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Editorial

Novel developments in agricultural sciences in the light of agricultural symposia

In the light of the newest developments in the world of agricultural production it is necessary once more to emphasize the importance of science and scientific research. This conference and papers submitted and presented here are one of the most important components in this respect in our region. The research is on topics from all fields of agricultural science and it is important to have from time to time in one place. As many conferences nowadays are narrow and specific for the field and rightfully so, there is a need to have a general conference where the wider aspects of agricultural science and research are discussed in multidisciplinary environments.
The principal aim of this annual conference is to get the scientists from the agricultural field from the region but also from the whole world. This is to present their most recent scientific results and discuss about the future directions in which the agricultural science and production will go. Farmers and scientists are faced with dynamics in the field and disturbances like never before in modern era. Pandemics that occurred in last few years have disturbed the markets, labour distribution and work organization as whole.
Inputs in agriculture have skyrocketed as recent as in the last year. It went down and in the same sudden manner as the global prices declined to the base. Farmers and industries would be lost in those conditions without scientific inputs and academia guiding the way and providing directions to the future trends. The current floods in the region have highlighted the weak points and once again reminded all of us that climate disturbances are real and more frequent than ever in modern times.
Those who fail to adjust and fail to listen, understand and ultimately rely on the scientific research and its findings will continue to struggle at the cost of food shortages and high prices for the basics. This became even more obvious given the recent political disturbances in Europe which let to shortages in grain and sunflower supplies, which reflected in prices of those commodities.
Sustainable use of the resources and its conservation for future generations is on of the major issues this generation of agricultural scientists should have always in mind while doing its work. We can make impressive results now, but how sustainable those results are over the time, and how long we will be able to keep the tempo is the real question. Responsible science and innovation must and basically is obliged to go hand in hand.
This conference proceedings have presents many of the current issues researched. And all of them definitively in the light of in the shade of those events. It is in these Proceedings and in person at the conference that us, agricultural scientists together, present and share the research, issues, problems, findings, results, conclusions and the steps forward. The Proceedings contains 31 papers presented at XII International Symposium on Agricultural Sciences "AgroReS 2023" in Trebinje, Bosnia and Herzegovina, from 24 to 26 May, 2023.

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Effects of cultivar and plant origin on the aeroponic production of potato minitubers

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Abstract

Aeroponics is eco-friendly, soilless technology for the cultivation of vegetable plants that can be used for the production of pathogen-free pre-basic seed potato, namely minitubers. In aeroponic modules, the underground parts of potato plants grow suspended in the mist of finely dispersed nutrient solution to produce tubers, while the shoots grow above the module under greenhouse conditions. This study aimed to evaluate the effects of the cultivar and origin of planting material on the minituber production in an aeroponic facility in Guča, Serbia. Two potato cultivars, Sinora and Agria, and two types of planting material, acclimated microplants and plants originating from sprouted minitubers, were used in the study. Plants were grown in the 2019 season with a planting density of 24 plants per m^2 and ~14-day harvest intervals. Agria plants of both plant origins steadily tuberized during most of the cultivation period and formed a significantly larger number of minitubers (13.61) compared to cultivar Sinora (3.35), which quickly completed the growth cycle. In both investigated cultivars, the mass of formed minitubers was significantly higher in the plants originating from minitubers (18.80 g) compared to plants of *in vitro* origin (9.04 g). Agria plants of minituber origin produced the heaviest minitubers (19.05 g), while Sinora plants of *in vitro* origin formed the least heavy tubers (5.29 g). The highest yield of minitubers, 6.26 kg m^{-2}, was recorded for Agria plants of minituber origin. The results of our study suggest that both plant origin and potato genotype significantly affect minituber production in aeroponics.

