Scientific Papers. Series B, Horticulture. Vol. LXVIII, No. 2, 2024
Print ISSN 2285-5653, CD-ROM ISSN 2285-5661, Online ISSN 2286-1580, ISSN-L 2285-5653

QUALITATIVE AND AGROPRODUCTIVE RESULTS REGARDING SUCCESSIVE CROP OF SWEET PEPPER IN PROTECTED SPACES

Ioana BUȚERCHI[1], Gabriel-Ciprian TELIBAN[1*], Lorena-Diana POPA[2], Marian BURDUCEA[1, 3], Ioan PUIU[1], Nicolae-Valentin VLĂDUȚ[4], Alina Laura AGAPIE[5], Gheorghe MATEI[6], Ilie BODALE[1], Liviu-Mihai IRIMIA[1], Alexandru COJOCARU[1], Mădălina TENIE[1], Vasile STOLERU[1]

[1]"Ion Ionescu de la Brad" Iaşi University of Life Sciences, 3 Mihail Sadoveanu, Iaşi, Romania
[2]ARDS Secuieni-Neamţ, 371 Principală Street, Secuieni, Romania
[3]"Al. I. Cuza" University of Iași, 11 Carol I Blvd, Iași, Romania
[4]INMA Bucharest, 6 Ion Ionescu de la Brad Blvd, District 1, Bucharest, Romania
[5]ARDS Lovrin, 200 Principală Street, Lovrin, Romania
[6]University of Craiova, 19 Libertății Street, Craiova, Romania

Corresponding author email: gabriel.teliban@iuls.ro

Abstract

Sweet peppers are among the most appreciated vegetable species, renowned for their important nutrients and organoleptic properties. Although their cultivation is mainly carried out in the main crop, for the present study, the sweet peppers were established in a tunnel, in a successive system of culture, after the early cabbage. The aim of this study was to evaluate the influence of the fertilization regime and the cultivar on biochemical and agroproductive characteristics of three sweet pepper hybrids grown in tunnel in a successive system. The experimental protocol consisted in the organization of a bifactorial experience, placed in subdivided plots, with three repetitions: Factor A – Sweet pepper hybrid (a1 - Reno F1; a2 - Traian F1; a3 - Bihar F1) and Factor B – Fertilization regime (b1 - unfertilized; b2 - organic fertilization; b3 - chemical fertilization). Results showed significant influence of the fertilization regime on yields, the best quantitative values being obtained following chemical fertilization (1.52 kg/plant). Conversely, the highest vitamin C content (127.40 mg/100 g product) was observed with organic fertilization.

Key words*: sweet pepper, hybrid, fertilization, yield, protected spaces.*

INTRODUCTION

Sweet pepper (*Capsicum annuum* L.), an annual herbaceous plant also known as pepper or capsicum, belongs to the *Solanaceae* family. It is part of the genus *Capsicum*, which encompasses approximately thirty species. Among these, it is one of the five domesticated species, alongside *C. chinense* Jacq., *C. baccatum* L., *C. frutescens* L., and *C. pubescens* (Akhtar et al., 2021). The most farmed spice in the world, *Capsicum annuum* L., is highly appreciated for its intense flavor, aroma, and vibrant color features. Vegetables serve as the primary dietary sources of bioactive compounds essential for human health and well-being (Florescu et al., 2022). Sweet peppers are utilized for various home dishes as fresh, preserved, and dried. However, the freshness of red peppers gradually diminishes during storage due to natural processes occurring under different conditions (Bita et al., 2009). Red fruits peppers are highly nutritious (Brezeanu et al., 2022), high in antioxidant-producing polyphenolic compounds, as well as a good source of vitamins A, C and minerals (Vlahova et al., 2011; Narayan et al., 2009; El-Ghorab et al., 2013; Kantar et al., 2016). However, several variables, including species, seasonality, environmental condition, and the plant's life cycle, affect the chemical profile of peppers (Antonio et al., 2018). High yields can be obtained through the judicious selection of hybrids, using an appropriate technology, with a particular focus on fertilization. Several factors also influence the vitamin C content in horticultural products, including cultivar, eco-pedoclimatic conditions, cultivation methods, harvest time and storage conditions. According

