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Development of greenhouse soilless system for production of strawberry potted plantlets

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Abstract

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The objective of this study was to produce high quality planting material in a soilless greenhouse system. Cv. Elsanta plants were planted in containers and set on a special rack in the greenhouse. Emerging plantlets were set (clipped with metal clips) in micro-pots filled with peat or coconut substrate and detached from mother plants after 7, 10 or 14 days. Efficiency of this nursery method depended on the number of runners emerging from mother plants and the number of plantlets on the runners. Plantlets rooted for a longer period showed greater tolerance to stress. Growing media used in the experiment did not have a significant influence on the dynamics and quality of plantlet rooting. Using the method developed in this study, all plantlets were properly rooted.

Keywords: *Fragaria* × *ananassa*; plug plants; soilless nursery

In many strawberry production areas, traditional bare-root transplants are being replaced by plug plants produced from runner tips for both soil and soilless production systems (Lieten 2000; Durner et al. 2002). Due to the strong root system, which is not disturbed by digging up, plug plants establish quickly after planting and renew their growth (Pritts, Handley 1998; Hochmuth et al. 2006). Water and nutrient uptake begins immediately after planting thus transplants need less water during the establishment period (Hochmuth et al. 2006). This way of growing in substrates reduces the infection of root diseases and provides a better health status and plant productivity (Milholland, Daykin 1993). Also, container-grown plantlets give a better opportunity to control critical production factors that influence plant health, early and total yield and fruit quality (Durner et al. 2002; Takeda, Newell 2006). Plug plants may be available earlier than fresh-dug bare-root plantlets (Hennion et al. 1993). They can also be used for growing strawberries in organic production systems (Dolgun 2007).

Plug plant technology is fast and relatively simple. Plugs are produced in no more than 5 weeks (Pritts, Handley 1998; Treder et al. 2007) and in warmer growing regions only 3.5 weeks (Durner et al. 2002). Tips (unrooted runners) are rooted into trays filled with peat, coco peat, vermiculite, washed granite sand or mixtures of various substrates. Mother plants can be grown under protection or outdoors in horizontal or vertical systems. Also, bags or containers with mother plants can be laid on top of elevated white polyethylene film covered beds or special constructions (Durner et al. 2002; Treder et al. 2007). Rooting process is carried out in greenhouses or in plastic tunnels. To lower the cost, plantlets can be rooted outside plastic tunnels under the cover with white foil (Lieten 1994). The number of rooted plantlets influences the effectiveness and cost of the whole technology. The success of rooting depends on various factors such as grow-

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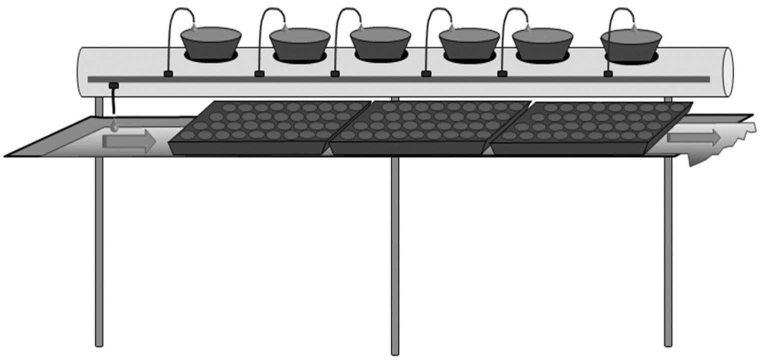

Fig. 1. Growing rack with platform for rooting plantlets

ing medium, air humidity and quality of plantlets (Lieten 1994). Plant size and position on the stolon also affect rooting and quality of plantlets (Takeda et al. 2004). During the rooting process the humidity should be high, plantlets should be therefore misted intermittently (Dolgun 2007). The basic characteristics used for quality evaluation are: plant health status, size of a root system and diameter of crown. Quick rate of establishment and optimum development after planting in the field depend mostly on the quality of the root system.

The objective of this study was to evaluate soilless greenhouse system to produce a high quality strawberry potted planting material.

