Adv. Hort. Sci., 2021 35(2): 195-205 DOI: 10.36253/ahsc-10277

AHS
Advances in Horticultural Science

Zucchini squash production in conventional and organic cultivation systems

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Key words: *Cucurbita pepo* L., fruit quality, protected cultivation, sustainability, water use efficiency, yield.

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Citation:
TOSCANO S., BRANCA F., FERRANTE A., ROMANO D., 2021 - *Zucchini squash production in conventional and organic cultivation systems.* - Adv. Hort. Sci., 35(2): 195-205.

Data Availability Statement:
All relevant data are within the paper and its Supporting Information files.

Author Contributions:
All authors contributed equally to the work.

Competing Interests:
The authors declare no competing interests.

Received for publication 31 December 2020
Accepted for publication 21 May 2021

Abstract: Organic production must be carried out following EU regulations and protocols. On the contrary, conventional cultivation instead can be carried out using the best agronomic approaches available and using the latest innovative resources. Organic cultivation is more widespread in permanent crops (olive and grape crops) than vegetable ones, and even less in protected cultivation systems, due to the high intensity production processes which render the application of organic growing protocols more complex. The comparison between the two systems of cultivation, organic and conventional, is difficult because the two cultivation methods are often carried out in different farms and hence in different environmental conditions. Cultivation using the two methods was conducted in a greenhouse from November to March 2017/2018. Results demonstrated that the total fruit yield zucchini squash in organic cultivation was not significantly different to the conventional one (43.2 Mg ha^{-1} and 46.4 Mg ha^{-1}, respectively). The agronomic inputs (fertilizers, fungicides, and insecticides) were higher in the organic cultivation system than conventional one. The water use efficiency was higher in the conventional cultivation system (150.6 kg m^{-3} ha^{-1}) compared to the organic one (147.6 kg m^{-3} ha^{-1}). No statistically significant differences were found for the fruit number per plant and for the marketable fruit at the end of the growing period. Significant differences for the harvest period were only detected for fresh weight, shape index, firmness, and titratable acidity. In conclusion, this work demonstrated that the organic system required higher inputs compared to the conventional cultivation. The extensive experience of the grower allowed for comparable yields between the two systems.

1. Introduction

Both the demand for organic vegetables and cultivation areas have been increasing following market demand. Environmental benefits claimed by organic producers clearly contributed to building a positive consumer attitude towards organic. The primary request for organic produce is the absence of pesticide residuals or the presence of any agrochemical that is not allowed in the EU-defined organic protocols in regulation n. 834/2007 and 889/2008, and more recently, n. 848/2018. Organic farming has become the fastest-growing agricultural sector, accompanied by a constantly increasing consumer demand for organic produce. The organic agriculture accounts for approximately 37.3 billion € in the European Union (EU) and it is the second-largest single organic market in the world. In 2018, the countries with the largest organic agricultural areas were Spain (2.2 million hectares), France and Italy (2.0 million hectares each) (Willer *et al*., 2020).

In Europe, the area dedicated to organic farming has increased in recent years, reaching 15.6 million hectares (Willer *et al*., 2020). The distribution of organic farmland by location is 15% in Spain, 12% in Italy, 11% in France, and 8% in Germany (Brzezina *et al*., 2017).

The total area of organic vegetables represents only 0.6% of the total area devoted to vegetables worldwide. Europe, with 184,373 ha, represents 47.6% of the total area and ranks first worldwide, followed at a distance by North America (73,238 ha). Italy with 60,732 hectares is at the second place worldwide after the United States (Willer *et al*., 2020).

Quality and safety of organic produce must be guaranteed at harvest and during postharvest. The restricted use of pesticides and fungicides, and the predominant use of organic matter for fertilization during cultivation may increase the microorganism contamination of the product. The organic rules are stringently applied to vegetable production because the growing cycles are short and the rapid turnover of crops requires frequent soil tillage, with a negative effect on the soil structure and organic matter content. Soil fertility can be maintained by frequent organic material supply and adequate crop rotation (Watson *et al*., 2002).

Organic agriculture is considered one of the best alternatives for sustainable and good quality food production (Aninowski *et al*., 2020). The comparison between organic and conventional cultivation systems is very difficult to perform because the agronomic management and strategies cannot be the same. Organic vegetable production must follow EU regulations, which outline specific protocols to follow and the agronomic choices are limited. Therefore, organic production is sometimes difficult, especially in environments with high levels of biotic stresses such as pests and diseases (Raigon *et al*., 2010). Agronomists can use only organic certified products and exploit the positive interactions among crops for controlling pests and diseases and for plant nutrition. The conventional vegetable cultivation system has a wide range of choices and the experience of the agronomist can play an important role in increasing the yield and quality of the products. Conventional cropping systems follow innovative technologies and year-by-year, new hybrids or cultivars can be adopted as well as new fertilizers, plant growth regulators, pesticides, etc. (Odegard and Van der Voet, 2014).

