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PRODUCTION OF POTATO MINI-TUBERS IN THE AEROPONIC GROWING SYSTEM

PROIZVODNJA MINI KRTOLA KROMPIRA U AEROPONIK SISTEMU GAJENJA

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ABSTRACT

At the micropropagation laboratory of the Potato Research Centre in Gucha, the following five virus-free in vitro potato cultivars are produced: 'Desiree', 'Kennebec', 'Agria', 'Cleopatra' and 'Sinora'. Acclimatized and rooted plants were transplanted and grown in the three production systems: 1) the aeroponic system, 2) the substrate system, and 3) a combination of the substrate and aeroponic systems. The results obtained indicate that the cultivation system exerts a significant effect on the number and the total yield of potato mini-tubers. In the aeroponic production system, 4.08 times as many mini-tubers were produced compared to the number of mini-tubers produced in the substrate system, whereas 1.29 times as many mini-tubers were produced compared to the number of mini-tubers produced in the combined production system (substrate + aeroponics). The aeroponic mini-tuber production system offers an opportunity to improve the production of seed potatoes in Serbia..

Key words: *decay, pomegranate aril, edible coating, minimally processed*

REZIME

Proizvodnja bezvirusnog semenskog krompira danas se odvija preko metode poznate kao kultura tkiva (mikropropagacija in vitro), čija je suština da se za relativno kratko vreme, i u kontrolisanim uslovima, dobije veliki broj bezvirusnih mini ili mikro krtola. U laboratoriji za mikropropagaciju Centru za krompir u Guči proizvedene su bezvirusne biljke in vitro pet sorti krompira: Desiree, Kennebec, Agria, Cleopatra i Sinora. Aklimatizovane i ožiljene biljke presađene su i gajene u tri sistema proizvodnje: 1) aeroponik, 2) u supstratu i 3) kombinaciji dva sistema gajenja (supstrat+aeroponik). Cilj rada je bio da se izvrši poređenje aeroponik sistema gajenja sa druga dva sistema proizvodnje mini krtola. Mini krtole u aeroponik sistemu posle 40-45 dana gajenja sukcesivno su ubirane u četiri roka berbe u intervalima od 10-15 dana. U ostala dva sistemima gajenja mini krtole su vađene na kraju vegetacionog perioda. Analiziran je broj mini krtola po m^2, prosečna masa krtola i ukupan prinos. Najveći prosečan broj mini krtola utvrđen je kod sorte Desiree, dok je najmanji broj mini krtola zabeležen kod sorte Sinora i Cleopatra. Kod sorte Agria konstatovan je najveći prosečnan prinos mini krtola, a zatim kod sorte Kennebec. Dobijeni rezultati ukazuju da sistem gajenja značajno utiče broj mini krtola i ukupan prinos. Kod aeroponik sistema proizvodnje postignut je 4,08 puta veći broj mini krtola, u odnosu na broj mini krtola dobijen u supstratu, odnosno 1,29 puta veći broj mini krtola, u odnosu na kobinovani način proizvodnje (supstrata+aeroponik). Aeroponik sistem proizvodnje mini krtola nudi potencijalnu mogućnost za poboljšanje proizvodnje semenskog krompira u Srbiji.

Ključne reči*: semenski krompir, in vitro, mini krtole, aeroponika, supstrat*

INTRODUCTION

At present, the production of virus-free seed potatoes (Solanum tuberosum L.) is carried out using the method of tissue culture (*in vitro* micropropagation). The essence of this technology is producing a large number of non-virus-free mini- or micro-tubers under controlled conditions and in a relatively short period of time. Virus-free plants obtained *in vitro* are transplanted into different types of substrates for the purpose of acclimatizing and producing mini-tubers. This method is considered a classical method for obtaining the initial virus-free base material that is further multiplied in the commercial seed production. The use of micro- and mini-tubers has revolutionised the potato production industry. This resulted in decreasing the number of cycles in the field needed to obtain an adequate amount of seed potato tubers, thus facilitating the high quality of basic material (Vrobel, 2014).

Micro-tubers are formed *in vitro*. These tubers are miniature seed potatoes. They are the first generation (nucleus) of seed potatoes with a mass ranging from 24 to 273 mg, a diameter of 4-7 mm and a length of 10-12 mm (Ranalli, 2007). Mini-tubers have a greater practical significance. They are obtained under *ex vitro* conditions from acclimatized plants obtained *in vitro* or from multiplied micro-tubers. The term refers to their size because they are smaller than conventional seed tubers, but larger than *in vitro* tubers produced under aseptic conditions on artificial media (Struik, 2007). The size of the mini-tubers usually ranges from 5-25 mm.