to Szafirowska and Elkner (2008), pepper fruits grown in an organic system had increased levels of beta-carotene, vitamin C, and total flavonoids. Caruso et al. (2019) assessed the effects of conventional and organic farming, with microorganism-enriched fertilization, on two pepper cultivars 'Brillant' and 'Yolo Wonder'. Conventionally grown plants had higher assimilatory pigment levels, while microorganism-enriched fertilization increased yields. 'Yolo Wonder' red fruits had higher carotenoids and antioxidants, particularly under organic farming with microorganism-enriched fertilization. Barcanu et al. (2021) explored the impact of organic and chemical fertilization on 'Regal' and 'Cantemir' sweet peppers. Their findings revealed that the 'Cantemir' responds differently to fertilization compared to 'Regal' which remained unaffected. More recent, Stoleru et al. (2023) investigated the cultivation of two sweet pepper cultivars, 'Blancina' and 'Brillant', using different fertilization approaches: chemical, organic, and biological. Biological and organic fertilizations significantly improved most parameters analyzed, such as yield, acidity, and phytonutrient content. However, chemical treatment outperformed them only in mineral content.

The objective of this study was to assess the influence of fertilization regime and the hybrid on the biochemical and agroproductive characteristics of three sweet pepper hybrids grown in a wood tunnel using a successive crop system.

MATERIALS AND METHODS

The biological material and working methodology

The research was carried out in an experimental farm in the village of Corod, Galați County, in 2023 (Figure 1). The experimental protocol was organized as bifactorial in the form of subdivided plots with three repetitions. The two experimental factors studied were represented by Factor A - Sweet pepper hybrid (a1 - Reno F1; a2 - Traian F1; a3 - Bihar F1) and Factor B - Fertilization regime (b1 - unfertilized; b2 - organic fertilization; b3 - chemical fertilization).

The biological material used consisted of three sweet pepper hybrids suitable for cultivation both in the field and in protected spaces.

The Reno F1 cultivar is an early sweet pepper variety with good stress tolerance. Its excellent fruits guarantee a high production yield, featuring bright red color, thick flesh, and a weight ranging between 160-180 grams.

The Traian F1 cultivar is a semi-late sweet pepper hybrid with indeterminate growth and high production capacity. The fruits are large, intensely red, with a weight of 150-190 grams and a high dry matter content.

The Bihar F1 cultivar is characterized by indeterminate growth and good resistance to dropping. The fruits are large, dark red, with thick flesh and a fruit weight ranging between 150 and 220 grams.

Figure 1. Aspects from the experimental crop of sweet pepper

The experimental fertilization regime involved a control variant - unfertilized, and two different types of fertilizers - organic and chemical.

Organic fertilization was carried out with Orgevit, while chemical fertilization was done with Nutri Top NPK 5.10.15, applied once, at the preparation of the seedbed, before planting the seedlings.

Orgevit is a granular fertilizer with a 100% content of organic substances of natural origin (poultry), containing all the necessary micro and macroelements for plants (65% organic matter, 90% dry matter, 4% N, 3% P_2O_5, 2.5% K_2O, 1% MgO, 0.02% Fe, 0.01% Mn, 0.01% B, 0.01% Zn, 0.001% Cu, 0.001% Mo).

Nutri Top NPK 5.10.15 is a solid chemical fertilizer containing humic extracts, macro and microelements (5% N, 10% P_2O_5, 15% K_2O,

37% SO_3, 10% CaO, 1.3% MgO, 0.5% Fe, 0.01% Mn, 0.02% B, 0.01% Zn, 0.007% Cu), with a complex effect on plants and soil, maximizing nutrient availability and yields.

The crop was established by planting the seedlings on May 31, as a successive crop after early cabbage, in a tunnel covered with polyethylene film. Cultivation practices were carried out according to recommendations from specialized literature (Ciofu et al., 2003; Munteanu, 2003). Pepper fruits harvesting was done in four stages, starting with 801 BBCH (Meier, 2001), followed by productivity indicators and biochemical determinations.

