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THE INFLUENCE OF ATONIK SL, BETOKSON SUPER 050 SL AND INSOL CA ON YIELDING OF STRAWBERRY (*Fragaria* x *ananassa* Duch.) CV. 'SENGA SENGANA' AND 'KENT'

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Abstract

The chemical composition of strawberry fruit depends mainly on cultivar, fruit maturity degree and climatic conditions in the growing period. Fruit quality is also determined by a cultivation technology. The influence of two biostimulants (Atonik SL and Betokson Super 050 SL), which were used separately, in combination with each other or with the liquid fertilizer InsolCa, on yielding and fruit quality of two strawberry cultivars: 'Senga Sengana' and 'Kent', was tested. Betokson Super 050 SL + InsolCa tended to improve the yield of both cultivars. Significant differences compared to the control were evident especially in 2001. Fruits of 'Senga Sengana' started ripening later and had more ascorbic acid, anthocyanins and acidity than 'Kent'. The use of Betokson Super 050 SL + InsolCa improved the content of ascorbic acid, anthocyanins and sugar as well as acidity in strawberries of both cultivars. The use of Betokson Super 050 SL + Atonik SL significantly increased the content of ascorbic acid and sugar in fruits of both cultivars. 'Kent' strawberries also responded to the treatment with an increase in anthocyanin content and acidity.

Key words: *Fragaria* x *ananassa* Duch., fruits, fresh matter, chemical composition of fruit, biostimulants, fertilizer

INTRODUCTION

Strawberries are in the group of highly valued fruits in the world. They are grown in large commercial plantations as well as in amateur gardens. Strawberries have a special position because of their many properties. The relationship between fruit consumption and human health has been recognized since ancient times. Epidemiological studies have noted a consistent association between diet with fruits and the lower risk for chronic diseases, including cancer, heart disease and stroke [1–3]. The shape and chemical composition of strawberries allow us to use these fruits for different purposes. They are consumed fresh as well as in the form of various types of processed and frozen products. These fruits are one of rich sources of vitamin C in Polish conditions. The chemical composition of berries varies depending on genetic factors (cultivar), climate, weather conditions, and agronomic practices. Technologies aiming to improve only cultivation are not sufficient, because they do not use a wide variety of the biological potential. This is the reason for seeking the best conditions to ensure plant growth and development that will not cause the biotic and abiotic stresses. One of the methods which could improve fruit yield and quality is the use of biostimulants and fertilizers. Biostimulants are natural growth regulators or chemicals. They are used in many agriculture and horticulture crops to improve fruit quality and to protect plants against environmental stress [4–7]. Biostimulants used during the flowering period help the plants concentrate on flower development and fruit setting [8].

Foliar application of macro- and micronutrients has a very important role in improving fruit set, productivity and quality. It is well known that calcium plays an important role in maintaining the quality of fruits. S e r r a n o et al. [9] found that peach and nectarine trees sprayed with a formulation containing Ca^{2+} produced fruits of higher weight and pulp firmness. W ó j c i k et al. [10] recommended foliar Ca fertilization as a way to make strawberry fruits firmer and less sensitive to *B. cinerea*. M a k u s and M o r r i s [11] stated that Ca treatments reduced decay of strawberry fruits during storage.

The aim of this study was to compare the influence of biostimulants, which were used separately, in combination with each other or with the liquid fertilizer InsolCa, on yielding and fruit quality of strawberry cv. 'Senga Sengana' and 'Kent'.

MATERIALS AND METHODS

Strawberry plants (*Fragaria* x *ananassa* Duch.) cv. 'Senga Sengana' and 'Kent' were planted in the first decade of September in 1999 at Felin, close to Lublin (NL: 51°, EL: 22°). The soil was characterized as clay loam, with acidic to alkaline pH (6.1–7.2) and rich in organic matter content (3.6%). Plant protection treatments were performed according to the recommendations of the Research Institute of Pomology and Floriculture in Skierniewice, with the same treatments used for both cultivars tested. The soil in the plantation was mechanically tilled.

Each treatment consisted of 120 plants (in five replications with 20 plants per plot in a split-block design). Plants were planted at 30 cm x 75 spacing, without irrigation. To avoid the potential movement of the preparations between the plots, 1m separation strips were used. All treatments were applied as a foliar spray during flowering 3 times (beginning of flowering, full flowering and end of flowering). The substances were dissolved in tap water.

