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Melon (*Cucumis melo* L.) Fruit Yield under Irrigation and Mycorrhiza Conditions

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Abstract: The size and quality of the melon fruit yield depend on the cultivar, climatic and agronomic factors. A three-year field experiment investigated the effect of arbuscular mycorrhizal fungi (AMF) application and irrigation (IR) on the fruit yield of melon (*Cucumis melo* L. var. *saccharinus* Naud.) cultivars. The study was conducted on a certified organic farm located in south-eastern Poland (51.36° N, 22.83° E). The factors of the experiment were as follows: cultivar (Melba, Emir F1, Seledyn F1, Oliwin) and cultivation method (AMF and IR; AMF and non-IR; non-AMF and IR; non-AMF and non-IR as control). The dry matter (%), soluble solid (%), total sugar and reducing sugar (% fresh weight, FM), L-ascorbic acid (mg · 100 g^{-1} FM), and carotenoid (mg · 100 g^{-1} FM) contents of the fruit were determined. The highest total and marketable fruit yields were obtained using AMF and IR. Fruit from the AMF series (IR and non-IR) had the most carotenoids (respectively: 801.5 and 788.8 µg · 100 g^{-1} FM). The fruits of the AMF and IR plants contained the most total sugars (5.98%) and reducing sugars (2.91%) compared to the others. The control plants had the lowest number of marketable fruit, total and marketable fruit yield, and accumulated the least L-ascorbic acid, total sugars and reducing sugars. We suggest that AMF and IR can be recommended as a practical agronomic solutions for the field cultivation of melon under temperate climate conditions.

Keywords: sustainable horticulture; AMF; vegetable crops; plant growth; sugars; carotenoids; L-ascorbic acid

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1. Introduction

Water scarcity is a significant constraint on agricultural production. Effective irrigation practices can improve crop yields while reducing water use and conserving natural resources. Irrigation scheduling is crucial in vegetable production; inadequate irrigation usually results in yield loss and poor crop quality [1,2]. Using low-cost drip systems saves more than 50% more water than surface irrigation systems (ISs); this type of IS also significantly impacts vegetable yields [3]. Adaptive mechanisms that make plants more tolerant to the adverse effects of drought stress have been achieved through evolution. Microorganisms play an essential role in reducing the adverse effects of drought stress and thereby improve plant productivity [4]. Arbuscular mycorrhizal fungi (AMF) facilitate the vigorous growth of host plants under stressful conditions. Numerous reports describe increased resistance to various stresses, including drought, salinity, temperature, metals and disease, due to fungal symbiosis [5,6]. Unfortunately, there has recently been a gradual reduction in the diversity and incidence of AM fungi in agricultural soils and substrates due, in part, to modern tillage methods, the use of mineral fertilizers and the sterilization of substrates. In response, the external application of mycorrhizal spores is practiced, either by adding AMF inoculum to the growing medium or directly to the soil. Beneficial rhizosphere microorganisms can not only improve the nutritional status of crops [7] but also their quality, affecting, among other things, the production of carotenoids, anthocyanins, some

volatile compounds, flavonoids, sugars, organic acids, vitamin C, tocopherols, chlorophylls, and minerals [6].

Natural antioxidants have been the subject of much recent interest due to their potential impact on reducing the incidence of cardiovascular disease and several types of cancer [8]. These compounds, found in vegetables, fruits and herbs, are divided into three main classes: phenolic compounds, vitamins and carotenoids [9]. Vegetables contain significant amounts of antioxidants and are gaining importance in the human diet as anticancer agents. A diet rich in fresh vegetables protects against the risk of most common epithelial cancers, including those of the gastrointestinal tract and several nondigestive cancers [10]. Melons are one of the most widely grown vegetable crops in warmer regions worldwide. Ripe melons are prized for sweetness and eaten raw as a cooling dessert [11]. Melon fruit is valued for its taste, dietary qualities, and medicinal properties [12–15]. The biological value of melon, related to the presence of sugars, carotenoids, polyphenols, vitamin C and other vitamins and trace elements, is subject to genetic variation [15–17]. The medicinal profile of melon is extensive; antiulcer, analgesic, anti-inflammatory, antioxidant, anthelmintic, diuretic, antiplatelet, antimicrobial, hepatoprotective, antidiabetic, and anticancer activities are mentioned [12,18]. A study by Zulfikar et al. [19] showed that the antioxidant activity of melon fruit is positively correlated with the content of ascorbic acid and flavonoids. In Poland, despite less favorable environmental conditions, an increasing number of producers are interested in melon cultivation. Currently, the National List of Vegetable Cultivars includes seven varieties suitable for cultivation in Poland, and their number steadily increases [20]. The size and quality of melon yield are influenced by climatic and agrotechnical factors [16,17,21]. Melon has high moisture requirements [22–24], although some varieties perform better under drought or salt stress conditions [25–28]. Pandey et al. [29] found 14 of the 48 *C. melo* genotypes tested to be highly drought tolerant. Kıran et al. [30] demonstrated humic acid's beneficial effect regarding its ability to increase melon genotypes' tolerance to drought stress. To maximize melon fruit yield and quality, it is recommended to keep plants free from water stress from flowering until the end of harvest [31]. A study by Nut et al. [24] showed that the type and frequency of irrigation (IR) play an important role in melon growth and fruiting. When grown on very light soils with low water and nutrient retention capacity, drip IR and nitrogen fertigation significantly improve melon fruit yield and nutritional value [20].

