WSDM, %) in fruit juice were measured using a refractometer (ATAGO PAL-1). pH was determined with a digital pH meter (Mettler Toledo Seven Compact). Titratable acidity (TA, %) was calculated by titrating fruit juice with 0.1 N NaOH to pH 8.01, using a burette and pH meter, expressed as citric acid equivalent. Electrical conductivity (EC, mS/cm), indicating ion content, was measured with an EC meter (Mettler Toledo Seven 2 Go S3). This methodology enabled comprehensive evaluation of vegetative traits, yield and fruit quality of standard and hybrid bell pepper cultivars under field conditions.

Data evaluation

Data were analyzed using SPSS 23. A two-way ANOVA compared vegetative growth, fruit quality and yield of standard and hybrid bell pepper cultivars, assessing main and interaction effects. Duncan's multiple range test ($P \leq 0.05$) identified group differences, with means ranked and labeled to show statistical significance (Duncan, 1955).

RESULTS AND DISCUSSION

Measurements of plant growth parameters and their evaluation

The analysis revealed statistically significant differences ($P \leq 0.05$) between standard and hybrid cultivars in plant

Table 2: Organic fertilizers and pesticides used during the study.

Application date	Commercial plant nutrition product name	Dosage
20.04.2022	Andromeda (Organic matter 55%, Organic carbon 23%, Organic nitrogen 3.8%, Free amino acid 16%, pH 4.3-6.3)	2 ml/1 lt
22.06.2022	Calcium sett [Water soluble calcium oxide (CaO) 12%, Water soluble boron (B) 0.5%]	37 ml/16 lt
22.06.2022	Quatro oliver [Water Soluble Boron (B): 4, Water soluble zinc (Zn): 12, Chlorine (Cl): 0]	16 gr/16 lt
11.07.2022	Liquid vermis (Organic matter 43%, Organic carbon 16%, Total nitrogen 3%, Water soluble Potassium (K_2O) 4%, pH 3.5-5.5)	200 ml/100 lt
12.08.2022	Penergetic boden (Carrier material: ultra-fine bentonite; free of N, P, K and organic matter; bio-stimulant processed using a proprietary activation technology)	50 ml/100 lt
	Protective drug name	
18.05.2022	Keylate copper (Copper 5%)	20 ml/10 lt
18.06.2022	Keylate copper (Copper 5%)	300 ml/100 lt
19.06.2022	Microthiol (80% Kükürt)	400 gr/100 lt
17.07.2022	Keylate copper (Copper 5%)	300 ml/100 lt

height and diameter (Fig 3). Standard cultivars showed higher values, with average plant height and diameter of 41.30 cm and 27.24 cm, respectively. Among hybrids, 'İstek' recorded the highest plant height (48.10 cm), while 'Dut' had the largest diameter (28.82 cm). These results are consistent with Başay (2020), who reported 43.27 cm height and 39.07 cm diameter for the organic 'Kandil' cultivar. Gülcan (2020a) found plant heights between 38.0 and 41.1 cm. Özgen and Balkaya (2021) reported fruit lengths ranging from 59.63 to 76.93 mm and widths from 47.31 to 55.86 mm for hybrid bell pepper candidates grown in the autumn greenhouse season. Similarly, De Lima *et al*. (2019) and Binbir and Baş (2010) observed a wider plant height range (25-65 cm) in local *Capsicum annuum* L. cultivars.

These variations are attributed to genetic diversity, environmental adaptation and compatibility with organic farming conditions. The superior performance of standard cultivars in organic systems may be linked to their growth stability under low-input conditions (Rahmann *et al*., 2017). In contrast, hybrids bred for conventional systems may have reduced nutrient uptake and stress tolerance in organic environments (Mäder *et al*. 2020). Therefore, breeding programs should be redesigned to enhance hybrid adaptability to organic farming (Rahmann *et al*., 2017). From a food security perspective, using cultivars well-suited to organic conditions is crucial for ensuring sustainable productivity. Future research should focus on improving stress resistance in breeding programs tailored for organic systems (De Lima *et al*., 2019).