The experimental design was as follows:

1. Control
2. 0.2% Atonik SL;
3. 0.1% Betokson Super 050 SL;
4. 0.1% Betokson Super 050 SL + 0.2% Atonik SL;
5. 0.1% Betokson Super 050 SL + 0.3% InsolCa.

Atonik SL – a biostimulant containing 0.3% sodium para-nitrophenolate, 0.2% sodium ortho- nitrophenolate, 0.1% sodium 5-nitroguaiacolate;

Betokson Super 050 SL – a biostimulant containing 25 g L^{-1} salt of 2-naphtoxyacetic acid with triethanolamine.

Insol Ca – a liquid fertilizer with the following composition: 10% nitrate N, 14% CaO, 2% MgO, 0.02% B, 0.1% Mn, 0.02% Zn.

The total yield of 'Senga Sengana' was divided into marketable yield and non-marketable fruits, which means visibly damaged or rotten fruits. The yield of 'Kent' (kg/plot) was recorded by successive harvesting of marketable fruits from each field every 2–3 days. In the case of this cultivar, the total yield was equal to the marketable yield because of a limited number of poor quality fruits at the sixth harvest. A sample of about one kilogram from each cultivar was taken for analysis during the full fruiting period.

A quality evaluation was performed on fresh fruits using standard analytical test methods.

- Dry matter content – in five replications – by the oven-drying method [12].
- Soluble solids content was determined with an Abbé refractometer – in ten replicates;
- Ascorbic acid content was determined in five replicates – by the colorimetric method of Roe and Kuether [13];
- Anthocyanin content expressed as cyanidin chloride equivalents – in five replicates by the colorimetric method [14];
- Reducing sugar content was determined according to the Loof-Schoorl method – in five replicates [15];
- Acidity was determined potentiometrically in five replicates by titration with 0.1 N NaOH solution and was expressed as malic acid equivalents [16].

The experimental data were statistically analyzed using analysis of variance for two-factorial experiments and Tukey's test at P=0.05. The data were analyzed with 'STATISTICA' software.

RESULTS

The climatic conditions at the beginning of the growing season as well as during flowering and fruiting of strawberry plants were similar in both seasons (2001 and 2002) – the differences were only 1°C in relation to the long-term average. However, the total precipitation significantly differed from the long-term average, especially in June 2002 when it was approximately 178% of the long-term average (Table 1).

The harvests of 'Senga Sengana' fruits were performed on 11 dates in 2001 (from the 1st to the 20th of June), while in the case of 'Kent' from the 25th of May to the 18th of June, but in 2002 the harvest of cv. 'Senga Sengana' fruits lasted from the 3rd of June to the 24th of June and for 'Kent' from the 27th of May to the 20th of June.

During the two seasons of the study, the strawberry cultivar 'Senga Sengana' produced yields at a similar level. In 2002 cv. 'Kent' gave an average yield 1.5 kg lower than in 2001. The yield of 'Kent', in comparison to 'Senga Sengana', was lower each year, but taking into account that there were non-marketable fruits in the total yield of 'Senga Sengana', the marketable yields were comparable. The yield of 'Kent' obtained from the second to the tenth harvest was at a similar level (from 0.5 to 1.0 kg/plot). In the case of 'Senga Sengana', the weight of the crop up to the fourth harvest did not exceed 0.5 kg/plot, while from the fifth to tenth harvest it remained at a level of more than 1 kg/plot (Tables 2 and 3). In 2001 (Table 3) a significantly higher yield of marketable fruits of cv. 'Senga Sengana', compared to the control, was found after the application of Betokson Super 050 SL + InsolCa. In the following year of the study, no beneficial effect of the biostimulants was observed in the case of both cultivars (Tables 3 and 5). In 2001 a significant increase in marketable yield was found for cv. 'Kent' in all treatments with Betokson Super 050 SL. Plants of cv. 'Kent' responded with a significant increase in marketable yield when treated with Betokson Super 050 SL, Betokson Super 050 SL + Atonik SL, or Betokson Super 050 SL + InsolCa (Table 4).