Over the past few decades, various techniques such as hydroponic systems (Chang et al., 2012) and the NFT (Rolot et al., 2002) have been studied in order to increase the degree of

reproduction of the *ex vitro* seed material. However, most of these techniques have limitations due to the inadequate aeration of the root.

The aeroponic production of potato mini-tubers started at the beginning of the 21st century due to an increased demand for more efficient, high-quality seed production methods (Ritter et al., 2001, Nickols, 2005). In the aeroponic cultivation system, the root is free in the air of the dark chamber (the aeroponic module). The plant is attached to the aeroponic module cover on the passage of the tree into the root. The plant receives water and nutrients through an aerosol of the nutrient solution. According to Farran and Mingo-Castel (2006), the number and harvest intervals are one of the key factors in optimizing the production of mini-tubers. According to Mateus-Rodriguez et al. (2012), the aeroponic technology is potentially more efficient for specific potato varieties.

In the research of Abdullateef et al. (2012) including 25 plants per m^2, more mini-tubers were obtained per plant compared to 35 and 50 plants per m2. One of the most important parameters in the production of mini-tubers is their number per plant and per m^2. According to Rykaczewska (2016), 32.5-36.0 mini-tubers per plant were obtained on average, as well as 1,268-1,396 per m^2, depending on the cultivar. The number of mini-tubers was two to three times larger in the aeroponic production than in the traditional method. The application of new methods in obtaining mini-tubers creates the preconditions for the production of seed potatoes, which is necessary for the development of the potato sector in the Serbian agriculture, especially in mountainous areas (Brocić et al., 2017).

MATERIAL AND METHOD

In the experiment, virus-free *in vitro* plants were used, produced in the Potato Research Center in Gucha. At the micropropagation laboratory, plants of the following potato cultivars were obtained: 'Desiree', 'Kennebec', 'Agria', 'Cleopatra' and 'Sinora'. On 20th August 2017, plants were transplanted from the *in vitro* conditions to insect free screen houses, and planted in a sand and perlite substrate (1:1). These plants were used in the experiment involving the aeroponic cultivation system and the aeroponics + substrate combination. The number of plants per m^2 was 24 in these two growing systems. The acclimatization lasted for 20-25 days, after which the acclimatized and rooted plants were transferred to the prepared aeroponic modules (September 10-15). In the planting system with the substrate, the plants were directly planted in the Plantaflor substrate. The number of plants per m^2 was 100.

In the aeroponic growing system, a one-factorial_experiment was conducted with four replicates including five potato cultivars. The number of plants was 48. During the day, a nutrient solution was applied for 20 seconds every five minutes from 8 to 18 h, whereas at night the solution was applied every 10 minutes for 20 seconds from 18-8 h. In order to monitor the temperature conditions, thermometers were placed in the modules, in the insect free screen houses and outside of the network. Temperatures were measured at 7 am and 3 pm. Insect free screen houses were additionally covered with PVC foil.

During the observation period in the aeroponic system, mini-tubers were successively harvested four times at a 12-19 day interval, starting from 25th October to 12th December. The mass and number of mini-tubers were recorded. In the other two systems of cultivation, mini-tubers were harvested at the end of the vegetation period. The experiment was interrupted after the last harvest due to frosts. Statistical analyses of the results were performed using the variance analysis and the Statistica 5.0 program. The differences in the means of the factors examined were determined using the F-test, and the differences between the median factor treatment using the LSD test at the significance level of 5 % and 1 %.

RESULTS AND DISCUSSION

Temperature conditions. The optimal temperature for the initial growth of potato tubers is 16-19 °C, or 18-22 °C in the formation and filling phase of the tubers. It can be concluded from Chart 1 that the temperature fluctuation in the aeroponic chamber (At) was significantly lower than the temperature in the insect free screen houses (Mt) and the outside temperature (St). This is accounted for by the fact that aeroponic chamber is insulated with Styrofoam, an outer and inner foil that significantly mitigated the fluctuation of temperature. The inlet tubes and the nutrient tank are underground, so the outside