MATERIAL AND METHODS

The study was carried out in years 2009–2011 in a greenhouse located at the Research Institute of Horticulture in Skierniewice, Poland. Strawberry cv. Elsanta (*Fragaria* × *ananassa* Duch.) frigo plants of category A (the crown diameter more than 15 mm) were planted in 1.5 dm^3 containers as mother plants. The containers were filled with a 3:1 mixture of peat and coconut substrate (type ¼") and set on a special rack (Fig. 1) in the greenhouse in the density of 20 plants/m^2. The plants were irrigated and fertigated by drip irrigation system (1 CNL dripper 2 l/h per pot; Netafim, Hanegev, Israel). A standard nutrient solution (N – 150 ppm, P – 45 ppm, K – 130 ppm, Mg – 20 ppm, Ca – 120 ppm) was supplied to the mother plants. The electric conductivity of 1.4–1.6 mS/cm was maintained. The strawberry plants were irrigated automatically based on the measurements of growing medium moisture carried out using capacitance probes (EC-5; Decagon Devices, Pullman, USA). The greenhouse climatic conditions were controlled by the Priva (Priva, De Lier, The Netherlands) climate computer. In 2009, the greenhouse was heated starting in March, in 2010 heating was not used except to prevent the freezing of the heating system. In 2011, the greenhouse was heated since the moment of planting (Tables 1 and 2). No supplemental lighting was used.

Main features of the greenhouse soilless system for production of strawberry plug plants:

– Rooting of plantlets was carried out before detaching them from the mother plants (Treder et al. 2007). For this purpose a growing rack was constructed on which the mother plants and multipots were set (Figs 1 and 2).
– All inflorescences emerging from the mother plants were removed to promote runnering (Lieten 2000).
– A capillary system for irrigation the plantlets was developed. The multipots were placed on the capillary mat set on the platform with 0.5% decline. The mat was irrigated with a drip emitter connected to the irrigation system. The water coming out from the emitter positioned at the higher end of the platform flew down in accordance with the decline, watering the individual multipots (Fig. 1).
– Plantlets were set (clipped with metal clips) in micro-pots of 50 cm^3 each (the density of 367 pcs/m^2) filled with two types of growing media: peat (fraction of 0–35 mm, pH_{H_2O} of 5.5–5.2) or coconut substrate (type ¼", pH_{H_2O} of 6.67).

Table 1. Setting temperature control in the greenhouse (day/night, °C)

	2009	2010	2011
February	no heating*	no heating	15/12
March	15/13	no heating	18/15
April	20/16	no heating	18/15
May	20/16	no heating	18/15

*temperature in the greenhouse did not drop below 5°C

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Fig. 2. Greenhouse nursery (a) growing and (b) rooting plantlets

Plantlets were rooted for a period of 7, 10 or 14 days. Then, the plantlets were detached from the mother plants and their root systems were assessed. Fresh weight of roots was determined using an electronic balance. Root length measurements were carried out using root scanner and the WinRhizo software (Regent Instruments, Québec, CA). Evaluation of the root systems was performed on 10 plantlets taken from each combination.

In 2009 the plantlets' response to the stress associated with their cutting off from the mother plants was determined. The intensity of leaf gas exchange (photosynthesis and transpiration rate) was evaluated using the LCpro+ analyser (ADC Bioscientific, Hoddesdon, UK). The measurements were carried out on the plug plants cut off from the mother plants (1 h after the cut-off) and 24 h after cutting.

In another experiment, the quality of planting material obtained after transplanting the rooted plantlets into bigger containers was assessed. Plantlets of uniform size (rooted for 14 days) were transplanted to containers (200 cm^3) and placed outside the greenhouse. The density was 126 plantlets/m^2 and the containers were filled with peat or coconut substrate. Both growing media were supplemented with Multicote fertiliser (Haifa Chemicals, Haifa Bay, Israel) 18:6:12:2 at a dose of 2 g/l. After 6 weeks of growing, the plantlets were evaluated morphologically. The surface leaf area was measured using the WinDias 2.0 (Delta-T Devices, Burwell, UK) image analysis system. Root length measurements were carried out using root scanner and the WinRhizo software (Regent Instruments, Québec, Canada); the weight of plant organs was determined using an electronic balance (g); the diameter of the crown was measured with a slide caliper (mm). The experiment was carried out in 10 replications. The time schedule of investigations is shown in Table 2.

Experimental data were statistically analyzed using the analysis of variance, followed by means separation using the Duncan's multiple-range *t*-test at $P \leq 0.05$. The standard error of the mean (SE) was calculated and used to indicate error ranges on graphs. All calculations were performed using the Statistica software (StatSoft Polska, Kraków, Poland).

