

## Article

# Minituber Production of Some Potato Varieties in Aeroponics Comparing with Substrate Culture

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<https://doi.org/10.37229/fsa.fjh.2026.04.28>

## Future Science Association

Available online free at  
[www.futurejournals.org](http://www.futurejournals.org)

Print ISSN: 2692-5826

Online ISSN: 2692-5834

Received: 26 February 2026

Accepted: 10 April 2026

Published: 28 April 2026

**Publisher's Note:** FA stays neutral with regard to jurisdictional claims in published maps and institutional affiliations.



**Abstract:** The study was conducted in a plastic greenhouse located in Dokki, Giza, Egypt (Potato and Vegetatively Propagated Vegetables Research Department, Horticulture Research Institute, Agricultural Research Center, Giza, Egypt) during two seasons November-February 2021/2022 and 2022/2023. The aim of this study was to investigate minituber production for three potato varieties in aeroponic culture system versus peat moss based substrate. The differences between aeroponic and peat moss based substrate were significant with the superiority of aeroponic culture system in vegetative growth characteristics and minituber yield number. However, the substrate culture system produced lower minituber numbers per area unit with higher average minituber weights. Furthermore, the three tested potato varieties (Diamant, Hermes and Lady Rosetta) differed significantly in vegetative growth parameters and minitubers yield. The results recommend the use of aeroponic culture system in Egyptian local seed potato production as a tool to maximize the number of pre-basic seed potato minitubers production per unit of area.

**Keywords:** Potato, Seed potato production, Minituber, Aeroponic.

## 1. Introduction

Potato (*Solanum tuberosum* L.) occupies the third food crop in terms of human consumption, after wheat and rice (Devaux *et al.*, 2020). The potato global production in 2022 was 390.4 million tons (FAO, 2026). Potatoes are propagated vegetatively, causing the accumulation of diseases and degeneration (Struik and Wiersema, 2012). To avoid seed potato degeneration, Egypt yearly imports large quantities (116-140 thousand tons) of seed potatoes from Europe; for summer. Advanced seed potato production systems depend on the production of nuclear stock (Germplasm) of plantlets free from diseases specially virus diseases and preserved in plant tissue culture laboratories then propagation of these nuclear stocks *in vitro* (Kawakami *et al.*, 2015). After micropropagation *in vitro* the obtained materials (plantlets or microtubers) are transferred to *semi-in vivo* conditions (greenhouses) for

minituber production as an intermediate stage between plant tissue culture lab, and production of potato basic seeds in open fields (Struik, 2007). Minitubers are planted in isolated open fields or in screen houses for basic seed production. Increasing multiplication rate and reducing number of generations in open fields is critical issue in reducing diseases accumulation in progeny tubers. The use of soilless culture attracted the attention as a tool for pre-basic seed potato production avoiding soil born diseases (Boersig and Wagner, 1988; Millam and Sharma, 2007 and Bročić *et al.*, 2021) and increasing the number of produced minitubers which can reduce generations especially in some countries lacking isolated cool area with low population of virus transmitting insects (peach aphids; *Myzus persicae*) needed for pre-basic and basic seed potato production (Buckseth *et al.* 2016). In South Korea hydroponic or aeroponic culture is used for minituber production in solution culture (Kang *et al.*, 1996; Kim *et al.*, 1997 and Chang *et al.*, 2000). The common production procedure for minitubers is by transplanting *in vitro* plantlets in substrate i.e., peat moss, perlite, vermiculite (Struik and Wiersema, 2012). The main limitations in substrate production are the multiplication rate (2–5 tubers per cultivated microplant) and variable size of minitubers (Bročić *et al.*, 2021). However, growing potatoes in hydroponics produced more tubers than peat moss and sand mixture (Muro *et al.*, 1997). Furthermore, hydroponic culture produced two folds tuber per square meter comparing with peat moss (Rolot and Seutin, 1999). Potato plants in aeroponics show extended vegetative growth and delayed in tuber production with higher minituber yield than hydroponics and beds (Ritter *et al.*, 2001). Also, Factor *et al.* (2012) obtained higher multiplication rate in aeroponics than in nutrient film technique or deep flow culture.

In the current study the possibility of using aeroponic culture system was examined under Egyptian conditions for three varieties as substitute for minituber production in peat moss based substrates. The studied varieties were three potato varieties of importance in Egypt consumed for processing as crisp (Hermes and Lady Rosetta) or as French fries and table variety (Diamant).