Significant differences (P≤0.05) were observed between standard and hybrid *Capsicum annuum* L. cultivars in root fresh/dry weight, shoot fresh/dry weight and leaf fresh/dry weight (Table 3). Hybrid cultivars generally showed higher biomass accumulation. The hybrid 'Dut' recorded the highest root fresh (40.98 g) and root dry weight (13.86 g), while 'Aktör' had the highest shoot

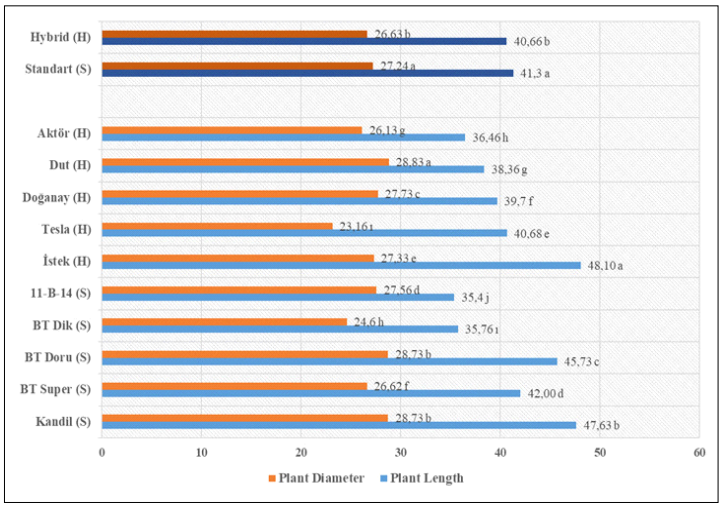


Fig 3: Plant height and plant diameter according to hybrid and standard cultivars.

Table 3: Comparison of vegetal characteristics of standard and hybrid bell pepper cultivars.

		RFW (g)	RDW (g)	SFW (g)	SDW (g)	LFW (g)	LDW (g)
Feature							
Hybrid (H)		37.29a	12.19a	243.90 a	48.7b	10.56a	1.85b
Standard (S)		34.64b	10.82b	218.40b	49.0a	10.31b	1.90a
Feature × Cultivar							
Hybrid (H)	İstek	33.21ı	12.26c	208.0h	44.0f	10.75a	2.02b
	Tesla	38.25d	11.93d	225.5f	54.5c	10.79a	2.06a
	Doğanay	33.57g	10.62g	216.5g	40.0h	10.52c	1.94c
	Dut	40.98a	13.86a	249.5d	44.5e	10.18e	1.61g
	Aktör	40.45b	12.30c	320.0a	60.5b	10.49c	1.63f
Standard (S)	Kandil	39.55c	12.49b	260.0b	65.5a	10.22e	1.88d
	BT Süper	35.55e	11.19e	155.0j	28.0ı	10.67b	2.05a
	BT Doru	30.78j	10.82f	178.5ı	41.5g	10.21e	2.05a
	BT Dik	34.07f	10.20h	246.0e	49.5d	10.30d	1.88d
	11-B-14	33.26h	9.44ı	252.5c	60.5b	10.17e	1.65e

**Significant at the p≤0.05 level (two-tailed). RFW: Root fresh weight, RDW: Root dry weight, SFW: Shoot fresh weight, SDW: Shoot dry weight, LFW: Leaf Fresh weight, LDW: Leaf dry weight, H: Hybrid, S: Standard.

fresh weight (320.0 g) and 'İstek' showed the highest leaf fresh weight (10.75 g). In contrast, standard cultivars outperformed in tissue density-related traits. 'Kandil' had the highest shoot dry weight (65.5 g) and 'BT Süper' showed the highest leaf dry weight (2.05 g). These results suggest that while hybrids are superior in fresh biomass production, standard cultivars may offer structural resilience advantageous in organic farming systems.

A significant feature × cultivar interaction (P≤0.05) was found for all measured parameters. The findings indicate that hybrids like 'Dut', 'Aktör' and 'İstek' have strong vegetative growth, whereas standard cultivars such as 'Kandil' and 'BT Süper' provide higher tissue density. This reflects a trade-off between biomass accumulation and structural integrity under organic conditions.

The findings align with Lee and Son (2019), who developed a nondestructive system for continuously measuring fresh weight in soilless bell pepper cultivation, confirming its reliability. Similarly, Lee *et al*. (2018) reported 54.638 g root fresh weight and 7.267 g root dry weight for 'Fabris RZ F1', along with 301.019 g leaf and 195.685 g stem fresh weight. Erel *et al*. (2020) found that salinity stress significantly enhanced root growth, while fruit load had a lesser effect, supporting our observation that hybrids generally produce higher fresh biomass. Singh *et al*. (2021) also reported high leaf fresh (10.60 g) and dry weight (2.21 g) in 'Bachata RZ F1'.

These findings underscore the importance of genetic improvement for enhancing biomass, root development and productivity. While hybrids excel in fresh biomass, standard cultivars offer higher dry weight, suggesting advantages in tissue density and structural integrity. This balance between productivity and resilience is crucial for sustainable agriculture in both high-input and organic systems. Moreover, enhanced root traits in hybrids can contribute to food security through improved nutrient uptake and stress tolerance.