RESULTS AND DISCUSSION

Efficiency of the nursery depends upon the number of runners emerging from mother plants and the number of plantlets on the runners (Treder et

Table 2. Time schedule of investigations

Year	2009	2010	2011
Establishment of nursery	Feb. 17	Feb. 12	Feb. 15
Clipping plantlets	Jun. 30	Jun. 22	Jun. 28
Cutting off plantlets after 7 days of rooting	Jul. 7	Jun. 29	Jul. 05
Cutting off plantlets after 10 days of rooting	Jul. 10	Jul. 02	Jul. 08
Cutting off plantlets after 14 days of rooting	Jul. 14	Jul. 06	Jul. 12
Evaluation of plantlets (14 day old) after 6 week long growing	Aug. 25	Aug. 17	Jul. 23

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al. 2007). The biggest number of runners was obtained from mother plants in 2010 and 2011 (Table 3) regardless of the greenhouse temperatures (in 2010, the greenhouse was heated only to prevent the temperature falling below 5°C, Table 1). However, the highest efficiency of the nursery and the number of plantlets from a runner were recorded in 2011. The improved efficiency was due to the higher temperatures in the greenhouse at the time of planting. Strawberry plants do not require high greenhouse temperatures, which was confirmed by the lower efficiency of the nursery in 2009 (greenhouse temperature in the springtime was kept higher compared with 2011, Table 1). On average, in the course of investigations each mother plant produces 7.63 runners, which gave 27.58 plantlets per single mother plant (Table 3). The oldest runners made it possible to root even seven plantlets. Lieten (1997) carrying out his experiments in Belgium obtained 12–20 runners. In similar investigations carried out in Poland, Lisiecka et al. (2002) got 7–13 runners form one mother plant. The nursery's efficiency may depend on various factors; one of them is the planting density of mother plants. The study performed by Treder et al. (2007) showed that one mother plant (grown at the density of 12 plants/m^2) produced 18.7 runners whereas the plants grown at double density produced 10.6 runners. Too high density leads to the lack of light and therefore to the blanching of runners (Hennion et al. 1997). The efficiency of the nursery is also affected by the length of the growing period. According to Lisiecka et al. (2002) the delay (almost 2 weeks) in planting mother plants and earlier harvesting of cuttings led to a decrease in the number of runners. It is possible to increase the efficiency of the nursery through delaying the time of plantlet rooting. According to Bish et al. (2001) there are also significant differences among the efficiency of various cultivars of strawberry. For example cv. Oso Grande produced 6.6 runners per plant, and cv. Sweet Charlie 25.7.

Due to the lack of a misting system in the greenhouse, the air humidity often dropped below 40% during the day (Table 4). Lieten (2000) suggested that the relative humidity in the greenhouse should be maintained at the level of 90–100%. Bish et al. (1997) recommended misting for a period of 10 to 12 days. As an alternative solution, plantlets can be covered with plastic for a period of 2 weeks and the temperature of the growing medium kept at 20°C. In the case of our proposed technology, even at the relatively low humidity in the greenhouse in three consecutive years of investigations, the rooting efficiency of plantlets was 100% (Table 3). According to Lieten (2000), the low humidity in a greenhouse causes the runner tips to bear fewer root nodules. These often become too corky, which makes rooting less successful. According to the same author, very poor rooting was observed on too small and too young plantlets. Such opinions were not confirmed in our study, in the case of the plantlets which were not cut off from the mother

Table 3. Efficiency of mother plants

	No. of runners (pcs/plant)	No. of plantlets (pcs/plant)	Average No. of plantlets (pcs/runner)	Rooting (%)
2009	6.89^{b}	25.22^{b}	3.66^{b}	100^{ns}
2010	8.28^{a}	24.0^{b}	2.90^{c}	100
2011	7.72^{ab}	33.52^{a}	4.34^{a}	100
Average	7.63	27.58	3.63	100

means marked with the same letter do not differ at the significance level of α= 0.05 according to the Duncan's test, ns – not significant

Table 4. Relative air humidity (%) in greenhouse in period while strawberry plantlets were rooted (day/night)

	2009			2010			2011		
	avg.	max	min	avg.	max	min	avg.	max	min
June	59/78	93/93	33/38	53/73	89/91	33/41	55/62	88/87	30/31
July	58/77	88/88	38/42	50/70	77/87	35/43	69/75	89/88	37/37

