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SEASON EXTENSION POSSIBILITIES IN TWO POLISH JUNE-BEARING STRAWBERRY CULTIVARS

Agnieszka Masny, Edward Żurawicz
Research Institute of Horticulture, Skierniewice

Abstract. Extending the harvesting time allows the consumers to eat fresh strawberries from the spring to the autumn. It also creates the opportunity to increase profits for the growers. However, such production requires new technologies and appropriate cultivars. Studies on extending (delaying) of the fruit harvesting period of two Polish strawberry cultivars – 'Grandarosa' and 'Pink Rosa' – were conducted at the Research Institute of Horticulture in Skierniewice (Central Poland) in 2012–2013. The productivity, fruit ripening time and fruit quality of both cultivars were assessed in the open field conditions (three dates of delayed planting, frigo potted and bare-root plants) as well as in soilless cultivation in gutters under plastic canopies and in a high tunnel (delayed planting, frigo potted plants). 'Elsanta' was used as the reference cultivar. It was found that delayed planting of frigo plants resulted in extending the harvest time by roughly 10 weeks in field condition and up to 12 weeks in soilless cultivation under cover. Both Polish cultivars were suitable for the cultivation in the open field and under covers for the delayed harvest. In both types of cultivation the peak of harvesting was 8 to 12 days earlier in 'Elsanta' as compared to 'Grandarosa' and 'Pink Rosa'. The overall productivity as well as average fruit weight and fruit firmness of both Polish cultivars were significantly higher in comparison with 'Elsanta'. The production under covers was more effective than in the open field, where the high temperatures of soil and air prevailing after planting resulted in decrease of yield and fruit quality. Moreover, plants under covers did not suffer from the early autumn frosts and they were harvested in a longer period of time as compared to plants grown in the open field.

Key words: *Fragaria* × *ananassa* Duch., soil and soilless cultivation, delayed planting, frigo plants, marketable yield, fruit quality

Corresponding author: Agnieszka Masny, Research Institute of Horticulture, Konstytucji 3 Maja 1/3, 96-100 Skierniewice, Poland, e-mail: agnieszka.masny@inhort.pl

INTRODUCTION

The strawberry (*Fragaria* × *ananassa* Duch.) is a small fruit species commonly cultivated in many countries of the world, especially in the northern hemisphere. In Europe, around 1.3 million tonnes of strawberries are produced annually, which represents nearly 30% of the global production. Poland, producing over 150 thousand tonnes per year, is ranked 4th in Europe and 10th in the world [FAOSTAT 2014]. Most of the European fruit production is destined for the fresh market. Therefore, producers of fresh strawberries introduce new cultivation techniques that allow them to extend the harvesting season without reducing fruit quality, such as protected cultivation systems [Takeda 1999]. However, production of strawberries under high covers for early harvesting is not recommended in Poland because of specific winter conditions, especially large fluctuations of outside temperatures and low light intensity resulting in relatively low yield in addition to higher production costs. Therefore cultivation for delayed harvesting is more profitable [Brzozowski 2005].

Delayed strawberry harvesting can be achieved by using day-neutral varieties, that continue producing flowers and fruits beyond typical peak season, or by delaying the time of planting frigo plants of the short-day varieties, such as 'Elsanta' [Palha 2005]. The latter method allows precise control of plant growth and development so that the berries ripen at the time scheduled by the grower. It has been established that, depending on the weather in Poland, from 6 to 8 weeks pass from the time of planting frigo plants to the time when first strawberries are harvested. In some regions of Poland, establishing a field plantation for delayed harvesting is associated with high risk of failure due to the frequent occurrence of abundant rainfall in June and July. Several days of rain can make plantations waterlogged as well as hinder or prevent efficient pollination by insects, leading to deterioration in fruit quality [Lopez-Medina et al. 2006]. Therefore, for such regions it is better to grow strawberries in gutters, using partial covers in the form of polyethylene canopies above the plants, or in high tunnels with a possibility of ventilation along entire length of the tunnel to prevent diseases and overheating.

The aim of the study was to determine the suitability of two Polish strawberry cultivars ('Grandarosa' and 'Pink Rosa') for late harvesting through controlled cultivation in the open field (soil production) as well as under polyethylene canopies and in a high tunnel (in gutters lined with cocomats) using the technique of delayed planting of frigo plants.

MATERIAL AND METHODS

The study was conducted in 2012–2013 in the Pomological Orchard of the Research Institute of Horticulture in Skierniewice (central Poland, 51.96ºN, 20.14ºE) on the basis of two separate experiments.

