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STUDIES ON THE EFFECT OF GROWING MEDIUM AND MONOPOTASSIUM PHOSPHATE ON ROOTING AND QUALITY OF STRAWBERRY POTTED PLANTLETS

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Abstract. Strawberry is propagated vegetatively. Nowadays, traditional bare-root transplants are often replaced with plantlets (plug plants) produced from runner tips. The nutrient level and type of growing medium may influence the quality of planting material. *Phosphorus and potassium are important* elements for plant metabolism. Insufficient supply of plants with these elements negatively influences the rooting and plant vegetative growth. The objective of the study was to evaluate the influence of substrate and monopotassium phosphate (MKP) on rooting and quality of strawberry plantlets grown in the greenhouse soilless system. 'Elsanta' mother 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. Four concentrations of MKP in the growing medium were applied: 0, 0.22, 0.44, 0.66 g dm^{-3}. Rooting of plantlets was carried out before cutting them off from the mother plants for a period 7, 10 or 14 days. The investigations have showed a very similar dynamics of root formation both in coconut substrate and in peat. A significant effect of the application of monopotassium phosphate on rooting of strawberry plantlets was observed. The optimal dose of MKP depended on the length of rooting period of plantlets. After 7 days of rooting the highest root weight was recorded in case of plantlets rooted in the growing media supplemented with 0.44 or 0.66 g dm^{-3} MKP. After 10 and 14 days of rooting even the lowest dose of MKP (0.22 g dm^{-3}) resulted in significantly stronger root growth in comparison with not fertilized control plantlets. MKP also significantly influenced the growth of plantlets after transplanting them into bigger containers. The highest quality plantlets were obtained at the dose 0.44 or 0.66 g MKP dm^{-3} of substrate.

Key words: *Fragaria* × *ananassa*, planting material, soilless culture, phosphorus

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INTRODUCTION

In horticultural practice strawberry is propagated vegetatively. Nowadays, traditional bare-root transplants are more and more often replaced with plug plants produced from runner tips [Durner et al. 2002, Lieten 2013]. Plug plants may be available earlier than freshly dug transplants [Hennion et al. 1993]. Earlier planting date improves plant establishment and enables yielding in the earlier period. They can also be used for growing strawberries organically [Dolgun 2007]. Nowadays, plug plants have also become a dominant plant type for soilless production [Lieten 2013]. Plug transplant technology is fast and relatively simple. Plantlets are produced in no more than 5 weeks [Pritts and 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. 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 takes place in greenhouses or under plastic tunnels. To lower the cost, plantlets can be rooted outdoors covered with white foil [Lieten 1994].

Growing conditions and properties of the substrate show significant influence on the rooting of plantlets. Quantity and quality of rooted plantlets influence significantly the cost of planting material obtained. In experiments carried out by Takeda et al. [2006] 62-83% of plantlets formed a healthy, well developed root system. Treder et al. [2007] suggested that plantlets could be rooted before cutting them off from mother plants in order to get 100% successful establishment. In their experiment, the plantlets rooted while still being connected to mother plants had higher weight, longer roots and their crown diameter was significantly bigger in comparison with the plantlets rooted after the cutoff.

The most important parameters used for evaluation of the quality of strawberry plantlets include crown diameter and size of root system [Kramer and Schultze 1985, Pérez de Camacaro et al. 2004]. Quick rooting of plantlets means shorter process of their production, which allows to earlier getting of planting material. The ability of plantlets to quick establishment and proper growth after planting in the field depends on the quality of root system. Due to the well developed and undisturbed (during digging up) root system, potted plantlets establish better after planting and start growing quickly [Pritts and Handley 1998]. Immediately after planting their roots can uptake water and minerals from the soil, which results in smaller quantities of water required during the establishment period [Hochmuth et al. 2006].

The root system results from the coordinated control of both genetic endogenous programs and the action of environmental stimuli [Malamy 2005]. The nutrient level and type of substrate strongly influence the rooting, growth and architecture of root system. The bioavailability of nutrients in the soil solution determines root growth and root proliferation. Following nitrogen, phosphorus is quantitatively the most important inorganic nutrient for plant growth, and it often limits the primary productivity in natural systems as well as cropping systems, unless supplied as fertilizer [Vance et al. 2003]. It is generally known that plants acquire phosphorus under phosphorus stress conditions through changes in root physiology and morphology [Schachtman et al. 1998]. Insufficient supply of plants with phosphorus mainly influences the protein synthesis. The reduction of protein synthesis inhibits the vegetative growth, which, among other factors, may limit the growth of root system. Phosphorus has a very low diffusion coefficient, can be easily fixed by the soil and become relatively immobile. Therefore, phosphorus acquisition by plants mainly depends on the absorption of available phosphorus exposed to the root system [Barber 1995].