A variation in climatic conditions between the years of study was observed which might have affected the results to a greater extent than the treatments. For example, precipitation (Table 1) was much higher in June 2002 (116.8 mm) in comparison to 2001 (47.6 mm). The growing period had a great influence on most of the examined features of 'Senga Sengana' fruits. The content of soluble solids extract, ascorbic acid and anthocyanins was significantly higher in 2001 than in the subsequent year of the study. A significant increase in the content of sugars and acids, compared to the previous year, was noted in 2002 (Table 6).

There was no significant effect of growing season on the content of soluble solids and anthocyanins in fruits of cv. 'Kent', however strawberries harvested in 2002 had much more sugar, acid and dry matter, and much less ascorbic acid than in the previous year (Table 8). There were no significant differences in dry matter content of fruits cv. 'Senga Sengana' between seasons. The application of Atonik SL and Betokson Super 050 SL + InsolCa significantly increased the values of the above-mentioned feature as compared to the control (Table 7). The dry matter content in fruits of cv. 'Kent' in 2001 was significant lower than in 2002. However, there was no significant effect of chemical treatment on the values of the above described feature.

Betokson Super 050 SL + InsolCa application was found to have a clear positive effect of on soluble solids content in 'Senga Sengana' fruits, especially in the second year of the study. The soluble solids extract in 'Kent' fruits was similar in both growing seasons, but a significant effect on increasing the values of this trait was detected after the application of Betokson Super 050 SL (Table 9). All treatments improved the values of ascorbic acid content in 'Senga Sengana' fruits as compared to the control (Table 7), while fruits of cv. 'Kent' responded with an increase in the values of the above-mentioned feature after the application of Betokson Super 050 SL + Atonik SL or Betokson Super 050 SL + InsolCa (Table 9). In our study, the content of ascorbic acid ranged from 40.29 mg% ('Kent' control in 2002) to 59.73 mg% ('Senga Sengana' treated with Betokson Super 050 SL+Atonik SL in 2001). The anthocyanin content in 'Senga Sengana' fruits was significantly higher in 2001 than in the following year (Table 6). A significant positive effect of Betokson Super 050 SL + InsolCa application, as compared to the control, was found (Table 7). The growing seasons had no significant effect on the content of anthocyanins in 'Kent' fruits (Table 8). The application of Betokson Super 050 SL + Atonik SL and Betokson Super 050 SL + InsolCa increased the anthocyanin content compared to control (Table 9). Each of the treatments caused a significant increase in sugar content in fruits of both cultivars, in comparison to the control (Tables 7 and 9). The acidity of fruits of cvs. 'Senga Sengana' and 'Kent' was much higher in 2002 than in the previous year. Only the use of Betokson Super 050 SL + InsolCa resulted in a significant increase in acid content in fruits of 'Senga Sengana'. 'Kent' fruits were characterized by a significant increase in acid content after the application of Betokson Super 050 SL, Betokson Super 050 SL + Atonik SL or Betokson Super 050 SL + InsolCa.

Table 1
Climate conditions. Mean monthly air temperature and total precipitation in 2001 and 2002 versus the long-term average

	Month	2001				2002				1951–2005
		Decade			Mean	Decade			Mean	
		I	II	III		I	II	III		
Temperature (°C)	April	9.6	5.3	10,5	8.5	3.5	10.3	12.0	8.6	7.4
	May	15.4	14.2	12.3	13.9	11.1	11.2	14.8	12.4	13.0
	June	13.7	14.9	17.2	15.3	15.8	18.9	18.7	17.8	16.2
Precipitation (mm)0	April	15.0	3.2	46.7	64.9	5.8	2.2	10.3	18.3	40.2
	May	0.0	2.5	17.4	19.9	–	2.8	25.8	28.6	57.7
	June	27.7	12.7	7.2	47.6	65.1	32.7	19	116.8	65.7

Table. 2
The influence of biostimulants and fertilizer on marketable yield, non-marketable fruit yield and total yield of strawberry cv. 'Senga Sengana' in 2001