In organic cropping systems, the nutrients must be provided by certified organic fertilizers or through appropriate crop rotations (Thorup-Kristensen *et al*., 2012). In long term organic vegetable cultivation, the nutrients are provided by manure or by catch crops and intercrops. However, organic farming is strictly regulated by rules and laws thus allowing a better comparison of its performances with conventional farming methods, with and without the use of agrochemical inputs and/or the adoption of specific growing practices (Gomiero *et al*., 2011).

Organic farms which specialize in vegetable production have more difficulty compared to farms involved in livestock and mixed production. These difficulties are represented by the lack of manure produced in the farms and the supply of organic matter must be provided by green manure that represents a loss of a cultivation cycle.

In many studies (Raviv, 2010; Campanelli and Canali, 2012; Rahmann *et al*., 2017) the great majority of organic systems are refer to open field conditions; only recently such alternative organic systems of production have been tested in protected conditions (Tittarelli *et al*., 2017). In fact, organic greenhouse production is still a small sector of the organic industry and constitutes only a small proportion of total greenhouse production (Gamliel and Van Bruggen, 2016).

The different studies that have compared organic and conventional production systems have provided inconsistent results with regard to the sensorial quality and nutritive value of fruits (Bourn and Prescott, 2002; Lester, 2006; Zhao *et al*., 2006) but organically grown foods have lower pesticide residues (Trewavas, 2004). This is not surprising because comparing the effect of organic and conventional farming systems on fruit quality is inherently difficult due to the wide range of factors that can potentially affect crop composition such as climate, soil conditions, cultivar, soil type, planting date, harvesting time, and growing seasons (Goldman *et al*., 1999; Adam, 2001; Magkos *et al*., 2003). In other studies, however, where organic vegetables were compared to conventional ones, a higher concentration of health promoting components has been found (Brandt and Mølgaard, 2001; Rembialkowska, 2003, 2007). Rembiałkowska (2000) found a higher content of total sugars in organically produced vegetables (carrots, sugar beet, red beetroot, potatoes, spinach, savoy cabbage). Hallmann (2012) showed that organic tomatoes presented a higher ratio of reducing sugars/organic acids, and contained significantly more total sugars, vitamin C and total flavonoids, 3-quercetin rutinoside, and myricetin in comparison with the conventionally-grown fruits.

The main difference between conventional and organic cultivation systems is that conventional agricultural systems are continuously evolving due to the introduction of innovative techniques, while organic cultivation must follow fixed protocols that are revised at an interval of several years. In general, organic farming is represented by an articulated series of variables related to the biotic and abiotic factors affecting growth and the final product (Lester and Saftner, 2011). The physical, chemical and biological/nutritional attributes of soils, the irrigation management and water quality, the crops/genotypes and the growing cycles, the harvesting, handling and storage methodologies are the main variables which affect organic and conventional produce quality.

Zucchini squash and pumpkins within the three major species of *Cucurbita* are important crops worldwide. In the Mediterranean region, and in particular in Italy, zucchini squash (*Cucurbita pepo* L.) is an important commercial crop, both in the open field and in the greenhouse. Zucchini squash is generally cultivated in soil under greenhouse conditions for off-season production, but in the last years soil-less cultivation has been strongly developed because it improves the product quality and increases plant defenses against diseases (Van Os *et al*., 2002). For these reasons, greenhouse zucchini crops are usually cultivated during two growing seasons (Spring-Summer and Summer-Autumn seasons) to respond to the high demand for this fresh vegetable in national and international markets (Rouphael and Colla, 2005).

The aim of this work was to compare the productivity and inputs (fertilizers, insecticides, and fungicides) of conventional and organic zucchini squash cultivation systems carried out in a greenhouse. Both farms were in the same geographical area allowing for a comparison under reduced environmental interferences so that differences could be attributed to the crop management systems.

