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Effects of different substrates on the runner production of the June-bearing strawberry cv. 'Senga Sengana'

Vahid Avdiu, Bedri Dragusha, Egzona Hajra, Gezim Hodolli*

Faculty of Agriculture and Veterinary, University of Prishtina "Hasan Prishtina", Prishtine, Kosovo, Albania

**Corresponding author: bedri.dragusha@uni-pr.edu*

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Abstract: Producing high-quality daughter plants of the June-bearing strawberry is very important for fruit production around the year. This study was conducted to investigate the impacts of different substrates on the runner production of the June-bearing strawberry cultivar 'Senga Sengana'. In April 2019, strawberry mother plants were planted while the daughter plants were examined November 2019. The nursery trial field was separated into four substrate treatments, each included ten strawberry mother plants, approximately homogeneous. The place where the mother plants were planted was with the same substrate (PTS substrate "Pindstrup") and separated from the field for the rooting of the daughter plants. In the field for the rooting of the daughter plants, four types of substrates were used: The first substrate treatment (S_1) (soil 50% – decomposed manure 50%); the second substrate treatment (S_2) (PTS substrate "Pindstrup" with modules (pots) with a volume of 200 mL/daughter plant); the third substrate treatment S_3 (river sand 50% – soil 50%); lastly, substrate treatment four S_4 (sawdust 100%). During the research, several parameters were determined for the mother plants: the crown diameter, number of flowers, number of runners per plant, number of daughter plants per runner and number of daughter plants per plant. The examination of some of the qualitative parameters was also performed on the daughter plants: the crown diameter, root length and number of roots. Based on these parameters, the daughter plants were categorised according to the standards: A++, A+, A, A–, OS (out of the standard). From the examined results, it was concluded that S_3 formed the largest number of daughter plants at 123 (A++ 19.1, A+ 45.1, A 28.7, A– 17.8, OS 12.3 plants); S_2 formed 69.4 daughter plants, but with the highest standards (A++ 34.7, A+ 33.6, A– 1.1 plants); S_4 formed 74.8 daughter plants (A++ 26.2, A+ 30.4, A 14 OS 4.2 plants), while S_1 formed 62 daughter plants and showed the worst results for both the number of plants and the standard (A+ 7, A 3.8, A– 0.8, OS 50.4 plants).

Keywords: mother plant; daughter plant; Pindstrup; roots; stolons

Kosovo has suitable conditions for strawberry cultivation. Therefore, it has a special economic interest with regards to strawberry cultivation. Ensuring high-quality planting material is crucial to have sustainable productivity. The cultivated strawberry (*Fragaria* × *ananassa* Duch., family Rosaceae) is a perennial plant adapted to a wide range of climates that can naturally propagate by seed (gamic) or runners (vegetatively, agamic) (Savini et al. 2005; Zhao 2007). Propagation by seed is almost exclusively used in breeding for genetic improvement in order to obtain new genotypes from which the breeders can select new varieties. In some cases, the seed is also used as a propagation system to produce fruit, for example with some varieties of *Fragaria vesca*, or with varieties adapted to garden cultivation. However, the great industry of strawberry plants is based on their ability to produce stolons and runner chains capable of developing new self-rooted plants (Savini et al. 2008).