## 2. Materials and Methods

The study was conducted in a plastic greenhouse located in Dokki, Giza, Egypt (Potato and Vegetatively Propagated Vegetables Research Department, Horticulture Research Institute, Agricultural Research Center, Giza, Egypt) during two seasons November 2021- February 2022 and November 2022- February 2023. The greenhouse was equipped with fan and bad cooling system to automatically control temperature ( $25 \pm 2^{\circ}\text{C}$ ). The light intensity inside the greenhouse average was 300 micromole/m<sup>2</sup>.s during the study period (November- February). This experiment included 6 treatments which were the combinations between 2 cultures systems and 3 varieties.

### Plant material

In February 2022 and 2023 *in vitro* meristem cultures of three potato (*Solanum tuberosum* L.) varieties (Diamant, Hermes and Lady Rosetta; as processing cultivars cultivated in Egypt) were obtained by excision of apical meristem from sprouts after surface sterilized with sodium hypochlorite (1%) then meristematic tips were excised under stereomicroscope in sterile conditions (laminar flow hood) and planted on MS medium (Murashige and Skoog, 1962) salts and vitamins (Caisson Laboratories Inc. USA) supplemented with 10 mg/l adenine sulfate, 2 mg/l calcium pantothenate, 0.1 mg/l GA<sub>3</sub>, 30 g/l sucrose and 7 g/l agar. *In vitro* produced potato plantlets derived from meristem culture were tested for freeness of viruses (Potato Virus X, Potato virus Y, Potato leaf roll virus); the free virus plantlets were multiplied *in vitro* every 21 days for 5 subcultures (from June till October 2022 and 2023, respectively) then acclimatized in greenhouse for three weeks by planting in seedling trays filled with peat moss substrate and covered with polyethylene sheet for three days thereafter the cover was gradually removed

(Fig. 1-a& 1-b). The produced transplants were used as the plant material for culture in aeroponic modules (Fig. 1-c). or in peat moss substrate (Fig. 1-f). The transplanting occurred in two years 2021 and 2022 on 1st November.

### Treatments and experiment design

This experiment included 6 treatments which were the combinations between 2 culture systems and 3 varieties. A split plot design with three replications was used to compare the production of the two culture systems; substrate versus aeroponic culture in the main plot and three varieties (Diamant, Hermes, and Lady Rosetta) in the subplot.

### Substrate culture

A substrate consisting of peat moss, perlite, and vermiculite (2:1:1) was used for substrate culture (which is followed in the commercial production scheme). The culture containers were plastic trays (54, 35, and 29 cm; length, width and height, respectively) containing 20 cm depth substrate. Each 4-plastic trays were considered an experimental unit (each 4 tray contained 24 plants). Each treatment contained three replicates (33 plants/ m<sup>2</sup>). Trays were irrigated with the same nutrient solution used in aeroponic culture (Chang *et al.*, 2000).

**The aeroponic culture system** consisted of modules (replicate) 1 m height above ground concrete brick walls 1.20 m wide and 5 m in length the inner side of the module leaned with black polyethylene sheets, the upper side was covered with 120 cm length and 60 cm width styrofoam sheets (3 cm thickness) with holes (15 x 20 cm distance) for transplanting the plantlets, 33 plant/m<sup>2</sup>. The running nutrient solution in a closed circle was used by spraying the nutrient solution on plant roots inside the module through fine mist foggers (6 L/hr, 55-micron droplet size) spaced 50 cm between each other; the nutrient solution was collected back to the tank by drainage tubes for recirculation. The foggers were automatically operated to deliver the nutrient solution every 7 minutes for 30 seconds. Each of three modules was connected to a nutrient solution tank (500 Liter). The nutrient solution was substituted completely every 7 days. The pH (5.5-6.5) and EC (1.8- 2.5 mS/cm) were measured and followed during the growth period. The used nutrient solution was developed by Chang *et al.* (2000), containing macro-nutrients: N, P, K, Ca, and Mg at 200, 42, 293, 42, and 110 mg/l, respectively in the first two months then N, P, K, Ca, and Mg at 200, 42, 332, 36, and 130 mg/l till the end of the culture period, also, contained Fe, Mn, B, Zn, Cu, and Mo at 3.0, 0.5, 0.5, 0.05, 0.02, and 0.01 mg/l, respectively, as micro-nutrients for all the production period.