Experiment I was conducted in the open field (soil-bound cultivation) in two one-year series: Series I in 2012 and Series II in 2013. Both series consisted of three independent factors: (A) cultivar (three June-bearing strawberry cultivars: 'Grandarosa', 'Pink Rosa', and 'Elsanta' used as reference, (B) planting date (three dates of planting), and (C) type of frigo plants (two types of plants with a 10–15 mm diameter crown

(grade A): bare-root and potted plants). In 2012, the plants were planted in two-weeks intervals on: 1st June, 15th June and 29th June, while in 2013, on 17th June, 1st July and 10th July. The delay in planting in 2013 compared to 2012 was a consequence of heavy rains that had caused waterlogging of the field designated for Series II. Both series of the experiment were set up in a split-plot design, with four replications of 15 plants per plot each, planted at a spacing of 0.25 × 1.1 m. The management of plots followed recommendations for commercial plantations [Masny and Żurawicz 2013]. Weeds and runners emerging in the inter-rows were systematically destroyed with a mini-rototiller, while those in the rows were removed by hand. During rain-free periods, the plants were watered at least once a week with a Polymat 130 self-propelled sprinkler.

Experiment II was conducted by a soilless method, similarly to the experiment I in two one-year series: Series I in 2012 and Series II in 2013. Both series consisted of two independent factors: (A) cultivar (three June-bearing cultivars: 'Grandarosa', 'Pink Rosa', and 'Elsanta' used as reference), and (B) cultivation conditions. Three different variants of cultivation were used: (i) cultivation in gutters lined with cocomats, arranged in an open field and protected with polyethylene canopies (partial cover) from rain and hail, (ii) cultivation in cocomat-lined gutters in a high plastic tunnel with tilt windows for ventilation along the entire length of the tunnel, on both sides and at both ends, and (iii) traditional cultivation of plants in soil in an open field used as the control. Each combination was set up in five replications; a replication was a cocomat (plot) with 6 plants growing in it. Frigo potted plants in the cocomats were planted on 17th July 2012 (series I) and 19th July 2013 (series II), while in the open field conditions – on 17th July 2012 (and grown during two seasons). All the plants (both in the field and on the gutters) were watered and fertilized three times a day (at 9 a.m., 12 noon, and 3 p.m.) by means of a computer-controlled capillary system.

In both experiments the same pest treatments were performed before flowering, the plants were treated against the strawberry blossom weevil (*Anthonomus rubi*), while during flowering they were sprayed three times at weekly intervals against grey mould (*Botrytis cinerea*) with the fungicides Thiram Granuflo 80 WG, Signum 33 WG and Switch 62,5 WG. No additional protection against fungal diseases of leaves was used.

In both experiments, the same measurements and observations were performed as follows:

– fruit ripening time (Faedi Index, specifying the number of days from 1 January until the time when 50% of the crop has been collected),

– marketable yield in $g \cdot plot^{-1}$ (all fruit of Class 'Extra' and Class I – with a diameter greater than 1.8 cm),

– weight of 100 fruits in g (the ratio of the total yield and the total number of all healthy fruit harvested),

– fruit firmness in N (using INSTRON 5542 penetrometer, based on 3 samples of 20 Class 'Extra' fruit, uniform in size and fully colored. The berries were collected at three harvest times at the peak of harvesting* – 3rd, 4th, and 5th harvest),

– extract in °Brix (soluble solids content; using a Rudolph J-157 refractometer, based on 3 samples of 20 Class 'Extra' fruit, collected at three harvest times at the height of fruiting – 3rd, 4th, and 5th harvest),

– ascorbic acid content in mg·100 ml^{-1} (using an RQ-Easy reflectometer and Merck test strips, based on 3 samples of 20 Class 'Extra' fruit, collected at three harvest times at the peak of harvesting* – 3rd, 4th, and 5th harvest).

Statistical analysis of results was performed using R.A. Fischer's analysis of variance, and the differences between means were assessed using Duncan's t-test at a significance level of 5%.

RESULTS AND DISCUSSION

Delaying the planting date of frigo plants in soil-bound field cultivation made it possible to extend the fruit ripening by approximately 10 weeks (end of August) (tab. 1), whereas in soilless cultivation in gutters under cover (plastic canopies and tunnel) by 12 weeks (mid-September) (tab. 3), in comparison to the traditional cultivation in soil, where fruiting usually begins around mid-June (tab. 3 – field production in 2013) [Masny and Żurawicz 2009]. In all the techniques of cultivation used in the study, the selection of the proper cultivar was of particular importance in delaying the time of fruit harvest. It was found that in the field cultivation the peak fruit ripening time (Faedi Index) in 'Elsanta' occurred approximately 7–10 days earlier than in 'Grandarosa' and 10–12 days earlier as compared to 'Pink Rosa', in spite that the plants of these cultivars were planted in the same time (tab. 1). In soilless cultivation in gutters, the berries of 'Elsanta' were also the earliest to ripen, followed by those of 'Grandarosa' and 'Pink Rosa' (eight and 12 days later respectively). This could be explained with cultivar-dependent differences in the time of vegetative growth till the flowering, fruitlet development and ripening.

