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Original Research

Effects of Biological and Fungicidal Environmental Protection on Chemical Composition of Tomato and Red Pepper Fruits

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Abstract

The experimental materials comprised the fruits of tomato cv. Robin F1 and red pepper cv. Mira harvested from plants sprayed three times with the growth regulator Asahi SL, the biostimulator Biochikol 020 PC, the biocontrol agent Polyversum, and the fungicide Bravo 500 SC. Control plants were sprayed with sterile water. Total fruit yield, average fruit weight, and the concentrations of total extract, pectin, reducing sugars, carotenoids, and phenolic compounds were determined.

Biological and fungicidal control contributed to an increase in the yield and average weight of tomato and pepper fruit. The protective treatments had no effect on the content of extract and reducing sugars in tomato and red pepper fruit. The applied biological and fungicidal control agents were negatively correlated with the concentrations of carotenoids and phenolic compounds in tomato fruit, and positively with the pectin content of tomato and red pepper fruit.

Keywords: tomato and red pepper fruits, biological and fungicidal control, chemical composition

Introduction

Plants are a valuable source of nutrients and bioactive compounds that deliver numerous health benefits [1, 2]. Tomato and red pepper fruits contain large amounts of minerals (K, Ca, Mg, Na), sugars, pectin, vitamins, and antioxidants (phenolic compounds and carotenoids, including lycopene and vitamin C). Consumers pay attention to the quality, morphological characteristics, and nutritional values of vegetables and fruits. The yield and quality of tomato and red pepper fruits are determined by the cultivar, harvest date, weather conditions [3, 4], substrate type, mineral content [5], technological processes [6, 7], and the health status of plants. Fungicides are routinely and frequently applied to control fungal pathogens (*Colletotrichum coccodes* Wallr. /Hughes/, *Botrytis cinerea* Pers., *Rhizoctonia solani* Kühn, the genera *Phytophthora*, *Alternaria*, *Fusarium*, *Verticillium*, and *Sclerotinia*) in tomatoes and red peppers [8, 9].

In recent years, human health and environmental safety concerns have spurred considerable interest in non-chemical approaches to disease control in horticulture [10, 11]. Seed dressing, crop rotation, adequate soil type, optimum fertilization rates, and the maintenance of adequate soil organic matter levels are important considerations in the organic production system [12, 13]. Fungicides have been

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increasingly replaced with biocontrol agents including bacteria and yeast-like fungi with antagonistic potential against fungal pathogens [14], compost extracts [15], mycorrhizae [16], plant growth regulators [17], chitosan [18], and *Pythium oligandrum* oospores [19]. All of them are involved in the induction of defense mechanisms in plants, such as induced systemic resistance (ISR), structural defense responses (including H_2O_2 generation in the leaves, lignin accumulation in the stems, changes in cell membrane permeability), and chemical defense (including the production of phenolic compounds) [15, 20-22].

Research results show that organic fertilizers contribute to the production of carbon-containing compounds in plants, including sugars, phenolic compounds, and carotenoids, as well as vitamin C [23, 24]. However, there is a scarcity of published data regarding the impact of biological and chemical control agents on the quality of fruit and vegetables.

In view of the above, the objective of this study was to determine the effects of biological and fungicidal control on the concentrations of select bioactive compounds in tomato and red pepper fruits.

Materials and Methods

Tomato (*Lycopersicum esculentum* L.) plants cv. *Robin* F1 and red pepper (*Capsicum annuum* L.) plants cv. *Mira* were grown in the greenhouse of the University of Warmia and Mazury. Four-week-old seedlings were planted in pots filled with peat substrate and garden soil at a ratio of 1:3. The plants were sprayed three times, in six replications (pots), with 0.2% solution of the growth regulator Asahi SL (20 ml/plant), 0.2% solution of the biostimulator Biochikol 020 PC (40 ml/plant), 0.1% solution of the biocontrol agent Polyversum (40 ml/plant), and the fungicide Bravo 500 SC (50% chlorothalonil, according to the recommendations of the Institute of Plant Protection in Poznań). Unprotected plants served as control. During the growing season, fertilization and irrigation levels were identical in all treatments.