Data of vegetative growth after 60 days, i.e., stem length, leaves number, fresh and dry weight of stems, leaves.

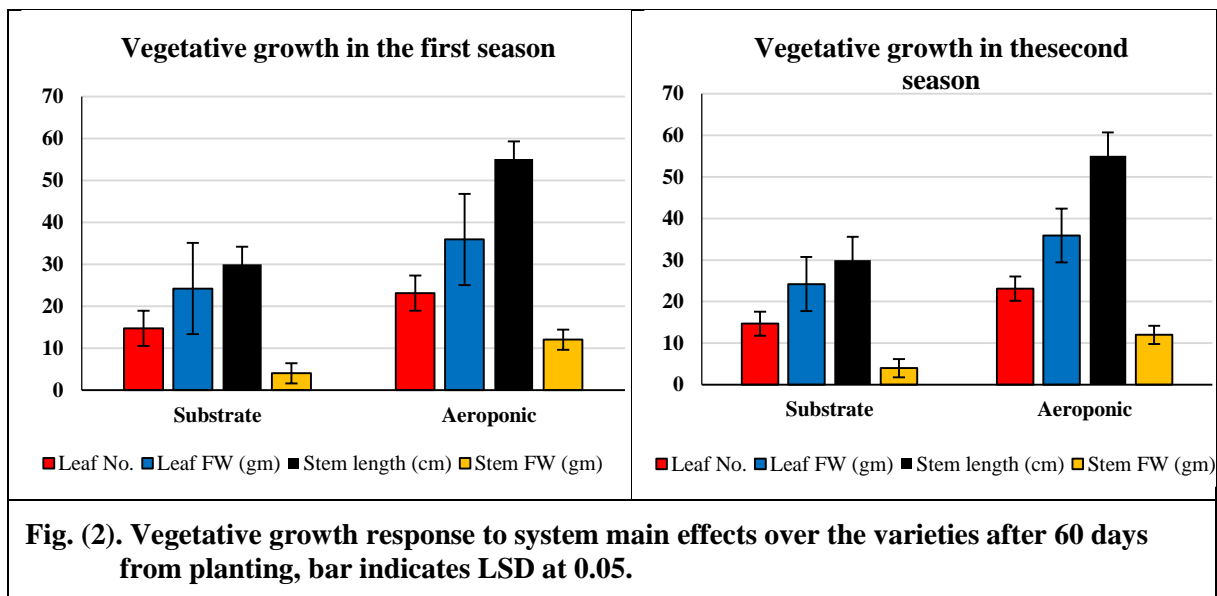
Minituber yield data were collected at harvest time (one time) in substrate cultures (after 120 days) while in aeroponic cultures were collected in multiple harvests (10 harvests); beginning from the first week in January, tubers larger than 20 mm were harvested weekly while in the last harvest (after 120 days) minitubers were divided to large minitubers (>20 mm) and small minitubers (<20 mm). Data were subjected to ANOVA using Statistix 10 software. Means were compared using least significant difference ( $P \leq 0.05$ ).



**Fig. (1).** a: virus free plantlets produced in vitro; b: acclimatized plantlets; c: transplanting in aeroponic system; d: growing in aeroponics e: growth and yield in aeroponic; f: Plants in substrate after 60 days.

