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Comparison of Aeroponics and Conventional Production System of Virus-free Potato Mini Tubers in Serbia

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Abstract

Virus free mini tubers are starting materials for the production of seed potatoes without the diseases. Conventionally, mini-tubers are produced from *in vitro* plants in various solid media. The aeroponics system refers to the process of growing plants in the air or in the fog environment without the use of soil or any other substrate. The aim of this study is to assess the application of aeroponics and conventional production system of virus-free potato mini tubers in Serbia. The experiment included three varieties of potatoes: Cleopatra, Kennebec and Agria. All three varieties were cultivated within two systems: aeroponics and conventional rooting in the substrate. In the aeroponics system, with all three varieties, an average of 17.87 mini tubers was obtained, which is 5.39 times more than in the conventional substrate. This ratio was the highest in the variety Kenebec (6.46), followed by Agria (5.71) and the lowest in Cleopatra (4.01). The average weight of mini tubers produced in the conventional substrate was higher by 3.49 g compared to the aeroponics system. The aeroponics system offers a potential opportunity to improve the production of mini potato tubers in Serbia.

Key words: aeroponics, potato, *in vitro*, virus-free mini tubers

Introduction

Mini tubers are produced *ex vitro* from acclimatized plants obtained *in vitro* or from multiplied micro-tubers (Otazu, 2010). They are often produced from *in vitro* plants acclimatized in various solid substrates. Their size ranges from 5 to 25 mm, evidently smaller than conventional tuber seed potatoes, but higher than the *in vitro* microtubers produced under aseptic conditions on artificial media (Struik, 2007).

Virus-free mini-tubers are starting materials for the production of seed potatoes without diseases. Conventionally, mini-tubers are produced from *in vitro* plants in various solid media such as soil, peat, peat + vermiculite /perlite, sand, etc. Plants are planted in high density of 50-180 plants per m^2. Around 2-8 mini-tubers are normally produced per plant.

The low rate of reproduction and uneven sized mini-tubers are considered as the main limitation in substrate production. In order to overcome the above problems, the aeroponic system of mini-tuber production has been recently developed (Ritter et al., 2001). It refers to the process of growing plants in the air or in a mist environment without the use of soil or any other substrate. This system allows the production of 20-50 mini tubers per plant with several harvest dates. The size of mini-tubers is more uniform in this system due to successive harvesting (Otazu, 2010).

The application of aeroponics for production of pre-seed potatoes (virus-free mini tubers) started at the beginning of the 21st century (Ritter et al., 2001, Nickols, 2005, Otazu, 2010). The root of the plant is kept in the air in a darkroom (module), while nutrient solution is sprayed in the form of fine particulate mist of 50-60 microns. Full access to the available oxygen in the air promotes the growth rate of roots and plants. Such an environment also gives plants full access to carbon dioxide in the range of 450 to 780 ppm for photosynthesis, so that plants in the aeroponic environment grow faster and absorb more nutrients than ordinary hydroponic plants (Ritter et al., 2001).

Mini-tubers are successively collected at intervals of 10 to 15 days, when they reach desired size.

The aeroponic technique is successfully applied to the production of various horticultural species, including lettuce, tomato, cucumber and ornamental plants (Bucksetha et al., 2016).

According to Farran and Mingo-Castel (2006), the number and timing of the harvest are key factors to optimizing the production of mini-tubers. Aeroponic technology is not potentially more effective for all potato varieties (Mateus-Rodriguez et al., 2012).

Broćić et al. (2018b) obtained the highest average number of mini-tubers for the Desiree cultivar, while the lowest number was registered in the Sinora and Cleopatra cultivars. Moreover, Tierno et al. (2014) showed that plants in the aeroponic system increased their vegetative cycle by 12 to 36% compared to the plants grown in the substrate.

According to Abdullateef et al. (2012), a larger number and larger mini-tubers per plant were obtained with 25 plants per m^2, compared to 35 and 50 plants per m^2. In the production of mini-tubers, five mutually dependent yield parameters are significant as indicators of successful production: (1) the number of mini-tubers per *in vitro* plant, (2) the number of mini-tubers per unit area, (3) the average weight per mini-tuber (4) minimum yield per plant and (5) minimum yield per unit of production. Which parameters will be evaluated will depend on the cost, availability of facilities, labour and the intended use of mini-tubers.