Productivity indicators

The yield determinations aimed at analyzing the main productivity indicators such as: the number of fruits per plant, the total yield per plant, the average weight of a fruit, and the height and diameter of the fruits.

Color parameters

To determine color parameters, the MiniScan XE Plus device manufactured by HunterLab, Reston, VA, USA, was employed. The parameters examined included L, a, and b. L denotes brightness (ranging from 0 to 100), a indicates redness to greenness (0 to 100 = red and −80 to 0 = green), and b represents yellowness to blueness (0 to 70 = yellow; −100 to 0 = blue).

Biochemical analyses

Total Soluble Solids content (TSS) was evaluate using a Refractometer. The results were expressed in °Brix according to OECD standards, 2018 and Irimia, 2013.

Titratable acidity (TA) was determined by titrimetric method. Sweet pepper samples were homogenized with distilled water and titrated with NaOH until reaching of 8.1 pH. Results were expressed as % citric acid.

Ascorbic acid (Vitamin C) content was determined with a Reflectoquant, a dispositive that measures light reflected from the test strip. The determination range is between 25 and 450 mg/L ascorbic acid and the results are expressed in mg/100 g fresh product (Irimia, 2021).

Moisture (M) was carried out by oven drying method at 105 degrees for 4 hours and Total Dry Matter was calculated based on the formula, TDM % =100 - M%.

Ash (A). Sweet pepper samples were set on fire at 550 ± 20ºC in ash oven (AOAC, Method Number 930.05, http://www.eoma.aoac.org/methods/info.asp?ID=31326).

Biochemical parameters were determined in triplicate according to the standards, averages being statistically analyzed.

Statistical analyses

The experimental data obtained were analyzed using appropriate statistical methods recommended by the specialized literature (Jitareanu, 1999; Leonte and Simioniuc, 2018; Chiruță, 2019).

The results were reported as means ± standard error after data processing through ANOVA, and differences between variants were highlighted using the Tukey test, employing SPSS software v21.

RESULTS AND DISCUSSIONS

Sweet pepper productivity

The influence of the hybrid and fertilization regime on sweet pepper productivity indicators is presented in Table 1.

Table 1. Results regarding the influence of the hybrid and fertilization regime on the main productivity indicators

Experimental variant	No. of fruits/plant	Fruit weight (g)	Total yield (kg/plant)	Plant height (cm)	Fruit diameter (cm)
Hybrid					
Reno F1	9.08 ± 0.21 ns	140.56 ± 3.92 ns	1.28 ± 0.04 ns	5.02 ± 0.14 ns	8.50 ± 0.08 b
Traian F1	8.78 ± 0.39 ns	128.51 ± 0.36 ns	1.12 ± 0.05 ns	5.07 ± 0.15 ns	8.76 ± 0.03 a
Bihar F1	9.55 ± 0.55 ns	123.15 ± 5.76 ns	1.19 ± 0.10 ns	5.06 ± 0.04 ns	8.55 ± 0.02 ab
Significance	ns	ns	ns	ns	*
Fertilization regime					
Unfertilized	7.50 ± 0.39 b	126.30 ± 2.57 ns	0.94 ± 0.06 b	4.20 ± 0.12 b	7.87 ± 0.03 c
Organic	8.69 ± 0.10 b	130.09 ± 1.34 ns	1.13 ± 0.00 b	4.90 ± 0.25 b	8.60 ± 0.06 b
Chemical	11.22 ± 0.63 a	135.84 ± 2.48 ns	1.52 ± 0.08 a	6.03 ± 0.07 a	9.30 ± 0.00 a
Significance	*	ns	*	*	*

Within each column, * - statistically significant difference, ns - no statistically significant difference, values associated to different letters are significantly different according to Tukey's test at $p<0.05$.

Regarding the hybrid factor, there were no significant differences observed in the total number of fruits per plant, total yield per plant, fruit weight, and plant height, between the Reno, Traian, and Bihar hybrids.
The significant differences between the hybrids were only noticed in fruit diameter, with the highest value belonging to the hybrid Traian. However, concerning the fertilization regime, significant variations were observed.
The variants to which chemical fertilization was applied recorded the highest values for all the indicators measured, with significant differences except for the average fruit weight, which showed statistically insignificant differences.
Conversely, plants in the unfertilized variants displayed the lowest values across these productivity indicators.