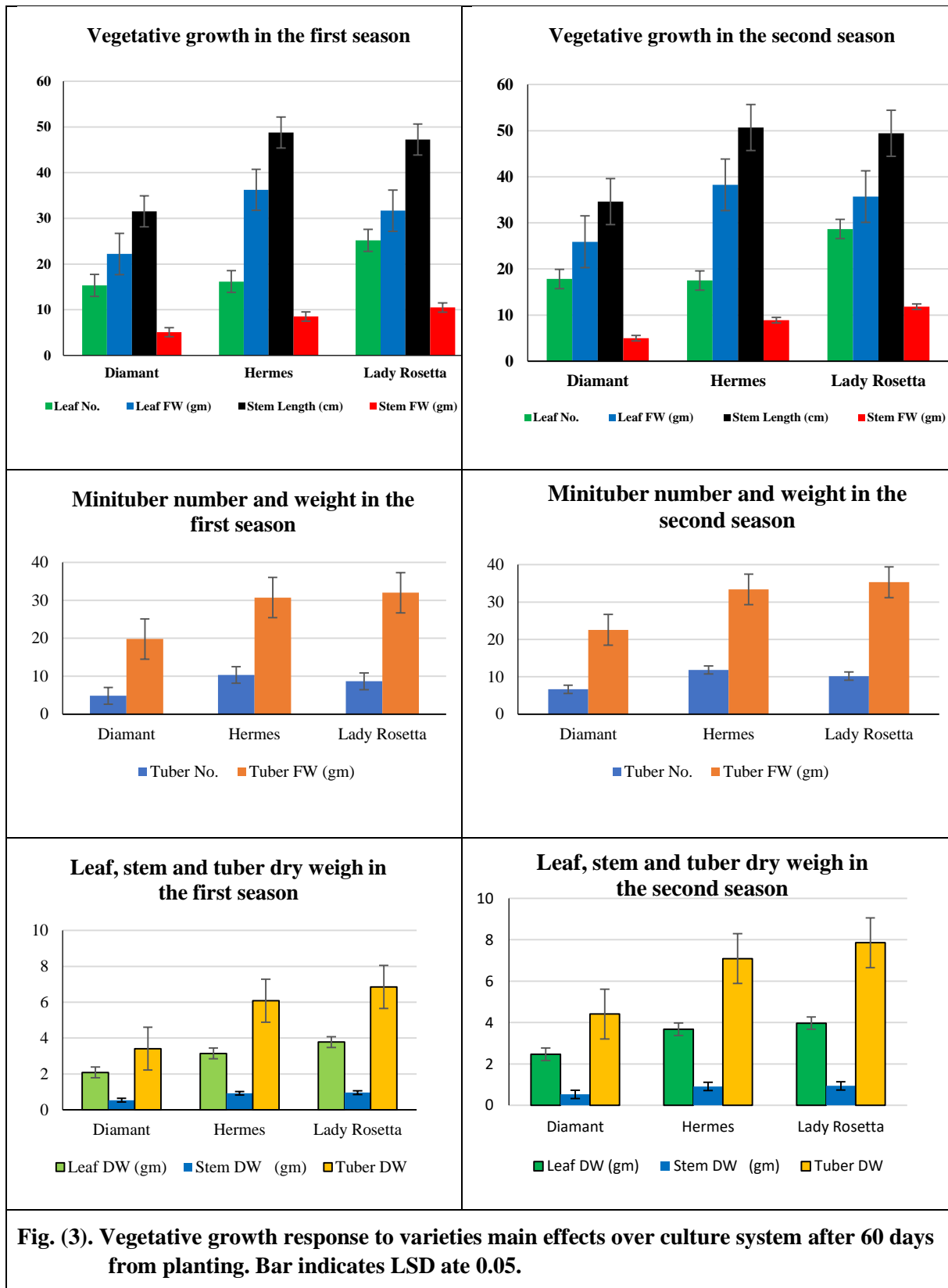
### 3. Results

After 60 days from transplanting vegetative growth parameters showed significant differences between the two culture systems (average of the three varieties) in both seasons. The aeroponic culture system enhanced leaf number, fresh weight and stem fresh weight more than the substrate culture system in both seasons (Fig. 2). However, the differences between the two systems for leaves dry weight were not significant for both seasons. Furthermore, obtained data showed significant differences between varieties (average of the two culture systems) for leaf number, leaf fresh weight, stem length, stem fresh and stem dry weight after 60 days from planting in both seasons (Fig. 3). Leaf number, leaf dry weight, stem fresh and stem dry weight in both seasons were highest in Lady Rosetta compared to Hermes or Diamant. Stem length and leaf fresh weight values were highest in Hermes followed by Lady Rosetta. However, Diamant recorded the lowest leaf number and stem length (Fig. 3).



At the end of the season, the characteristics of minitubers yield obtained results showed superiority for the aeroponic system (as average of the three tested varieties) for the number of minitubers were produced per square meter and per plant (Table 1, Fig. 4). Aeroponic produced more than three folds the number of minitubers produced in peat moss substrate per unite of area and per plant. Also, the weight of minitubers per plant was higher in aeroponic. Furthermore, larger than 20 mm minitubers were significantly higher in the aeroponic system. Also, aeroponic gave a higher average tuber number per plant. On the other hand, the average weight per minituber was higher significant in substrate culture system.