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The strawberry plant has trifoliate leaves arranged spirally around a compressed stem, called a crown. The crown is a compressed stem from which leaves, runners, and flowers arise, and contains smaller branch crowns in addition to the original crown. The buds in the axils of each leaf may develop into a branch crown, inflorescence, a runner, or remain dormant. The temperature and day length determine which plant parts are being grown and how quickly. Branch crowns tend to develop under a short day length (less than 10 hours) as Zhao (2007) stated, whereas runners are promoted under long days in the middle of summer (more than 10 hours) (Pritts et al. 1998; Zhao 2007; Savini et al. 2008; LeBrun et al. 2014; Bolda et al. 2015;). Mother plants should be established in mid-spring on light textured soils for the runner production, as their growth is favoured by high temperatures (over 24 °C) and long photoperiods, greater than 16 hours (Rowley et al. 2010). Plants produce long sympodial runners (stolons) able to create daughter plants (rooted rosettes). Runners are long stolons on which daughter plants are produced. Each daughter plant (a new individual clonal plant) shows the capacity to immediately produce a stolon at the axil of the basal bract, even before root formation. Over time, strawberries, thus, create a chain of daughter plants connected by runners. When each daughter plant starts to grow as a new plant, it may produce other runners from axillary meristems depending on the rosette-growing conditions. Therefore, if the daughter plant also has its own root system and is in fertile soil, the growth will be rapid and new runners and daughter plants will be formed, but if the daughter plant has poor growing conditions, there will only be the runner chain, with the growth of a single runner that is preformed inside each daughter plant (Zhao 2007; Husaini, Neri 2016). The original plant established is often called the "mother plant." Some types or cultivars of strawberry produce more runners than others depending on the genetic properties of the cultivar, climate conditions, cultivation way, age and the plant's condition (Zhao 2007). Strawberry types cheat sheet: June-bearing (short-day) produce lots of runners; day-neutral produce some runners; everbearing produce few runners; Alpine are small berries, can be grown from seed and produce no runners (LeBrun et al. 2014).

One of the most important factors on which the rooting depends is the choice of an adequate substrate (Selamovska, Najdenovska, 2012) the time of rooting and the genotype on the percent of rooting of the rosettes of the strawberries and their quality. For that purpose, fresh, unrooted rosettes of two sorts of strawberry ('Senga Sengana' and 'Pocahontas').

Substrate characteristics include the water and nutrient retention, ensuring good root system ventilation, a light weight, and free of pathogenic organisms and substances that are toxic to plants (Johnson et al. 2010). The use of different organic and inorganic substrates allows plants to get better nutrients, sufficient growth and development to optimise water and oxygen retention (Albaho et al. 2009).

The strawberry yield is strongly affected by the physiological quality of daughter plants. Young and vigorous daughter plants produce plants with higher vegetative growth and fruit yield than weak and old ones, and also reduce management practices (Hicklenton, Reekie 2002).

During the assessment of the strawberry daughter plant quality, the development of a good root system, crown diameter, length and number of roots play an important role.

Marketable daughter plants have been classified by the shoot diameter (crown diameter): class A++ ($ø \geq 15$ mm); class A+ ($12.0 \leq ø \leq 14.9$ mm); class A ($8.0 \leq ø \leq 11.9$ mm); class A– ($6.0 \leq ø \geq 7.9$ mm); discarded runners ($ø < 5.9$ mm) (Lucchi et al. 2004).

Frigo rosettes (FR) are rosettes produced in a mother orchard (end of November to December) and stored and kept in a freezer for 7–8 months at a temperature of –2 °C. They are used for summer planting in the following year. Based on the thickness of the root's crown and length of the root, they are classified in four classes: A++ (diameter of root crown over 14 mm, length of the root over 12 cm), A+ (diameter of root crown 10–14 mm, length of the root 12 cm), A (diameter of root crown 8–10 mm, length of the root 10 cm) and A– (diameter of root crown 6–8 mm, length of the root) (Selamovska, Nathan 2014).

Producing as many high-quality daughter plants as possible per the mother plant is very important for growers, so we tested four substrates to establish the best nursery system to meet the strawberry growers' demand.

MATERIAL AND METHODS

To establish the strawberry nursery trial field, we selected the standardised planting material (mother plants) of the cultivar 'Senga Sengana'. We ap-

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plied the production technology according to the cultivation method of Cold stored runner plants (*Frigo rosettes*), mother plants are planted in April and the harvesting of the daughter plant was undertaken at the end of November to December (Lieten 2014; Selamovska, Nathan 2014).

For the research, the experiment is divided into four substrates (S). Each substrate had ten mother plants. In all the substrates, the mother plants had the same conditions: substrate, fertiliser, irrigation and other services.

In the fields for the rooting of the daughter plants according to the substrate, four types of substrates were used (Figure 1):

– S_1 – soil 50% – decomposed manure 50%;
– S_2 – PTS substrate "Pindstrup" with plastic modules and a volume of 200 mL / daughter plant;
– S_3 – river sand 50% - soil 50%;
– S_4 – sawdust, 100% ratio.