Key words: potato, aeroponics, pre-basic seed potato, minitubers

Introduction

The high yields of potato, *Solanum tuberosum* L., largely depend on the use of healthy planting material, that is, pathogen-free seed potato. Conventional seed potato-production currently includes several phases: *in vitro* propagation of pathogen-free plant material (microplants or microtubers), production of minitubers by the cultivation of *in vitro*-obtained plant material on a substrate under controlled environments (greenhouses) and minitubers' vegetative propagation in the field to increase the volume of seed material (Broćić et al., 2021). Minitubers are accepted worldwide as a starting material for the field propagation of seed tubers in potato seed production systems. They are more robust and produce a larger number of stems and, therefore, a more significant number of new tubers per plant than *in vitro*-obtained plantlets and microtubers (Broćić et al., 2021). Minitubers of size over 1 cm are usually used as planting material in field production (da Silva Filho et al., 2020). The low reproduction rate and variable size of minitubers are the main limitations of conventional production (Buckseth et al., 2016). The number of minitubers produced in a substrate usually is 2–5 tubers per cultivated microplant (Struik, 2007). Due to the low minitubers' yield, a common practice in seed production programs is the production of the final seed tubers after three to five generations of cultivation in the open field, with every cycle increasing the risk of pathogen infection (Thomas-Sharma et al., 2016). During the last 20 years, aeroponic systems were established to improve seed potato production (Broćić et al., 2021).

Aeroponics is a modern soilless growing technology that enables the production of a large number of high-quality potato minitubers and reduces the number of multiplication cycles in the field for two to three generations. Besides, plants grown in an aeroponic system are well-protected from pests and soil-borne diseases. In aeroponics, the plant's foliage is grown exposed to greenhouse conditions (insect- and pest-free greenhouses/net houses), while the roots and underground stems grow inside an aeroponic module, suspended in the mist of finely dispersed nutrient solution (Lakkireddy et al., 2012). Consequently, minitubers are formed on underground stems - stolons. Minitubers are harvested upon reaching the desired size, which stimulates the initiation of novel tubers and the enlargement of smaller, uncropped tubers for future collecting (Broćić et al., 2021).

Aeroponics excels in producing seed potatoes due to exceptional yields resulting from plants' vigorous growth, prolonged growing season, and multiple harvests. Previous research revealed that the number of minitubers per plant produced during the season, depending on the cultivar, can range from 36 to over 100 (da Silva Filho et al., 2018; Broćić et al., 2022). Broćić et al.

(2019a) reported that acclimated microplants yielded 5.39 times more minitubers when grown in the aeroponic system (9 harvests) compared to conventional cultivation in substrate. Besides, successive harvesting during the production cycle allows minitubers to reach the desired size. Farran and Mingo-Castel (2006) collected tubers with an average weight of 8 g, considering these tubers optimal in terms of weight and diameter. According to Ritter et al. (2001), the average weight of the minitubers was 13.3 g. Duration of the pre-harvest period (harvest intervals) is also important, and various harvest intervals were reported in the literature, ranging from 7 to 20 days (Broćić et al., 2021). Mbiyu et al. (2012) recommended that the collection of minitubers should be done every 10-14 days.

The starting plant material for the aeroponic production of potato minitubers may include acclimated microplants and microtubers delivered from *in vitro* culture, as well as rooted stem cuttings and rooted shoots obtained from *in vitro*-originated plants after acclimatization (Mbiyu et al., 2018; Ritter et al., 2001; Muthoni et al., 2017). In addition, rooted sprouts, previously separated from the nuclear seed tubers, can be used as starting material (Broćić et al. 2019b, 2022; da Silva Filho et al., 2020).

This study aimed to evaluate the effects of the cultivar and origin of planting material on the production of pre-basic seed potatoes (virus-free potato minitubers) in an aeroponic facility in Serbia.

Material and Methods

The experiment was conducted in 2019 (May - November) at the aeroponic facility in Guča, Serbia (Figure 1). Two potato cultivars, Sinora and Agria, were used in the research. Potato *in vitro* cultures were established from surface-sterilized tuber sprouts as described by Momčilović et al. (2014). Microplants were grown in a climate-controlled room (21 ºC, 16 h photoperiod, light flux 90 µmol m^{-2} s^{-1}) and were subcultured every 30 days by single-node stem cuttings. Before planting in aeroponics, microplants were planted in the substrate of perlite and sand (1:4) and acclimated in the greenhouse for 25 days. Sprouted minitubers, obtained as an aeroponic crop in a previous season, were also planted in the perlite and sand substrate (1:4). Plants from both sources were regularly watered and treated with a nutrient solution. After 20 days, plants developed from minitubers were transferred to aeroponics. The experiment in the aeroponic system started on May 28, 2019, organized in a complete randomized block design with 3 replications for each cultivar-plant origin combination and 10 plants per replica. The planting density in the aeroponic module was 24 plants per m^2 and the aeroponic system operated according to the fertigation regime described by Broćić et al. (2022). The minitubers were collected at ~ 14-day interval (from July to December), and the number of minitubers (tuber length ≥ 2 cm) per plant and minitubers mass were measured at the end of each harvest interval.