Treatment	Average marketable yield per plot on individual harvest dates (kg/plot)											Non-marketable fruit yield (kg/plot)	Total yield (kg/plot)
	1 VI	3 VI	5 VI	7 VI	8 VI	10 VI	12 VI	14 VI	16 VI	17 VI	20 VI		
Control	0.11 a*	0.12 a	0.17 a	0.32 a	0.88 a	2.25 ab	0.88 a	1.22 a	1.14 a	0.76 a	0.79 a	0.58 a	9.22 a
Atonik SL	0.07 a	0.11 a	0.22 a	0.29 a	0.89 a	1.58 a	1.01 ab	1.31 a	1.61 b	1.34 b	1.08 b	1.14 b	10.62 ab
Betokson Super 050 SL	0.01 a	0.11 a	0.16 a	0.31 a	0.80 a	2.36 b	1.13 ab	1.39 ab	1.42 b	1.17 b	0.89 ab	0.87 ab	10.62 ab
Betokson Super 050 SL + Atonik SL	0.11 a	0.13 a	0.24 a	0.31 a	0.91 ab	2.31 b	1.04 ab	1.31 a	1.44 b	1.14 b	0.91 ab	0.79 ab	10.64 ab
Betokson Super 050 SL +InsolCa	0.08 a	0.17 a	0.27 a	0.39 a	1.11 b	2.59 b	1.27 b	1.63 b	1.63 b	1.15 b	0.97 ab	0.95 b	12.21 b

*Means within column with the same letter are not significantly different by Tukey's Multiple Range Test at PŁ0.05.

Table. 3
The influence of biostimulants and fertilizer on marketable yield, non-marketable fruit yield and total yield of strawberry cv. 'Senga Sengana' in 2002

Treatment	Average marketable yield per plot on individual harvest dates (kg/plot)											Non-marketable fruit yield (kg/plot)	Total yield (kg/plot)
	3 VI	5 VI	7 VI	9 VI	11 VI	13 VI	15 VI	17 VI	19 VI	21 VI	24 VI		
Control	0.12 a*	0.15 a	0.28 a	0.45 ab	1.0 a	1.01 a	1.28 b	1.64 b	2.21 b	1.47 bc	0.99 a	0.78 b	11.38 b
Atonik SL	0.06 a	0.14 a	0.45 a	0.31 a	0.99 a	0.98 a	0.74 a	1.0 a	1.24 a	0.94 a	0.68 a	0.53 a	8.06 a
Betokson Super 050 SL	0.12 a	0.19 a	0.25 a	0.51 b	1.0 a	1.11 ab	1.24 b	1.57 b	1.85 ab	1.70 c	0.97 a	0.75 ab	11.26 b
Betokson Super 050 SL + Atonik SL	0.09 a	0.17 a	0.26 a	0.51 b	1.01 a	1.11 ab	1.22 b	1.46 ab	1.86 ab	0.99 ab	0.74 a	0.63 ab	10.05 ab
Betokson Super 050 SL +In-solCa	0.23 b	0.20 a	0.30 a	0.49 b	1.01 a	1.35 b	1.27 b	1.44 ab	2.13 b	1.24 a-c	1.01 a	0.75 ab	11.42 b

*Means within column with the same letter are not significantly different by Tukey's Multiple Range Test at PŁ0.05.

Table. 4
The influence of biostimulants and fertilizer on marketable yield of strawberry cv. 'Kent' in 2001

Treatment	Average marketable yield per plot on individual harvest dates (kg/plot)											Marketable fruit yield (kg/plot)
	25 V	27 V	29 V	31 V	2 VI	4 VI	6 VI	9 VI	12 VI	15 VI	18 VI	
Control	0.41 a*	0.64 a	0.70 a	0.54 a	0.57 a	0.86 a	2.04 a	0.57 a	0.70 a	0.54 a	0.34 a	7.92 a
Atonik SL	0.35 a	0.63 a	0.65 a	0.98 b	0.58 a	1.19 b	2.34 ab	0.69 a	0.87 a	0.68 ab	0.38 a	9.33 ab
Betokson Super 050 SL	0.44 a	1.96 a	0.80 a	0.68 a	0.68 a	1.27 b	2.45 ab	0.74 a	0.80 a	0.73 ab	0.39 a	10.93 b
Betokson Super 050 SL + Atonik SL	0.42 a	0.67 a	0.78 a	0.97 b	0.70 a	1.29 b	2.77 b	0.74 a	0.77 a	0.75 ab	0.37 a	10.23 b
Betokson Super 050 SL +InsolCa	0.44 a	0.64 a	0.79 a	0.92 b	0.67 a	1.32 b	2.93 b	0.76 a	0.76 a	0.77 b	0.33 a	10.32 b

*Means within column with the same letter are not significantly different by Tukey's Multiple Range Test at PŁ0.05.