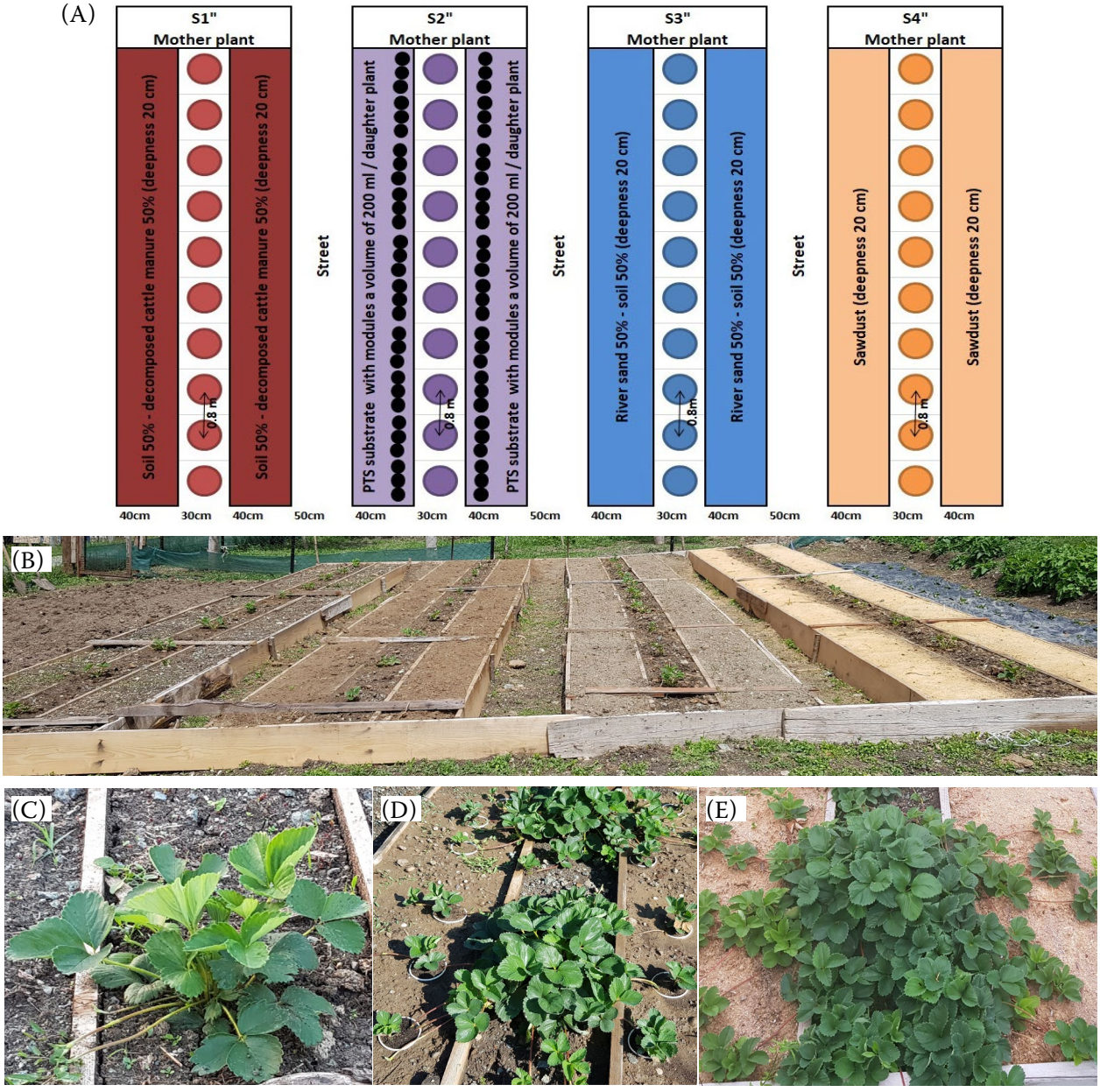

Figure 1. Schemes of the experimental field

(A) – experimental scheme; (B) – realisation of the experiment in the field; (C) – first stage of the runners arrives; (D) – the process of the daughter plant development; (E) – the process of the daughter plant development in the different substrates

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From the moment of planting, all the plants included in the experiment were carefully monitored and examined for some specific bio-morphological parameters.