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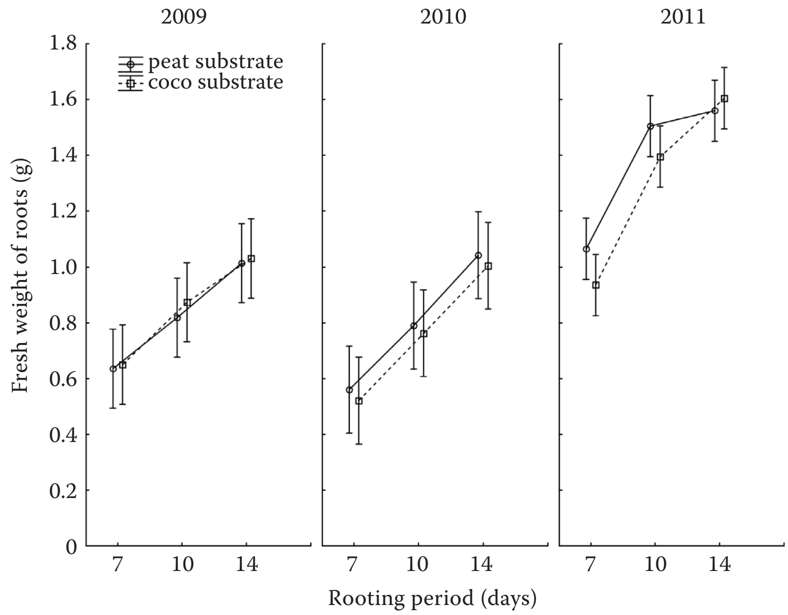

Fig. 3. Fresh weight of roots of strawberry plantlets depending on growing medium used and length of rooting period
vertical bars represent the standard error of the mean

plants. Earlier investigations of Treder et al. (2007) showed that rooting the plantlets before their cutting off from mother plants significantly influenced the quality of the obtained planting material. The plantlets rooted while still being connected to the mother plants had bigger weight, longer roots and their crown diameter was significantly bigger in comparison with the plantlets rooted after being cut off. Using this method, 100% plantlets are properly rooted and the greenhouse does not have to be equipped with a misting system. In the case of traditional method of rooting the results are not always 100% effective. In the experiment carried out by Takeda and Newell (2006), only 74–83% of plantlets formed normal root system. Treder et al. (2007) reports 65% successful rooting. Higher rooting efficiency (up to 95–100%) was obtained by Takeda et al. (2004) and by Dolgun (2007) by misting runner plants during rooting period.

Growing media did not influence the dynamics and quality of plantlet rooting. The weight and root length were affected by the duration of rooting period and the year of the experiment (Figs 3 and 4). In 2009 and 2010, a clear linear relationship was observed between the length of the rooting period and the weight of roots. The correlation coefficients (r) between the length of rooting period and root weight were 0.87 and 0.75, respectively. Such

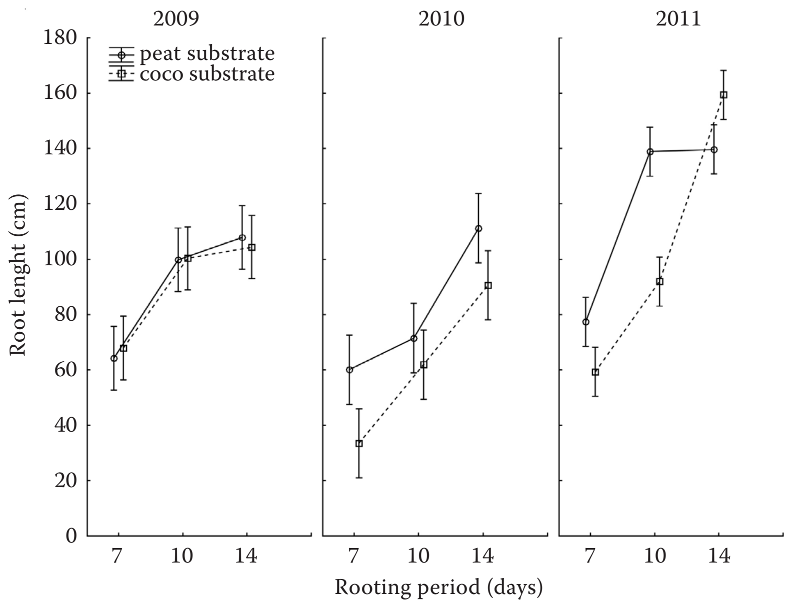

Fig. 4. Root length of strawberry plantlets depending on growing medium used and length of rooting period
vertical bars represent the standard error of the mean