Depending on the weather conditions during the growing season, the time from planting frigo plants to the peak of fruiting ranks from 44 to 52 days in 'Elsanta', from 48 to 60 days in 'Grandarosa', and from 52 to 62 days in 'Pink Rosa', and it is usually shortened by 1–2 days when the planting time is delayed for another two weeks. Our results are similar to previously reported data from experiments involving frigo plants [Radajewska 1998, Laugale and Bite 2002]. Radajewska [1998] reported average time of blooming and fruit ripening to occur four and eight respective weeks after planting some June-bearing cultivars, which is consistent with rapid growth and development of frigo plants. Laugale and Bite [2002] observed first ripen fruits even at 6th week after planting in 'Elsanta' in the condition of high average temperatures. Knowing the time required to reach the peak of fruit ripening in a given cultivar, counting from the time of planting frigo plants into the ground, allows accurate determination of the planting dates of successive plants to ensure continuity of harvest until the first autumn frosts.

The fruit crop harvested from plants in delayed soil-bound cultivation was in 2013 lower compared to 2012 despite using frigo plants similar in size (grade A of crown' diameter) to establish series I and series II of the experiment I. Regardless of cultivar used, the lowest yield was recorded for plants planted on 17th June and 1st July 2013 (1st and 2nd planting date). The reason for those low yields were unfavorable weather conditions (high air temperatures occurring immediately after planting; fig. 1), which interfered with plantlets' adaptation. Regardless of cultivar both, the yield and the aver-

Table 1. Time of fruit ripening, plant productivity and average fruit weight of strawberry cultivars 'Grandarosa' and 'Pink Rosa' and the reference cultivar 'Elsanta' recorded in exp. I (different planting dates using frigo potted and bare root plants, Skierniewice, Poland, 2012–2013)

Cultivar (factor A)	Date of planting* (factor B)	Type of plants (factor C)	Ripening time				Marketable yield (g·plant^{-1})		Average weight of 100 fruits (g)	
			2012		2013					
			date	faedi index	date	faedi index	2012	2013	2012	2013
Elsanta	1st	potted plants	18.07–10.08	205.6 a	25.07–05.08	209.7 a	63.6 ef	19.2 c–e	735 c–g	484 ab
		bare root plants	18.07–24.08	205.7 a	25.07–12.08	218.4 b	69.1 ef	3.3 a	716 c–g	484 ab
	2nd	potted plants	25.07–24.08	218.6 c	12.08–23.08	227.3 c	38.8 a–c	19.5 c–e	603 a–c	398 a
		bare root plants	25.07–24.08	217.4 c	12.08–23.08	229.2 c	55.7 c–e	15.8 b–d	661 a–d	569 bc
	3rd	potted plants	10.08–05.09	231.1 f	14.08–06.09	233.5 de	35.0 ab	25.6 ef	540 a	577 bc
		bare root plants	10.08–05.09	228.0 e	19.08–06.09	236.2 ef	40.0 a–c	30.9 fg	560 ab	525 a–c
Grandarosa	1st	potted plants	18.07–17.08	212.6 b	05.08–12.08	218.8 b	65.7 ef	12.9 bc	1094 k	475 ab
		bare root plants	18.07–24.08	213.6 b	05.08–12.08	219.4 b	59.5 d–f	14.3 bc	846 g–i	488 ab
	2nd	potted plants	02.08–30.08	225.4 d	12.08–30.08	232.3 d	67.3 ef	22.0 de	1004 jk	779 de
		bare root plants	02.08–05.09	226.7 de	12.08–30.08	228.8 c	64.0 ef	36.5 gh	900 h–j	663 cd
	3rd	potted plants	10.08–05.09	235.3 g	19.08–06.09	239.9 g	50.1 b–e	40.0 h	963 i–k	847 ef
		bare root plants	10.08–05.09	235.3 g	19.08–06.09	239.7 g	42.4 a–d	21.4 de	809 e–h	817 d–f
Pink Rosa	1st	potted plants	25.07–24.08	212.5 b	05.08–12.08	220.5 b	63.0 ef	11.8 b	916 h–j	537 a–c
		bare root plants	18.07–24.08	217.8 c	05.08–12.08	219.8 b	77.1 f	14.2 bc	701 b–f	778 de
	2nd	potted plants	02.08–30.08	225.6 d	14.08–30.08	237.9 fg	68.4 ef	32.3 g	786 d–h	763 de
		bare root plants	02.08–05.09	230.5 f	12.08–30.08	232.9 d	68.3 ef	17.6 b–d	690 b–e	754 de
	3rd	potted plants	17.08–05.09	239.4 h	27.08–06.09	245.4 h	42.6 a–d	37.6 gh	634 a–c	1225 g
		bare root plants	17.08–05.09	240.1 h	27.08–06.09	243.6 h	27.1 a	32.0 fg	838 f–i	945 f
Mean value for cultivar (factor A)		Elsanta	18.07–05.09	217.7 a	25.07–06.09	225.7 a	50.3 a	19.1 a	636 a	506 a
		Grandarosa	18.07–05.09	224.8 b	05.08–06.09	229.8 b	58.2 b	24.5 b	936 c	678 b
		Pink Rosa	18.07–05.09	227.6 c	05.08–06.09	233.4 c	57.8 b	24.2 b	761 b	834 c
Mean value for planting time (factor B)		1st date of planting	18.07–24.08	211.3 a	25.07–12.08	217.8 a	66.3 b	12.6 a	834 b	541 a
		2nd date of planting	25.07–05.09	224.0 b	12.08–30.08	231.4 b	60.4 b	23.9 b	774 a	654 b
		3rd date of planting	10.08–05.09	234.9 c	14.08–06.09	239.7 c	39.5 a	31.3 c	724 a	823 c
Mean value for plant type (factor C)		potted plants	18.07–05.09	222.9 a	25.07–06.09	229.5 a	54.9 a	24.5 b	808 b	676 a
		bare root plants	18.07–05.09	223.9 b	25.07–06.09	229.8 a	55.9 a	20.7 a	747 a	669 a