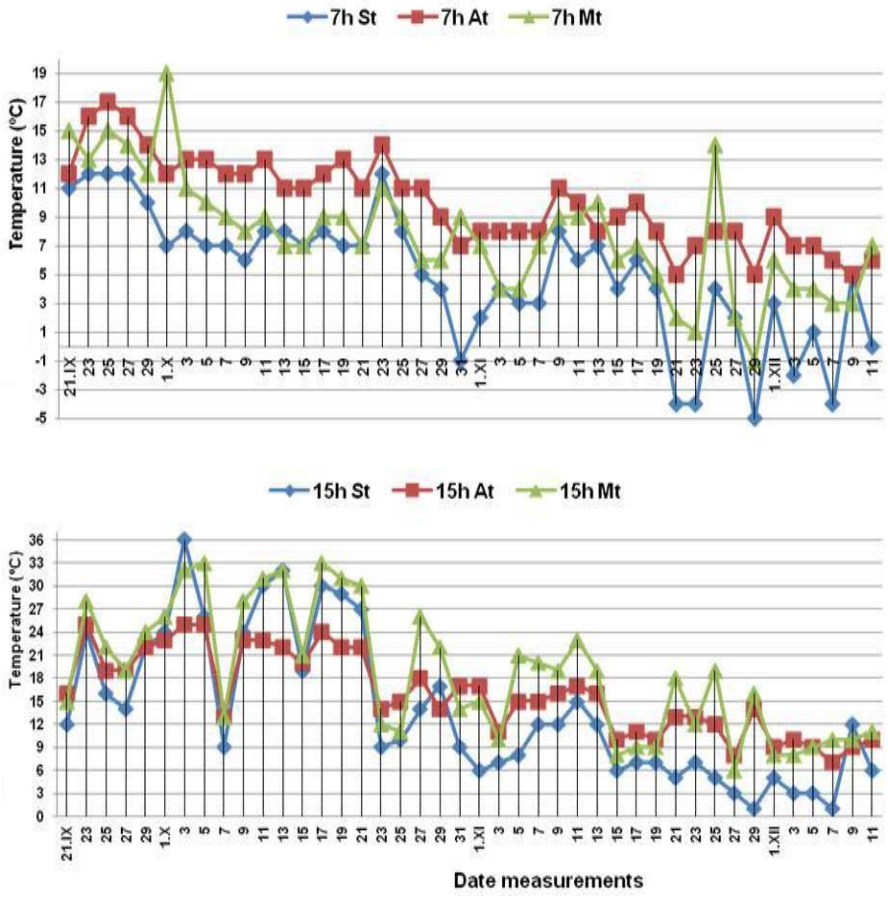

Fig 1. Temperature conditions during the research

temperatures have had a lesser effect on the nutrient solution temperatures. By the end of October, the temperatures in the aerospace chamber ranged 10-24 ^{o}C, which can be considered favourable temperatures for the formation and growth of mini-tubers. In November and December, the lowest temperatures in the aeroponic chamber were up to 5 ^{o}C, and the highest up to 16 ^{o}C. Stronger and more frequent frosts in late November and early December impeded the growth of plants and the formation of mini-tubers, so the experiment was interrupted on 12th December as the vegetation period was forcibly interrupted due to frost damage.

Number and mass of mini-tubers in the aeroponic system. From the results obtained (Table 1), it is evident that the largest average number of mini-tubers per m^2 was recorded in the 'Desiree' cultivar (373.26). This is significantly higher compared to all the other cultivars. The smallest number of tubers was produced by 'Cleopatra' cultivar (252.36), followed by the 'Sinora' (255.84) and 'Agria' (256.86) cultivars. The 'Desiree' cultivar also had a significantly larger average number of mini-tubers per plant (15.55) compared to all the other cultivars. The 'Kennebec' cultivar produced a significantly larger number of mini-tubers compared to the 'Agria', 'Sinora' and 'Cleopatra' cultivars. The difference in the number of mini-tubers between the cultivars 'Agria', 'Sinora' and 'Cleopatra' was not statistically significant. The highest average yield of mini-tubers per m^2 (2,304.03 g) was recorded in the 'Agria' cultivar, followed by the Kennebec cultivar (2,189.85 g).

The highest average mass of a mini-tuber per plant was measured in the 'Agria' cultivar (8.97 g), followed by the 'Kennebec' (7.61 g) and 'Cleopatra' (6.36 g) cultivars.