2. Materials and Methods

Greenhouse conditions

Zucchini squash (*Cucurbita pepo* L.) 'Sibilla' was grown under conventional and organic procedures, commonly adopted in the Sicily Region for zucchini squash production. The experiment was conducted in 2017/2018 in two 240 m^2 unheated polyethylene tunnels located in Syracuse (36°59.1' N, 15°12.6' E, 30 m above the sea level), Sicily, Italy: one devoted to organic (20 years under organic regime) and other to conventional horticulture systems. Plants were grown under natural light conditions. The mean temperature was 16.5 °C and the mean relative humidity levels were 75.5%. The total radiation levels ranged from 4.5 to 14.6 MJ m^{-2}. Zucchini squash seedlings were transplanted at the two-leaf stage on 2nd November 2017 for both methods of cultivation, in rows 1.1 m apart, with an along-row spacing of 0.8 m, giving a planting density of 0.88 plant m^{-2}. Preliminarily, bottom fertilization was performed with cattle manure at a dose of 1500 kg ha^{-1} in organic system and a total amount of phosphorus (P_2O_5 as triple super phosphate), and potassium (K_2O as potassium sulfate) and one-third of the nitrogen (as ammonium sulfate) were applied for the conventional cultivation system. Specifically, 120 kg ha^{-1} of N, 45 kg ha^{-1} of P_2O_5, and 265 kg ha^{-1} of K_2O were added.

The following products were used during the preparation of the soil and cultivation of the plants:

Organic cultivation system system

Pre-trasplant: Siveg GR (Biolchim S.P.A.); 6: 6: 12 Orga Kem (Biolchim S.P.A).

After transplanting: NOV@ (Biolchim S.P.A.); Folicist® (Biolchim S.P.A.); zsdqdaEDTA Zinc (Biolchim S.P.A.); Keliron® (Biolchim); Bio Energy® VEG (Biolchim S.P.A.); Glibor Ca (Biolchim S.P.A.); Mn sulfate (Biolchim S.P.A.); Protamin Cu 62 (Fertilgest); Mg sulphate (Biolchim S.P.A.); Fylloton (Biolchim S.P.A.); Cremalga (Biolchim S.P.A.); Microfol mix (Biolchim S.P.A.); Mg sulphate (Biokimia International S.r.l.).

Fertigation: NOV@ (Biolchim S.P.A.); Bio Energy® VEG (Biolchim S.P.A.); Glibor Ca (Biolchim S.P.A.); Mg sulphate (Biokimia International S.r.l.).

Foliar application: NOV@ (Biolchim S.P.A.); Bio Energy® VEG (Biolchim S.P.A.); Fylloton (Biolchim S.P.A.); Folicist® (Biolchim S.P.A.); Cremalga (Biolchim S.P.A.); Glibor Ca (Biolchim S.P.A.); Mg sulphate

(Biokimia International S.r.l.).
Pesticide: Sulphur 95% (Mannino S.P.A.).

Conventional cultivation system

Pre-trasplant: Siveg GR (Biolchim S.P.A.); 6: 6: 12 Orga Kem (Biolchim S.P.A).

After transplanting: Phostart Zn (Biolchim S.P.A.); Urea sulfate 70 (Fertilgest); Fulvumin (Biolchim S.P.A.); Keliron® (Biolchim S.P.A.); Kemical® (Biolchim S.P.A.); 20.20.20 fertilizer (Valagro S.P.A); Protamin Cu (Fertilgest).

Foliar fertilizations: Microfol® Mix (Biolchim S.P.A.); Urea sulphate low biuret (Fertilgest); Nitrocam® (Biolchim S.P.A.); Loker® (Biolchim S.P.A.); Green-Go 12.8.24+10 (Fertilgest); Magnitron (Biolchim S.P.A.); Fulvumin (Biolchim S.P.A.).
Foliar application: Nitrocam® (Biolchim S.P.A.); Kriss (Biolchim S.P.A.); Rizzamina® 42 (Fertilgest).

Pesticide: Karma® 85 (Certis Europe, Italia); Tiovit® JET (Syngenta Italia).

Similar types of machinery were used in both cultivation systems. The final stage of cultivation involved the harvesting of zucchini squash fruits, which was performed manually and so did not affect the relative environmental performance of conventional and organic systems (Table 1).

Organic cultivation system

The zucchini squash cultivation was performed following the procedures described in EU n. 834/2007 and 889/2008.

In this system Siveg GR and 6: 6: 12 Orga Kem were applied at 35 cm depth in pre-transplant, respectively at doses of 400 and 1500 kg ha^{-1}; after the spreading, the products were appropriately topped up.

During the preparatory phase of the organic growing media, in addition to the background fertilization, biostimulants and nutrients were added according to the following scheme:

- seventh day: NOV@ (15 L ha^{-1}), Folicist® (2 L ha^{-1}), EDTA Zinc (2.5 L ha^{-1}) and Keliron® (2 kg ha^{-1});
- twentieth day: NOV@ (10 L ha^{-1}), Folicist® (1.3 L ha^{-1}), Bio Energy® VEG (20 L ha^{-1}), Glibor Ca (3.5 L ha^{-1}) and Mn sulfate (5 kg ha^{-1});
- thirtieth day: Protamin Cu 62 (3.5 L ha^{-1}), Mg sulphate (7 kg ha^{-1}) and Keliron® (3.5 kg ha^{-1}).