Total fruit yield per plant (8 and 5 harvest dates for tomatoes and red peppers, respectively) and average fruit weight were determined. Samples of red tomato fruit and red pepper fruit harvested at the same time were collected for biochemical analyses.

The content of total extract was determined using a refractometric method [25], reducing sugars by method of Luff-Schoorl [26], pectins using a method of Carre-Haynes [27], carotenoids using a colourimetric method [28], and total phenolics using a Folin-Ciocalteu's phenol reagent [29].

Results were analyzed using one-way ANOVA and Duncan's test (Statistica® 2007/2008).

Results and Discussion

Biological and fungicidal control contributed to an increase in the yield and average weight of tomato and red pepper fruits (Table 1). In both plant species, Biochikol 020 PC provided the best control. Significant differences in the average weight of tomatoes were noted between plants treated with Asahi SL (81.80 g) and control plants (65.80 g). In a study by Pięta et al. [30], chitosan prevented water loss in plants, thus increasing the yield. Hermández-Lauzardo et al. [31] reported that chitosan effectively inhibited the mycelial growth and sporulation of *Rhizopus stolonifer* in tomatoes, which prevented yield loss. As demonstrated by Janas et al. [32], Polyversum, Biosept 33 SL and the fungicide Amistar 250 EC increased the yield and average fruit weight of eggplants. The growth regulator Asahi SL positively affected the yield of three raspberry varieties [17], while the biostimulator Bio-algeen S-90 had a beneficial influence on the total yield, marketable yield and concentrations of and N, P, K, Ca, Zn, Fe, and nitrates in cherry tomato fruit [33]. In another experiment [34], organic fertilizers (*Brassica* green manure, composted household wastes, cattle manure compost) significantly reduced the severity of tomato infections caused by *Verticillium albo-atrum* and *Pyrenochaeta lycopersici*, which supported fruit yield increments.

Table 1. Effect of biological and fungicidal environmental protection on fruit yield of tomatoes and red peppers.

Plant	Treatment	Fruit weight per plant (g)	Fruit weight (g)
Tomato	Control	1198±37	70.6±2.0
	Asahi	1349±64	92.3±3.0
	Biochikol 020 PC	1548±31	96.2±2.9
	Bravo 500 SC	1431±44	87.9±2.4
	Polyversum	1214±16	82.3±2.3
Red pepper	Control	542±10	77.6±3.0
	Asahi	744±57	92.3±3.0
	Biochikol 020 PC	962±35	96.2±2.9
	Bravo 500 SC	760±33	87.9 ±2.4
	Polyversum	730±30	82.3±2.3

The applied control agents significantly increased the average weight of red peppers in comparison with the control treatment. There were no significant differences in the total yield and average fruit weight between fungicidal and biological control treatments (except for chitosan treatment). Szafirowska and Elkner [35] noted a higher pepper fruit yield in the organic farming system, compared with the conventional system. Kaya et al. [21] observed a yield-increasing effect of mycorrhizae.

The highest content of extract was found in untreated tomato fruits (Fig. 1). The protective treatments of Asahi SL, Bravo 500 SC, and Polyversum decreased the content of extract in tomato fruit in relation to the control. The difference between the control treatment and the Biochikol 020 PC treatment was not statistically significant. The highest quantity of red pepper extract was obtained from plants sprayed with Asahi SL, and the differences between this value and those noted in the other treatments (except for the Bravo 500 SC treatment) were statistically significant. According to Hallmann and Rembiałkowska [24], the fruits harvested from organically-fertilized tomato plants had a higher content of dry matter and reducing sugars than those harvested from mineral-fertilized plants.