– Mother plant: the crown diameter (ø mm) was measured before planting by digital callipers, the number of flowers, number of runners (stolons), number of daughter plants (runner plans, rooted rosettes) per plant and runner were also counted.
– Daughter plant: all the plants were taken out of the soil and cleaned after the vegetation period and then measured by digital callipers along with the crown diameter and the root length, and the number of roots were also counted.

Based on these parameters, the daughter plants were categorised according to the marketable standards: A++, A+, A, A–, OS (out of standards) (Lucchi et al. 2004; Lieten 2014; Selamovska, Nathan 2014). All the daughter plants, one by one, were examined according to the standards according to the order in the runner chain daughter plant 1 (DP_1); daughter plant 2 (DP_2); daughter plant 3 (DP_3) (Table 1).

The data on the obtained parameters were subjected to a statistical analysis with the JMP 2010 program, and a one-way analysis of variance (ANOVA).

RESULTS AND DISCUSSION

Producing high-quality daughter plants of the June-bearing strawberry is very important, as the most appropriate planting time for the mother plant is considered to be the period March–April (Lieten 2014; Selamovska, Nathan 2014). In our case, the planting was carried out on 14.04.2019 and, after 20 days, the first flowers appeared, while the first stolons appeared after 42 days (Table 2). The entire flowering period lasted 22 days and the flowers were plucked three times during this time in order to reduce the competition for the formation and development of runners (Figure 2). According to Beniwal et al. (2017), the initiation of runners appeared between 29.5 and 35.4 days after the planting of the mother plants.

Table 1. Standard used for the daughter (runner) plant classification (Lucchi et al. 2004; Lieten 2014)

Standards	Crown diameter (ø mm)	Length of roots (cm)	Number of roots
A++	> 15	> 12	> 12
A+	12.0–14.9	10–11.9	10–11.9
A	8.0–11.9	8–9.9	8–9.9
A–	6.0–7.9	6–7.9	6–7.9
OS	< 5.9	< 5.9	< 5.9

Table 2. Development of the mother plants Cultivar of cv. 'Senga Sengana' according to dates

	Dates
Mother plant planting	14. 04. 2019
Beginning of flowering	04. 05. 2019
Beginning of runners development	26. 05. 2019

The selection of mother plants from a morphological point of view is very important, the runner plants with a crown diameter lower than 12 mm, are often used as mother stock material (Lieten 2014). In this study, the average crown diameter of all plants was 12.55 mm. So, based on the crown diameter, it is noted that all the mother plants for all the treatments were quite homogeneous. Also, to the number of the flowers, no significant differences were observed between the mother plants used in the experiment (Table 3).

The production capacity of the mother plants is closely related to the number of runners, the number of daughter plants per runner and the number of daughter plants per plant. The time and intensity of their formation depends on the cultivar, climate conditions, cultivation method, age and health condition of mother plant, etc. June-bearing strawberry cultivars form a larger number of rosettes on the plant than the ever-bearing cultivars. On one runner, 2 to 6, and rarely 7 to 8 rosettes can usually be formed (Selamovska, Nathan 2014). The number of runners per plant tended to increase significantly with the shading levels, registering its highest value (13.89 runners per plant) with 50% shading, whereas with the increasing and decreasing levels of shading, the number of runners will be reduced (Sharma et al. 2013). According to Beniwal et al. 2017, the number of strawberry runners per plant was the maximum (10.19) under a shade net house. A mother plant could produce about 60–100 daughter plants during the season (8–9 months), but this depends on the variety, nursery location and agricultural works carried out (Husaini, Neri 2016; Strand 2008). The one-time harvest of multiple daughter runners from the Chandler mother plant produced about 12 runners with two to six daughter plants per runner (Takeida et al. 2004).