Vegetable production is hampered by, among other things, several abiotic stresses. An essential task of correct agronomic management today is to increase the tolerance of plants to abiotic stresses. Choosing the suitable variety, cultivation period, sowing standards, and IR are among the most common strategies used to mitigate abiotic stresses' adverse effects. In crop production, attention is given to biostimulants, defined as organic or inorganic substances, microorganisms that are capable of mitigating the adverse effects of stress, or both, improving plant growth and productivity [32]. Bagheri et al. [33] showed that adding palm leaf biochar to the soil, especially under drought stress conditions, reduces the rate of water use and improves the growth and yield of melon plants. Mycorrhizae improve plant tolerance to a range of abiotic stresses through various physiological, functional and biochemical changes in plants [34]. AMF increase crop yields and crop water use efficiency [35]. The fertilizer type, substrate and mycorrhizae strongly influence melon's vegetative and reproductive growth. Melons appear to readily establish arbuscular mycorrhiza symbiosis with different substrate types, and fungal species, substrate and fertilizer types increase the plant yield and nutrient uptake [36]. Mycorrhizae improve the physiological and photosynthetic parameters of inoculated melon plants compared to plants without AMF under water-deficit conditions [37]. AMF inoculation improves plant growth, total fruit yield and the Brix of melon fruit [38], increases chlorophyll, carotenoids and mineral content in the plant [37], and has a positive effect on plants' tolerance to moderate water stress and some fruit quality parameters [39]. However, there is still a lack of information on environmentally friendly methods of intensifying the yield of thermophilic vegetables in temperate climate conditions. Such research will also be important for other regions of

vegetable production due to climate change. This work was designed to determine the size and quality of the melon fruit yield of six genotypes under IR and mycorrhization, and to determine the most favorable growing system for *C. melo* under field conditions in a temperate climate.

2. Materials and Methods

2.1. Place of Cultivation and Plant Material

The study was conducted between 2018 and 2020 on a private, certified organic farm (Agrobiotest 04557) located in south-eastern Poland (51.36° N, 22.83° E). The soil in this area is characterized as podzolic, very acidic, low in humus, and low in potassium and phosphorus. Appropriate agricultural technology is used on the farm, thanks to which the structure of the soil and its fertility have been increased. Four Polish cultivars of sugar melon (*Cucumis melo* L. var. *saccharinus* Naud.) were selected for the study: Melba, Emir F_1, Seledyn F_1, and Oliwin, which were bred at the Department of Plant Genetics, Breeding and Biotechnology SGGW, Warsaw. The plants of Polish melon cultivars show great adaptation to less favorable environmental conditions and, when grown in cooler climates, are characterized by lower yield unreliability [17,40,41].

2.2. Experimental Design

The agrotechnical experiment was conducted as a two-factorial experiment in a randomized block design with 4 replications. Melon plants were grown at a spacing of 1.2 m × 0.5 m (10 plants in each replicate plot of 6.0 m^2). The experimental factors were as follows: factor I (cultivar): Melba, Emir F1, Seledyn F1, Olive; factor II (mode of cultivation): 1. AMF and IR; 2. AMF and non-IR; 3. non-AMF and IR; 4. non-AMF and non-IR as a control. A commercial mycorrhizal inoculum (Mycoflor Mycorrhizal Fungi Laboratory, Końskowola, Poland) containing spores and dormant mycelium of MF (*Rhizophagus aggregatus*, *R. intraradices*, *Claroideoglomus etunicatum*, *Endogone mosseae*, *Funneliformis caledonium*, and *Gigaspora margarita*) mixed with peat was used in the experiment [42]. The endomycorrhizal inoculation used is for all vegetables and herbs except plants of the Brassicaceae family. Inoculation was performed according to the manufacturer's recommendation once, dosing the suspension under the roots of each plant. The forecrop for the melon was runner beans (*Phaseolus coccineus* L.). Organic fertilization (manure at 30 t · ha^{-1}) was applied in autumn. In spring, the mineral content of the soil arable layer was determined (Table 1). Two weeks before planting melon seedlings, a multi-nutrient (NPK 4-3-3 + 1 MgO BIO) organic fertilizer, Fertikal (Beveren, Belgium), was applied at a rate of 0.1 kg · 1 m^{-2} in 2018 and 0.8 kg · 1 m^{-2} in 2019 and 2020. Melon plants were foliar fed twice: 2 and 4 weeks after planting the seedlings, using a 0.5% solution of Bio-Algeen S90 fertilizer (Schulze & Hermsen GmbH, Dahlenburg, Germany), composed of N—0.02%, P—0.006%, K—0.096%, Ca—0.31%, Mg—0.021% and B—16 mg·kg^{-1}, Fe—6.3 mg·kg^{-1}, Cu—0.2 mg·kg^{-1}, Mn—0.6 mg·kg^{-1}, Zn—1.0 mg·kg^{-1}.

Table 1. The content of mineral components in the plough lager.

Year	Mineral Components (mg·dm^{-3})					pH_{H_2O}	Salinity (mg KCL·dm^{-3})
	$N\text{-}NO_3$	P	K	Ca	Mg		
2018	37	75	128	1480	105	6.5	0.17
2019	45	90	145	1250	90	6.4	0.23
2020	25	87	160	1620	110	6.7	0.25

Potted melon seedlings were prepared in the experimental greenhouse of the Department of Vegetable and Herb Crops of the University of Life Sciences in Lublin (Poland). Seeds were sown on the second decade of May (Table 2). At the 4–5-leaf growth stage, the plants were cut off the main shoot above the third leaf. One week before the scheduled planting date, a 16 mm diameter T-Tape drip tape with an emitter spaced every 30 cm was spread along the designated rows, and the soil was then covered with black agro-textile

fabric (Agrosak, Lodz, Poland). Melon seedlings were planted on the second day of June at a spacing of 1.2 m × 0.5 m (1.67 plants·m^{-2}) while applying mycorrhizal vaccine to the soil at a rate of 3 mL under each plant.