The aim of the study was to evaluate the influence of the growing medium and monopotassium phosphate on rooting and quality of strawberry plantlets grown in the greenhouse soilless system.

MATERIAL AND METHODS

Rooting (trial 1). The study was carried out in years 2010 and 2011 in a greenhouse of the Research Institute of Horticulture in Skierniewice, Poland. 'Elsanta' strawberry (*Fragaria* × *ananassa* Duch.) frigo plants of category A (the crown diameter bigger than 15 mm) were planted in 1.5 dm^3 containers as mother plants. The containers were filled with a mixture of peat substrate and coconut substrate type ¼″ (3:1) and set on a special rack 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^{-1} per pot, Netafim, 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^{-1} 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, USA). The greenhouse climatic conditions were controlled by the Priva (Holland) climate computer. In the year 2010 the greenhouse was practically no heated except for the protection of the heating system from freezing (the temperature in the greenhouse did not drop below 5°C). In the year 2011 the greenhouse was heated since the moment of planting (tabs. 1, 2).

Table 1. Setting temperature control in greenhouse (trial 1)

Month	Year	
	2010	2011
	day/night	day/night
February	no heating *	15/12
March	no heating	18/15
April	no heating	18/15
May	no heating	18/15

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

Table 2. Time schedule of investigations

	Activity	Year	
		2010	2011
Trial 1	Establishemnt of nursery	12 Feb.	15 Feb.
	Clipping plantlets	22 Jun.	28 Jun.
	Cutting off plantlets after 7 days of rooting	29 Jun.	05 Jul.
	Cutting off plantlets after 10 days of rooting	02 Jul.	08 Jul.
	Cutting off plantlets after 14 days of rooting	06 Jul.	12 Jul.
Trial 2	Evaluation of plantlets (14 day old) after 6 week long growing	17 Aug.	23 Aug.

The inflorescences emerging from the mother plants were removed to promote runnering. Rooting of plantlets was carried out before cutting them off 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. A capillary system for irrigation the plantlets is an original solution here. 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. 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_{H2O} = 5.2–5.5),
– coconut substrate – type ¼″ (pH_{H2O} = 6.67)

As a source of phosphorus, four concentrations of monopotassium phosphate (MKP, 52% P_2O_5, 34% K_2O) in the growing medium were applied, respectively: 0, 0.22, 0.44, 0.66 g dm^{-3}. Thus, depending on the dose it corresponded to the content of phosphorus (P): 0, 50, 100, 150 mg dm^{-3} and potassium (K): 0, 62, 124, 186 mg dm^{-3}.

During rooting, after 7, 10 and 14 days since clipping the plantlets, 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, Canada). Evaluation of the root systems was performed on 10 plantlets taken from each combination.

Growing of plantlets after transplanting into bigger containers (trial 2). In an additional experiment influence of growing media and MKP fertilization after transplanting the rooted plantlets into bigger containers (200 cm^3) was assessed. The same growing media (peat and coconut substrate), and same dose of MKP (0, 0.22, 0.44, 0.66 g dm^{-3}) were used.

Plantlets of uniform size (rooted for 14 days in trial 1) were transplanted to bigger containers and placed outside the greenhouse (density 126 plantlets m^{-2}). After 6 weeks of growing, the diameter of the crown and root weight were measured. The experiment was carried out in 12 replications (1 plant per replication). The time schedule of investigations is shown in Table 2.

Experimental data were statistically elaborated using analysis of variance, followed by means separation using Duncan's multiple-range t-test at $P \leq 0.05$. Regression analyses were applied to examine the relationship between root weight and length for each substrate and fertilizer dose. Correlations were tested by computing Pearson correlation coefficients. The standard error of the mean (SE) or the least significant difference (LSD) was calculated and used to indicate error ranges on graphs. All calculations were performed using Statistica software (StatSoft Polska, Poland).