The smallest mini-tubers were measured in the 'Desiree' and 'Sinora' cultivars (5.32 g and 4.83 g respectively). The analysis of variance showed a statistically significantly higher average mass of a mini-tuber in the 'Agria' cultivar compared to all the other cultivars (Table 1). The cultivars 'Sinora' and 'Desiree' yielded significantly smaller mini-tubers compared to the 'Kennebec' and 'Cleopatra' cultivars. A significant difference in the mass of the mini-tubers was found between the cultivars 'Kennebec' and 'Cleopatra', as well as between the cultivars 'Desiree' and 'Sinora'. In the production of mini-tubers in the aeroponics, the most important parameter is the number of mini-tubers per plant. According to other researchers (Farran et al., 2006, Mateus-Rodriguez et al., 2012, Rykaczewska, 2016), this is mainly dependent on the cultivar specificity. According to Mateus-Rodriguez et al. (2013), the multiplication factor of 1:45 is possible and is based on specific cultivars. The size of individual mini-tubers in the aeroponics, shown in the literature, is quite diverse and depends on the harvest interval, cultivar, density of plants per m^2, fertilization and temperature conditions (Chang et al., 2012).

Influence of the growing system on the yield and the characteristics of potato mini-tubers. Upon comparing different cultivation systems, it is evident (Table 2) that the total number of mini-tubers per m^2 was largest in the substrate growing system (291), followed by the aeroponic system (285.12). The smallest number of tubers was obtained in the combined growing system (216.48).

The average number of mini-tubers per plant in the experiment with the substrate was at least 2.91, and the average mass was 7.69 g per mini-tuber. Regardless of the cultivar, the average mass of all mini-tubers was slightly lower in the aeroponics than in the substrate, amounting to 6.62 g, whereas 11.88 mini-tubers per plant were obtained. In the aeroponic production system, 4.08 times as many mini-tubers were produced compared to the number of mini-tubers produced in the substrate system, whereas 1.29 times as many mini-tubers were produced compared to the number of mini-tubers produced in the combined production system (substrate + aeroponics).

Table 1. Influence of the cultivar on the number and mass of potato mini-tuber in the aeroponic system

Cultivars	Number of mini-tubers / m^2	The yield of mini-tubers / m^2 (g)	Average number of mini-tubers per plants	Average mass of a mini-tuber (g)
Desiree	373.26	1.985,42	15.55	5.32
Kenebbec	287.76	2.189,85	11.99	7.61
Agria	256.86	2.304,03	10.70	8.97
Cleopatra	252.36	1.605,00	10.52	6.36
Sinora	255.84	1.235,70	10.66	4.83
Average	285.22	1.888,15	11.88	6.62
LSD $_{0,05}$	27.16	136.2	1.13	0.57
LSD $_{0,01}$	37.25	186.8	1.55	0.78

Tabele 2. The influence of different cultivation systems on the yield and properties of potato mini- tubers

Growing system	Number of mini-tubers / m^2	The yield of mini-tubers / m^2 (g)	Average number of mini-tubers per plants	Average mass of a mini-tuber (g)
Supstrat Substrate	291.00	2.237,79	2.91	7.69
Combinid (substrate + aeroponics)	216.48	1.381,14	9.02	6.38
Aeroponics	285.12	1.887,49	11.88	6.62

CONCLUSION

The results obtained indicate that the cultivation system exerts a significant influence on the number and the total yield of potato mini-tubers.

In the aeroponic system of cultivation, the largest number of mini-tubers per m^2 was recorded in the 'Desiree' cultivar (373.26). The smallest number of mini-tubers was produced by the cultivars 'Cleopatra' (252.36), 'Sinora' (255.84) and 'Agria' (256.86). The cultivar 'Desiree' also had a significantly larger average number of mini-tubers per plant (15.55) compared to all the other cultivars. The 'Kennebec' cultivar yielded a

significantly larger number of mini-tubers compared to the 'Agria' cultivar. The total number of mini-tubers (291) per m^2 was the highest in the substrate growing system, whereas the average number of mini-tubers per plant (2.91) was the smallest in the substrate system in comparison with all the other systems. The average mass of mini-tubers of all the cultivars grown in the aeroponics was slightly lower than in the substrate, amounting to 6.62 g, whereas11.88 mini-tubers per plant were obtained.

In the aeroponic production system, 4.08 times as many mini-tubers were produced compared to the number of mini-tubers produced in the substrate system, whereas 1.29 times as many mini-tubers were produced compared to the number of mini-tubers produced in the combined production system (substrate + aeroponics). The aeroponic mini-tuber production system offers an opportunity to improve the production of seed potatoes in Serbia.

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