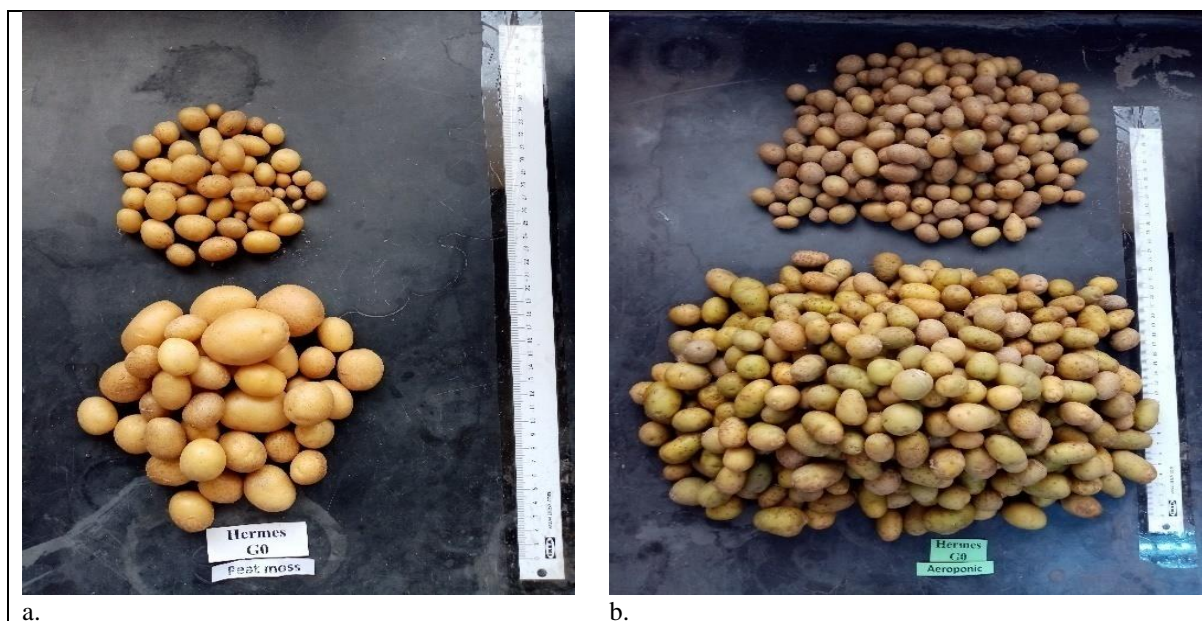
Concerning the main effect of the varieties factor (average of the two culture systems), the differences between varieties were significant for minituber number, weight, and number of large minitubers per square meter. The minituber number per square meter was higher in Hermes and Lady Rosetta than in the Diamant variety in both seasons. Furthermore, the same was true for the minituber weight per square meter and the number of large minituber per square meter in the first season only. While in the second season larger minituber per square meter were produced by Lady Rosetta than Hermes and Diamant varieties. Data were not significant concerning smaller than 20 mm size minitubers number per square meter in both seasons. Average minituber size was higher in Hermes and Lady Rosetta variety in both seasons. However, minituber average weight results were significant in the second season only, with superiority for the Lady Rosetta variety, followed by the Diamant and Hermes variety, which came in the last rank.



Interaction between culture system and varieties was significant; Lady Rosetta and Hermes varieties under the aeroponic culture system produced the highest minituber number and weight per m<sup>2</sup> in both seasons. Also, the average tuber number per plant was higher in Lady Rosetta and Hermes in both seasons. On the other hand, Lady Rosetta and Diamant varieties in substrates produced higher average minituber weight. However, Interaction between culture system and varieties was not significant in smaller than 20 mm size minitubers number per square meter in both seasons.