Table 2. The melon cultivation schedule in 2018–2020.

Year	Sowing Seeds	Thinning Seedlings	Soil Mulching	Planting Seedling	First Harvest	Last Harvest
2018	14.05	29.05	8.06	14.06	7.08	1.09
2019	15.05	27.05	6.06	13.06	9.08	4.09
2020	12.05	27.05	7.06	12.06	10.08	2.09

In 2018–2020, there were favorable thermal conditions for the growth and yield of thermophilus plants (Table 3). The irrigation treatment was started when the soil water potential value at a depth of 25 cm was equal to or less than 30 kPa, with a single application of 15–20 mm. The soil water potential value was measured using a tensiometer (TENSJOMETR MMM, STANDARD, Agrosimex, Goliany, Poland). During the research period, depending on the humidity, the following frequency of irrigation was used: 6 (2018), 8 (2019) and 6 (2020) water doses. The total water doses applied to the irrigated sites in 2018–2020 were 90, 150 and 90 mm, respectively.

Table 3. Weather conditions during the experiment relative to long-term date.

Year	Temperature (°C)					Precipitation (mm)				
	June	July	August	September	Mean	June	July	August	September	∑
2018	18.8	20.5	20.8	15.5	18.9	65	125	72	70	332
2019	21.5	19.4	20.3	15.5	19.2	37	38	102	68	245
2020	23.1	19.2	20.3	15.3	19.5	168	29	45	172	414
1951–2010	16.3	18.0	17.2	12.6	16.0	66	82	71	54	273

2.3. Morphological and Chemical Measurements

The start of harvesting was on the first decade of August. Melon fruits were harvested as they matured, at full physiological maturity. Harvesting was carried out weekly and completed on the first day of September. Commercial fruit is conventionally considered to be fruit weighing no less than 300 g, fully ripe and without disease symptoms. Fruits were harvested from each plot separately, and the following were determined: total yield, marketable yield (kg·m^{-2}) and the number of total and marketable fruits (pcs·m^{-2}). Fruit weight (g) and flesh weight (g) were determined on 4 fruits randomly selected from each combination of the experiment in each harvest, and measurements of flesh thickness (cm) and fruit skin thickness (mm) were taken.

2.4. Chemical Analysis of Melon Fruit

Plant material (melon fruit) from 2019–2020 was subjected to chemical evaluation. The selected chemical composition parameters were determined using commercial fruit harvested on the second decade of August. Fruits were taken randomly from each repetition, and a mixed sample was prepared for each combination tested. The fruit's dry matter (%), soluble solid (%), total sugar and reducing sugar (% fresh weight, FM), L-ascorbic acid (mg 100·g^{-1} FM), and carotenoid (µg 100·g^{-1} FM) contents were determined. Chemical analyses were performed in 3 replicates.

2.5. Dry Matter (%)

Aliquots of approximately 1 g (0.0001 g accuracy) of raw and ground fruits were weighed. Samples were dried in a drier at 105 °C for 6 h. The drying process was repeated until a constant weight of samples was reached (the difference between two subsequent

weighings should not be greater than 0.5 g). The difference in weights before and after drying was water loss; the result was then recalculated into the percentage of dry matter.

2.6. Soluble Solids (%)

The total content of water-soluble nonvolatile substances up to a temperature of 100 °C was determined using a refractometer (RE 50, Mettler Toledo, Greifensee, Switzerland) according to the PN-90 A-75101/02 standard [43].

2.7. L-Ascorbic Acid (mg · 100 g^{-1} FM)

The melon fruit (10 g) was extracted twice for 30 min with 2.5 mL of 4.0% (m/V) L-cysteine and 10.0 mL of water by sonification. All aqueous extracts were combined and diluted with water to 25 mL. L-ascorbic acid was quantified via high-performance liquid chromatography (HPLC) analysis using a reversed-phase C18-silica analytical column (LiChrospher 100RP dp = 5 × M 4 mm × 250 mm dimensions). The mobile phase, standard solutions, and samples were prepared as described by Najda et al. [44]. The results were expressed in mg of L-ascorbic acid per 100 g of FM.

2.8. Total Sugars (% FM)

The determination was performed according to the Schoorl–Luff method [45]. For this,10 g of the crushed material was placed in a beaker, topped with distilled water to 50 cm^3, boiled under cover and filtered while hot. After filtration, it was made up to 100 cm^3. For sucrose inversion, 5 cm^3 of HCl was added to 25 cm^3 of filtrate, heated in a water bath to 70 °C for 5 min, cooled rapidly and neutralized with a 30% NaOH solution. It was then made up to 100 cm^3 with distilled water. Then, 25 mL of Luff's solution was measured in a 250 mL conical Erlenmeyer flask, 10 mL of the analyzed solution was added, distilled water was added to the volume of 50 mL, and the whole was brought to the boil for 2 min, maintaining the gentle boiling process for 10 min. Then, the solutions were cooled to 20 °C, and 3 g of KJ and 25 mL of 25% sulfuric acid solution were added. Then, the solution was titrated with sodium thiosulfate (0.1 M), adding 2 mL of 2% starch solution at the end until it was creamy. At the same time, a blank test was performed (distilled water was used instead of the test solution).