The total number of produced minitubers per plant, tuber mass and yield were quantified at the end of the cultivation period. The temperature was recorded in the aeroponic module and greenhouse during the experiment. Statistical analysis was performed using STATISTICA 12 (StatSoft, Inc. 1984-2014, Tulsa, OK, USA). The data regarding the number of minitubers per plant, the minituber's mass, and yield were analyzed using a two-factor analysis of variance (ANOVA) with plant origin and cultivar as the categorical predictors. The means were compared using Tukey's multiple comparison test. For the data analysis, the significance level $p < 0.05$ was used.

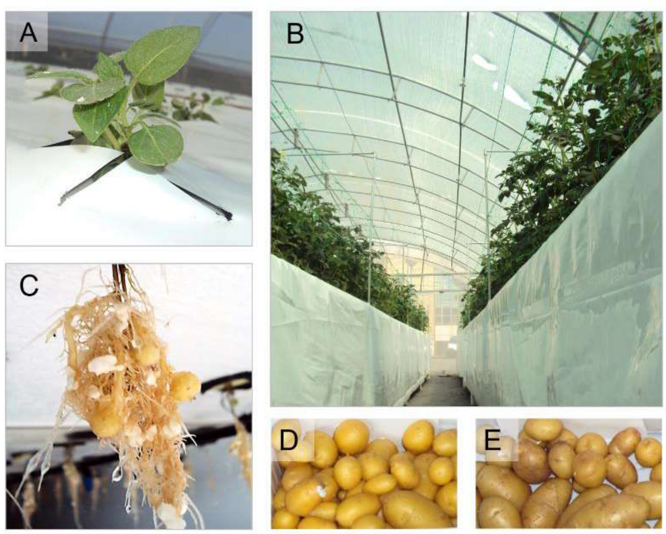

Figure 1. Cultivation of potato plants in the aeroponic system. (A) The foliage of potato plants after transfer to aeroponics. (B) Aeroponic facility for potato cultivation. (C) Belowground parts of potato plants in the aeroponic module at the beginning of tuber bulking. (D) Minitubers collected from aeroponically grown Agria plants. (E) Minitubers collected from aeroponically grown Sinora plants

Temperatures were measured in the aeroponic module (root zone) and greenhouse (haulm and leaves zone) of the aeroponic facility during the entire period of plant cultivation (Figure 2). The temperatures in the root zone of potato plants are especially important for the initiation and bulking of tubers, with the optimum for tuber initiation and tuber filling/growth in the 16-19 °C and 18-22 °C range, respectively (Broćić et al., 2019a). In the aeroponic module, daily average temperatures were significantly higher in the first half of the growing period (22.6 ºC) compared to the second part (16.6 ºC).