The interaction effect of the studied factors on sweet peppers productivity indicators is presented in Table 2. Chemical fertilization in different combinations with the hybrid factor resulted in the highest values for each of the productivity indicators considered. Thus, the chemically fertilized Bihar hybrid variant recorded the highest values for total fruit/plant and total yield/plant, with statistically significant differences being achieved. The Reno hybrid variant, which also received a chemical fertilization, registered the highest values for plant height and fruit diameter, with significant differences, but also for fruit weight, in which case the differences were insignificant.
These findings underscore the importance of considering both cultivar characteristics and fertilization methods to optimize the sweet pepper productivity in agricultural practices.

Table 2. Results on the influence of hybrid x fertilization regime interaction on the main productivity indicators

Experimental variant	No. of fruits/plant	Fruit weight (g)	Total yield (kg/plant)	Plant height (cm)	Fruit diameter (cm)
Reno F1 x Unfertilized	7.63 ± 0.93 b	134.26 ± 3.38 ns	1.01 ± 0.10 bc	3.82 ± 0.26 e	7.29 ± 0.08 d
Reno F1 x Organic fertilization	8.77 ± 0.54 ab	140.89 ± 10.19 ns	1.22 ± 0.02 abc	4.82 ± 0.39 cde	8.80 ± 0.20 abc
Reno F1 x Chemical fertilization	10.93 ± 0.70 ab	146.53 ± 7.93 ns	1.59 ± 0.01 ab	6.41 ± 0.36 a	9.40 ± 0.21 a
Traian F1 x Unfertilized	7.43 ± 0.64 b	125.20 ± 5.88 ns	0.92 ± 0.07 c	4.23 ± 0.03 de	8.32 ± 0.07 c
Traian F1 x Organic fertilization	8.77 ± 0.43 ab	127.34 ± 3.46 ns	1.11 ± 0.04 abc	4.75 ± 0.27 cde	8.58 ± 0.14 bc
Traian F1 x Chemical fertilization	10.20 ± 1.93 ab	133.00 ± 7.85 ns	1.34 ± 0.23 abc	6.23 ± 0.21 ab	9.37 ± 0.15 a
Bihar F1 x Unfertilized	7.53 ± 0.72 b	119.44 ± 8.66 ns	0.89 ± 0.10 c	4.57 ± 0.08 cde	8.07 ± 0.15 c
Bihar F1 x Organic fertilization	8.60 ± 0.49 ab	122.04 ± 7.11 ns	1.04 ± 0.01 abc	5.09 ± 0.21 bcd	8.48 ± 0.17 bc
Bihar F1 x Chemical fertilization	12.60 ± 1.32 a	127.98 ± 4.14 ns	1.62 ± 0.21 a	5.51 ± 0.24 abc	9.09 ± 0.13 ab
Significance	*	ns	*	*	*

Within each column, * - statistically significant difference, ns - no statistically significant difference, values associated to different letters are significantly different according to Tukey's test at $p<0.05$.

Sweet pepper biochemical composition

The results regarding the influence of hybrid and fertilization regime on various chemical parameters of sweet peppers are summarized in Table 3.
Bihar hybrid recorded the highest TSS (8.38°Bx) and dry matter (10.32%) values, correlated with the lowest titratable acidity (0.19% citric acid), moisture (89.68%) and ash content (0.28%) values. The highest titratable acidity (0.21% citric acid) and moisture (90.55%) values were found in the Reno hybrid and the highest ash content in the Traian hybrid (0.55%). The differences between the experimental variants were significant in this case.
Regarding the influence of fertilization regime, the differences obtained between the different experimental variants were statistically confirmed. The chemically fertilized variant determined the highest values of total soluble

solids (8.08°Bx) and ash content (0.50%), with significant differences compared to the other two variants. The non-fertilized variant registered the highest values for titratable acidity (0.20% citric acid) and total dry matter (9.98%), while the organically fertilized variant had the highest moisture content (90.66%), the differences found were also significant.