In the present study, the lowest contents of reducing sugars were found in the fruits harvested from tomato plants sprayed with Biochikol 020 PC and the fungicide Bravo 500 SC (0.39 to 0.40 mg/100g, respectively) (Fig. 2). The highest amount of reducing sugars was noted for fruits treated by Polyversum. The reducing sugar content of red pepper fruit was similar in all treatments, and the highest concentrations of reducing sugars were noted in the fruit from Biochikol 020 PC-treated plants. Mikos-Bielak [17] observed a 6.3-9.1% drop in the levels of reducing sugars in raspberry fruit from shrubs sprayed with Asahi SL, compared with the control treatment (plants sprayed with water), accompanied by a significant rise in the concentrations of soluble sugars (except for glucose and fructose). In a study by Hallmann and Rembiałkowska [36], red onions grown in the organic system had a higher content of total sugars, including reducing sugars, compared with NPK-fertilized plants. Di Cesare et al. [37] reported that nitrogen

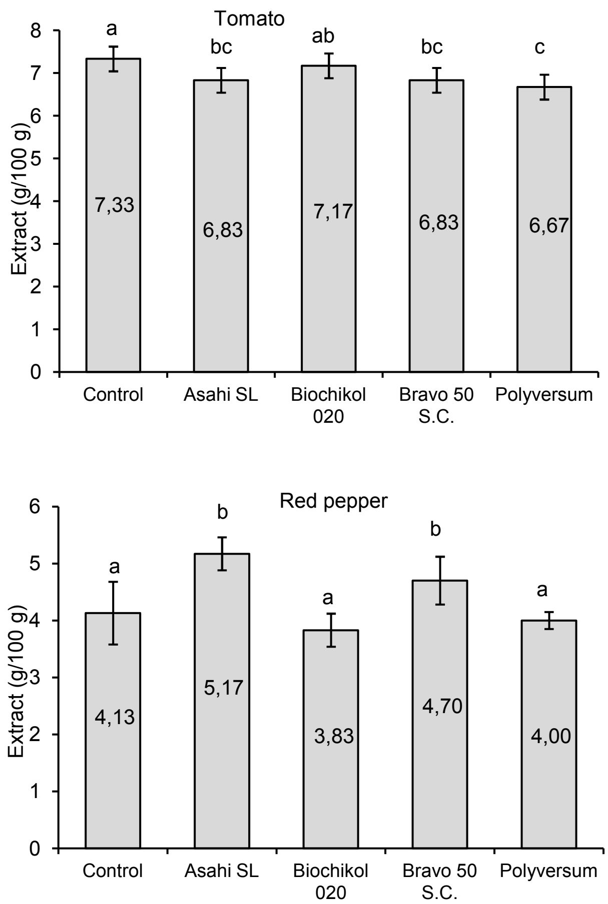

Fig. 1. Effects of biological and fungicidal environmental protection on the content of extract in tomato and red pepper fruits. Data are expressed as means±standard deviations on fresh weight basis; values having the same letters are not significantly different (P>0.05).