Explanation: * – 1st date of planting – 1 June 2012 and 17 June 2013; 2nd date of planting – 15 June 2012 and 1 July 2013; 3rd date of planting – 29 June 2012 and 10 July 2013

Values within columns followed by the same letter do not differ significantly at $P < 0.05$ according to the Duncan's multiple range test

Table 2. Fruit quality of strawberry cultivars 'Grandarosa' and 'Pink Rosa' and the reference cultivar 'Elsanta' recorded in exp. I (different planting dates using frigo potted and bare root plants, Skierniewice, Poland, 2012–2013)

Cultivar (factor A)	Date of planting* (factor B)	Type of plants (factor C)	Fruit firmness (N)		Soluble solids content (Brix)		Ascorbic acid content (mg·100 g^{-1})	
			2012	2013	2012	2013	2012	2013
Elsanta	1st	potted plants	1.34 ab	1.55 ab	12.52 f	11.67 d	54.00 b–d	49.67 a
		bare root plants	1.28 a	1.71 a–c	11.05 c–f	9.75 a–d	49.33 a–d	43.00 a
	2nd	potted plants	1.33 ab	1.47 ab	11.58 d–f	9.55 a–c	47.33 a–d	41.00 a
		bare root plants	1.42 ab	1.27 a	10.81 b–f	9.30 a–c	46.00 a–d	38.00 a
	3rd	potted plants	1.40 ab	1.07 a	11.26 c–f	10.47 b–d	49.00 a–d	40.00 a
		bare root plants	1.79 a–d	1.14 a	11.24 c–f	10.27 b–d	49.00 a–d	50.00 a
Grandarosa	1st	potted plants	2.07 cd	4.15 g	12.17 ef	9.41 a–c	58.00 d	42.67 a
		bare root plants	1.68 a–d	3.70 e–g	10.52 b–e	8.69 ab	47.33 a–d	40.67 a
	2nd	potted plants	1.85 a–d	3.40 e–g	12.36 f	10.60 b–d	56.00 cd	46.67 a
		bare root plants	1.37 ab	2.5 d–f	11.07 c–f	9.81 b–d	50.67 a–d	34.33 a
	3rd	potted plants	2.66 e	3.96 fg	11.74 ef	11.08 cd	37.00 a	39.00 a
		bare root plants	1.93 a–d	3.68 e–g	9.23 ab	10.13 b–d	42.67 a–d	40.67 a
Pink Rosa	1st	potted plants	1.96 b–d	2.86 c–f	11.30 c–f	9.50 a–c	40.67 a–c	37.00 a
		bare root plants	1.44 a–c	2.68 b–e	9.69 a–c	7.86 a	48.00 a–d	41.33 a
	2nd	potted plants	1.65 a–d	2.07 a–d	9.94 b–d	9.83 b–d	46.67 a–d	46.33 a
		bare root plants	1.68 a–d	2.58 b–e	9.53 a–c	9.36 a–c	46.00 a–d	38.67 a
	3rd	potted plants	1.89 a–d	2.14 a–d	10.80 b–f	10.45 b–d	45.00 a–d	41.67 a
		bare root plants	2.28 de	1.59 ab	8.19 a	9.78 b–d	38.00 ab	38.00 a
Mean value for cultivar (factor A)		Elsanta	1.43 a	1.37 a	11.41 b	10.17 a	49.11 a	43.61 a
		Grandarosa	1.93 b	3.64 c	11.18 b	9.95 a	48.61 a	40.67 a
		Pink Rosa	1.82 b	2.32 b	9.91 a	9.46 a	44.06 a	40.50 a
Mean value for planting time (factor B)		1st date of planting	1.63 a	2.77 b	11.21 b	9.48 a	49.56 b	42.39 a
		2nd date of planting	1.55 a	2.29 a	10.88 ab	9.74 ab	48.78 ab	40.83 a
		3rd date of planting	1.99 b	2.26 a	10.41 a	10.36 b	43.44 a	41.56 a
Mean value for plant type (factor C)		potted plants	1.80 a	2.52 a	11.52 b	10.28 b	48.19 a	42.67 a
		bare root plants	1.65 a	2.37 a	10.15 a	9.44 a	46.33 a	40.52 a