2.9. Reducing Sugars (% FM)

Reducing sugars were determined by the titration method following Schoorl–Luff [45]. The extracts were prepared using water by grinding 10 g of fruit and 50 mL of distilled water in a mortar. A quantity of 10 mL of hydrolyzed sample was diluted up to 20 mL with distilled water and inserted into a 250 mL flask, to which 25 mL of Luff–Schoorl reactant was added, and the mix was heated in a Bunsen burner and kept boiling for 2 min. It was quickly cooled in an ice bath to room temperature, and 10 mL of potassium iodide 30% (*w*/*v*) solution, 10 mL of 10 N sulfuric acid and 3 drops of 1% starch were added. The iodine produced was titrated with 0.1 N sodium thiosulfate until the blue-black color disappeared. The blank test was performed using distilled water instead of the extract.

2.10. Calculation of Results

The calculations were made as follows:

$$X_1 = x \times 0.95 \times V/1000 \times m_p \times V_1$$

where X is the invert sugar content (mg), read from the table for calculating sugars using the Luff–Schoorl method; V is the volume of solution containing the entire sample weight (100 cm^3); m_p is the sample weight of 9 g; V_1 is the volume of invert sugar measured for the determination (10 cm^3); and 0.95 is the multiplier resulting from the mass ratios of the reactants during sucrose inversion.

2.11. Carotenoids (mg · 100 g^{-1} FM)

The carotenoid content was determined using a spectrophotometric method proposed by Hornero and Mínguez [46]. A quantity of 2 g of fruit was extracted in a volumetric flask containing 100 mL of acetone and then filtered, and absorbance measurements were made in a diode array spectrophotometer (Spectrophotometer UV–Vis Hitachi U-2900, Tokyo, Japan) at 472 and 508 nm. To obtain both isochromatic carotenoid and total carotenoid fractions, the absorbance values obtained are introduced in the following equations:

$$C^R = A508 \times 2144/A472 \times 403.3270.9$$

$$C^Y = A472 \times 1724.3/A508 \times 403.3270.9$$

$$C^T = C^R + C^Y$$

where C^R represents the red isochromatic fraction content, C^Y represents the yellow isochromatic fraction content, and C^T represents the total carotenoid content.

2.12. Statistical Analysis

Data were processed by analysis of variance (ANOVA), and mean separations were performed using the Tukey multiple range test $p < 0.05$. The Statistica software package ver. 13.0 PL (StatSof Inc., Tulsa, OK, USA) was used.

3. Results

The results indicate the significant effect of AMF and IR on melon growth, development and fruit yield (Table 4). Among the cultivars tested, plants of the Melba cultivar produced the highest total and marketable fruit. The highest total yield significantly distinguished plants of the Melba and Oliwin F_1 cultivars, while the highest marketable yield was found in the Emir F_1 and Seledyn F_1 cultivars. The share of marketable yield in the total yield was comparable in the cultivars tested. The application of AMF and IR proved to be the best for achieving the highest number of total and marketable fruit, as well as the highest total and marketable yield. The application of AMF and IR achieved the best melon fruit yield parameters, while the control without these treatments proved the least favorable. The results from the three years of trials indicate the possible influence of weather factors on melon yield.

By analyzing the melon fruit quality traits (Table 5), it can be seen that the cultivars Emir F_1 and Seledyn F_1 stood out in terms of fruit weight, flesh weight and flesh thickness (only the cultivar Emir F_1). In contrast, plants of the Melba variety had the highest proportion of flesh weight to fruit weight (88.6%), but also the highest skin thickness (4.1 ± 0.2 mm). AMF and IR, similar to AMF and non-IR, produced fruit with the highest fruit weight and flesh weight, while the untreated control had the lowest fruit weight and flesh thickness. Weather conditions influenced some melon fruit quality traits (flesh weight and thickness).

Interesting results were obtained by analyzing the chemical composition of melon fruit (Table 6). Cultivar, AMF, and IR, as well as the growing season, significantly modified the chemical composition of melon fruit. Fruits of the cultivar Emir F_1 were distinguished by the highest content of dry matter (6.07 ± 0.69%), soluble solids (7.79 ± 0.63%), total sugars and reducing sugars (respectively: 6.64 ± 0.33% and 3.35 ± 0.71%). The highest amount of L-ascorbic acid (15.61 ± 0.44 mg · 100 g^{-1} FM) was found in fruits of the Olivin variety, while carotenoids were found in fruits of the Melba variety (949.7 ± 211.1 µg · 100 g^{-1} FM). Fruits of the cultivar Seledyn F_1 contained the least L-ascorbic acid and carotenoids. AMF and irrigation treatments affected the accumulation of nutrients in melon fruit differently. The AMF and IR treatments showed the highest total and reducing sugars in the fruit, while the AMF and IR and AMF and non-IR treatments showed the highest levels of L-ascorbic acid and carotenoids.

Table 4. Fruit number and fruit yield of studied melon cultivars (mean for 2018–2020).