Statistically significant differences (P≤0.05) were observed between standard and hybrid *Capsicum annuum* L. cultivars in yield (g/plant), number of fruits per plant, fruit fresh weight and fruit dry weight (Fig 4, Table 4). Hybrid

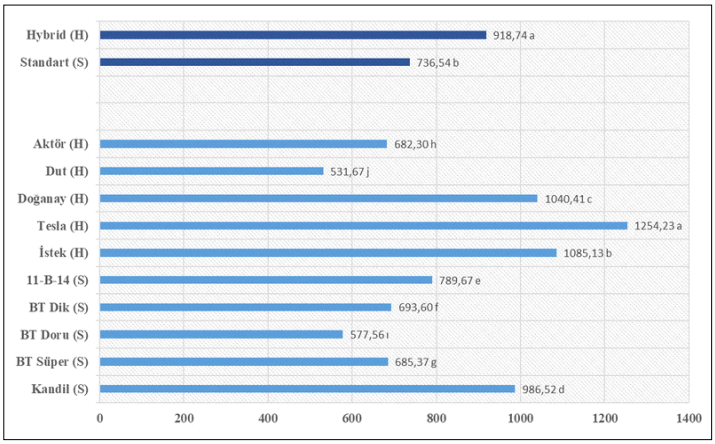


Fig 4: Yield according to hybrid, standard and different pepper cultivars (g/plant).

Table 4: Comparison of fruit characteristics of standard and hybrid bell pepper cultivars.

		Number of fruits per Plant (pieces/plant)	FFW (g)	FDW (g)
Feature				
Hybrid (H)		26.63b	66.89a	5.42a
Standard (S)		27.24a	32.26b	2.78b
Feature × Cultivar				
Hybrid (H)	İstek	27.33e	44.02d	3.16e
	Tesla	23.16ı	42.96e	3.09f
	Doğanay	27.73c	62.29c	4.44c
	Dut	28.83a	86.26b	8.71a
	Aktör	26.13g	98.94a	7.73b
Standard S)	Kandil	28.73b	39.86f	3.21d
	BT Süper	26.62f	28.15ı	2.75h
	BT Doru	28.73b	27.60j	2.61ı
	BT Dik	24.60h	37.26g	2.94g
	11-B-14	27.56d	28.45h	2.39j

**Significant at the p≤0.05 level (two-tailed). FFW: Fruit fresh weight, FDW: Fruit dry weight, H: Hybrid, S: Standard.

cultivars showed higher yield (918.74 g/plant), fruit fresh weight (66.89 g) and fruit dry weight (5.42 g), while standard cultivars had a higher average fruit number per plant (27.24). These results reflect genetic breeding efforts to enhance productivity traits in hybrids, whereas standard varieties favor fruit quantity over size.

A significant feature × cultivar interaction (P≤0.05) was found for all traits. Among hybrids, 'Tesla' had the highest yield (1254.23 g/plant), indicating improved photosynthetic capacity and nutrient use. 'Dut' recorded both the highest fruit number (28.83) and fruit fresh weight (98.94 g), showing its genetic potential for combining fruit load and size. 'Aktör' had the highest fruit dry weight (8.71 g), suggesting suitability for processing and storage due to higher dry matter.

These findings highlight the role of breeding in improving yield and biomass. Hybrids offer clear advantages for high-input systems, while standard cultivars, with more fruits per plant, may better suit organic systems emphasizing adaptability and disease resistance.The results of this study align with previous findings. Koner *et al*. (2020) reported the highest number of fruits per plant as 11.76 units and the maximum yield as 854.69 g/plant in bell pepper. Hassan *et al*. (2021) found that the 'Lady F1' bell pepper variety exhibited the highest average fruit weight (132.9 g) and number of fruits per plant (41.8 units/plant). Pérez *et al*. (2022) observed maximum values for fruit weight (178.7 g), yield per plant (1922.2 g) and number of fruits per plant (11.8 units/plant). Reyes-Pérez *et al*. (2023) reported a range of 11.9-18.7 fruits per plant and a yield of 15.0–24.0 t/ha. Similarly, Ranjitha *et al*. (2018) reported that the hybrid chilli cultivar 'Sitara', when grown under organic conditions with integrated nutrient management (INM), achieved a significantly higher yield, with 1.7 kg per plant and 26.7 t/ha, highlighting the potential of hybrids to enhance productivity in organic systems (Ranjitha *et al*., 2018).