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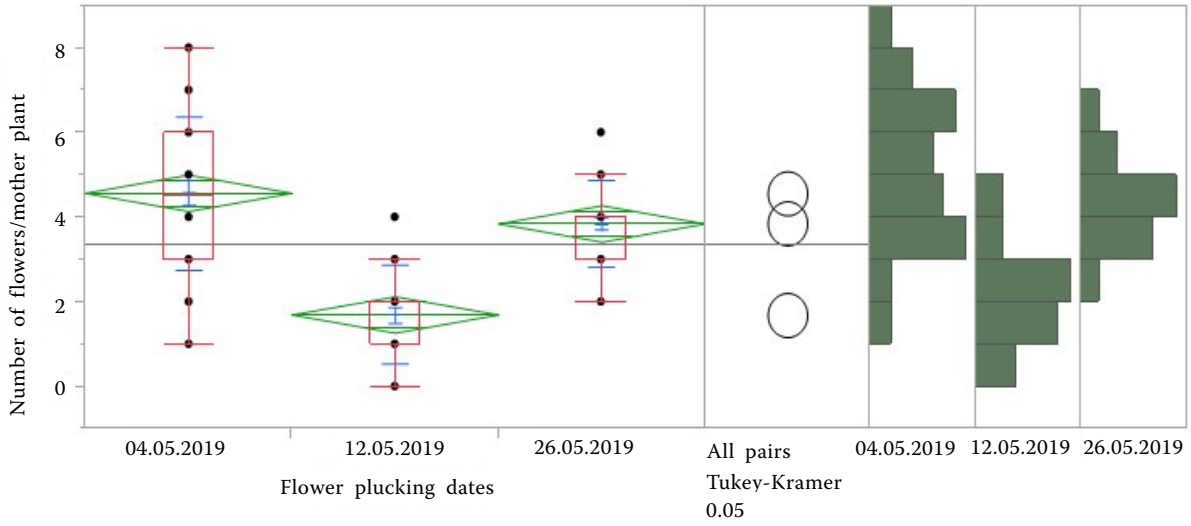

Figure 2. Dynamics of the mother plant flowering, the one-way analysis of the number of flowers/mother plant by flower plucking dates

In this study, treatments S_3 and S_2 formed the largest number of runners (47.7 and 34.7 runners per plant). In addition, the S_3 treatment managed to create a larger number of daughter plants per runner (3.3) and daughter plants per mother plant (135.7) in relation to the other three treatments (Table 3).

According to the data in Table 4, it can be seen that, in all the analysed parameters for the first daughter plants in the runner chain (DP_1), treatment S_2 (PTS substrate "Pindstrup") showed higher values, then treatment S_4 and the treatment with weakest indicators was S_1 (soil 50% – decomposed manure 50%).

In the analysed parameters for the second daughter plant in the runner chain (DP_2), treatment S_1 and S_4 showed the highest of crown diameter values. Regarding the other parameters – the length of the roots, the number of roots of the plant, the weight of the plant and the root weight – treatment S_2 and treatment S_4 showed higher values, while the treatment with weaker indicators was S_1.

In all the analysed parameters for the third daughter plant in the runner chain (DP_3), treatment S_4 showed the highest values for all the analysed parameters in relation to the other three treatments. On the other hand, treatment S_2 had no daughter plants in the runner chain (DP_3).

The fulfilment of the relevant standards for all the main parameters together, as well as according to the order of the plants in the runner chain, are reflected in (Table 5). The first daughter plants in the runner chain (DP_1) for standard A++, has treatment S_2 had the largest number of plants, in the standards A+, A and A–, treatment S_3 had the largest number of plants, whereas, in the out of standard (OS) category, only treatment S_1 had no daughter plants.

In the second daughter plants in the runner chain (DP_2) for the standards A++ and A+, the treatment

Table 3. Morphological parameters of the mother plants, in the strawberry cultivar 'Senga Sengana', year 2019

Variants	Crown diameter/mm	No. of flower/plant	No. of runners/plant	No. of daughter plant/runner	No. of daughter plant/plant
S_1	12.6[a]	11.1[a]	22.7[b]	2.7[b]	62.0[b]
S_2	12.7[a]	9[a]	34.7[a]	2.0[c]	69.4[b]
S_3	12.3[a]	11.3[a]	40.7[a]	3.3[a]	135.7[a]
S_4	12.6[a]	9.1[a]	25[b]	3.1[ab]	76.7[b]
Comparisons for all pairs		q*		alpha	
Tukey-Kramer HSD		2.69323		0.05	

[a, b, c]levels not connected by the same letters are significantly different; q* – confidence quantile; alpha – significant parameter

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Table 4. Morphological parameters of the daughter (runner) plants in the runner chain – cv. 'Senga Sengana', year 2019