Cultivar	Treatment	Total Fruit Number (TF) (pcs·m^{-2})	Marketable Fruit Number (MF) (pcs·m^{-2})	MF in TF (%)	Total Yield (TY) (kg·m^{-2})	Marketable Yield (MY) (kg·m^{-2})	MY in TY (%)
Melba	AMF and IR *	5.2 ± 0.6 a	4.6 ± 0.5 a	88.5	3.55 ± 0.54 bcd	3.01 ± 0.39 bc	84.8
	AMF and non-IR	5.0 ± 0.8 ab	4.4 ± 0.8 ab	88.0	3.23 ± 0.67 cde	2.67 ± 0.5 ab	82.7
	non-AMF and IR	4.9 ± 0.8 ab	4.4 ± 0.7 ab	89.8	3.06 ± 0.56 de	2.5 ± 0.47 cde	81.7
	non-AMF and non-IR	4.6 ± 0.7 bc	3.9 ± 0.7 bc	84.5	2.71 ± 0.47 e	2.12 ± 0.40 e	78.2
	Mean	4.9 ± 0.7 A	4.3 ± 0.7 A	88.7	3.14 ± 0.63 A	2.58 ± 0.54 B	82.2
Emir F_1	AMF and IR *	4.6 ± 0.7 abc	3.9 ± 0.4 bc	84.8	4.29 ± 0.73 a	3.75 ± 0.53 a	87.4
	AMF and non-IR	4.2 ± 0.6 bcde	3.5 ± 0.5 cde	83.3	4.16 ± 0.58 ab	3.41 ± 0.42 ab	82.0
	non-AMF and IR	3.8 ± 0.7 cde	3.0 ± 0.8 def	78.9	3.64 ± 0.51 abcd	2.87 ± 0.64 bcd	78.8
	non-AMF and non-IR	3.4 ± 0.8 d	2.7 ± 0.6 f	79.4	3.12 ± 0.48	2.50 ± 0.40 cde	80.1
	Mean	4.0 ± 0.9 B	3.3 ± 0.7 B	82.5	3.80 ± 0.85 B	3.13 ± 0.74 A	82.4
Seledyn F_1	AMF and IR *	4.4 ± 0.6 bcd	3.8 ± 0.4 bc	86.4	4.30 ± 0.32 a	3.72 ± 0.30 a	86.5
	AMF and non-IR	4.1 ± 0.3 cde	3.3 ± 0.3 cdef	80.5	4.02 ± 0.32 ab	3.29 ± 0.37 ab	81.8
	non-AMF and IR	3.9 ± 0.4 cde	3.2 ± 0.5 cdef	82.0	3.69 ± 0.40 abcd	3.14 ± 0.38 bc	85.1
	non-AMF and non-IR	3.4 ± 0.4 e	2.8 ± 0.4 ef	82.3	3.27 ± 0.22 cde	2.55 ± 0.25 cde	78.0
	Mean	4.0 ± 0.6 B	3.3 ± 0.5 B	82.5	3.82 ± 0.50 B	3.18 ± 0.53 A	83.4
Oliwin F_1	AMF and IR *	4.3 ± 0.6 bcd	3.6 ± 0.6 bc	83.7	3.92 ± 0.57 abc	3.30 ± 0.50 ab	84.2
	AMF and non-IR	4.0 ± 0.5 cde	3.2 ± 0.5 cdef	80.0	3.49 ± 0.42 bcd	2.92 ± 0.42 bcd	83.7
	non-AMF and IR	3.7 ± 0.4 de	3.0 ± 0.3 def	81.1	3.18 ± 0.24 de	2.45 ± 0.25 cde	77.0
	non-AMF and non-IR	3.7 ± 0.5 de	2.9 ± 0.5 def	78.4	3.05 ± 0.26	2.37 ± 0.29 de	77.7
	Mean	3.9 ± 0.5 B	3.2 ± 0.5 B	82.1	3.41 ± 0.51 A	2.76 ± 0.53 B	80.9
Mean	AMF and IR *	4.6 ± 0.7 A	4.0 ± 0.6 A	87.0	4.02 ± 0.62 A	3.45 ± 0.53 A	85.8
	AMF and non-IR	4.3 ± 0.7 B	3.6 ± 0.7 B	83.7	3.72 ± 0.63 B	3.07 ± 0.50 B	82.5
	non-AMF and IR	4.1 ± 0.8 C	3.4 ± 0.9 B	82.9	3.39 ± 0.66 C	2.74 ± 0.58 C	80.8
	non-AMF and non-IR	3.8 ± 0.8 C	3.1 ± 0.7 C	81.6	3.04 ± 0.42 D	2.38 ± 0.37 D	78.3
	Mean	4.2 ± 0.8	3.5 ± 0.8	83.3	3.54 ± 0.69	2.91 ± 0.64	82.2
Mean	2018	4.0 ± 0.9 B	3.4 ± 0.8 A	85.0	3.44 ± 0.80 A	2.86 ± 0.71 A	83.1
	2019	4.3 ± 0.8 A	3.5 ± 0.8 A	81.4	3.64 ± 0.69 A	2.98 ± 0.65 B	81.9
	2020	4.3 ± 0.8 A	3.5 ± 0.8 A	81.4	3.54 ± 0.60 A	2.89 ± 0.54 A	81.6

* IR = Irrigation. The same letters indicate no statistically significant differences; lowercase letters refer to the significance of interactions, and uppercase letters refer to differences in the mean values for the studied factors.

Table 5. Fruit quality features of studied melon cultivars (mean for 2018–2020).