The most important parameter in the production of mini-tubers is their number, and according to Tierno (2014), 35-40 per plant is average in the aeroponic system of cultivation, depending on the variety. In aeroponics, individual potato plants can produce more than 100 mini tubers (Otazu, 2010). Experiences with aeroponics in the production of mini-potato tubers exist in Korea (Kang et al., 1996; Kim et al., 1997; 1999), Spain (Ritter et al., 2001; Farran and Mingo-Castel, 2006), and Sri Lanka (Nugaliiadde et al., 2005). The International Centre for Potatoes (CIP) also promotes the production of mini-tubers using the aeroponic system under the Andean mountain conditions at 3200 metres above the sea level (Otazu and Chukuillankui, 2007).

In Serbia, the production yields of potato are around 15 tons per ha, significantly lower than those of the EU countries. One of the main causes of very low yield of potatoes in Serbia is insufficient use of quality seed in the absence of production of pre-basic and basic seed potatoes. The aim of this study is to assess the application of aeroponics in Serbia in comparison with the conventional production system of virus-free potato mini-tubers in three varieties of potatoes that are widely demanded in the country.

Material and Methods

The experiment was conducted in 2018 at the Centre for Potato in Guca, the western part of Serbia. The experiment included three varieties of potatoes: Cleopatra, Kennebec, and Agria. All three varieties were cultivated in two systems: aeroponic and conventional substrate.

Rooted plants from *in vitro* conditions were acclimatized in the substrate of sand and perlite (1:1) for 20 days, then washed and transferred to aeroponics. Transplanting of acclimated and rooted plants into aeroponics was carried out on 25 June 2018. The plants that were grown in the substrate were planted directly *in vitro* on 5 June, where their acclimatization took place. The experiment was set up as a two factorial with three potato varieties and two technologies of production in four repetitions. There were 24 plants per m^2 in the aeroponic system and 60 plants per meter squared in the substrate.

The aeroponic system consists of the following elements:

- aeroponic modules (chambers construction of wood and styrofoam) and

- installation (a pump, installation for supply and drainage of nutrient solution, a tank for nutrient solution, foggers and software that regulates day and night mode).

The aeroponic system was implemented using the modules according to Brocić et al. (2018a; 2018b). Network conditions in the module (root zone), mesh (zone of stems and leaves) and outside the network (external conditions) were monitored during the experiment. Temperatures were monitored at 7 am and 3 pm. During the observation of mini-tuber in the aeroponic system, they were successively collected at intervals of 7 to 20 days, starting from 2 August to 23 November (Figure 2). There were in total 10 harvest dates. Mini tubers from the substrate were harvested at the end of November, according to the physiological maturity of the plants.

Results and Discussion

Temperature conditions

Temperatures in the root zone are very important for the initiation, development and launch of root growth, as well as potato tubers size (Chang et al., *2006*). The best and most active root development takes place at temperatures around 20 °C. The optimal temperature for initiation and initial growth of potato tubers is 16-19 °C, i.e. 18-22 °C in the formation and filling phase of the tuber.

Based on Figure 1, it can be concluded that the daily maximum temperatures in the root zone (aeroponics) from the beginning of the experiment (25 June) to the end of August were dominantly in the interval of 26-29 °C.

Such high temperatures reduced the number of initiated tubers and slowed their filling (Figure 2). Temperature range from September to the second half of November was optimal for the formation of tubers in the aeroponic chamber and ranged from 12 to 20 °C.

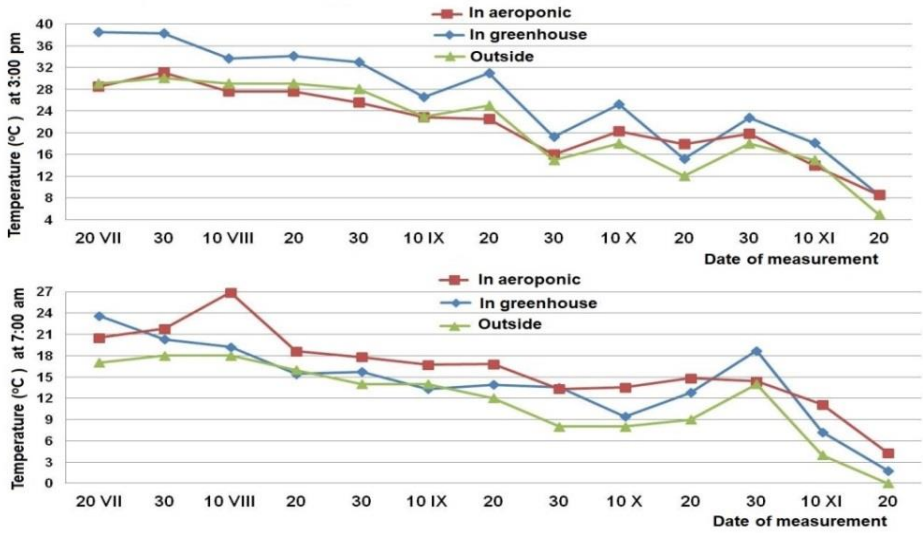

Fig. 1. Temperature conditions during the research period

The aeroponic production system

The number and weight of mini-tubers

The analysis of the average number of mini-tubers per plant and the average weight of a mini-tuber showed statistically very significant differences under the influence of the variety (Table 1).