The following top dressings were applied 10 and 20 days after transplanting:
tenth day: Fylloton (1.5 L ha^{-1}), Folicist® (1 L ha^{-1}), Cremalga (1 L ha^{-1}) and Microfol mix (1 kg ha^{-1}).
twentieth day: Cremalga (1 L ha^{-1}), Mg sulphate (1.5 kg ha^{-1}) and Folicist (1 L ha^{-1}).

During cultivation, fertigation and foliar application were performed starting from the fourteenth day and at two week-intervals.

The fertigation was carried out with the addition of NOV@ (15 L ha^{-1}), Bio Energy® VEG (20 L ha^{-1}), with Glibor Ca (7 L ha^{-1}), and Mg sulphate (20 kg ha^{-1}); Foliar application was performed with a solution containing NOV@ (15 L ha^{-1}), Bio Energy® VEG (20 L ha^{-1}), Fylloton (1.5 L ha^{-1}), Folicist® (1 L ha^{-1}), Cremalga

Table 1 - Cultivation procedures (inputs) of the organic and conventional systems per hectare of squash cultivation

Cultivation procedures (inputs)	Cultivation systems	
	Organic	Conventional
Land use (m^2)	10.000	10.000
Mean yield (Mg)	43.2	46.4
Irrigation		
PE irrigation hoses (m)	6667	6667
Submersible electric pump SHANKTY, QF 106/9 + pump motor HP 50 8’’(h)	45	45
Water (m^3)	2100	2100
Fruit harvesting (h)	19	19
Machinery		
Harrowing (h)	8	8
Tillers (h)	8	8
Fertilizer spreader (h)	5	5
Spreading plastic mulching (h)	16	16
Soil tillage (h)	15	15
Spreading plastic tunnel coverage (h)	98	98
Plastic maintenance	28	28

(1 L ha^{-1}), Glibor Ca (4.5 L ha^{-1}), and Mg sulphate (2.5 kg ha^{-1}).

Manual weed control was carried out twice, to eliminate the weeds that grew during the cultivation period.

The defence against Oidium was carried out weekly with the use Sulphur 95% (35 kg ha^{-1}), after 3-4 days from the foliar fertilization (Fig. 1).

Conventional cultivation system

In this system Siveg GR and 6: 6: 12 Orga Kem, as for the organic system, were applied in pre-transplant, respectively at doses of 400 and 1500 kg ha^{-1}; after the spreading, the products have been appropriately topped up. After transplanting, the following products were applied on the indicated day:
seventh day after transplantation: Phostart Zn (20 L ha^{-1}), Urea sulfate 70 (10 L ha^{-1}) and Fulvumin (15 L ha^{-1});
fifteenth day: Keliron® (3.5 kg ha^{-1}), Kemical® (15 L ha^{-1}) and Fulvumin (15 L ha^{-1});
twenty-eighth day: the 20.20.20 fertilizer) (20 kg ha^{-1}), Fulvumin (10 L ha^{-1}) and Protamin Cu (3.5 kg ha^{-1}).
In the same period two foliar fertilizations were applied;
tenth day: Microfol® Mix (1 kg ha^{-1}) and Urea sulphate low biuret (5 kg ha^{-1});
twentieth day: Nitrocam® (2 L ha^{-1}) and Loker® (3 L ha^{-1}).

Weekly fertigation and foliar application were applied during plant cultivation. Fertigation was performed with Green-Go 12.8.24+10 (35 kg ha^{-1}), Magnitron (15 kg ha^{-1}) and Fulvumin (10 L ha^{-1}), until the end of crop production. Foliar application consisted of of Nitrocam® (3 L ha^{-1}), Kriss (0.85 L h^{-1}), and Rizzamina® 42 (1.8 kg ha^{-1}).

Defence against Oidium was carried out weekly with the use of Karma® 85 (3 kg ha^{-1}), and Tiovit® JET (0.3 kg ha^{-1}) after 3-4 days from the foliar fertilization.

Manual weed control was carried out as described for organic cultivation system (Fig. 1).

Sampling procedure and measurements

The fruits were harvested every two days and those obtained at the beginning, in the middle and at the end of the harvest were transported to the laboratory of the Department of Agriculture, Food and Environment Science (Di3A) of Catania University (Italy), and immediately analyzed.

Agronomic data and fruit physical parameter from the greenhouse experiment such as plant productivity, fruit weight, shape index, color, thickness epicarp etc. were measured. Water Use Efficiency (WUE) was calculated as yield/water consumed (kg m^{-3}) (Yaghi *et al.*, 2013).