Table 3. Results regarding the influence of hybrid and fertilization regime on biochemical parameters of sweet pepper

Experimental variant	TSS (°Bx)	TA (% citric acid)	Moisture %	TDM %	Ash %
Hybrid					
Reno F1	7.40 ± 0.03 b	0.21 ± 0.00 a	90.55 ± 0.10 a	9.45 ± 0.10 b	0.44 ± 0.01 b
Traian F1	7.52 ± 0.05 b	0.19 ± 0.00 b	90.52 ± 0.09 a	9.48 ± 0.09 b	0.55 ± 0.01 a
Bihar F1	8.38 ± 0.07 a	0.19 ± 0.00 b	89.68 ± 0.01 b	10.32 ± 0.01 a	0.28 ± 0.00 c
Significance	*	*	*	*	*
Fertilization regime					
Unfertilized	7.73 ± 0.02 b	0.20 ± 0.00 a	90.02 ± 0.02 b	9.98 ± 0.02 a	0.35 ± 0.00 c
Organic fertilization	7.49 ± 0.03 c	0.19 ± 0.00 b	90.66 ± 0.04 a	9.34 ± 0.04 b	0.42 ± 0.01 b
Chemical fertilization	8.08 ± 0.03 a	0.19 ± 0.00 ab	90.08 ± 0.19 b	9.92 ± 0.19 a	0.50 ± 0.01 a
Significance	*	*	*	*	*

Within each column, * - statistically significant difference, values associated to different letters are significantly different according to Tukey's test at p<0.05. TSS - Total soluble solids; TA - Titratable acidity; TDM - Total dry matter.

Total Soluble Solids (TSS) is a quality index for vegetables and fruits. The Bihar hybrid has a high potential for accumulating soluble solids matter, with the unfertilized variant showing the highest value for this parameter (8.93 °Bx), followed by the chemically fertilized variant of the same hybrid (8.67 °Bx). In the case of each experimented cultivar, chemical fertilization positively influenced the accumulation of water-soluble biochemical compounds to a greater extent than organic fertilization (Table 4).

Table 4. Results regarding the influence of the hybrid x fertilization regime interaction on biochemical parameters of sweet pepper

Experimental variant	TSS (°Bx)	TA (% citric acid)	Moisture %	TDM %	Ash %
Reno F1 x Unfertilized	6.60 ± 0.12 d	0.24 ± 0.00 a	90.27 ± 0.03 bc	9.73 ± 0.03 bc	0.32 ± 0.00 d
Reno F1 x Organic fertilization	7.77 ± 0.03 b	0.20 ± 0.00 b	90.60 ± 0.05 b	9.40 ± 0.05 c	0.45 ± 0.01 c
Reno F1 x Chemical fertilization	7.83 ± 0.07 b	0.20 ± 0.00 b	90.78 ± 0.30 b	9.22 ± 0.30 c	0.54 ± 0.01 b
Traian F1 x Unfertilized	7.67 ± 0.09 b	0.20 ± 0.00 b	90.35 ± 0.04 bc	9.65 ± 0.04 bc	0.45 ± 0.02 c
Traian F1 x Organic fertilization	7.17 ± 0.03 c	0.18 ± 0.00 d	91.62 ± 0.02 a	8.38 ± 0.02 d	0.47 ± 0.01 c
Traian F1 x Chemical fertilization	7.73 ± 0.03 b	0.18 ± 0.00 d	89.59 ± 0.24 d	10.41 ± 0.24 a	0.72 ± 0.01 a
Bihar F1 x Unfertilized	8.93 ± 0.09 a	0.16 ± 0.00 e	89.43 ± 0.03 d	10.57 ± 0.03 a	0.28 ± 0.01 e
Bihar F1 x Organic fertilization	7.53 ± 0.03 b	0.19 ± 0.00 c	89.77 ± 0.05 cd	10.23 ± 0.05 ab	0.33 ± 0.00 d
Bihar F1 x Chemical fertilization	8.67 ± 0.09 a	0.20 ± 0.00 bc	89.86 ± 0.04 cd	10.14 ± 0.04 ab	0.22 ± 0.01 f
Significance	*	*	*	*	*

Within each column, * - statistically significant difference, values associated to different letters are significantly different according to Tukey's test at p<0.05. TSS - Total soluble solids; TA - Titratable acidity; TDM - Total dry matter.