Variants	Crown diameter (mm)	Length of roots (cm)	No. of roots/plant	Weight of daughter plant (g)	Weight of daughter plant roots (g)
		First daughter plant in the runner chain (DP_1)			
S_1	14.34^{ab}	3.22^{c}	8.60^{d}	13.52^{c}	1.03^{c}
S_2	15.90^{a}	24.03^{a}	51.53^{a}	34.03^{a}	10.82^{a}
S_3	12.99^{b}	15.83^{b}	19.77^{c}	22.00^{b}	5.99^{b}
S_4	14.71^{ab}	23.15^{a}	35.03^{b}	22.51^{b}	9.59^{a}
		Second daughter plant in the runner chain (DP_2)			
S_1	15.05^{a}	3.59^{c}	7.10^{c}	11.92^{b}	0.85^{c}
S_2	13.22^{ab}	21.37^{a}	37.30^{a}	22.62^{a}	6.82^{ab}
S_3	11.57^{b}	14.32^{b}	14.43^{b}	18.41^{ab}	4.37^{bc}
S_4	14.37^{a}	22.97^{a}	34.17^{a}	22.85^{a}	10.09^{a}
		Third daughter plant in the runner chain (DP_3)			
S_1	11.79^{a}	3.28^{c}	6.74^{c}	7.20^{b}	0.68^{c}
S_2	0	0	0	0	0
S_3	9.46^{ab}	10.87^{b}	12.50^{b}	10.06^{ab}	2.91^{b}
S_4	10.70^{b}	19.29^{a}	22.71^{a}	13.91^{a}	5.39^{a}
Comparisons for all pairs		q*		alpha	
Tukey-Kramer HSD		2.60667		0.05	

$^{a, b, c}$levels not connected by the same letters are significantly different; q* – confidence quantile; alpha – significant parameter

S_2 had largest number of plants, in the standards A and A–, treatment S_3 had the largest number of plants, while the plants in the out of the standards (OS) category, only treatments S_1 and S_3 were identified, where the largest number daughter plants were obtained in treatment S_1 (Table 5).

For the third daughter plants in the runner chain (DP_3) in the standard A++, only treatment S_4 had plants in it, in the standards A+, A and A–, treatment S_3 had the largest number of plants and in the out of the standards (OS) category, treatment S_1 had the largest number of plants (Table 5). The order of the daughter plants in the runner chain after the development cycle is presented in Figure 3.

Similar results, but from a different point of view, were published by other authors. Takeida et al. (2004) studied the percentage of daughter plants that developed an adequate root mass for field

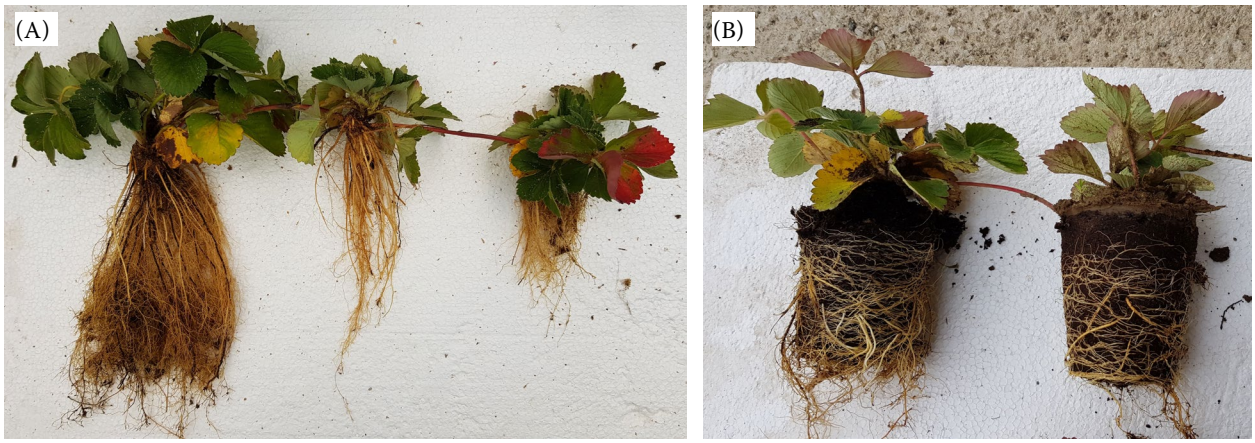

Figure 3. Daughter plants (DP)
(A) – sawdust treatment DP_1, DP_2 and DP_3, (B) – substrate pots DP_1 and DP_2