RESULTS AND DISCUSSION

Trial I. The analysis of variance for growing years and applied factors showed a significant influence of year, the length of rooting period and monopotassium phosphate (MKP) fertilization on the root weight of strawberry plantlets (tab. 3). A highly significant interaction between the applied fertilization and the length of rooting period was shown. The type of growing medium used for rooting had no significant influence on root weight of strawberry plantlets. There was also no interaction between the used growing medium and fertilization. For this reason, further analyses will be presented as mean data for the growing media. The physical properties of substrates can have a major influence on rooting capacity of cuttings [Hartman et al. 2002]. Lack of statistical differences between the growing media used in the experiment confirms the opinion of Lennartson [1997] that both substrates have similar physical properties and that is why coconut substrate can be substituted for peat.

Table 3. Analysis of variability during rooting – fresh weight of roots (trial 1)

Source of variation	df	F	p
(1) year	1	62.63	**0.000**
(2) growing medium	1	0.070	0.792
(3) MKP dose	3	47.45	**0.000**
(4) duration of rooting	2	69.54	**0.000**
1*2	1	0.015	0.903
1*3	3	0.24	0.868
2*3	3	0.72	0.541
1*4	2	0.39	0.679
2*4	2	0.39	0.679
3*4 (MKP dose*rooting period)	6	3.34	**0.003**
1*2*3	3	0.04	0.991
1*2*4	2	0.38	0.685
1*3*4	6	0.23	0.965
2*3*4	6	1.04	0.400
1*2*3*4	6	0.53	0.790