**Table (1). Minituber yield characteristics of three potato varieties as affected by Substrate and aeroponic culture system**

System	Variety	Minituber No./m <sup>2</sup>	Minituber Weight (g)/m <sup>2</sup>	Large minituber (>20 mm) No./m <sup>2</sup>	Small minituber (<20 mm) No./m <sup>2</sup>	Average minituber No./plant	Average minituber weight (g)/plant
<b>First season (2021/2022)</b>							
<b>Substrate</b>		<b>140.3</b>	<b>1140.3</b>	<b>43.7</b>	<b>96.8</b>	<b>4.2</b>	<b>8.4</b>
<b>Aeroponic</b>		<b>741.9</b>	<b>3551.9</b>	<b>464.0</b>	<b>277.8</b>	<b>22.3</b>	<b>4.8</b>
<b>LSD at 0.05</b>		<b>457.9</b>	<b>2233.4</b>	<b>226.6</b>	<b>NS</b>	<b>13.7</b>	<b>2.7</b>
	<b>Diamant</b>	<b>368.3</b>	<b>1770.8</b>	<b>183.8</b>	<b>184.5</b>	<b>11.1</b>	<b>6.4</b>
	<b>Hermes</b>	<b>491.5</b>	<b>2659.2</b>	<b>284.3</b>	<b>207.3</b>	<b>14.8</b>	<b>6.2</b>
	<b>Lady Rosetta</b>	<b>463.5</b>	<b>2608.3</b>	<b>293.3</b>	<b>170.0</b>	<b>13.9</b>	<b>7.1</b>
	<b>LSD at 0.05</b>	<b>82.9</b>	<b>152.2</b>	<b>41.6</b>	<b>NS</b>	<b>2.5</b>	<b>NS</b>
<b>Substrate</b>	<b>Diamant</b>	<b>134.3</b>	<b>1134.3</b>	<b>29.0</b>	<b>105.7</b>	<b>4.0</b>	<b>9.0</b>
	<b>Hermes</b>	<b>162.0</b>	<b>1162.0</b>	<b>64.3</b>	<b>98.0</b>	<b>4.9</b>	<b>7.2</b>
	<b>Lady Rosetta</b>	<b>124.0</b>	<b>1124.7</b>	<b>37.7</b>	<b>86.7</b>	<b>3.7</b>	<b>9.1</b>
<b>Aeroponic</b>	<b>Diamant</b>	<b>602.3</b>	<b>2407.3</b>	<b>338.7</b>	<b>263.3</b>	<b>18.1</b>	<b>3.9</b>
	<b>Hermes</b>	<b>821.0</b>	<b>4156.3</b>	<b>504.3</b>	<b>316.7</b>	<b>24.6</b>	<b>5.3</b>
	<b>Lady Rosetta</b>	<b>802.3</b>	<b>4092.0</b>	<b>549.0</b>	<b>253.3</b>	<b>24.1</b>	<b>5.2</b>
<b>LSD at 0.05</b>		<b>461.4</b>	<b>2235.2</b>	<b>228.4</b>	<b>NS</b>	<b>13.8</b>	<b>2.9</b>
<b>Second season (2022/2023)</b>							
<b>Substrate</b>		<b>145.7</b>	<b>1287.0</b>	<b>45.3</b>	<b>107.7</b>	<b>4.4</b>	<b>9.1</b>
<b>Aeroponic</b>		<b>786.1</b>	<b>4006.2</b>	<b>518.3</b>	<b>300.1</b>	<b>23.6</b>	<b>5.1</b>
<b>LSD at 0.05</b>		<b>146.9</b>	<b>401.9</b>	<b>208.1</b>	<b>11.5</b>	<b>4.4</b>	<b>2.1</b>
	<b>Diamant</b>	<b>389.2</b>	<b>2053.3</b>	<b>193.7</b>	<b>200.5</b>	<b>11.7</b>	<b>6.9</b>
	<b>Hermes</b>	<b>513.0</b>	<b>2827.9</b>	<b>302.2</b>	<b>216.2</b>	<b>15.4</b>	<b>6.4</b>
	<b>Lady Rosetta</b>	<b>495.5</b>	<b>3053.3</b>	<b>349.7</b>	<b>195.3</b>	<b>14.9</b>	<b>7.9</b>
	<b>LSD at 0.05</b>	<b>65.4</b>	<b>225.1</b>	<b>11.3</b>	<b>NS</b>	<b>2.0</b>	<b>0.6</b>
<b>Substrate</b>	<b>Diamant</b>	<b>143.3</b>	<b>1303.5</b>	<b>30.3</b>	<b>113.1</b>	<b>4.3</b>	<b>9.4</b>
	<b>Hermes</b>	<b>164.7</b>	<b>1260.8</b>	<b>65.0</b>	<b>110.3</b>	<b>4.9</b>	<b>7.7</b>
	<b>Lady Rosetta</b>	<b>129.0</b>	<b>1296.9</b>	<b>40.7</b>	<b>99.7</b>	<b>3.9</b>	<b>10.2</b>
<b>Aeroponic</b>	<b>Diamant</b>	<b>635.0</b>	<b>2813.6</b>	<b>357.0</b>	<b>288.1</b>	<b>19.1</b>	<b>4.5</b>
	<b>Hermes</b>	<b>861.3</b>	<b>4395.1</b>	<b>539.3</b>	<b>322.3</b>	<b>26.2</b>	<b>5.1</b>
	<b>Lady Rosetta</b>	<b>862.0</b>	<b>4809.8</b>	<b>658.7</b>	<b>290.3</b>	<b>25.9</b>	<b>5.6</b>
<b>LSD at 0.05</b>		<b>158.3</b>	<b>456.7</b>	<b>208.2</b>	<b>NS</b>	<b>4.7</b>	<b>2.2</b>