The epicarp and mesocarp color was measured using a Chroma Meter CR-200 (Konica Minolta, Japan) based on light reflectance. The color was expressed using the Commission Internationale de l'Eclairage (CIE) system where the L*, a* and b* values represent the lightness, green-red and blue-yellow, respectively. The dry matter (DM) content was obtained by drying samples in a thermo-ventilated oven at 70°C to constant weight.

The firmness of the zucchini squash was measured using a compression test based on the resistance of the fruit to deformation in the middle portion using a texture analyzer (TA.XT2i, Stable Micro Systems Ltd., Godalming, UK) incorporating a 2 mm diameter probe. Eighteen recordings were performed for each treatment. The values were expressed as the maximum shear force (N).

Titratable acidity (TA) was measured by titration with a solution of sodium hydroxide 0.1 mol L^{-1}, up to the point of phenolphthalein turning, and expressed as meq L^{-1} of citric acid. Total soluble solids (TSS, °Brix) were read in a digital refractometer with automatic compensation for temperature (model Brix PR-

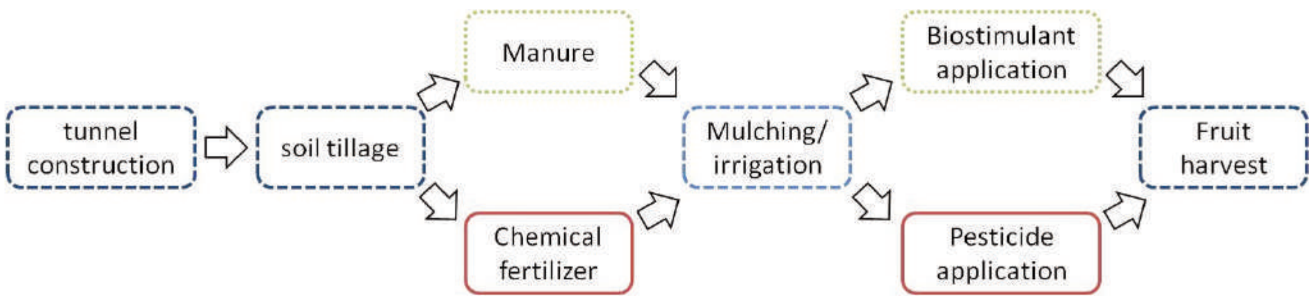

Fig. 1 - Processes included in the conventional and organic cultivation systems.

1, Atago CO., Ltd, Tokyo, Japan).

Statistical analysis

The experiment was conducted as a randomized complete-block design with three replications to compare two cultivation methods: conventional and organic. Each experimental unit consisted of six plants (18 plants for cultivation methods). The statistical analyses were performed using CoStat version 6.311 (CoHortSoftware, Monterey, CA, USA); pairwise comparisons for productivity parameters were done using t-test for means of samples with unequal variances. Two-way ANOVA for quality and color parameters was used. The differences between the means were determined using Tukey's test (P<0.05). Interaction effects were calculated using the Tukey's test at a 5% level of significance.

3. Results

Crop productivity

The harvest period lasted nine weeks, with the first and last harvest dates on the 16th December 2016 and 7th March 2017, respectively; in total, 57 harvests were done during this period for both cultivation methods. The average harvesting interval was 1.4 days during the cultivation period.

The total fruit yield of conventional zucchini squash was similar to the organic cultivation method (46.4 Mg ha^{-1} and 43.2 Mg ha^{-1} respectively) (Fig. 2). No statistically significant differences were found for the fruit number per plant at the end of the growing period (21.5 fruits $plant^{-1}$ in conventional cultivation and 22.9 fruits $plant^{-1}$ in organic cultivation). Similarly, no significant differences between the conventional and organic cultivation were recorded for the marketable fruit yield plant: 4.1 and 3.8 kg $plant^{-1}$, respectively (Table 2). The percentage of unmarketable fruit weight was 3.5% and 2.6% in organic and conventional, respectively, without significant differences.

Water use efficiency and external inputs

The water use efficiency (WUE) was higher in the conventional than in organic cultivation system with 150.6 and 147.6 kg m^{-3} ha^{-1}, respectively. In the conventional production system, the amount of fertilizers used were 4.8 kg Mg^{-1} ha^{-1} and 0.3 L Mg^{-1} ha^{-1}, solid and liquid, respectively (Table 2). The organic vegetable production showed higher fertilizers input compared with conventional cultivation system, with 11.4 kg t^{-1} ha^{-1} and 0.5 L t^{-1} ha^{-1}, solid and liquid, respectively. For plant protection purposes, solid fungicides were used in both growing systems.