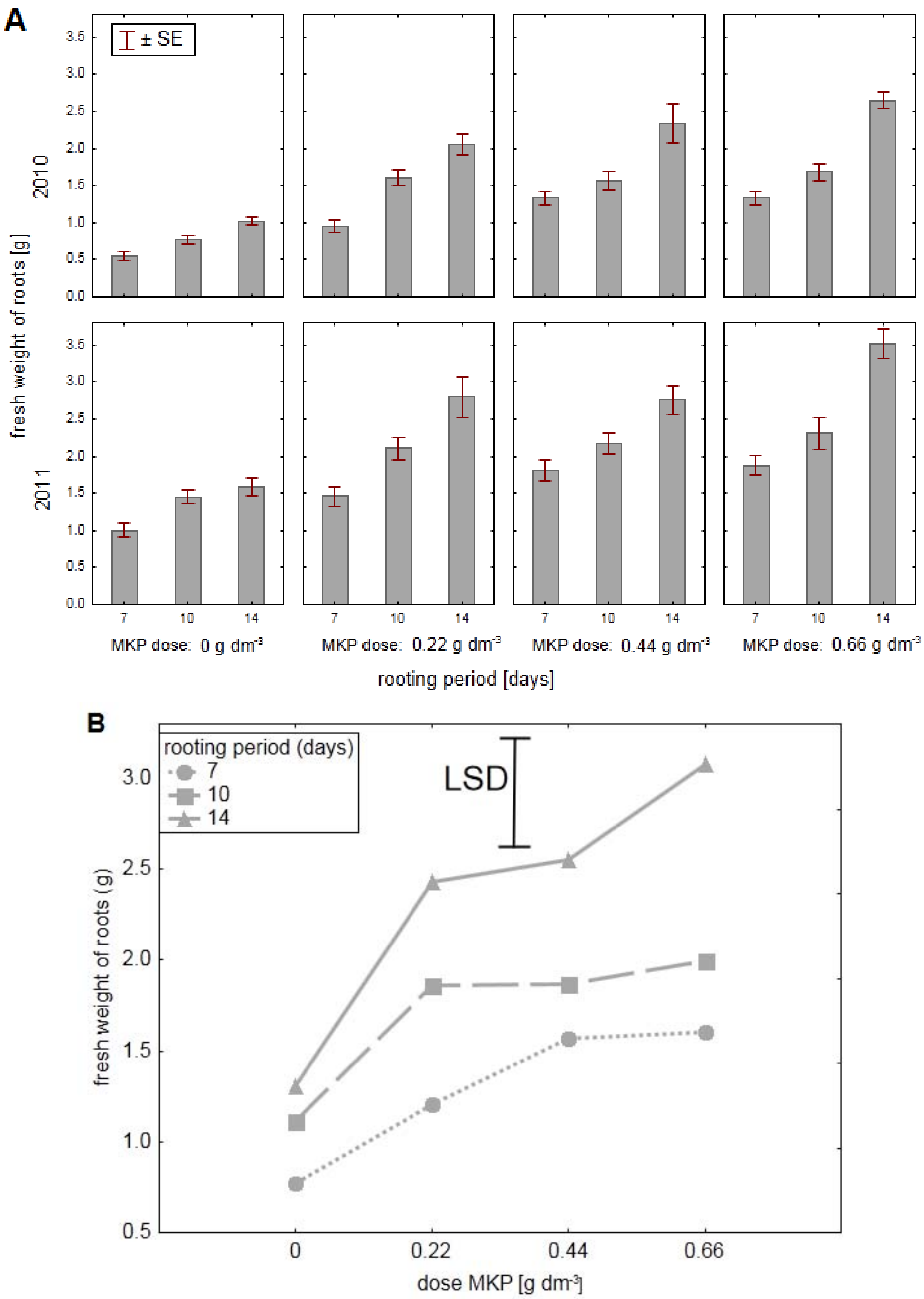

Fig. 1. Fresh weight of strawberry roots depending on the fertilization and length of rooting period (A – analysis performed for the subsequent years, B – averages for growing media and years)

Due to greenhouse heating the average night temperature during rooting was 2.4°C higher in 2011 than in the corresponding period of 2010. Therefore, in 2011 regardless of the growing medium used, the length of rooting period or the MKP fertilization used, the plantlets formed larger root system (higher fresh weight of roots) in comparison with the plantlets rooted in 2010 (fig. 1). The average difference was 28%. No significant interaction was stated between the season in which the observations were carried out and the other factors.

The fresh weight of the roots formed by the plantlets increased significantly along with the length of rooting period and the applied doses of MKP (fig. 1). After 7 days of rooting, a significantly bigger root weight was recorded in case of plantlets rooted in the growing media containing 0.44 or 0.66 g dm^{-3} MKP (compared with the control plantlets). After 10 or 14 days of rooting even the lowest dose of MKP (0.22 g dm^{-3}) resulted in significantly stronger root growth in comparison with not fertilized control plantlets. However, after 10 days of rooting there were no differences between the applied doses of fertilizer. After 14 days, the highest dose of MKP (0.66 g dm^{-3}) caused a statistically significant increase in the root growth in comparison with the not fertilized control and the lowest dose used. MPK is the source of phosphorus and potassium and it is not possible to finally conclude (on the basis of the data obtained) whether the positive result of fertilization is caused by the applied phosphorus, potassium or the interaction between the two.

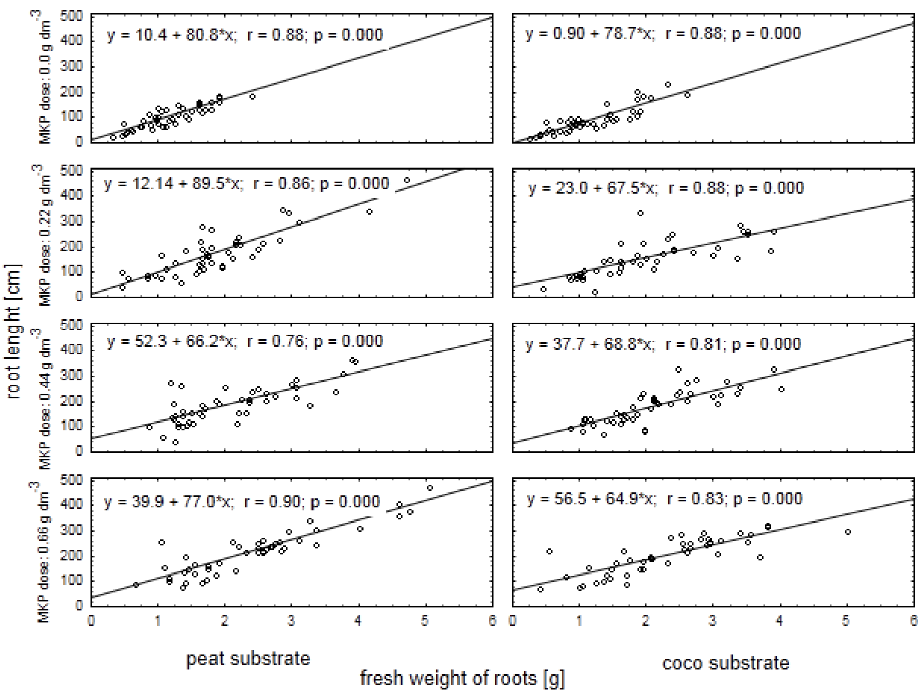

Fig. 2. Relationship between the weight and length of roots of strawberry plantlets