Taking into account the measurement results, it can be seen that Kennebec (19.15) and Agria (18.95) had a significantly higher number of mini-tubers per plant than Cleopatra (13.96).

The average weight of mini-tubers in Kennebec (9.30 g) and Agria (9.08 g) compared to Cleopatra (6.66 g) was significantly higher. The Kennebec and Agria varieties had mini-tubers weighing over 8 g, which is higher than the results obtained by other authors (Chang et al., 2006; Struik, 2007) and our previous research (Brocić et al., 2018a; 2018b).

Tab. 1. The influence of the production system and the variety on the number and weight of mini-tubers

Production system (A)	Variety (B)	Total number of mini tubers per plant	The average weight of mini tubers
Aeroponics	Cleopatra	15.53	6.66
	Agria	18.95	9.08
	Kennebec	19.15	9.30
	Average	17.87	8.34
Substrate	Cleopatra	3.87	9.98
	Agria	3.49	11.63
	Kennebec	2.96	13.89
	Average	3.44	11.83
$LSD_{0,05}$	(A)	2.03	1.24
	(B)	2.82	2.56
	(A × B)	4.48	3.23
$LSD_{0,01}$	(A)	2.57	2.11
	(B)	3.13	2.41
	(A × B)	5.39	4.23

The dynamics of the formation of mini-tubers

The Agria and Kennebec mini-tubers had nine harvests, whereas Cleopatra had 10. The first harvest of the Cleopatra mini-tubers (early variety) began on 2 August, 43 days after planting in the aeroponics, while Agria and Kennebec were harvested 20 days later, on 22 August. Similar results were obtained by other researchers (Farran et al., 2006; Mateus-Rodriguez et al., 2012; Abdullateef et al., 2012). The number of mini-tubers was the lowest in all three varieties in the first and second harvest, while the average weight of these tubers was the highest, from 10 to 15 g.

For the Agria and Kennebec varieties in the last three terms of harvest (Figure 2), the mass of mini-tubers decreased and their number increased. In Cleopatra, the mass of mini-tubers, as well as their number, decreased from the harvest term.

Successive harvesting of mini-tubers allows them to reach the desired mass of over 8 g, as confirmed by the results of other authors (Ritter et al., 2001; Struik 2007; Rykaczewska 2016).

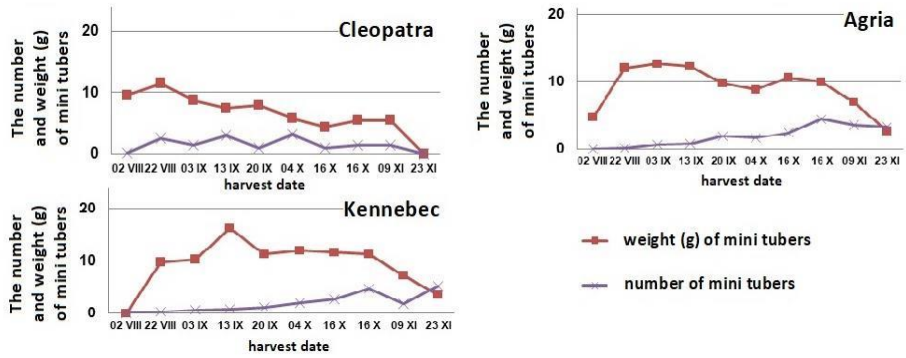

Fig. 2. The dynamics of development of potato mini tubers in the aeroponic system

The substrate production system

The number and weight of mini-tubers

In the conventional system, the average number of mini-tubers per plant produced in the substrate was 3.44. The largest number of mini-tubers was achieved with Cleopatra (3.87), followed by Kennebec (3.49) and the lowest in the Agria variety (2.96). These differences are not statistically significant.

The average weight of the tubers grown in substrate for all three varieties was 11.83 g. The average weight of mini-tubers in Kennebec (13.89 g) and Agria (11.63 g) compared to the Cleopatra variety (9.98 g) is significantly higher.