Cultivar	Treatment	Fruit Weight (FW) (g)	Flesh Weight (FLW) (g)	FLW in FW (%)	Skin Thickness (mm)	Flesh Thickness (cm)
Melba	AMF and IR *	655 ± 65 d	585 ± 55 d	89.3	4.2 ±0.1 a	2.6 ± 0.1 gh
	AMF and non-IR	613 ± 44 d	543 ± 39 de	88.6	4.0 ± 0.2 ab	2.5 ± 0.1 hi
	non-AMF and IR	567 ± 42 d	499 ± 37 de	88.0	4.2 ± 0.1 abc	2.5 ± 0.1 hi
	non-AMF and non-IR	555 ± 68 d	488 ± 61 d	87.9	4.1 ± 0.3 bcde	2.4 ± 0.1 i
	Mean	597 ± 67 C	529 ± 61 C	88.6	4.1 ± 0.2 A	2.5 ± 0.1 D
Emir F_1	AMF and IR *	970 ± 74 a	836 ± 59 a	86.2	4.0 ± 0.2 abcde	3.7 ± 0.1 a
	AMF and non-IR	982 ± 61 a	848 ± 54 a	86.4	3.9 ± 0.1 cde	3.6 ± 0.2 ab
	non-AMF and IR	959 ± 69 a	828 ± 60 a	86.3	4.0 ± 0.2 cde	3.5 ± 0.1 bc
	non-AMF and non-IR	930 ± 62 ab	803 ± 55 ab	86.3	3.9 ± 0.2 abcd	3.4 ± 0.1 cde
	Mean	960 ± 68 A	829 ± 58 A	86.4	4.0 ± 0.2 B	3.6 ± 0.2 A
Seledyn F_1	AMF and IR *	1011 ± 131 a	876 ± 114	86.6	3.9 ± 0.2 de	3.6 ± 0.1 bc
	AMF and non-IR	1010 ± 122 a	878 ± 106 a	86.9	3.8 ± 0.2 de	3.5 ± 0.2 bcd
	non-AMF and IR	994 ± 83 a	859 ± 70 a	86.4	4.1 ± 0.2 abcde	3.4 ± 0.1 cde
	non-AMF and non-IR	939 ± 123 ab	819 ± 111 a	87.2	4.0 ± 0.1 abcde	3.4 ± 0.1 cde
	Mean	988 ± 115 A	858 ± 101 A	86.8	3.9 ± 0.2 B	3.5 ± 0.1 B

* IR = Irrigation. The same letters indicate no statistically significant differences; lowercase letters refer to the significance of interactions, and uppercase letters refer to differences in the mean values for the studied factors.

Table 5. *Cont.*

Cultivar	Treatment	Fruit Weight (FW) (g)	Flesh Weight (FLW) (g)	FLW in FW (%)	Skin Thickness (mm)	Flesh Thickness (cm)
Oliwin F_1	AMF and IR *	924 ± 49 abc	800 ± 43 abc	86.6	3.8 ± 0.2 e	3.4 ± 0.1 de
	AMF and non-IR	910 ± 97 abc	788 ± 85 abc	86.6	3.9 ± 0.2 de	3.3 ± 0.2 e
	non-AMF and IR	840 ± 112 bc	726 ± 98 bc	86.4	3.9 ± 0.1 bcde	3.1± 0.2 f
	non-AMF and non-IR	822 ± 94 c	711 ± 83 c	86.5	3.9 ± 0.1 bcde	2.7 ±0.3 g
	Mean	874 ± 99 B	756 ± 86 B	86.5	3.9 ± 0.2 B	3.1 ± 0.3 C
Mean	AMF and IR *	890 ± 164 A	744 ± 134 A	87.0	4.0 ± 0.2 A	3.4 ± 0.5 A
	AMF and non-IR	879 ± 180 AB	764152 A	86.9	3.9 ± 0.2 A	3.3 ± 0.5 A
	non-AMF and IR	840 ± 187 BC	728 ± 158 B	86.7	4.0 ± 0.2 A	3.2 ± 0.4 B
	non-AMF and non-IR	812 ± 180 C	705 ± 155 B	86.8	4.0 ± 0.2 A	3.0 ± 0.5 C
	Mean	855 ± 179	743 ± 151	86.9	4.0 ± 0.2	3.2 ± 0.5
Mean	2018	855 ± 167 A	744 ± 143 AB	87.0	4.0 ± 0.2 A	3.1 ± 0.5 A
	2019	870 ± 209 A	757 ± 176 A	87.0	4.0 ± 0.3 A	3.2 ± 0.4 B
	2020	840 ± 159 A	727 ± 132 B	86.5	3.9 ± 0.2 A	3.2 ± 0.5 B

* IR = Irrigation. The same letters indicate no statistically significant differences; lowercase letters refer to the significance of interactions, and uppercase letters refer to differences in the mean values for the studied factors.

Table 6. Qualitative features of studied melon fruit (mean for 2019–2020).