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Table 5. Achieving marketable standards from the daughter plants according to the variants based on three main parameters

Daughter plant	Standards	Number and % of daughter plant / mother plant							
		S_1		S_2		S_3		S_4	
		No	(%)	No	(%)	No	(%)	No	(%)
DP_1	A++	0.0	0.0	20.8	60.0	9.6	23.3	10.0	40.0
	A+	3.1	13.3	13.9	40.0	19.1	46.7	13.3	53.3
	A	1.5	6.7	0.0	0.0	8.2	20.0	1.7	6.7
	A–	0.0	0.0	0.0	0.0	4.1	10.0	0.0	0.0
	OS	18.4	80.0	0.0	0.0	0.0	0.0	0.0	0.0
DP_2	A++	0.0	0.0	13.9	40.0	9.6	23.3	10.8	43.3
	A+	2.3	10.0	19.7	56.7	12.3	30.0	11.7	46.7
	A	2.3	10.0	0.0	0.0	8.2	20.0	2.5	10.0
	A–	0.8	3.3	1.1	3.3	8.2	20.0	0.0	0.0
	OS	17.6	76.7	0.0	0.0	2.7	6.7	0.0	0.0
DP_3	A++	0.0	0.0	0.0	0.0	0.0	0.0	5.4	21.4
	A+	1.7	10.5	0.0	0.0	13.7	33.3	5.4	21.4
	A	0.0	0.0	0.0	0.0	12.3	30.0	9.8	39.3
	A–	0.0	0.0	0.0	0.0	5.5	13.3	0.0	0.0
	OS	14.3	89.5	0.0	0.0	9.6	23.3	4.2	16.7
Total	A++	0.0	0.0	34.7	50.0	19.1	15.6	26.2	34.9
	A+	7.0	11.4	33.6	48.4	45.1	36.7	30.4	40.5
	A	3.8	6.2	0.0	0.0	28.7	23.3	14.0	18.7
	A–	0.8	1.2	1.1	1.7	17.8	14.4	0.0	0.0
	OS	50.4	81.2	0.0	0.0	12.3	10.0	4.2	5.6

S_1, S_2, S_3, S_4 – substrates (treatments); A++ , A+, A, A–; OS – standards determinated by the crown diameter, lenght of roots and number of roots/plant (see Table 1 for the values)

transplanting and concluded that, about the range of daughter plants, it was achieved by 98% of them from the second node and 88% from the tenth node. Also, about the standards of the daughter plant production, Lisiecka (2009), conclude that, with the mother plants of the standards A and A+, 18.45 to 22.35 daughter plants with crown diameter 5.74 mm to 6.97 mm can be obtained from the fresh and frigo of the strawberry cv. 'Elsanta' .

On the other hand, Türkben (2008) analysed the quality of daughter plants of five different strawberry cultivars, cultivated in three types of rooting medium, according to the order in the runner chain (1, 2, 3 nodes), and found that daughter plants formed from 13 to 16 roots, with a length of 8.7 to 12.68 cm and with a crown diameter from 8.1 to 13 mm. Other authors published results about the runners produced under shading conditions from 25–75%, which significantly impacted the crown diameter, with a maximal value of 13.49 mm and a maximal root length of 11. 26cm (Sharma et al. 2013). Also, the effect of different protected conditions on the crown diameter of runners after 110 days from planting resulted in a mean value of 5.61 mm (Beniwal et al. 2017).

CONCLUSION

Based on the conducted research on four types of substrates and their impact on the development of the strawberry runner plants, we can conclude:

- Treatment S_2 produced the highest number of quality daughter plants in accordance with standard A++.
- Treatment S_3 produced the highest number of quality daughter plants in accordance with standard A+.
- Treatment S_3 produced the highest number of daughter plants per mother plant.

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– Treatment S1 showed weaker results for each of the analysed parameters.

As the overall conclusion, the best treatment in relation to other treatments substrate, is Professional Tested Substrate (PTS) because it offers higher quality standard of strawberry propagation plants.

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