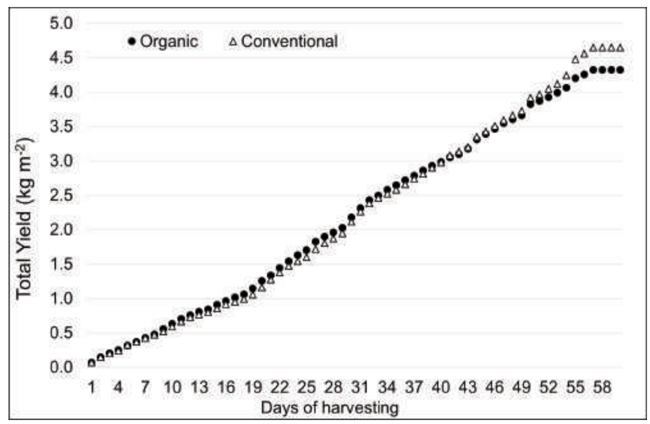

Fig. 2 - Cumulative trends of zucchini squash yield (kg m^{-2}) during the harvesting period (60 days) under conventional (•) and organic (Δ) cultivation methods.

The amount of fungicides used was almost indistinguishable, with 0.11 kg Mg^{-1} ha^{-1} used in the conventional cultivation system as compared to 0.12 kg Mg^{-1} ha^{-1} applied in the organic cultivation regime. Solid insecticides used were 103-fold higher in organic cultivation system compared to the conventional one, while the liquid insecticides were 4.8-fold higher in the organic compared to the conventional cultivation system.

Fruit quality parameters

During the cultivation period, three samples of

Table 2 - Productivity parameters of zucchini squash grown under different cultivation methods

Method of cultivation	Fruit yield (Mg ha^{-1})		WUE (Kg m^{-3} ha^{-1})	Fruit number (n. $plant^{-1}$)	Fruit yield plant (kg)
	Early	Total			
Conventional	8.0±0.6	46.4±3.1	150.6 a	21.5±0.8	4.1±0.4
Organic	7.9±0.7	43.2±2.9	147.6 b	22.9±0.9	3.8±0.4
Significance	NS	NS	*	NS	NS

Means within columns separated using t-test (P<0.05).

fruits were taken for quality evaluation (one at the beginning, one approximately in the middle, and one at the end of production).

Significant differences for fresh weight, shape index, firmness, and titratable acidity were only detected for the harvest period (Table 3). No significant difference for dry biomass percentage was found (Table 3).

With regard to the total soluble solids content, the conventional cultivation method showed an effect of interaction (Cultivation methods x Harvesting time): the fruits of the plants cultivated using the organic method have maintained, for the entire cultivation period, higher values, while those harvested in conventional cultivation have shown a reduction at the end of the growing period (by 7%) (Table 3 and Fig. 3).

Measurements of surface color demonstrated significant differences between the cultivation methods only with regard to L* mesocarp, which was reduced: the fruits obtained in the organic method have recorded a uniformity of the values, while those obtained in conventional cultivation method have shown lower values corresponding to the second harvest (Table 4 and Fig. 4).

4. Discussion and Conclusions

In greenhouses, where intensive cultivation systems are widely used, the differences between conventional and organic approaches are especially evident. Organic production in greenhouse operations is

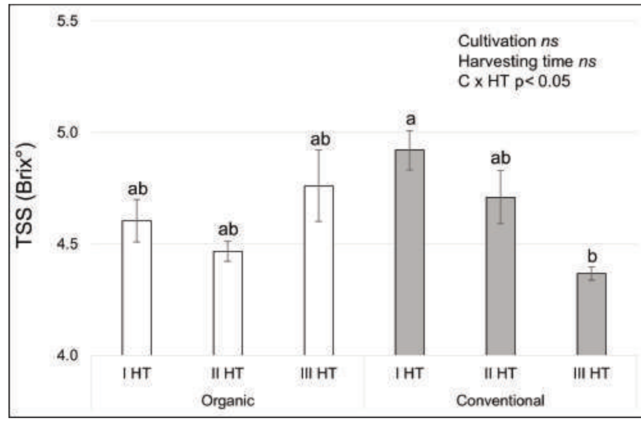

Fig. 3 - Interactions between the two cultivation methods, Organic (I, II, III HT) and Conventional (I, II, III HT), and harvesting time on TSS (Brix°). The vertical bars indicate ± S.E. of means (n=18). Columns denoted with the same

a challenging task (Gamliel and Van Bruggen, 2016).

The production of vegetables in organic conditions presents more technical challenges than conventional cultivation, because many practices, such as the use of non-natural agrochemicals, are not permitted in organic production under the regulations of many countries (Raigon *et al.*, 2010). Consequently, organic production is sometimes difficult, especially in environments with high levels of pests and disease pressure.