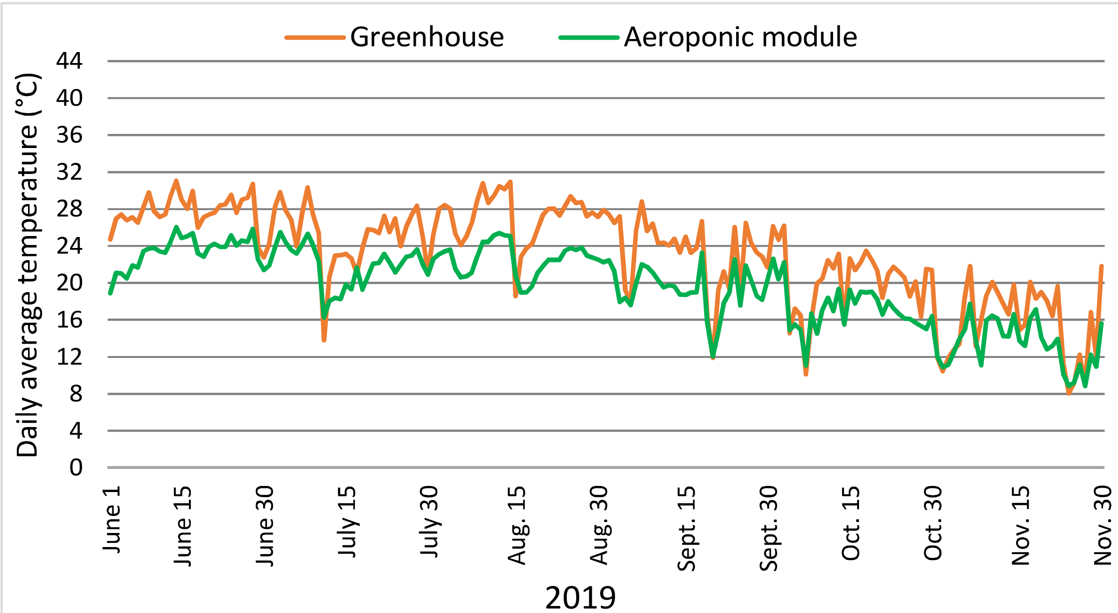

Figure 2. Temperature conditions in the aeroponic module and greenhouse during plant cultivation in 2019

Results and Discussion

Dynamics of Minituber Formation

Tuberization of Agria and Sinora plants of minituber origin started in July, 30-40 days after planting in the aeroponics. Agria plants steadily tuberized during the rest of the cultivation period (Figure 3A) and formed a significantly larger number of minitubers compared to cultivar Sinora which quickly completed the vegetative cycle (end of September). The highest number of minitubers was measured at the I-IV harvest in Sinora plants originating from minitubers and at the final harvest (X harvest) in Agria plants of the same origin (Figure 3A).

In general, a higher number of minitubers per harvest was collected from Sinora plants during the first part of the cultivation period and from Agria plants during the second half of the growing period. Sinora is an early maturing cultivar (85-90 days in open field production in Serbia), and it seems that aeroponic cultivation did not affect this developmental trait. On the other hand, Agria is a late maturing cultivar (120–135 days in open field production in Serbia) that was tuberizing during July – November, producing more tubers during the second half of the period when temperatures were closer to an optimum range for tuber initiation.

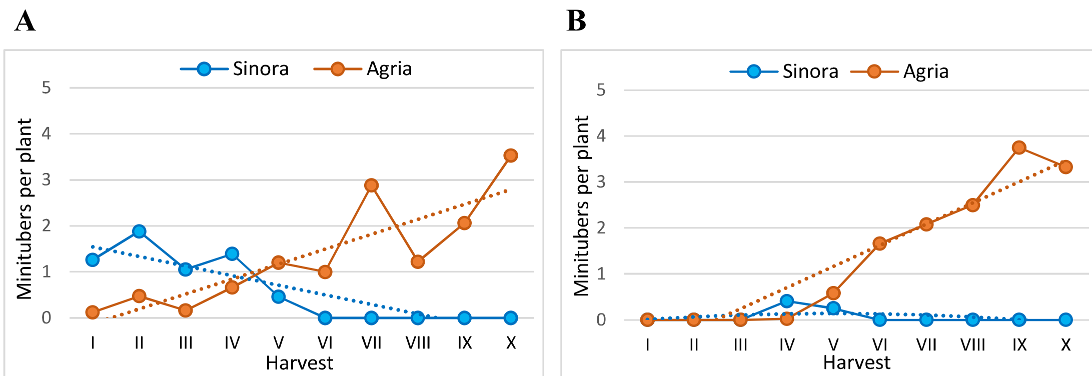

Figure 3. The dinamics of minituber formation for two potato cultivars grown in the aeroponic system. (A) The number of formed and collected minitubers per plant of minituber origin; (B) The number of minitubers per plant of *in vitro* origin

Concerning plants of *in vitro* origin, the first minitubers of Sinora and Agria were collected at the end of August (IV harvest). Rates of minituber formation were minor in Sinora plants, and the final number of minitubers was reached at the V harvest (Figure 3B). In Agria, the highest number of minitubers per harvest was collected at the end of the cultivation period (IX-X harvest). The heaviest tubers formed by Sinora plants of minituber origin (Figure 4A) were recorded at the beginning of the cultivation period (I and II harvest), while the lightest were measured at the harvest in mid-September (V harvest).