Every horticulture product's distinctive flavor must be correlated with the levels of organic acids (malate and citrate) and sugars (sucrose, glucose, galactose, and fructose).

Regarding the accumulation of organic acids (TA), the unfertilized Reno hybrid

demonstrated the highest potential, with a titratable acidity of 0.24% citric acid, the difference being significant compared to the rest of the variants.
Other researchers show higher values of acidity of peppers compared to those obtained in this study, the values registered by Pérez-Grajales et al. (2019) varying between 0.31 and 0.45% citric acid.
The highest moisture value of 91.60% was obtained by the Traian F1 organically fertilized, followed by Reno F1 chemically fertilized (90.78%), the differences being statistically ensured.
Total dry matter (TDM) registered the highest value at the unfertilized variant of Bihar F1 (10.57%), followed closely by the Traian F1 under chemical fertilization (10.41%), with differences ensured at a significant statistically level.
The significant influence of the tested hybrid can be noticed in the following two values of TDM content, which also belong to the Bihar hybrid, in organic (10.23%) and chemically (10.14%) fertilized variants.
Ash content serves as an index for the mineral content of food. This parameter was influenced by both factors, the hybrid selected and the fertilization regime applied. The highest value was determined for the chemically fertilized hybrid Traian (0.72%), followed by the chemically fertilized hybrid Reno (0.54%). The subsequent values belong to the organically fertilized variants of the same hybrids, Traian (0.47%) and Reno (0.45%), as well as the non-fertilized hybrid Traian (0.45%), with the differences found to be significant.
Bihar F1 exhibited the highest potential for ascorbic acid accumulation, with a value of 122.7 mg/100 g product, followed by Traian hybrid with a value of 110.8 mg/100 g product (Figure 2). Organic fertilization favored ascorbic acid accumulation (127.4 mg/100 g product) to a greater extent than Chemical (118.4 mg/100 g product) and Unfertilized one (78.7 mg/100 g product).

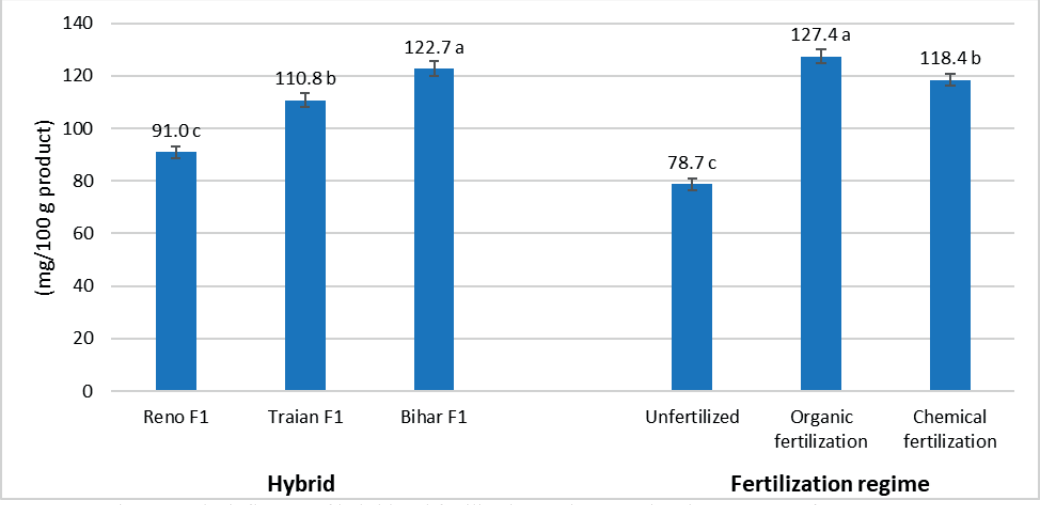

Figure 2. The influence of hybrid and fertilization regime on Vitamin C content of sweet pepper (values associated to different letters are significantly different according to Tukey's test at $p<0.05$)