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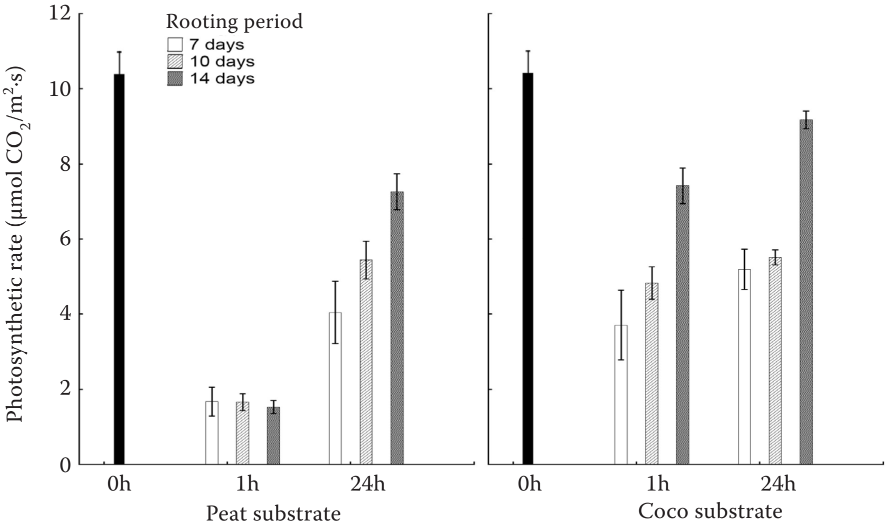

Fig. 5. Photosynthetic rate of strawberry plantlets as influenced by growing medium and duration of rooting (0, 1, 24 h – measurements taken before (black bar), 1 h and 24 h after cutting off the plantlets)
vertical bars represent the standard error of the mean

a strong relationship was not confirmed in 2011 (r = 0.45), where there were no distinct differences between the root weight of plantlets rooted in peat for 10 and 14 days. The difference in root lengths was even smaller. It indicates that under favourable thermal conditions plantlets with well-developed root system using the method described in the study can be obtained after 10 days of rooting. Plantlets rooted in the traditional method need at least 3 weeks of rooting before they get planted in the field (Durner et al. 2002).

Although rooted plantlets had well-developed root systems, a clear wilting of leaves was observed after cutting the plantlets off from the mother plants. The finding was confirmed by physiological observations. Immediately after the cut-off, a reduction in the leaf gas exchange of the plantlets rooted in peat or coconut substrate was found (Figs 5 and 6). The observed response indicates a stress caused by an insufficient water supply (Klamkowski, Treder 2008). The stress symptoms were observed despite the fact that the root system of the plantlets was already well-developed. This indicates that before cutting the plantlets off, they were supplied with water mostly through the stolon. The root system took over the function of providing water and minerals for plantlets only after they were cut off from the mother plants. In the case of plantlets rooted in the peat substrate, very low photosynthesis rate values were found for all the lengths of rooting periods (7, 10, 14 days). In the case of coconut substrate, relatively higher photosynthesis values were noted on plantlets rooted for 14 days. A strong decrease in the transpiration of plantlets grown in the peat substrate was stated too, regardless of the length of rooting period. The findings obtained while a 14 day-long rooting in the coconut substrate seem