Organic cultivation systems that are specifically dedicated to the vegetable production do not have their own manure supply and must buy a majority of their most of agronomic inputs, as such as fertilizers, biocontrol agents, natural compounds, and biostimulants for controlling pests and diseases and for plant nutrition from the market. Results demonstrate that

Table 3 - Quality parameters of zucchini squash grown under different cultivation methods

Factors		Fresh weight (g)	Shape index	Firmness (N)	% DM	TSS	Titratable acidity
Method of cultivation (C)	Harvesting Period (H)						
Conventional		188.7±6.6	4.7±0.1	12.3±3.3	6.01±0.1	4.7±0.1	0.6±0.0
Organic		183.5±7.8	4.6±0.1	12.5±2.7	5.99±0.1	4.6±0.1	0.7±0.0
	I	158.7±3.0 b	4.6±0.1 b	11.6±1.2 b	6.00±0.1	4.8±0.1	0.7±0.0
	II	200.6±3.8 a	4.9±0.0 a	12.2±2.2 b	6.01±0.1	4.6±0.1	0.7±0.0
	III	199.0±2.5 a	4.4±0.1 c	13.4±1.4 a	6.00±0.0	4.6±0.1	0.6±0.0
Significance							
Cultivation (C)		NS	NS	NS	NS	NS	NS
Harvesting period (H)		***	***	***	NS	NS	NS
C x H		NS	NS	NS	NS	*	NS

Values are means of main effects of method of cultivation and harvesting period.
The statistical analysis was two-way ANOVA;
NS not significant; * significant at P<0.05; *** significant at P<0.001. The values in the same column followed by the same letter are not significantly different at P<0.05 (Tukey's test).

Table 4 - Color parameters (L*, a* and b*) in epicarp and mesocarp of zucchini squash grown under different cultivation methods

Factors		Epicarp			Mesocarp		
Method of cultivation (C)	Harvesting Period (H)	L*	a*	b*	L*	a*	b*
Conventional		56.8±0.1	-27.3±0.1	10.8±0.1	63.4±0.2 b	-29.6±0.1 a	14.3±0.3 b
Organic		56.8±0.1	-27.1±0.1	10.6±0.1	64.0±0.1 a	-29.8±0.1 b	14.6±0.2 a
	I	56.9±0.1	-27.5±0.1 b	11.0±0.1 a	64.1±0.1 a	-30.0±0.0 b	15.1±0.1 a
	II	56.8±0.1	-27.0±0.0 a	10.5±0.0 b	63.3±0.4 b	-29.5±0.1 a	14.6±0.1 b
	III	56.7±0.1	-27.1±0.1 a	10.6±0.1 b	63.7±0.1 ab	-29.5±0.1 a	13.7±0.1 c
Significance							
C		NS	NS	NS	**	**	*
H		NS	***	***	**	***	***
C x H		NS	NS	NS	*	NS	NS

Values are means of main effects of method of cultivation and harvesting period.
The statistical analysis was two-way ANOVA;
NS not significant; * significant at P<0.05; *** significant at P<0.001. The values in the same column followed by the same letter are not significantly different at P<0.05 (Tukey's test).

the grower, after years of cultivation, found a wide range of agronomic inputs that allowed for the highest yield that was similar to the conventional farm.

In literature, it is well-known that mineral elements released by the organic fertilizers are not promptly available and the lag of time may reduce growth and yield. This problem can be compensated by higher inputs of specific organic fertilizers and biostimulants.

The differences observed for crop yield between organic and conventional growing systems range from 5 to 34%, while on the average, organic cultivation can reach about 80% of the yield of conventional cultivation but with substantial variations depending on the growing system and site characteristics (De Ponti *et al*., 2012; Meier *et al*., 2015; Ciaccia *et al*., 2019). Some studies, however, point out that the effect of cultivation method disappears when the results are converted to absolute dry matter, because often differences are due to water content (Pieper and Barrett, 2009). The yield in organic cultivation system was about 30 Mg ha^{-1} and is similar to those observed in other open field cultivation experiments with yields averaging 30.7 Mg ha^{-1} (Conti *et al*., 2015). Colla *et al*. (2002) found similar results to our in tomato, with no differences in yield between the organic and conventional cultivation methods, whereas a lower yield was found in the organic growing system compared to the conventional one for zucchini (Maggio *et al*., 2013). A strong yield reduction of about 25% was observed in summer zucchini squash grown using organic fertilizers (Dasgan and Bozkoylu, 2007). Conventional mineral nutrition inputs can provide nutrients when plants really need them, while organic fertilizers or matrixes release nutrients following degradation kinetics that usually cannot promptly satisfy plant requirements. This long-term effect of the organic nutrient tools can slow down plant growth and negatively affect the yield. However, there is little information about nutritional and sensorial quality (aroma and volatile organic compounds between the two growing systems), and food safety of organic versus conventional crops (Gennaro and Quaglia, 2003).