These results suggest that hybrid cultivars provide a yield advantage due to their superior genetic makeup, which allows for larger and heavier fruits. On the other hand, standard cultivars demonstrate an alternative strategy by producing more fruits per plant, which may be beneficial in low-input or organic farming systems. The balance between yield potential, genetic breeding and sustainable farming approaches should be considered when selecting the appropriate cultivar for commercial or organic production.

Fruit quality parameters, statistically significant differences (P≤0.05) were observed between standard and hybrid bell pepper (*Capsicum annuum* L.) cultivars in terms of average fruit weight (g), fruit length (mm), fruit diameter (mm) and fruit flesh thickness (mm) (Table 5). Hybrid cultivars exhibited superior performance compared to standard cultivars, with values of 74.52 g for average fruit weight, 73.60 mm for fruit length, 60.94 mm for fruit diameter and 3.74 mm for fruit flesh thickness. This finding suggests that hybrid cultivars have been genetically improved to produce larger and fleshier fruits. Increased fruit weight and flesh thickness enhance marketability in commercial production, while also improving durability and shelf life, making them more suitable for long-distance transport and storage.

A significant feature × cultivar interaction (P≤0.05) was observed for all measured fruit quality parameters (Table 5). Among the hybrid cultivars, the 'Aktör ' cultivar exhibited the highest values, with an average fruit weight of 133.50 g, fruit length of 82.35 mm, fruit diameter of 78.94 mm and fruit flesh thickness of 4.86 mm. These results indicate that hybrid varieties offer significant advantages in commercial agriculture, as larger and thicker-fleshed fruits are more desirable for processed products and export markets.

Table 5: Fruit characteristics of standard and hybrid bell pepper cultivars.

		Average fruit weight (g)	Fruit length (mm)	Fruit diameter (mm)	Fruit flesh thickness (mm)
Feature					
Hybrid (H)		74.52a	73.60a	60.94a	3.74a
Standard (S)		37.20b	63.19b	50.97b	2.49b
Feature × Cultivar					
Hybrid (H)	İstek	51.57d	80.97b	45.31j	2.91e
	Tesla	45.54e	69.96c	54.68d	3.09d
	Doğanay	53.63c	66.96f	58.09c	3.17c
	Dut	88.40b	67.77d	67.70b	4.67b
	Aktör	133.50a	82.35a	78.94a	4.86a
Standard(S)	Kandil	42.69f	63.55g	53.71e	2.83f
	BT Süper	35.28ı	62.31ı	52.20g	2.39h
	BT Doru	32.51j	62.53h	45.53ı	2.39h
	BT Dik	40.09g	67.28e	52.30f	2.65g
	11-B-14	35.46h	60.29j	51.12h	2.23ı

**Significant at the p≤0.05 level (two-tailed) H: Hybrid, S: Standard.

Table 6: Comparison of fruit characteristics of standard and hybrid bell pepper cultivars.

		WSDM (%)	pH	TA (%)	EC (mS/cm)
Feature					
Hybrid (H)		5.28a	5.47b	0.09a	4.59b
Standard (S)		5.04b	5.67a	0.07b	5.35a
Feature × Cultivar					
Hybrid (H)	İstek	4.50e	5.52fg	0.10b	4.69f
	Tesla	4.10f	5.64cd	0.07e	4.24h
	Doğanay	4.83d	5.57ef	0.08d	5.02e
	Dut	7.46a*	5.14h	0.17a	4.69f
	Aktör	5.53b	5.51g	0.06f	4.33g
Standard (S)	Kandil	4.80d	5.69bc	0.09c	5.26c
	BT Süper	5.16c	5.73ab	0.07e	5.06d
	BT Doru	5.60b	5.60de	0.08d	5.84a
	BT Dik	4.56e	5.77a	0.06f	5.07d
	11-B-14	5.10c	5.57ef	0.07e	5.56b

**Significant at the p≤0.05 level (two-tailed). WSDM: Water soluble Dry Matter, H: Hybrid, S: Standard.

The findings of this study align with previous research. Kaymak *et al*. (2020) reported that the average fruit weight of the 'Kandil' variety ranged from 23.70 to 33.57 g. Similarly, Genç (2019) noted that the 'BT-İstek ' cultivar exhibited fruit lengths ranging from 52.48 mm to 74.76 mm and fruit diameters from 12.08 mm to 36.66 mm. Özgen *et al*. (2022) reported that hybrid bell pepper varieties had fruit diameters ranging from 47.31 mm to 55.86 mm, while Awuku *et al*. (2023) documented fruit lengths of 5.0-6.6 cm and diameters of 1.7-2.3 cm. These results confirm that hybrid varieties tend to produce larger, fuller fruits that are well-suited for commercial cultivation.