Explanation: * – 1st date of planting – 1 June 2012 and 17 June 2013; 2nd date of planting – 15 June 2012 and 1 July 2013; 3rd date of planting – 29 June 2012 and 10 July 2013

Values within columns followed by the same letter do not differ significantly at $P < 0.05$ according to the Duncan's multiple range test

Table 3. Fruit ripening time, plant productivity and fruit weight of strawberry cultivars 'Grandarosa' and 'Pink Rosa' grown in two soilless culture conditions (exp. II), using frigo potted plants (Skierniewice, Poland, 2012-2013)

Cultivar (factor A)	Cultivation conditions (factor B)	Ripening time				Marketable yield ($g \cdot plant^{-1}$)		Average weight of 100 fruits (g)	
		2012		2013					
		date	faedi index	date	faedi index	2012	2013	2012	2013
Elsanta	polyethylene canopies[1]	28.08–02.10	251.1 a	22.08–23.09	246.7 d	55.8 ab	69.4 c	987 a	1175 b
	high tunnel[1]	28.08–02.10	256.0 b	22.08–01.10	242.5 c	43.4 a	63.3 c	908 a	985 ab
	open field[2]	31.08–02.10	255.0 b	21.06–05.07	175.5 a	59.2 ab	9.7 a	896 a	611 a
Grandarosa	polyethylene canopies[1]	28.08–02.10	260.9 c	27.08–08.10	257.6 f	64.0 b	99.3 de	1573 bc	2473 d
	high tunnel[2]	29.08–02.10	262.4 cd	27.08–01.10	252.9 e	65.3 b	90.3 d	1618 c	1762 c
	open field	04.09–02.10	264.4 de	21.06–05.07	176.1 a	87.8 c	43.3 b	1958 d	815 ab
Pink Rosa	polyethylene canopies[1]	31.08–02.10	264.8 de	03.09–08.10	262.6 g	63.6 b	112.4 e	1420 b	4013 e
	high tunnel[2]	28.08–02.10	267.0 e	27.08–01.10	255.5 f	66.5 b	131.6 f	1616 c	2079 c
	open field	04.09–02.10	266.1 e	21.06–05.07	178.7 b	95.2 c	71.3 c	1627 c	846 ab
Mean value for cultivar	elsanta	28.08–02.10	254.0 a	21.06–01.10	221.6 a	52.8 a	47.5 a	931 a	924 a
	grandarosa	28.08–02.10	262.6 b	21.06–08.10	228.9 b	72.4 b	77.6 b	1716 c	1684 b
	pink rosa	28.08–02.10	266.0 c	21.06–08.10	232.3 c	75.1 b	105.1 c	1554 b	2313 c
Mean value for cultivation conditions	polyethylene canopies[1]	28.08–02.10	258.9 a	22.08–08.10	255.6 c	61.1 a	93.7 b	1327 a	2554 c
	high tunnel	28.08–02.10	261.8 b	22.08–01.10	250.3 b	58.4 a	95.1 b	1381 a	1609 b
	open field	28.08–02.10	261.8 b	21.06–05.07	176.8 a	80.8 b	41.4 a	1494 b	757 a

Explanations: [1] – one-year experiment was established on 17 July 2012 and 19 July 2013, respectively (plants grown in cocomats in gutters)
[2] – the field experiment was established on 19 July 2012 and performed during two seasons (2012– 2013)
Values within columns followed by the same letter do not differ significantly at $P < 0.05$ according to the Duncan's multiple range test

Table 4. Fruit quality of strawberry cultivars ‘Grandarosa’ and ‘Pink Rosa’ grown in two soilless culture conditions (Exp. II), using frigo potted plants (Skierniewice, Poland, 2012–2013)