Considering Sinora plants of *in vitro* origin, masses of minitubers were minor, and only two harvests were conducted in the middle of the cultivation period (Figure 4B). The highest masses of Agria minitubers, produced by plants of both origins (Figure 4A and B), were measured in the middle of the cultivation period (IV-VI harvest). A decrease in the mass of Agria minitubers was observed in later harvests (the second part of the cultivation period) when daily average temperatures were favourable for tuber initiation, but not optimal for tuber bulking.

Nevertheless, the tuber mass in the later harvests was mostly above 8 g, which is considered by Farran and Mingo-Castel (2006) as sufficient for further usage as planting material.

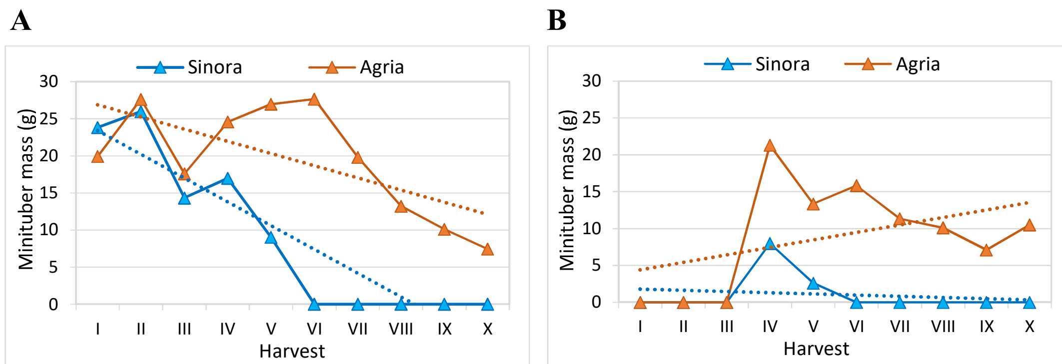

Figure 4. Tuber mass at harvest of two potato cultivars grown in the aeroponic system. (**A**) Minituber mass per harvest – plants of minituber origin; (**B**) Minituber mass per harvest – plants of *in vitro* origin

Effects of cultivar and plant origin on minituber production

Results of the two-way ANOVA revealed that both investigated factors, cultivar and plant origin, significantly affect the aeroponic production of minitubers (Table 1).

Table 1**.** Two-way ANOVA for potato minituber production in an aeroponic system

Parameter	Factor	df	SS	MS	F	*p*	Sig.
Number of minitubers per plant	Cultivar	1	307.446	307.446	137.889	2.53×10^{-6}	***
	Plant origin	1	15.098	15.098	6.771	3.15×10^{-2}	*
	Cultivar x Plant origin	1	24.596	24.596	11.031	1.05×10^{-2}	*
Minituber mass	Cultivar	1	59.541	59.541	29.108	6.50×10^{-4}	***
	Plant origin	1	285.480	285.480	139.562	2.42×10^{-6}	***
	Cultivar x Plant origin	1	27.816	27.816	13.598	6.15×10^{-3}	**
Yield per m^2	Cultivar	1	45.107	45.107	85.806	1.50×10^{-5}	***
	Plant origin	1	15.489	15.489	29.464	6.25×10^{-4}	***
	Cultivar x Plant origin	1	0.205	0.205	0.391	5.49×10^{-1}	-

Note: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

The investigated factors affected the total number of minitubers formed per potato plant. A significant two-way interaction of cultivar: plant origin (Table 1) indicated that the effect of plant origin differs between the cultivars. The largest number of minitubers per plant (13.92) was recorded in the Agria plants of *in vitro* origin, while the lowest number was registered in Sinora (0.93) of the same origin (Figure 5A). The post hoc analysis (multiple group comparison) revealed that the plant origin did not significantly affect the number of formed minitubers in Agria. This concurs with our previous findings for this cultivar obtained in the 2018 season (Broćić et al., 2019b). Conversely, plant origin significantly influenced the number of tubers produced by Sinora plants. Sinora plants of minituber origin formed a significantly larger number of minitubers than plants of *in vitro* origin (Figure 5A).