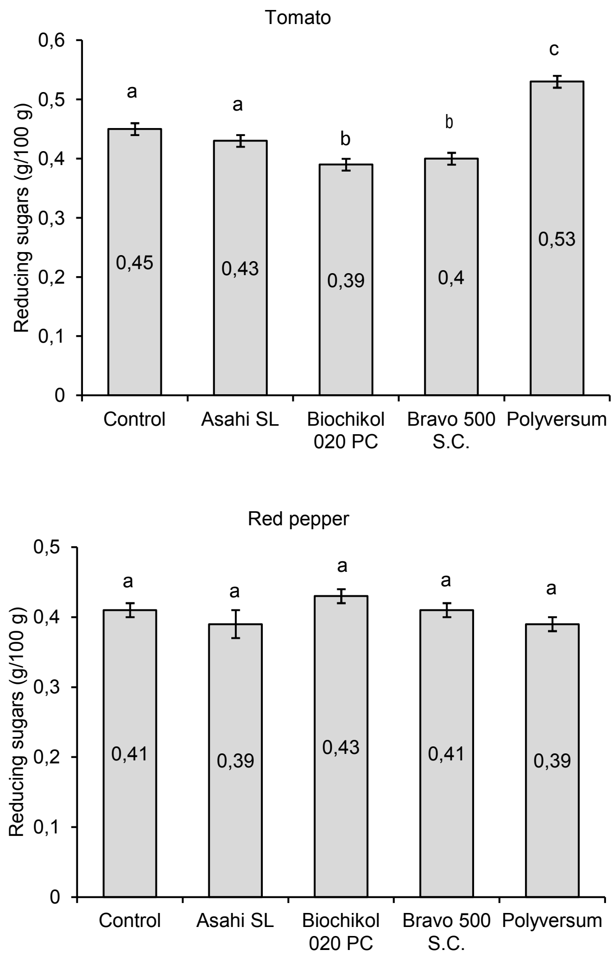

Fig. 2. Effects of biological and fungicidal environmental protection on the content of reducing sugars in tomato and red pepper fruits. Data are expressed as means±standard deviations on fresh weight basis; values having the same letters are not significantly different (P>0.05).

and phosphorus fertilization increased the concentrations of glucose, fructose, dry matter, and lycopen in cherry tomatoes.

Plants treated with biocontrol agents and fungicides (except for tomato fruits sprayed with Asahi SL) produced significantly higher amounts of pectin, in comparison with control plants (Fig. 3). Pectin content was higher in *L. esculentum* (from 0.37 g/100 g in the control treatment to 0.43 g/100 g in the Biochikol 020 PC treatment) than in *Capsicum annuum* (from 0.21 g/100 g in the control treatment to 0.36 g/100 g in the Polyversum treatment). In an experiment carried out by Elkner et al. [38], N and K fertigation caused an increase in the concentrations of pectin, lycopene, and ascorbic acid in tomato fruit. The content of the above compounds varied depending on cultivar. Literature provides no information on the correlation between pectin content and the application of non-chemical control agents in vegetables of the Solanaceae family.

In our experiment, the fruit of unprotected tomato plants had the highest content of carotenoids, including lycopene (Fig. 4). Among protective treatments, significantly higher carotenoid concentrations were noted in the fruits harvest-

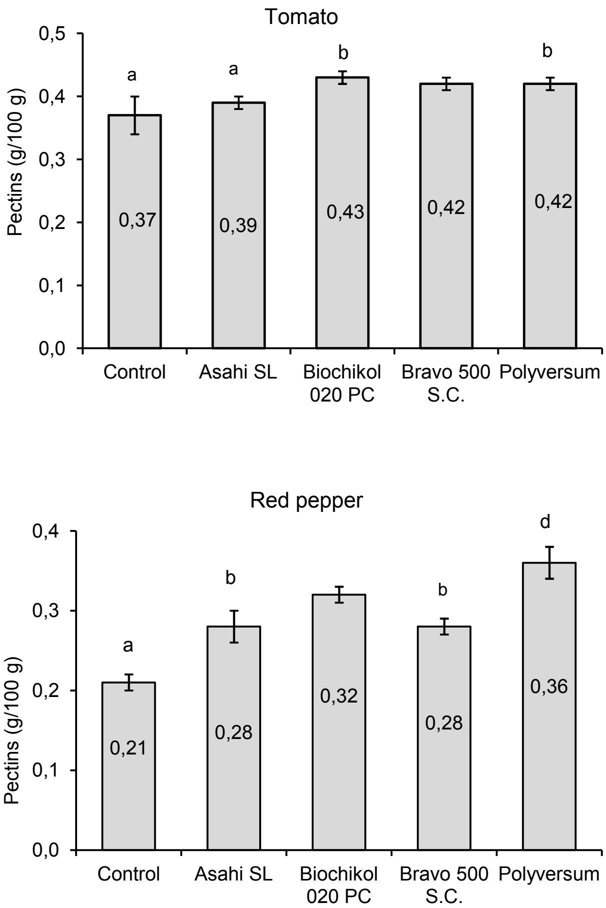

Fig. 3. Effects of biological and fungicidal environmental protection on the content of pectins in tomato and red pepper fruits. Data are expressed as means±standard deviations on fresh weight basis; values having the same letters are not significantly different (P>0.05).