Cultivar (factor A)	Cultivation conditions (factor B)	Fruit firmness (N)		Soluble solids content (Brix)		Ascorbic acid content (mg·100 g^{-1})	
		2012	2013	2012	2013	2012	2013
Elsanta	polyethylene canopies[1]	1.28 a	1.34 ab	9.57 a	10.69 bc	56.33 a	58.67 d
	high tunnel[1]	1.24 a	1.10 a	10.44 a–d	9.81 ab	55.33 a	53.33 cd
	open field[2]	1.15 a	1.46 ab	10.00 a–c	12.02 c	57.00 a	28.33 a
Grandarosa	polyethylene canopies[1]	2.39 bc	3.33 e	11.18 d	10.70 bc	50.67 a	45.33 bc
	high tunnel[2]	2.56 c	2.31 cd	11.15 cd	10.93 bc	68.00 a	36.33 ab
	open field	2.59 c	2.72 de	11.08 cd	9.26 a	64.67 a	39.33 ab
Pink Rosa	polyethylene canopies[1]	1.73 ab	1.98 bc	9.79 ab	10.10 ab	52.67 a	37.67 ab
	high tunnel[2]	1.45 a	1.57 ab	10.16 a–d	10.45 ab	59.33 a	34.33 ab
	open field	1.42 a	2.23 cd	10.87 b–d	9.74 ab	45.67 a	39.33 ab
Mean value for cultivar (factor A)	elsanta	1.22 a	1.30 a	10.00 a	10.84 a	56.22 a	46.78 b
	grandarosa	2.51 b	2.79 c	11.14 b	10.30 a	61.11 a	40.33 ab
	pink rosa	1.53 a	1.93 b	10.27 a	10.10 a	52.55 a	37.11 a
Mean value for planting time (factor B)	polyethylene canopies[1]	1.80 a	2.22 b	10.18 a	10.50 a	53.22 a	47.22 b
	high tunnel	1.75 a	1.66 a	10.59 a	10.40 a	60.89 a	41.33 ab
	open field	1.72 a	2.13 b	10.65 a	10.34 a	55.78 a	35.67 a

Explanations: [1] – one-year experiment was established on 17 July 2012 and 19 July 2013, respectively (plants grown in cocomats in gutters)
[2] – the field experiment was established on 19 July 2012 and performed during two seasons (2012–2013).
Values within columns followed by the same letter do not differ significantly at $P < 0.05$ according to the Duncan’s multiple range test

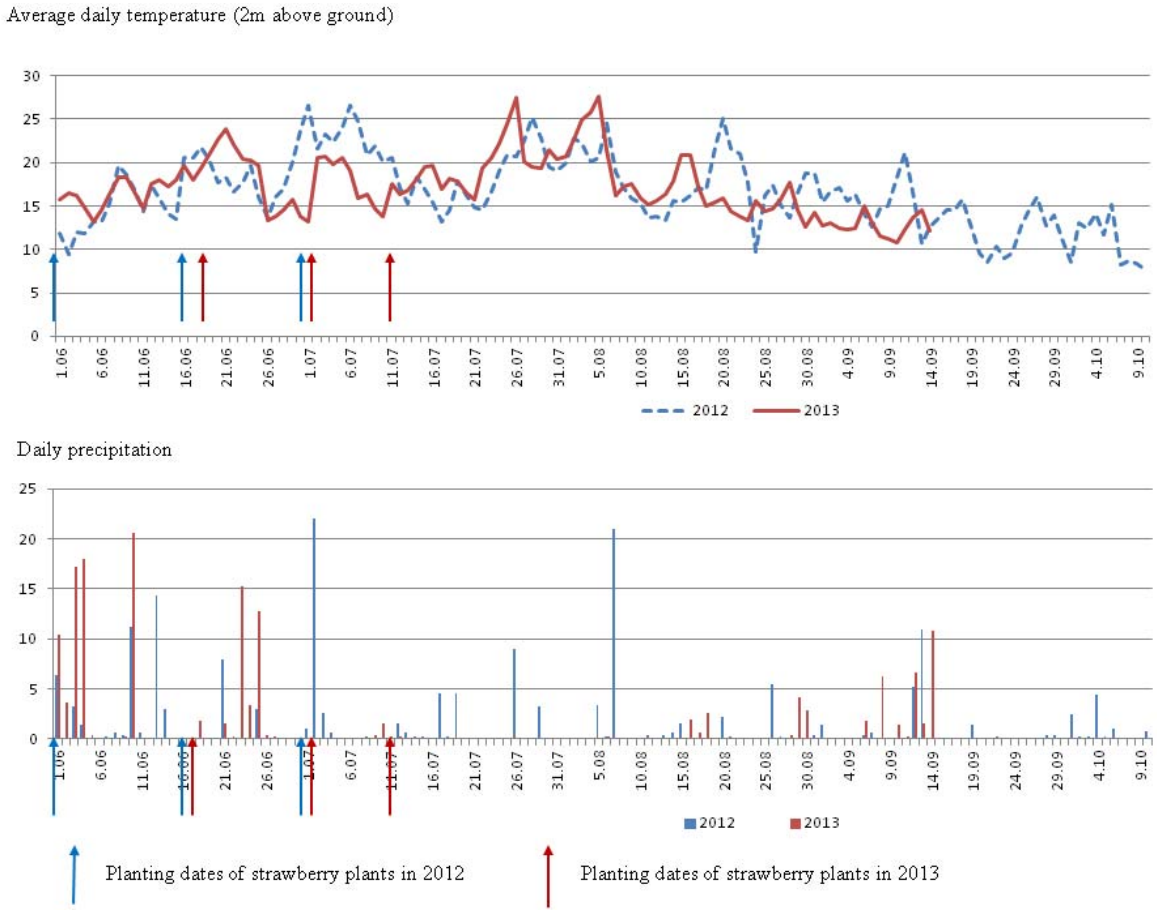

Fig. 1. Weather conditions during carrying out the experiments on strawberry season extension (delaying) in soil and soilless culture (Skierniewice, 2012–2013)