**Fig. (4).** Hermes variety yield of minitubers in a. substrate/24 plant) and b. yield of multiple harvests in aeroponic/24 plant of two sizes > 20 mm (bottom the photo) and < 20 mm (upper the photo)

#### 4. Discussion

The obtained results of the superiority of growing plants in aeroponics over those growing in substrates could be due to higher aeration for root systems and the continuous supply of nutrient solution supporting stronger growth of haulm and roots (Fig. 3). Also, in aeroponics minitubers yield was higher (Table 1). In the same respect, previously suggested manipulation of nutrition after the *in vitro* phase in the greenhouse improves potato minitubers yield and characteristics (Lommen and Struik, 1992; Ranalli, 1997 and Struik and Lommen, 1999). Moreover, aeroponics enhances extended vegetative growth and delayed tuber production with higher minituber yield than substrates (Ritter *et al.*, 2001). In the current study aeroponic system with multiple harvests were followed which allow small tubers to grow because of breaking of the dominance, reducing tuber resorption and initiation of new tubers (Lommen and Struik, 1992; Buckseth *et al.*, 2016; Tiwari *et al.*, 2022 and Buckseth *et al.*, 2024). Moreover, Rykaczewska (2016) reported that aeroponic produced two to three folds number of tuber more than in soil substrates. However, minitubers production in aeroponics or hydroponic produces larger numbers of smaller minitubers than in soil substrate (Muro *et al.*, 1997; Rolot and Seutin, 1999; and Rykaczewska, 2016). On the other hand, the lower number of potatoes minitubers were produced in peat moss substrate culture system allowing for higher assimilates translocation per single tuber which reflected on higher average minituber weight in substrate than in aeroponics (Table 3). In the same respect, it was reported that potato plants in aeroponic gave higher minitubers yield than substrate but with lower minituber weight (Ritter *et al.*, 2001 and Factor *et al.*, 2012).

The differences between varieties, either in vegetative growth or in minitubers yield are related to the genetic variation between different potato varieties (Gopal and Minocha, 1997; Rolot and Seutin, 1999; Ahloowalia, 1999 and Struik, 2007). Furthermore, the three varieties have different maturity behaviour; Lady Rosetta is medium early maturity variety, while Diamant and Hermes are medium early to medium late varieties. In the same respect, the growth of the medium early variety Superior was better in aeroponic than that of the medium late variety Atlantic (Chang *et al.*, 2012). Also, Monalisa and Zorba varieties were grown in aeroponic produced higher numbers of minitubers than Agria (Tierno *et al.*, 2014).

## 5. Conclusion

The current study illustrates that use of aeroponic is an efficient tool for maximizing the number of minitubers in pre-basic seed potato production and reducing the number of generations which could enhance local Egyptian seed potato production. For efficient local application of aeroponic system in pre-basic seed potato production different growth factors need to be considered in further studies.

## Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

## Acknowledgements

The authors are grateful to the Egypt governmental parties; Agricultural Research Center, Horticulture Research Institute and Science Technology & Innovation Funding Authority (STDF) for supporting this work.

## Funding

This study is based upon work supported by Science, Technology & Innovation Funding Authority (STDF), Egypt; under grant STDF Basic & Applied Research Grants (BARG Call 7 - Project ID 37069).

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