Literature underlines the role of phosphorus as a factor which might have influence on growth and architecture of the plant root system [Ericsson 1995, Lynch 1995, Vance et al. 2003, Rengel and Marschner 2005]. Drew [1975] showed that the low level of phosphorus in the substrate significantly decreased the root weight of barley. Such a relationship was not observed in the case of potassium. The roots of high P-grown plants have high auxin concentrations in their meristems and their cells have high mitotic activity [Colón-Carmona et al. 1999]. Auxin transport into the regions where lateral roots initiate also seems crucial for the regulation of root branching [Casimiro et al. 2001]. Plants growing in P-deficient soil allocate a greater proportion of assimilates to roots. Such a result confirms the opinion of Barber [1995] that more roots are distributed in the soil with high P availability. Similarly, Słowik and Włodek [1973] showed that black currant roots grew weaker in soils with a low phosphorus content. However, the investigation carried out by Zhang et al. [2012] on hydroponically grown cucumber plants revealed a stronger root development in plants growing in medium with limited amount of phosphorus. Greater investment in below ground root growth came at the expense of aboveground foliage and stem growth. Since the length of the roots is strictly correlated with the weight (fig. 2), the influence of the factors examined on the length of roots was very similar to the previously presented evaluation of their weight.

Trial II. The analysis of variance of the data collected after transplanting plantlets into bigger containers showed a significant influence of the years and the MKP doses applied on the root weight and the diameter of strawberry crown. Neither the significance of the growing media used nor the interaction between the investigated factors was confirmed (tab. 4). The obtained results confirm the usefulness of the two applied substrates for potted strawberry plantlet production [Lennartson 1997, Lieten 2013].

Table 4. Analysis of variability during cultivation – fresh weight of roots, crown diameter (trial 2)

Source of variation	df	Fresh weight of roots		Crown diameter	
		F	p	F	p
(1) year	1	4.90	**0.029**	36.30	**0.000**
(2) growing medium	1	0.92	0.340	0.31	0.586
(3) MKP dose	3	13.37	**0.000**	9.33	**0.000**
1*2	1	0.07	0.795	0.95	0.332
1*3	3	0.63	0.598	1.59	0.197
2*3	3	0.45	0.719	0.66	0.579
1*2*3	3	0.37	0.778	0.14	0.939

According to Drew [1975], Ericsson [1995] and Zhang et al. [2012] in plants grown in the conditions with limited access to phosphorus, the ratio between the aboveground and underground parts of a plant may be affected. Morphological measurements carried out after 6 weeks since the transplanting into bigger containers, showed a significant influence of monopotassium phosphate application on the crown diameter and root weight of plantlets (tabs 5, 6). The greatest root weight and the biggest average crown

Table 5. Diameter (mm) of crown of strawberry plantlets 6 weeks after transplanting

Year	Growing medium	Monopotassium phosphate dose (g dm^{-3})			
		0	0.22	0.44	0.66
2010	peat	7.95 ab	7.53 ab	8.95 bcd	9.74 cd
	coconut substrate	7.24 a	8.10 ab	8.40 abc	9.97 d
	average	7.60 A	7.82 AB	8.67 B	9.86 C
2011	peat	9.15 a	9.40 ab	10.71 b	10.26 ab
	coconut substrate	9.41 ab	10.14 ab	10.87 b	10.71.b
	average	9.28 A	9.77 AB	10.80 C	10.49 BC
Average for years	peat	8.75 ab	8.77 ab	9.97 bc	10.09 c
	coconut substrate	8.67 a	9.46 abc	10.04 c	10.47 c
	average	8.72 A	9.12 A	10.01 B	10.28 B

Means marked with the same letter do not differ at the significance level of α = 0.05 according to Duncan's test. Analyses were performed separately for years (lower case) and for average values for growing media (upper case). Average values for years are marked with underline

Table 6. Root weight (g) of strawberry plantlets 6 weeks after transplanting

Year	Growing medium	Monopotassium phosphate dose (g dm^{-3})			
		0	0.22	0.44	0.66
2010	peat	2.62 a	3.75 abc	4.29 bcd	5.01 cd
	coconut substrate	2.76 ab	4.11 abcd	4.70 cd	5.60 d
	average	2.69 A	3.93 B	4.50 BC	5.31 C
2011	peat	3.86 ab	3.26 a	5.61 c	5.97 c
	coconut substrate	3.49 a	4.56 abc	5.38 bc	6.13 c
	average	3.67 A	3.90 A	5.48 B	6.05 B
Average for years	peat	3.44 a	3.42 a	5.06 bc	5.65 bc
	coconut substrate	3.25 a	4.40 ab	5.15 bc	5.95 c
	average	3.34 A	3.91 A	5.11 B	5.80 B