age weight of fruits harvested from plants of all the cultivars planted on the above two dates (tab. 1 – average for factor B) were significantly lower compared to the yield and average weight of fruit from the plants planted on 10th July 2013 (3rd planting date). Our earlier studies have shown that, as a result of high temperatures occurring soon after planting, the young plants are not able to form a sufficient number of leaves and roots before flowering. This in turn reduces plants' ability to support rapidly developing flowers and buds and results fruit yield reduction [Masny and Żurawicz 2013].

Another factor affecting results of delayed planting is the weather. Highly elevated temperatures in May and abundant rainfall in June 2013 contributed to a significant reduction in the yield of two-year-old strawberry plants grown in the soil as a combination for comparison with soilless cultivation in gutters under plastic canopies and in the tunnel (tab. 3). Young, 2-month-old plants of all the cultivars in soilless cultivation yielded significantly better than two-year-old plants growing in the open field. Similar results were obtained in other strawberry research centers, where production under cover resulted much higher yield compared to traditional field cultivation. Reduction in the negative effect of environmental factors, such as frost, rain or hail certainly contributed to these results [Singh et al. 2012, Dávalos-González et al. 2014]. Moreover, Mattas et al. [1997] indicated that in polyethylene tunnels the soilless strawberry cultivation system was much more efficient in marketable fruit production than the traditional double-row bed system. Among all the cultivars evaluated in our experiment in soilless cultivation, 'Pink Rosa' produced the highest yield of fruits.

Strawberry fruit size varied significantly, being influenced mainly by the cultivar, and also by the planting date and cultivation technique. In both experiments, regardless of the planting date and the cultivation conditions, two new Polish cultivars 'Grandarosa' and 'Pink Rosa' produced fruit with a significantly greater weight compared to 'Elsanta' used as reference. However, the weight of the fruit harvested in all combinations studied revealed a wide variation in the results between years. This suggests that fruit size and fruit yield are largely dependent on weather conditions, especially soil moisture and air temperature. However, both Polish cultivars were more regular in terms of their productivity, but less stable in terms of fruit weight as compared to 'Elsanta' in different weather conditions. In 2012, strawberries with the highest weight were collected from the plants planted in the soil on 1st June, whereas in 2013 – from those planted on 10th July. Our earlier studies conducted on plants of 'Elsanta' and 'Ventana' cultivars, confirm that a planting date in early July is usually the most favorable one for obtaining large fruit and abundant crop [Masny and Żurawicz 2010].

It was also observed that the berries harvested from plants whose growth after planting was affected by high temperatures (3rd planting date in 2012 and 1st date in 2013, fig. 1), were smaller (tab. 1), but significantly firmer (tab. 2) compared to the berries obtained from the plants planted on the other dates. Analysis of the average results for each cultivar, obtained in the field experiment, revealed that the berries of the two new Polish cultivars, 'Grandarosa' and 'Pink Rosa', were in both years of the study significantly firmer than the berries of the standard cultivar 'Elsanta' (tab. 2). In the cultivation under cover, 'Grandarosa' produced, in both years of the study, berries with the highest firmness. Earlier, long-term experiments by Żurawicz and Masny [2012] on 'Grandarosa', grown by the traditional method in the soil, prove that in terms of fruit firmness

this cultivar considerably surpasses 'Elsanta' and 'Honeoye', widely grown in Central European countries. Strawberries of 'Pink Rosa' were significantly firmer than those of 'Elsanta' in 2013, and also slightly firmer than those of 'Elsanta' in 2012, although these differences have not been proven to be statistically significant (tab. 4).

Strawberries from the plants growing at a moderate temperature were not only better developed, but also the richest in soluble solids (extract, tab. 2). It is known from the literature that warm and sunny days and cooler nights favour the accumulation of large amounts of sugars in strawberry fruits [Masny and Żurawicz 2013]. On the other hand, Caracciolo et al. [2009] reported that different planting dates of plug plants do not have any influence on the soluble solids content and firmness of the fruits. In our experiments significant effect of the cultivar on the soluble solids content of the fruit was observed only in 2012. Significantly higher ($P < 0.05$) amounts of soluble solids, in comparison with 'Pink Rosa', both in the field experiment and under cover, were in the fruit of 'Grandarosa' (tabs 2 and 4). Unlike the other traits assessed in the field experiment, the type of plants used to establish the experiment, in both growing seasons, was found to have an effect on the soluble solids content of the fruit. Strawberries produced by the potted plants, regardless of the planting date and the cultivar, were richer in soluble solids than those from the bare-root plants (tab. 2). This observation is contradictory to these of Palha et al. [2009], whose research involving different types of 'Elsanta' frigo plants and various planting dates in soilless cultivation in gutters, had indicated that the type of the plants did not affect the quality: skin colour, firmness, and soluble solid content.