The influence of organic fertilization and the hybrid on the vitamin C content is shown through the interaction of these factors, represented in Figure 3. The mixture of the Bihar hybrid and organic fertilization resulted in the highest ascorbic acid content (148.6 mg/100 g product), followed by the Traian hybrid which also received organic fertilization (136.1 mg/100 g product). Similar results with high vitamin C content were obtained by other researches (Perez-Lopez, 2007; Brezeanu, 2022), the organic fertilization being in dependence with the cultivar, maturity, and fertilization regime. According to Hamed et al., 2019, ascorbic acid precursors like exposure to light and glucose level are responsible for the greater ascorbic acid levels in the developed stage.

The same two hybrids, Bihar and Traian, to which chemical fertilization was applied, produced the next highest values for ascorbic acid content (134.9 mg/100 g product; 120.6 mg/100 g product). In the opposite, the lowest vitamin C content was determined in the non-fertilized hybrid Traian (75.6 mg/100 g product).

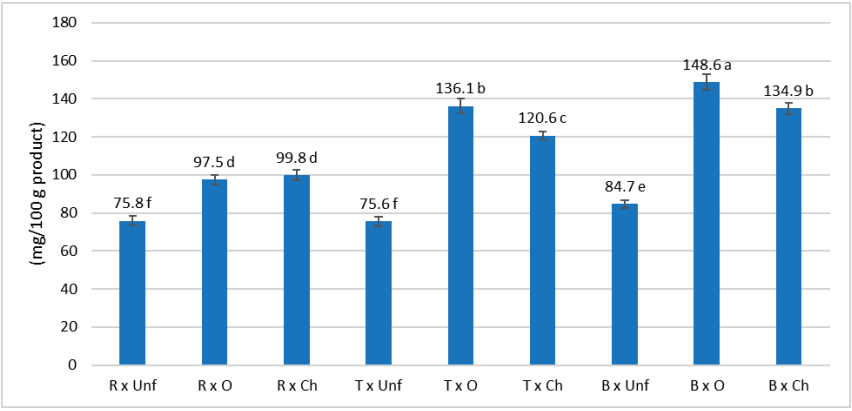

Figure 3. The influence of the interaction between hybrid and fertilization regime on Vitamin C content of sweet pepper (T-Traian F1, R-Reno F1, B-Bihar F1, Unf-Unfertilized, O-Organic fertilization, Ch-Chemical fertilization; values associated to different letters are significantly different according to Tukey's test at $p<0.05$)

CONCLUSIONS

Sweet pepper hybrids grown in tunnel and nutritional regimes had significant effects on yield and biochemical characteristics, the study revealing the importance of considering both hybrid selection and fertilization strategies to optimize this cultivation system.

The influence of the experimented hybrid determined values of the productivity indicators with insignificant differences between the experimental variants, except for fruit diameter.

Chemical fertilization had the strongest impact on productivity indicators, recording the highest values among these, with statistically significant differences, except for fruit weight which showed insignificant differences.

Chemical fertilization in various combinations with the hybrid factor resulted in the highest values for each of the productivity indicators considered. Thus, the chemically fertilized Bihar hybrid recorded the highest values for number of fruits per plant and sweet pepper yield per plant, while the Reno hybrid, also chemically fertilized, stood out for the other three productivity indicators (fruit weight, plant height and fruit diameter).

The fertilization application at Traian hybrid led to the highest values of moisture, dry matter and ash content, with statistically significant differences. The unfertilized variants of Bihar and Reno hybrids resulted in the highest values of total soluble solids and titratable acidity respectively with also significant differences.

The judicious choice of hybrid and fertilization regime significantly influences the content of vitamin C. The Bihar F1 hybrid stands out as having the highest potential for accumulating ascorbic acid, while the application of organic fertilization favors the synthesis of vitamin C to a greater extent compared to the other two fertilization regimes.

ACKNOWLEDGEMENTS

This research work was carried out with the support of Horticultural Reasearch Center of "Ion Ionescu de la Brad" Iasi University of Life Sciences.

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