Means marked with the same letter do not differ at the significance level of α = 0.05 according to Duncan's test. Analyses were performed separately for years (lower case) and for average values for growing media (upper case). Average values for years are marked with underline

diameter were observed in plantlets grown in growing media containing 0.44 or 0.66 g of MKP (per liter of substrate). Strawberry crown diameter is a very important parameter to evaluate the quality of plantlets. Peréz de Camacaroet al. [2004] showed a very strict correlation between the crown diameter of plantlets and the yield of strawberry plants. The obtained results indicate a better adaptation of plantlets (after planting), which already had a well-developed root system. Such plantlets were able to quickly develop their aboveground part which influenced the diameter of their crowns.

CONCLUSIONS

The results showed a significant effect of the application of monopotassium phosphate on rooting of strawberry plantlets. The optimal dose of MKP depends on the length of rooting period of plantlets. For 7 day rooting period it should be 0.44 g dm^{-3}. The MKP dose can be lowered to 0.22 g dm^{-3} for 10 day period of rooting. In the case of rooting lasting for 14 days, the highest increase in root weight was observed when MKP was applied at a dose of 0.22 g dm^{-3}. MKP also significantly influenced the growth of plantlets after transplanting them into bigger containers. High quality plantlets were obtained at the dose 0.44 g dm^{-3} of substrate. The investigations have showed a very similar dynamics of root formation both in coconut substrate and in peat. Likewise, no significant differences were observed between the tested substrates in the further cultivation of strawberry plantlets, which confirms the earlier opinion regarding coconut substrate as peat substitute.

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BADANIA NAD WPŁYWEM PODŁOŻA ORAZ FOSFORANU MONOPOTASOWEGO NA UKORZENIANIE ORAZ JAKOŚĆ DONICZKOWANYCH SADZONEK TRUSKAWKI

Streszczenie. Truskawka jest rozmnażana wegetatywnie. Obecnie tradycyjne sadzonki „kopane", pozyskiwane z mateczników polowych, są zastępowane sadzonkami doniczkowanymi, produkowanymi z rozetek liściowych ukorzenianych w podłożach bezglebowych. Rodzaj zastosowanego podłoża oraz nawożenie może mieć istotny wpływ na proces ukorzeniania. Celem prowadzonych badań była ocena wpływu zastosowanego podłoża oraz nawożenia fosforanem monopotasowym na ukorzenianie oraz jakość sadzonek truskawki pozyskiwanych z matecznika bezglebowego prowadzonego w szklarni. Rośliny mateczne odmiany 'Elsanta' posadzono do pojemników, a następnie ustawiono w szklarni na specjalnie skonstruowanym stelażu. Pojawiające się rozetki liściowe (sadzonki rozłogowe) były umieszczane (przypinane metalowym spinaczem) w mikrodoniczkach wypełnionych substratem torfowym lub kokosowym. Zastosowano cztery dawki fosforanu monopotasowego: 0, 0,22, 0,44, 0,66 g dm^{-3} podłoża. Sadzonki były ukorzeniane bez odcinania ich od roślin matecznych przez 7, 10 lub 14 dni. Wykazano istotny wpływ zastosowanego nawożenia na ukorzenianie sadzonek. W przypadku ukorzeniania trwającego 7 dni, największy przyrost masy korzeni stwierdzono po zastosowaniu fosforanu monopotasowego w dawce 0,44 lub 0,66 g dm^{-3} podłoża. Dla dłuższych okresów ukorzeniania (10 lub 14 dni) już najniższa zastosowana dawka (0,22 g dm^{-3}) korzystnie wpłynęła na rozwój systemu korzeniowego. Nawożenie fosforanem monopotasowym miało także wpływ na wzrost sadzonek po przesadzeniu ich do większych pojemników. Sadzonki najlepszej jakości (o największej średnicy korony) uzyskano, stosując nawóz w dawce 0,44 lub 0,66 g dm^{-3} podłoża. Nie stwierdzono znaczącego wpływu zastosowanego podłoża na proces ukorzeniania sadzonek oraz ich dalszy wzrost.

Słowa kluczowe: *Fragaria* × *ananassa*, materiał nasadzeniowy, uprawa bezglebowa, fosfor

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