Table. 5
The influence of biostimulants and fertilizer on marketable yield of strawberry cv. 'Kent' in 2002

Treatment	Average marketable yield per plot on individual harvest dates (kg/plot)										Marketable fruit yield (kg/plot)
	27 V	29 V	31 V	2 VI	4 VI	6 VI	9 VI	13 VI	17 VI	20 VI	
Control	0.32 a*	0.50 a	0.60 a	0.81 a	0.87 a	1.14 a	0.82 a	0.89 a	0.75 a	0.77 a	7.47 a
Atonik SL	0.29 a	0.66 a	0.76 ab	1.0 ab	0.92 a	0.84 a	0.98 a	1.02 a	1.13 b	0.76 a	8.36 a
Betokson Super 050 SL	0.38 ab	0.65 a	0.72 ab	1.06 b	0.93 a	1.08 a	0.91 a	0.88 a	1.02 ab	0.77 a	8.40 a
Betokson Super 050 SL + Atonik SL	0.47 b	0.67 a	0.74 ab	1.02 ab	0.89 a	1.11 a	0.88 a	0.87 a	0.90 ab	0.60 a	8.15 a
Betokson Super 050 SL +InsolCa	0.38 ab	0.68 a	0.81 b	1.13 b	0.94 a	1.08 a	0.93 a	1.09 a	0.88 ab	0.77 a	8.69 a

*Means within column with the same letter are not significantly different by Tukey's Multiple Range Test at PŁ0.05.

Table. 6
The influence of preparations and growing season on the content of dry matter, soluble solids, ascorbic acid, anthocyanins and sugar as well as on acidity of strawberries cv. 'Senga Sengana'

Treatment	Year	Dry matter (%)	Soluble solids (%)	Ascorbic acid (mg%)	Anthocyanins (%)	Sugar (%)	Acidity (%)
Control	2001	9.94 a-c*	7.82 a-c	44.30 a	0.066 ab	4.52 a	1.022 a
Atonik SL		10.15 bc	7.88 a-c	52.28 d	0.069 ab	5.23 bc	1.032 ab
Betokson Super 050 SL		9.31 ab	8.08 a-c	54.66 e	0.071 ab	5.32 b-d	1.030 a
Betokson Super 050 SL + Atonik SL		9.73 a-c	8.22 a-c	59.73 f	0.067 ab	5.08 ab	1.022a
Betokson Super 050 SL +InsolCa		9.82 a-c	8.42 bc	59.08 f	0.074 b	5.74 cd	1.040 ab
Mean for year		9.79 A	8.08 B	54.01 B	0.069 B	5.18 A	1.029 A
Control	2002	9.03 a	7.24 a	49.34 c	0.063 a	4.81 ab	1.032 ab
Atonik SL		10.18 bc	7.24 a	46.55 b	0.066 ab	5.05 ab	1.040 ab
Betokson Super 050 SL		9.61 a-c	7.72 a-c	50.05 c	0.067 ab	5.25 b-d	1.040 ab
Betokson Super 050 SL + Atonik SL		9.56 a-c	7.44 ab	49.84 c	0.066 ab	5.84 cd	1.050 b
Betokson Super 050 SL +InsolCa		10.43 c	8.64 c	49.41 c	0.070 ab	5.85 d	1.112 c
Mean for year		9.76 A	7.66 A	49.04 A	0.066 A	5.36 B	1.055 B

*Means within column with the same letter are not significantly differ by Tukey's Multiple Range Test at PŁ0.05.

Table. 7
The influence of preparations on the content of dry matter, soluble solids, ascorbic acid, anthocyanins and sugar as well as on acidity of strawberries cv. 'Senga Sengana'

Treatment	Dry matter (%)	Soluble solids (%)	Ascorbic acid (mg%)	Anthocyanins (%)	Sugar (%)	Acidity (%)
Control	9.49 a*	7.53 a	46.82 a	0.065 a	4.67 a	1.027 a
Atonik SL	10.17 b	7.56 a	49.42 b	0.068 ab	5.14 b	1.036 a
Betokson Super 050 SL	9.46 a	7.90 ab	52.36 c	0.069 ab	5.28 b	1.035 a
Betokson Super 050 SL + Atonik SL	9.65 ab	7.83 a	54.79 d	0.067 ab	5.46 bc	1.036 a
Betokson Super 050 SL +InsolCa	10.12 b	8.53 b	54.25 d	0.072 b	5.79 c	1.076 b

*Means within column with the same letter are not significantly differ by Tukey's Multiple Range Test at PŁ0.05.