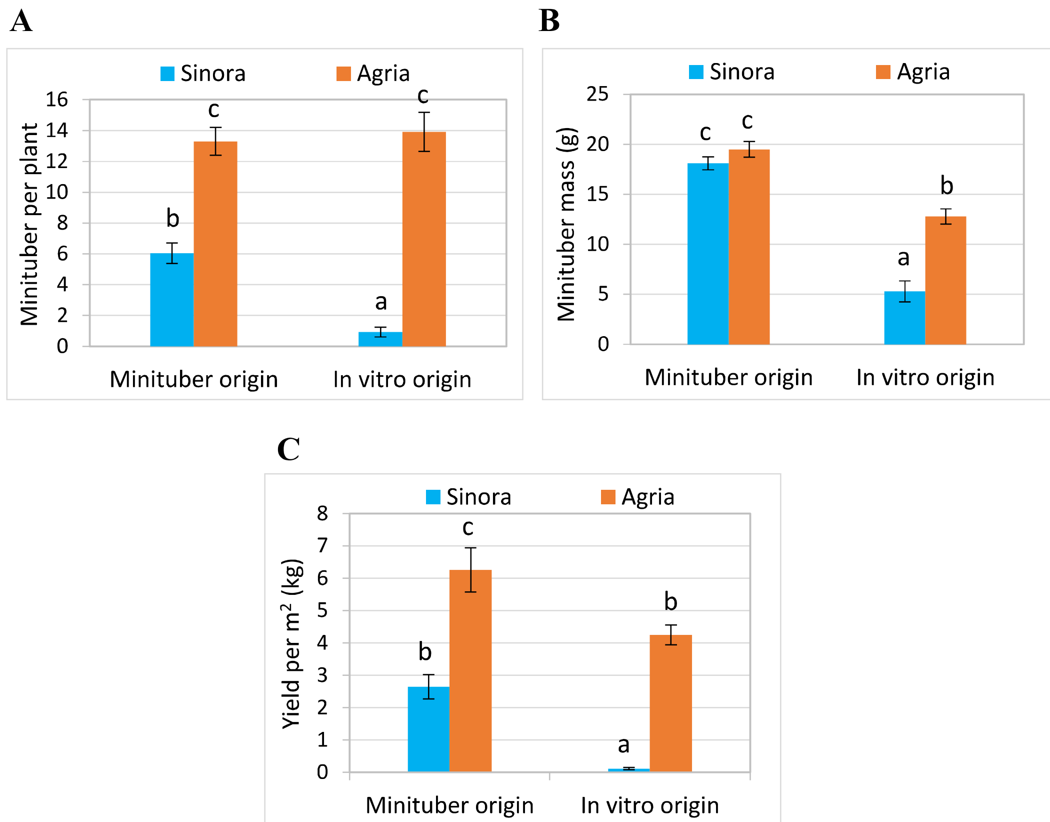

Figure 5. Effects of cultivar and plant origin on potato minituber production in aeroponic system. (A) The total number of minitubers formed per plant, (B) minituber fresh mass, and (C) yield per m^2 (24 plants) were quantified at the end of the cultivation period

The average mass of minitubers of two investigated cultivars was significantly higher in the plants originating from minitubers compared to plants of *in vitro* origin (Figure 5B). A significant two-way interaction of cultivar: plant origin (Table 1) indicated that the effect of factor cultivar differs between the plants of different origins. Indeed, Agria and Sinora plants of minituber origin produced tubers of similar mass, while Agria plants of *in vitro* origin produced significantly heavier tubers than Sinora. The yield was affected by the investigated factors of cultivar and plant origin (Table 1). Agria and Sinora plants of minituber origin gave a higher yield per m^2 than plants of *in vitro* origin (Figure 5C). The highest yield of minitubers (6.26 kg m^{-2}) was recorded in the Agria plants originating from minitubers, while the lowest yield was registered in Sinora of *in vitro* plant origin (0.11 kg m^{-2}).

Conclusion

The results of our study revealed that factors: plant origin and potato genotype affect the process of tuberization and, subsequently, minituber yield in aeroponically grown potato. In general, minituber-originated plants of both cultivars produced heavier tubers and gave better yields than plants of *in vitro* origin. However, Sinora plants of both origins quickly completed the growth cycle and had significantly lower yields than Agria plants, which indicates that it is not quite suitable cultivar for aeroponic cultivation.

Acknowledgments

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