Specific cultivars for organic cultivation are not available; in greenhouse tomato, the use of F_1 hybrid

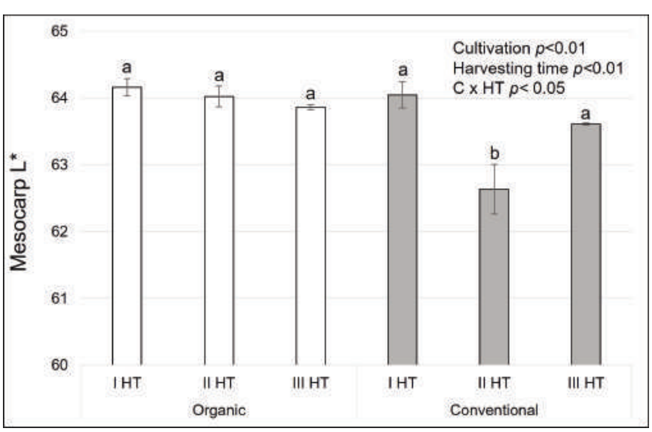

Fig. 4 - Interactions between the two cultivation methods, Organic (I, II, III HT) and Conventional (I, II, III HT), and harvesting time on mesocarp L* value. The vertical bars indicate ± S.E. of means (n=18). Columns denoted with the same letters are not significantly different, as determined by Tukey's test (P < 0.05).

cultivars was beneficial to the organic system, being superior to non-hybrids (Santa Rosa *et al*., 2019) as normally occurs in conventional cultivation systems.

Observation of consumer expectations on food quality presents the base for any successful food production system and marketing scheme. This is also true for fruits and vegetables which are increasingly valued as an important part of the diet (Péneau *et al*., 2006).

Appearance, colour, texture, and aroma are arguably the most important criteria used by consumers to evaluate the immediate quality of a product and thus, persuade them to buy it (Ragaert *et al*., 2004). In our experiment, quality parameters were not significantly affected by cultivation systems. Between the two cultivation systems, differences in fruit colour, firmness, and titratable acidity, were found in relation to the harvesting date. In analogous comparison experiments, fruit color between organic and conventional cultivation showed higher L*, a*, and b* values in the organic cultivation system. These results can be ascribed to agronomic management techniques but also to varieties and different geographical cultivation areas (Armesto *et al*., 2020).

Many studies on the quality of organic vegetables indicate a higher nutritional value and a higher content of biologically active compounds in agricultural crops from organic farming (Brandt and Mølgaard, 2001). In other related vegetable crops, such as tomato or pepper, it has also been found that production under organic conditions has a significant effect on fruit composition, which normally consists of an increase in the content of antioxidants and minerals (Chassy *et al*., 2006; del Amor *et al*., 2008). For this reason, organic agriculture is considered one of the best alternatives for sustainable and good quality food production (Aninowski *et al*., 2020).

Our results highlighted that the main significant changes were observed in growth parameters. The product quality was mainly influenced by environmental conditions that changed according to summer weather. Therefore, quality changes were visible at the different harvesting dates. It is known that vegetable crops have higher requirements compared to other crops and short cycles require appropriate agronomic management. The higher inputs do not always provide a better quality or higher yield in organic system. Meta-analysis performed on different crops highlighted a wide variability among crops in both organic and conventional systems. The majority showed higher inputs in conventional cultivations system (Seufert *et al*., 2012). However, the evaluation of both systems can provide useful information only if the cultivations are performed in the same environments and differences can be really attributed to the agronomic managements.

Our results showed that zucchini squash crop can be grown in organic or conventional cultivation systems with no significant changes in fruit quality. The organic system reduced the yield even if higher inputs of agronomic tools were required for the crop management. As reported by Rouphael *et al*. (2015), understanding the functional links between cultural factors and physiological responses is an important requisite to enhance the quality of organic products.

The organic cultivation was able to give comparable yield to conventional one under protected cultivation. Almost all the analysed qualitative parameters of fruits were not statistically different between the two systems, except for the TSS and L-mesocarp, to underline the possibility to adopt organic procedures also in greenhouse. The obtained results highlighted the difficulties of performing a comparison between these two cultivation systems because of the different variables that can change. Our study was carried out in a geographic area where the organic cultivation for vegetable crops has been long established and the contemporarily presence of organic and conventional cultivation systems allowed us to perform a scientific and reliable study. In conclusion, this work demonstrated that the organic system required higher inputs compared to the conventional cultivation system. The extensive experience of the grower allowed for comparable yields between the two systems. However, further evaluations should be performed for understanding the economic and environmental sustainability of zucchini squash production in the two cropping systems.

Acknowledgements

We would like to thank Sebastiano Azzarelli for his help in the field analysis.

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