Table. 8
The influence of preparations on the content of dry matter, soluble solids, ascorbic acid, anthocyanins and sugar as well as on acidity of strawberries cv. 'Kent'

Treatment	Year	Dry matter (%)	Soluble solids (%)	Ascorbic acid (mg%)	Anthocyanins (%)	Sugar (%)	Acidity (%)
Control	2001	9.33 b-d*	7.38 ab	49.70 c	0.055 a	4.49 a	0.770 a
Atonik SL		9.56 b-d	7.68 a-c	49.60 c	0.059 a-c	4.92 b	0.780 ab
Betokson Super 050 SL		9.10 a-c	8.32 c	49.20 c	0.055 a	5.95 f	0.864 a-d
Betokson Super 050 SL + Atonik		8.78 ab	7.30 ab	52.96 d	0.064 a-c	5.58 d	0.800 ab
Betokson Super 050 SL + InsolCa		8.24 a	7.92 a-c	52.98 d	0.062 a-c	5.35 c	0.910 d
Mean for year		9.00 A	7.72 A	50.89 B	0.059 A	5.26 A	0.825 A
Control	2002	9.62 b-d	7.72 a-c	40.29 a	0.058 ab	5.42 c	0.790 ab
Atonik SL		9.67 cd	7.42 ab	40.54 a	0.056 ab	5.57 d	0.810 a-c
Betokson Super 050 SL		10.11 d	8.12 bc	41.60 b	0.055 a	5.84 e	0.870 b-d
Betokson Super 050 SL + Atonik		9.98 d	7.40 ab	42.13 b	0.065 bc	5.54 d	0.900 cd
Betokson Super 050 SL +InsolCa		9.74 cd	7.16 a	40.55 a	0.068 c	5.97 f	0.930 d
Mean for year		9.82 B	7.56 A	41.02 A	0.060 A	5.67 B	0.860 B

DISCUSSION

The results of the present study showed that the fruiting pattern of the studied cultivars varied. Cv. 'Senga Sengana' produced yields at a similar level in both seasons, while 'Kent' gave a lower yield in 2002 than in the previous year. According to Karp and Starast [17], strawberry yield is the most abundant in the second and third year of cultivation. The yield from older plants decreases, while the percentage of 2nd grade fruits in total yield increases.

Betokson Super 050 SL + InsolCa tended to improve the yield of both studied cultivars. The beneficial effect of Betokson Super 050 SL on the yield of 'Senga Sengana' was found by Masny et al. [4, 6] and on black currant yield by Michalski [18]. However, Cholewiński [19] observed only a slight increase in strawberry yield after the application of this biostimulant. Similar strawberry yields from cvs. 'Senga Sengana' and 'Kent' were obtained by Kopytowski et al. [20] in the conditions of Warmia and by Pawłowska et al. [21] in the conditions of Lubelszczyzna. Biostimulants used during the flowering period help the plants concentrate on flower development and fruit setting [8]. This can be an explanation of a significantly higher yield, as compared to the control, at some harvest dates. The influence of the bioregulators differed between growing seasons. This might have resulted from the age of plants or from climatic conditions. Żmuda et al. [22] found that optimal environmental conditions promote fruit setting and then the effect of exogenous auxin is smaller. Strawberries have high water requirements due to their shallow root system, large leaf area and fruits with high water content [23]. Studying the effect of substrate moisture content on cv. 'Elkat' strawberry yield, Klamkowski et al. [24] found that the optimal moisture content was between 25 and 34% v/v or between 74 and 100% of water holding capacity. May and June in 2002 were more abundant in precipitation than in 2001.

The chemical composition of strawberry fruit depends mainly on cultivar, fruit maturity degree and climatic conditions during the growing period. It is also determined by cultivation technology [25]. The significantly higher amount of sugar and acid in fruits of both cultivars in 2002 may have resulted from the higher air temperatures in the first two decades of June. Besides light, air temperature is a major factor that influences the photosynthetic activity in plants, so that the starch concentration in leaves is higher in plants exposed to high air temperatures. Sugar accumulation in the plant is influenced by the sink strength, which means the fruit development stage [26]. Dantas et al. [27] found that higher sink strength occurred in the summer when the air temperatures were higher. Kitano et al. [28] suggested that respiration in fruits enhanced the effect of temperature on expansive growth and sugar accumulation through regulation of the energy-dependent postphloem sugar transport in the fruits.