ed from fungicide-treated plants. The fruit from plants sprayed with Asahi SL contained the lowest amounts of total carotenoids, including lycopene. Different results were reported by Caris-Veynad et al. [10], Hallmann and Rembiałkowska [24] – tomato fruits protected with biocontrol agents were more abundant in lycopene. Ordookhani et al. [39] demonstrated that rhizosphere bacteria applied to stimulate the growth of *L. esculentum,* as well as arbuscular mycorrhizal fungi (AMF), increased the levels of lycopene and potassium in tomato fruit. Mejia-Torres et al. [40] reported a positive effect of wax coating and low-temperature storage (5ºC) on lycopene synthesis in tomato fruit.

In the present study, a significant drop in the concentrations of phenolic compounds was observed in the fruits harvested from protected tomato plants, in comparison with control plants (Fig. 5). Tomato plants sprayed with the fungicide Bravo 500 SC and the biocontrol agent Polyversum had the lowest total phenolic content, and the differences between those treatments and the remaining experimental variants were statistically significant. The fruits harvested from red pepper plants treated with the biocontrol agent Polyversum had the lowest total phenolic content. The concentrations of phenolic compounds in the remaining experimental variants, including control, were similar. According to Hallmann and Rembiałkowska [24], tomatoes grown in the organic farming system contain larger amounts of bioactive compounds. Jiu et al. [18] demonstrated that chitosan applied to control *B. cinerea* and *P. expansum* on tomato fruit caused an increase in total phenolic content. Our findings disagree with those reported by Benhamou et al. [19] who noted enhanced production of phenolic compounds in tomato plants treated with *P. oligandrum*, which provided protection against *Fusarium oxysporum* f. sp. *radicis-lycopersici*. As demonstrated by Mikos-Bielak [17], Asahi SL increased the polyphenol content of fruit in three raspberry varieties (from 9.5% to 16.2%), compared with control plants. Anand et al. [3] found larger amounts of phenolic compounds in pepper fruit inoculated with *C. capsici* and *A. alternata*, in comparison with non-inoculated fruit. In the cited study, green fruit had higher concentrations of phenolics than ripe fruit. Panina et al. [41] treated tomato plants with non-pathogenic *F. oxysporum* strain CS-20, while Al-Askar and Rashad [16] applied arbuscular mycorrhizal fungi in the