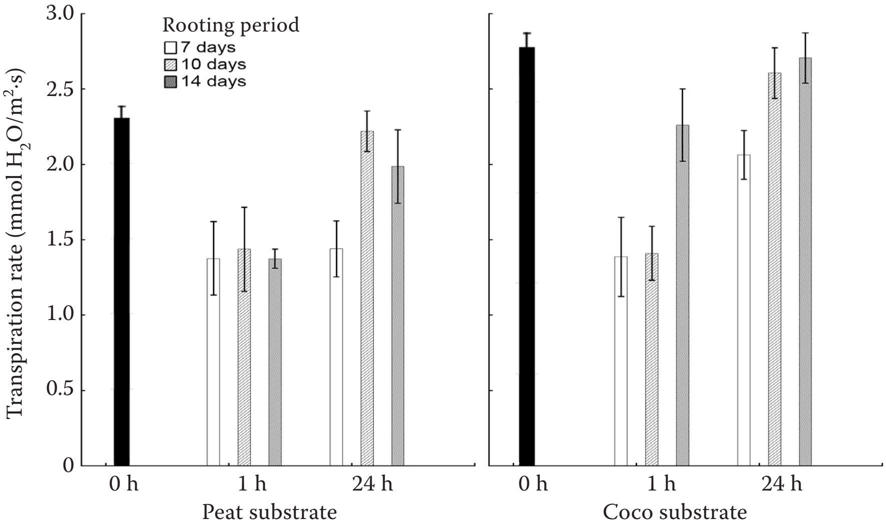

Fig. 6. Transpiration rate of strawberry plantlets as influenced by growing medium and duration of rooting (0, 1, 24 h – measurements taken before (black bar), 1 h and 24 h after cutting off the plantlets)
vertical bars represent the standard error of the mean

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Table 5. Morphology of plantlets after 6 weeks since planting

	Growing medium	2009	2010	2011
Fresh weight of leaves (g)	peat	3.31^{ns}	4.23^{a}	8.70^{ns}
	coconut substrate	3.64	2.59^{b}	7.29
Fresh weight of crown (g)	peat	2.33^{ns}	2.58^{ns}	2.41^{ns}
	coconut substrate	2.19	2.74	2.48
Fresh weight of roots (g)	peat	1.45^{ns}	2.67^{ns}	3.86^{ns}
	coconut substrate	1.35	2.76	3.49
Diameter of crown (mm)	peat	6.22^{ns}	7.94^{ns}	9.15^{ns}
	coconut substrate	7.17	7.24	9.41

means marked with the same letter do not differ at the significance level of α = 0.05 according to the Duncan's test; ns – not significant

noteworthy. In that case, higher transpiration rates were stated immediately after the cut-off.

24 h after the cut-off, a significant increase of the photosynthesis intensity was observed in plantlets grown in the peat substrate (Fig. 5). It was particularly evident in the case of plantlets grown in this medium for the longest period (14 days). 24 h was enough to observe an increase of the transpiration rate. It indicates an increase in the root system activity of plantlets. After 24 h, the transpiration of plantlets rooted for 10 or 14 days was similar to that observed before the cut-off (Fig. 6).

The results obtained indicate a strong reaction of the photosynthetic apparatus of plantlets to stress caused by their cutting off from mother plants. At 24 h after the cut-off, the photosynthesis rate values were still lower than the level observed before the cutting off (Fig. 5). According to Treder et al. (1997) the negative influence of water deficiency on a plant can persist for many days after the resumption of watering. It is worth noting, however, that plantlets rooted for a longer period (and thus having a more developed root system) showed greater tolerance to stress, and the high values of the intensity of photosynthesis recorded 24 h after the cut-off can prove it.

The above-described results of the experiments indicate that, despite the good rooting, a large part of the water that is essential to a plantlet's existence is not taken up through its own root system but it is provided through the stolon from the mother plant. In the case when plantlet rooting is carried out in the low air humidity conditions, the cut-off deprives plantlets of their basic source of water causing leaf wilting. However, the roots of plantlets quickly took over the function of water uptake and plantlets did not show severe stress symptoms after 24 h since their cutting off from the mother plants. On the basis of these observations, it is recommended that the plantlets should be covered with foil or filter fleece immediately after cutting them off for a period of 24 hours.

Just like in the case of rooting, no significant influence of the used growing medium on the further growth of the earlier rooted plantlets grown for 6 weeks in 200 cm^3 pots was observed (Table 5). Among all the parameters examined, only in the year 2010, a significantly higher fresh weight of leaves was observed on plantlets grown in the peat substrate.

CONCLUSION

The greenhouse soilless system for production of strawberry potted plantlets offers an important alternative to the conventional field grown strawberry plantlets. Rooting plantlets before they get cut off from the mother plants guarantees 100% successful rooting. This way of rooting allows to shorten the time of production of strawberry plantlets up to 10–14 days.

Obtained results showed that the plantlets while still being connected to the mother plants were supplied with water mostly through the stolon. The root system took over the function of providing water and minerals for plantlets after they were cut off from the mother plants. Therefore, despite the good rooting of plantlets, they should be covered with foil for 24 h after cutting them off from the

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mother plants. Both peat and coconut substrate can be recommended for further growing.

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