Cultivar	Treatment	Dry Matter (%)	Soluble Solids (%)	L-Ascorbic Acid (mg · 100 g^{-1} FM)	Total Sugars (% FM)	Reducing Sugars (% FM)	Carotenoids (µg · 100 g^{-1} FM)
Melba	AMF and IR *	4.82 ± 0.45 ghi	7.05 ± 0.49 cd	15.13 ± 0.67 ab	5.55 ± 0.81 d	3.07 ± 0.49 cd	987.2 ± 215.7 ab
	AMF and non-IR	4.88 ± 0.36 ghi	6.70 ± 0.45 ef	15.32 ± 0.64 ab	5.49 ± 0.79 d	3.01 ± 0.31 d	1016.8 ± 271.5 a
	non-AMF and IR	4.72 ± 0.48 hi	6.67 ± 0.49 ef	14.75 ± 0.59 bc	5.06 ± 0.87 ef	32.61 ± 0.46 efg	907.7 ± 199.3 c
	non-AMF and non-IR	4.80 ± 0.48 hi	6.85 ± 0.51 de	14.52 ± 0.68 bc	5.23 ± 0.74 e	2.64 ± 0.36 ef	887.3 ± 176.7 c
	Mean	4.81 ± 0.42 D	6.82 ± 0.48 B	14.93 ± 0.57 B	5.33 ± 0.79 C	2.82 ± 0.39 B	949.7 ± 211.1 A
Emir F_1	AMF and IR *	6.04 ± 0.80 b	8.28 ± 0.75 a	14.27 ± 0.35 cd	6.92 ± 0.51 a	3.53 ± 0.74 a	648.2 ± 116.1 e
	AMF and non-IR	6.06 ± 0.52 b	7.22 ± 0.47 bc	13.54 ± 0.75 de	6.87 ± 0.42 a	3.38 ± 0.75 ab	611.0 ± 131.8 f
	non-AMF and IR	5.84 ± 0.73 cd	7.47 ± 0.85 b	13.63 ± 0.79 d	6.41 ± 0.23 bc	3.26 ± 0.76 b	593.2 ± 130.3 fg
	non-AMF and non-IR	6.35 ± 0.76 a	8.18 ± 0.63 a	13.42 ± 0.75 de	6.37 ± 0.39 c	3.22 ± 0.78 bc	583.5 ± 132.2 fg
	Mean	6.07 ± 0.69 A	7.79 ± 0.63 A	13.72 ± 0.73 C	6.64 ± 0.33A	3.35 ± 0.71 A	609.0 ± 121.8 C
Seledyn F_1	AMF and IR *	5.53 ± 0.27 ef	6.05 ± 0.49 b	13.47 ± 0.67 de	6.57 ± 0.13 b	2.74 ± 0.19 e	583.2 ± 81.4 fg
	AMF and non-IR	5.84 ± 0.43 c	6.72 ± 0.37 ef	13.54 ± 0.59 de	6.46 ± 0.14 bc	2.54 ± 0.16 fgh	570.2 ± 68.6 g
	non-AMF and IR	5.37 ± 0.39 f	6.12 ± 0.45 h	13.43 ± 0.69 de	6.34 ± 0.17 c	2.43 ± 0.17 ghi	450.5 ± 68.0 h
	non-AMF and non-IR	5.63 ± 0.48 de	6.48 ± 0.48 fg	12.73 ± 0.35 e	6.35 ± 0.19 c	2.36 ± 0.14 hi	449.8 ± 56.8 h
	Mean	5.59 ± 0.42 B	6.34 ± 0.68 C	13.25 ± 0.42 D	6.43 ± 0.15 B	2.52 ± 0.19 C	513.4 ± 82.0 D
Oliwin	AMF and IR *	4.92 ± 0.37 gh	6.31 ± 0.38 gh	15.85 ± 0.45 a	4.89 ± 0.11 fg	2.28 ± 0.26 ij	987.5 ± 289.9 ab
	AMF and non-IR	4.90 ± 0.53 gh	6.25 ± 0.25 gh	15.69 ± 0.48 a	4.78 ± 0.19 gh	2.13 ± 0.198 jk	957.3 ± 257.9 b
	non-AMF and IR	4.69 ± 0.54 i	6.08 ± 0.29 h	16.62 ± 0.47 a	4.61 ± 0.13 hi	2.10 ± 0.25 jk	811.8 ± 261.6 d
	non-AMF and non-IR	5.01 ± 0.44 g	6.06 ± 0.34 h	15.26 ± 0.42 ab	4.53 ± 0.12 i	2.07 ± 0.17 j	790.8 ± 272.6 d
	Mean	4.88 ± 0.46 C	6.18 ± 0.65 D	15.61 ± 0.44 A	4.70 ± 0.18 D	2.15 ± 0.22 D	886.8 ± 285.8 B
Mean	AMF and IR *	5.33 ± 0.50 B	6.92 ± 0.42 A	14.68 ± 0.54 A	5.98 ± 092 A	2.91 ± 0.49 A	801.5 ± 290.1 A
	AMF and non-IR	5.42 ± 0.54 A	6.72 ± 0.66 B	14.52 ± 0.53 AB	5.90 ± 0.92 B	2.77 ± 0.35 B	788.8 ± 200.6 A
	non-AMF and IR	5.15 ± 0.33 C	6.59 ± 0.29 C	14.36 ± 0.57 B	5.60 ± 0.91 C	2.60 ± 0.39 C	690.8 ± 146.7 B
	non-AMF and non-IR	5.45 ± 0.41 A	6.89 ± 0.38 A	13.98 ± 0.52 C	5.62 ± 0.88 C	2.57 ± 0.33 C	677.8 ± 139.7 B
	Mean	5.34 ± 0.49	6.78 ± 0.58	14.39 ± 0.53	5.78 ± 0.91	2.71 ± 0.81	739.7 ± 272.1

* IR = Irrigation. The same letters indicate no statistically significant differences; lowercase letters refer to the significance of interactions, and uppercase letters refer to differences in the mean values for the studied factors.