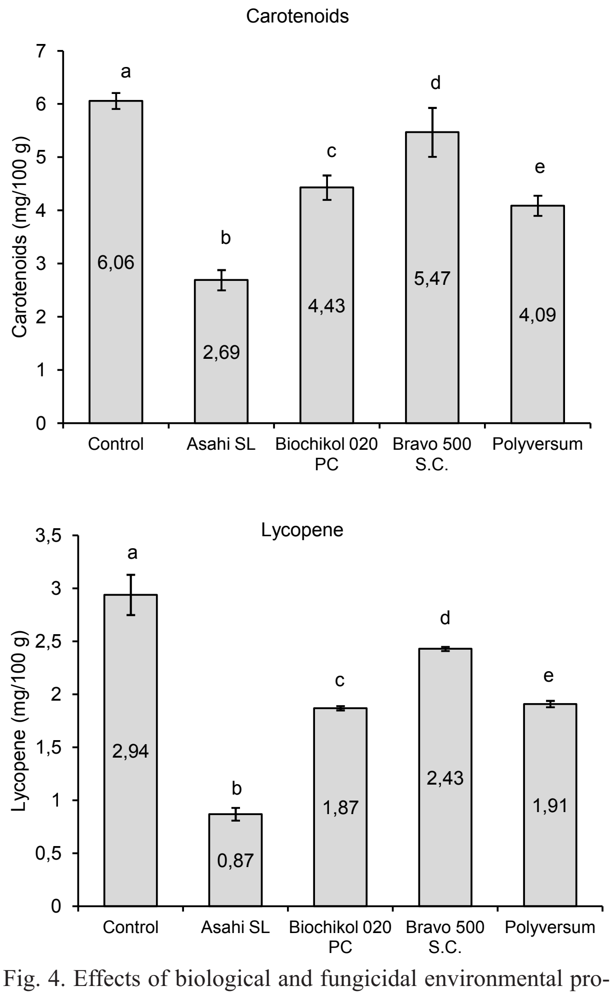

Fig. 4. Effects of biological and fungicidal environmental protection on the content of carotenoids and lycopene in tomato fruits. Data are expressed as means±standard deviations on fresh weight basis; values having the same letters are not significantly different (P>0.05).

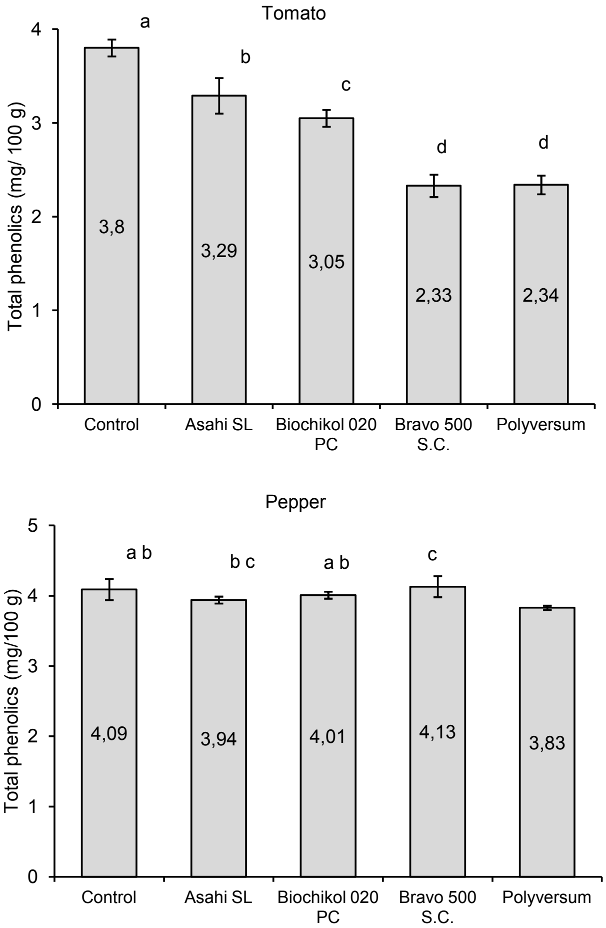

Fig. 5. Effects of biological and fungicidal environmental protection on the content of phenolic compounds in tomato and red pepper fruits. Data are expressed as means±standard deviations on fresh weight basis; values having the same letters are not significantly different (P>0.05).

protection of common bean plants. The above authors observed enhanced production of phenolic compounds, which supported the protection of the studied species against pathogenic fungi of the genus *Fusarium*. According to Materska and Perucka [42], phenolic compounds contained in pepper fruit are characterized by high antioxidant activity.

Conclusions

- Biological and chemical control contributed to an increase in the yield and average weight of tomato and pepper fruit.
- The protective treatments had no effect on the content of extract and reducing sugars in tomato and pepper fruit.
- The fruits harvested from control tomato plants were characterized by higher concentrations of carotenoids, including lycopene, and phenolic compounds, compared with protected plants.
- The applied biological and fungicidal control agents enhanced pectin production in tomato and pepper fruits.

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