The last character analyzed in our study was the content of ascorbic acid that affects fruit nutritional value. In the field experiment, the berries of all the cultivars in both years of the study were characterized by a comparable ascorbic acid contents, which only minor differences between the 1st and 3rd date of planting in year 2012 were observed (tab. 2). In experiment II, significant ($P < 0.05$) differences in the ascorbic acid content of the fruit were found in 2013 only (tab. 4). Significantly higher amounts of ascorbic acid were obtained in fruits of the plants grown in cocomats in gutters under plastic canopies compared to the fruit harvested from the open-field cultivation. The berries of 'Elsanta' cultivar contained the highest level of ascorbic acid, those of 'Pink Rosa' – the least. In studies by other Polish researchers [Bartczak et al. 2009], conducted under greenhouse conditions on plants of 'Honeoye' and 'Elsanta', it had been proved that neither the type of the planting material nor the planting date had a significant effect on the ascorbic acid content in the berries.

CONCLUSIONS

The study has shown that the planting date of frigo plants has a significant effect on the time of fruit ripening in all the strawberry cultivars tested. Weather conditions, particularly the range of average daily temperatures during the growth and development of plants and the ripening of fruit, determine the yield as well as the weight and firmness of strawberries and the amounts of soluble solids in them. The type of the planting material had no effect on most of the traits assessed, except the soluble solids content of the fruit. In soilless cultivation under cover, both the cultivar and cultivation conditions

were found to have an effect on fruit ripening time, fruit weight, firmness and ascorbic acid content in at least one growing season.

Two new Polish strawberry cultivars 'Grandarosa' and 'Pink Rosa' enable extension of harvesting time by additional 8 to 12 days compared to standard (reference) cultivar 'Elsanta'. In addition they produce substantially larger and firmer fruits.

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MOŻLIWOŚCI WYDŁUŻENIA OKRESU OWOCOWANIA DWÓCH POLSKICH ODMIAN TRUSKAWKI TYPU KRÓTKIEGO DNIA

Streszczenie. Wydłużenie okresu zbiorów umożliwia konsumentom spożywanie świeżych truskawek pochodzących z produkcji krajowej od wiosny do jesieni, zaś producentom – zwiększenie opłacalności produkcji. Jednak tego typu produkcja wymaga zastosowania nowoczesnych technologii i doboru właściwych odmian. Badania nad wydłużeniem (opóźnieniem) zbioru owoców dwóch polskich odmian truskawek ('Grandarosa' i 'Pink Rosa') prowadzono w Instytucie Ogrodnictwa w Skierniewicach (Centralna Polska) w latach 2012–2013. Plenność, termin dojrzewania oraz jakość owoców obu wymienionych odmian oceniano w produkcji polowej (trzy terminy opóźnionego sadzenia roślin frigo doniczkowanych i z „gołym" korzeniem), a także w uprawie bezglebowej na rynnach pod daszkami foliowymi oraz w wysokim tunelu (wykorzystując również technikę opóźnionego sadzenia roślin frigo). Odmianą standardową była 'Elsanta'. Opóźnienie sadzenia roślin frigo przyczyniło się do wydłużenia czasu dojrzewania truskawek o ok. 10 tygodni w warunkach polowych oraz o 12 tygodni w uprawie bezglebowej, w porównaniu z tradycyjną uprawą gruntową. W obu typach upraw pełnia zbioru owoców odmian 'Grandarosa' i 'Pink Rosa' przypadała od 8 do 12 dni później niż u odmiany 'Elsanta'. Obie polskie odmiany truskawki wykazały wysoką przydatność do uprawy na opóźniony zbiór owoców w gruncie oraz uprawy bezglebowej pod osłonami. Ich plenność, średnia masa owoców oraz jędrność owoców były istotnie większe w porównaniu z odmianą standardową 'Elsanta'. Produkcja bezglebowa truskawek pod osłonami była bardziej efektywna niż uprawa w gruncie, gdyż wysokie temperatury gleby i powietrza występujące bezpośrednio po posadzeniu roślin powodowały spadek plonowania i pogorszenie jakości owoców. Ponadto zastosowane osłony skutecznie zabezpieczały rośliny przed jesiennymi przymrozkami, dzięki czemu owocowały one dłużej w porównaniu z roślinami uprawianymi w polu.

Słowa kluczowe: *Fragaria* × *ananassa* Duch., uprawa glebowa i bezglebowa, opóźnione sadzenie, sadzonki frigo, plon handlowy, jakość owoców

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