All three varieties in this production system had mini-tubers weighing over 9 g. This size is highly desirable for further reproduction in field conditions.

Fraction content and average mass of mini tubers per fractions

Representation of individual fractions and their participation (%) is shown in Table 3. In all three varieties, the biggest share of small fractions is 56.67% and the mass of the mini-tuber is 4.90 g. The middle fraction has a share of 35.12% and an average weight of 16.06 g. The large fraction is represented by 8.19%, and the average weight of these mini-tubers is 41.9 g.

In the aeroponic system, with all three varieties, an average of 17.87 mini-tubers was obtained, which is 5.39 times more than in the substrate. This ratio (Table 2) was the highest in the Kennebec variety (6.46), followed by Agria (5.71), and the lowest in the Cleopatra variety (4.01).

Tab. 2. Comparison of the multiplication of mini tubers in the substrate and aeroponic production systems

Variety	The ratio of substrate / aeroponics
Cleopatra	1:4.01
Agria	1:5.71
Kennebec	1:6.46
Average	1:5.39

Varieties with longer vegetation in the aeroponics give a higher number of mini-tubers per plant, as confirmed by our previous research (Brocić et al., 2019), when we compared the Sinora variety with the Desiree variety. The average weight of mini-tubers produced in the substrate was significantly higher than the one obtained in the aeroponic system, namely by 3.49 g.

Tab. 3. Percentage distribution of fractions and average mass of mini-tubers per fraction produced in the substrate

Variety	Tubers share fraction and Average weight of a mini-tuber per fraction	Fractions of mini tubers		
		small	medium	big
Cleopatra	Tubers share fraction (%)	56.43	33.99	9.56
	Average weight of a mini tuber per fraction (g)	4.60	14.06	27.26
Agria	Tubers share fraction (%)	59.53	34.27	6.19
	Average weight of a mini tuber per fraction (g)	5.58	16.04	45.34
Kennebec	Tubers share fraction (%)	54.07	37.09	8.83
	Average weight of a mini tuber per fraction (g)	4.54	18.19	53.10
Average	Tubers share fraction (%)	56.67	35.12	8.19
	Average weight of a mini tuber per fraction (g)	4.90	16.06	41.90

Conclusion

This study analyzed the use of aeroponic and conventional production systems with virus-free potato mini tubers in Serbia using three varieties of potatoes. The experiment included three varieties of potatoes: Cleopatra, Kennebec and Agria. In the aeroponic system, with all three varieties, an average of 17.87 mini tubers was obtained, which is 5.39 times more than in the substrate.

This ratio was the highest in the Kennebec variety (6.46), followed by Agria (5.71), and the lowest in the Cleopatra variety (4.01). Varieties with longer vegetation in the aeroponics give a higher number of mini tubers per plant. The successive harvest of mini tubers in the aeroponic system allows them to reach the desired mass of over 8 g. The average weight of mini tubers in the substrate was higher by 3.49 g compared to the aeroponic system. The aeroponic system offers a potential opportunity to improve the production of mini potato tubers in Serbia.

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Компарација аеропонског и конвенционалног система производње безвирусних мини кртола кромпира у Србији

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Сажетак

Безвирусне мини кртоле кромпира представљају почетни материјал за производњу сјеменског кромпира без болести. Најчешће, мини кртоле се производе од *in vitro* биљака на различитим чврстим подлогама. Аеропонски систем односи се на процес узгајања биљака у окружењу ваздуха или магле, без употребе земљишта или било којег другог супстрата. Циљ овог истраживања је процјена могућности адекватне примјене аеропонског и конвенционалног система производње безвиррусних мини кртола кромпира у Србији. У експеримент су биле укључене три сорте кромпира: *Cleopatra*, *Kennebec* и *Agria*. Све сорте узгајане су у оквиру два система: аеропонског и конвенционалног система са укорјењивањем у супстрату. У аеропонском систему, код свих сорти, добијено је у просјеку 17,87 мини кртола, што је 5,39 пута више у поређењу са конвенционалним системом. Овај омјер је био најизраженији код сорте *Kennebec* (6,46), затим слиједе сорте *Agria* (5,71) и *Cleopatra* (4,01). Просјечна маса мини кртола произведених у конвенционалном систему била је већа за 3,49 g у поређењу са аеропонским системом. Аеропонски систем нуди потенцијалну прилику за побољшање производње мини кртола кромпира у Србији.

Кључне ријечи: аеропонски систем, кромпир, *in vitro*, безвирусне мини кртоле

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