4. Discussion

Melon (*Cucumis melo* L.) is a polymorphic taxon encompassing many botanical and horticultural cultivars, and exhibits high morphological and chemical diversity [47–49]. Chikh-Rouhou et al. [50] divided melon accessions into five groups, indicating a mixed genetic structure between local races and breeding lines belonging to different botanical groups. Two main sweet and nonsweet melon clusters were distinguished, and subgroups were inodorus, cantalupensis and reticulatus. *C. melo* var. *saccharinus* varieties are characterized by highly variable fruit characteristics, such as flesh color, sugar content and shape [51]. Our results confirm the high degree of morphological and chemical variation in *C. melo* L. The cultivars we studied differed in both fruit size and yield quality. In terms of yield characteristics, the Melba cultivar stood out (the highest number of total and marketable

fruit, the highest total yield, similar to Olivin, and the highest proportion of flesh weight in fruit weight), and the cultivars Emir F_1 and Seledyn F_1 (the highest marketable yield). Our previous research [17] demonstrated that the cultivars Emir F_1, Junior F_1 and Seledyn F_1 yield at an equal level. On the other hand, Rolbiecki et al. [20] found that the Seledyn variety is more prolific than the Melba variety. Al-Mefleh et al. [23] reported that the total yield of melon fruit varies from one growing season to another. Among the reasons for the high variation within the *C. melo* L. species, weather factors shaping melon fruit yield should also be considered.

C. melo var. *saccharinus* (Hami melon) is popular, among others, in China for its excellent taste [51]. The aroma of its fruit is very rich: the green, sweet, fruity notes of melon, other fruits, wine and special notes create a unique taste and aroma [52]. Albuquerque et al. [53] proved that flavor was the most crucial parameter determining consumers' decisions for different melon varieties and that sugars and organic acids improve the perception of specific flavor notes. Our study confirms the high quality of *C. melo* var. *saccharinus* fruit. Considering the biological qualities of the melon fruits studied, we distinguished the Olivin (L-ascorbic acid) and Melba (carotenoids) varieties, which confirms in part the results of Rolbiecki et al. [20]. In contrast, in our earlier study [17], we obtained the highest amount of L-ascorbic acid in the fruit of the cultivar Seledyn F_1 and highest carotenoids in the cultivars Emir F_1 and Junior F_1. Melons are consumed for their sweet taste, a trait attributed to sucrose accumulation at a late stage of fruit development [52]. This trait, according to our study, can also be genetically determined. Fruits of Emir F_1 were characterized by the highest contents of dry matter, soluble solids, total sugars and reducing sugars. It can be assumed that the accumulation of melon metabolites is genetically determined but also strongly influenced by weather conditions. In addition, Bouzo et al. [54] found different plant responses in two melon cultivars to potassium and calcium fertilization, suggesting that the chemical composition of melon fruit is also subject to environmental variability.

Water is crucial in shaping melon fruit growth and production [20,24,55]. Moderate to heavy deficit irrigation significantly reduces melon fruit's relative water content, yield, and firmness, and significantly increases the L-ascorbic acid content [39]. Plant biostimulants activate several biochemical and physiological mechanisms under water and nutrient stress conditions, such as improved leaf water relations and increased pigment biosynthesis, consequently improving water and nutrient absorption. Our study shows that AMF and IR are a promising combination of agronomic treatments that can be used to positively influence the melon fruit number, weight, chemical composition and yield. An increase in the water-use efficiency of microbial biostimulants, in particular AMF, has been reported in various crops [56]. AMFs, as natural root symbionts, provide host plants with essential inorganic nutrients, thereby improving growth and yield under different conditions [6]. The inoculation of melon plants with AMF positively affects their tolerance to moderate water stress and some fruit quality parameters (length, firmness and sugar content). The combined use of moderate deficit irrigation (80%) and AMF soil inoculation conserves water without affecting fruit yield and increases some fruit quality traits [39]. In our study, however, we proved that AMF and IR guarantee the highest number of melon fruits (total and commercial), the highest share of commercial fruit number in the total number of fruits and the highest fruit yield (total and commercial and share of commercial yield in the total yield). The treatments applied resulted in an increase in fruit yield and an improvement in the fruit structure. Abraham-Juárez et al. [57], using indigenous strains of *B. subtilis* in greenhouse cultivation, obtained high-quality melon fruit; they used the strain *B. subtilis* LAL-36, thus yielding the best production results and increasing the yield by 20%. Al-Mefleh et al. [23] reported that increasing irrigation levels increases melon fruit flesh's length, diameter, weight, Brix and firmness. This study showed that the sugar content of the fruit does not decrease with increasing IR levels. This is supported by our results showing that the highest contents of total sugars and reducing sugars accumulate in the fruit of plants treated with AMF and IR. Furthermore, in the AMF and IR and AMF and

non-IR series, the melon plants accumulated the most L-ascorbic acid in their fruit. The fruit of plants without AMF (both with and without IR) accumulated the least total sugars, reducing sugars, carotenoids, and L-ascorbic acid (similar to AMF and non-IR). Gómez-Bellot et al. [58] noted that the application of AMF in tomato cultivation only improved some parameters due to the low percentage of colonization, suggesting that the efficacy of AMF under field conditions is slower and dependent on several factors. One of them may be IR, as indicated by the results of our study.

5. Conclusions

The cultivars of sugar melon vary in terms of functional traits and chemical composition, which is also influenced by growing conditions. Melon cultivars intended for cultivation in a temperate climate show high yield stability regardless of weather conditions.

The AMF inoculation of melon can be used because it protects plants from undesirable abiotic stresses. In cultivating melon under temperate climate conditions, the combined application of AMF and IR can be recommended as a practical agronomic solution with positive effects on fruit yield and quality. The content of L-ascorbic acid and carotenoids in melon fruit was determined by mycorrhiza. Future research should focus on simple and environmentally friendly agronomic solutions in order to optimize melon production under different climatic (temperate, hot, semi-arid) and environmental conditions (water stress, salt stress, cold stress), and to elucidate the interaction between the genotype and environment.

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