Moreover, significant variability in fruit flesh thickness was observed among different varieties. Yalap (2020); Muhammad *et al*. (2021); Nkansah *et al*. (2022); Rubio *et al*. (2023) and Gülcan (2020b) reported that fruit flesh thickness ranged from 2.0 mm to 62.8 mm, depending on the variety. Elizondo-Cabalceta *et al*. (2021) found fruit widths of 6.85-9.28 cm, fruit lengths of 7.78-13.17 cm and fruit wall thicknesses of 4.84-6.31 mm. Additionally, Kayak *et al*. (2022) reported fruit flesh thickness values ranging from 2.04 mm to 2.89 mm. These differences indicate that although some standard varieties have thinner flesh, they may compensate by producing a higher number of fruits, which could be advantageous in organic farming systems.

Statistically significant differences (P≤0.05) were found between standard and hybrid *Capsicum annuum* L. cultivars in water-soluble solids (WSDM), pH, titratable acidity (TA) and electrical conductivity (EC) (Table 6). Hybrids had higher WSDM (5.28%) and TA (0.09%), indicating a sweeter and more aromatic flavor. In contrast, standard cultivars showed higher pH (5.47) and EC (4.59 mS/cm), suggesting a more neutral taste and greater mineral content. These differences suggest that hybrids are more appealing in terms of flavor, while standard cultivars may offer better nutritional value and durability. Such traits are important for selecting cultivars based on market preferences and intended use.

A significant cultivar × feature interaction (P≤0.05) was observed for WSDM, pH, TA and EC (Table 6), showing that chemical quality depends on both genetics and growing conditions. The hybrid 'Dut' had the highest WSDM (7.46%), indicating higher sugar and organic content, ideal for fresh or processed use. The standard 'BT Dik' showed the highest pH (5.77), suggesting a milder, less acidic flavor, which may appeal to certain markets. The standard 'BT Doru' had the highest EC (5.84 mS/cm), pointing to greater mineral content and nutritional value, as well as better adaptation to soil conditions. In summary, hybrids like 'Dut' offer superior flavor and aroma, while standard cultivars such as 'BT Dik' and 'BT Doru' provide advantages in pH balance and nutrient density. These traits can guide cultivar selection based on consumer preferences and end use. The results of this study are consistent with findings from previous research. Balcı (2019) and Tekeli (2010) reported WSDM values ranging from 5.74% to 6.04% and pH values between 5.32 and 6.19 in large-fruited bell pepper cultivars such as 'Doğanay' and 'Flamenco RZ F1'. Similarly, Rubio *et al*. (2023) and Aminifard *et al*. (2016) found pH values ranging from 5.09 to 5.17, while Lucien *et al*. (2019) observed WSDM values between 6.25% and 7.51% for the 'Yolo Wonder' variety. Keser (2021) reported WSDM values of 5.20% to 7.30% for the 'Altan F1' variety in both native and hybrid peppers.

Flores-Velazquez *et al*. (2022) emphasized the importance of TA in determining fruit taste, noting that fruits with higher citric acid content tend to have better taste quality. They reported TA values between 0.47% and 0.67% and EC values ranging from 1.38 to 1.53 dS/m. The higher TA values observed in their study compared to those in the present study may be attributed to their use of California Wonder-type varieties.

CONCLUSION

This study demonstrated that hybrid bell pepper (*Capsicum annuum* L.) cultivars exhibit significant advantages in

organic farming systems in terms of yield and fruit quality. The findings indicate that hybrid cultivars, particularly 'Tesla' and 'Aktör,' outperformed standard open-pollinated cultivars in key agronomic traits such as total yield, fruit size and fruit weight. These results suggest that incorporating hybrid cultivars into organic production systems may help overcome the common yield limitations associated with organic agriculture while maintaining high fruit quality. Additionally, hybrid cultivars showed higher levels of water-soluble solids dry matter (WSDM) and titratable acidity (TA), which may enhance fruit flavor and consumer appeal. In contrast, standard cultivars exhibited higher pH and electrical conductivity (EC) values, suggesting a higher mineral content and potentially greater nutritional value. These findings emphasize the need to consider both agronomic performance and market preferences when selecting bell pepper cultivars for organic farming. The study highlights the potential of hybrid bell pepper cultivars to improve productivity and fruit quality in organic agricultural systems. However, further research is needed to assess the long-term effects of hybrid cultivars on soil health, pest resistance and ecological sustainability. Future breeding efforts should focus on developing hybrids that maintain high yield potential while improving adaptability to organic conditions.

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Conflict of interest

All authors declared that there is no conflict of interest.

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