The beneficial influence of Ca spraying on vitamin C content in strawberry was reported by Naphun et al. [29]. Similar results were obtained by Poovaiah et al. [30], who found that $CaCl_2$ increased the ascorbic acid content in apples.

The values were similar to the results obtained by Skupień and Oszmiański [31] – 33.8–64.5 mg × 100 g^{-1} ('Kent' and 'Elkat'), and lower than those reported by Cordenunsi et al. [32] – 47–80 mg × 100 g^{-1}. In an experiment on raspberry, Grajkowski and Ochmian [8] found that the control plants and plants treated with Atonik SL had the highest vitamin C content. However, the experiment of Mikos-Bielak [33] showed that Atonik SL definitely lowered the vitamin C content in raspberries.

The red or scarlet color of the fruit and its flesh is one of the most important features of strawberry, because the color may be the most important quality factor that the consumer first realizes. Anthocyanins are accumulated in the inner flesh of the strawberry fruit during the late stage of development and their accumulation may be regulated by auxin [34].

Sugar content is one of important factors in determining the quality of strawberry fruits. Fructose accumulation in fruits is not only a result of sucrose transport and metabolism, but also occurs due to fructose metabolism. LeClere et al. [35] pointed out that the sugar concentration in maize kernels was affected by auxin biosynthesis. Wang et al. [36] found that exogenous auxin affected fructose accumulation, but their signaling and regulating mechanisms are still unclear.

CONCLUSIONS

1. Betokson Super 050 SL + InsolCa tended to improve the yield of both cultivars; especially in 2001 significant differences were evident as compared to the control.
2. The fruit of 'Senga Sengana started ripening later and had more ascorbic acid, anthocyanins and acidity than 'Kent'.
3. The use of Betokson Super 050 SL + InsolCa increased the content of ascorbic acid, anthocyanins and sugar as well as acidity in strawberries of both cultivars.
4. The use of Betokson Super 050 SL + Atonik SL significantly increased the content of ascorbic acid and sugar in fruits of both cultivars. 'Kent' strawberries also reacted with a higher content of anthocyanins and higher acidity.

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Authors' contributions

The following declaration about authors' contributions to the research has been made: study concept: IS and AB; field research and data collection: IS and TL; data interpretation: IS, TL, writing of the manuscript, table and figure arrangement: IS and TL.

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Wpływ atoniku sl, betoksonu super 050 sl and insolu ca na plonowanie truskawek (*Fragaria* x *ananassa* Duch.) odmian 'Senga Sengana' i 'Kent'

Streszczenie

Skład chemiczny truskawek zależy głównie od odmiany, stopnia dojrzałości owoców oraz warunków klimatycznych w danym sezonie wegetacyjnym. Na jakość owoców wpływają także zabiegi pielęgnacyjne prowadzone w czasie uprawy. W doświadczeniu badano wpływ dwóch biostymulatorów (Atonik SL i Betokson Super 050 SL), użytych samodzielnie lub w połączeniu, albo z płynnym nawozem InsolCa, na plonowanie i jakość owoców dwóch odmian 'Senga Sengana' i 'Kent'. Betokson Super 050 SL + InsolCa wpłynął na poprawę wielkości plonów obu odmian, zwłaszcza w 2001 roku różnice były wyraźnie widoczne w stosunku do kontroli. Owoce odmiany 'Senga Sengana' zaczęły dojrzewać później i miały więcej kwasu askorbinowego, antocyjanów i większą kwasowość, niż odmiany 'Kent'. Zastosowanie Betokson Super 050 SL + InsolCa istotnie wpłynęło na zwiększenie zawartości kwasu askorbinowego, antocyjanów, cukrów i kwasowości truskawek obu badanych odmian. Zastosowanie Betokson Super 050 SL + Atonik SL wpłynęło na wzrost zawartości kwasu askorbinowego i cukru w owocach obu odmian. Truskawki odmiany 'Kent' charakteryzowały się także wzrostem zawartości antocyjanów i kwasowości.

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