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Pre-Basic Seed Potato Production in Egypt: Comparative Studies on Potato Nutrition in Aeroponics

M.M. Khalil[(1)#], M.M. Samy[(1)], M.K. Abd El Halem[(1)], M.S. Emam[(2)]
[(1)]Potato and Vegetatively Propagated Vegetables Department, Horticulture Research Institute, Agricultural Research Center, Giza, Egypt; [(2)]Central Laboratory for Agricultural Climate, Agricultural Research Center, Giza, Egypt.

THE PRODUCTION of potato pre-basic seed in aeroponic cultures was compared using three different nutrient solutions. Significant differences were recorded in the leaf content of elements P, K, Mg, Fe, B, Mn, and Zn, but not N or Ca, during vegetative growth. The differences between the main effects of the three tested nutrient solution formulas in mini-tuber yield characteristics did not reach the significance level. However, varieties differed significantly in vegetative growth parameters, leaf content of elements, and mini-tuber yield. The Cara variety gave the highest large mini-tuber yield (>18 mm size) per plant in both seasons (20.5 and 27, respectively). Furthermore, the Cara variety yielded the highest total mini-tubers per plant in the second season (39.1). In contrast, in the first season, Cara and Hermes gave the highest significant total mini-tuber yield per plant (29.1 and 28.5, respectively). Diamant recorded the lowest values of mini-tuber number and weight per plant. The interaction between Cara and the second nutrient solution formula resulted in the highest number of large mini-tubers per plant in both seasons (25.4 and 33.4, respectively). The results support the aeroponic culture's use in the local production of pre-basic seed potato mini-tubers.

Keywords: Aeroponic, Mini-tuber, Potato, Seed potato production.

Introduction

Potato is one of the world's most important food crops (wheat, rice, corn, and potato). The global potato production in 2021 reached 376 million tons (FAO, 2023). The potato is propagated by vegetative means, causing the accumulation of diseases and degeneration (Struik & Wiersema, 2012). Egypt imports 120- 150 thousand tons of seed potatoes from northern European countries for summer season plantation annually. Modern seed potato production systems depend on a nuclear stock of plants free from diseases, especially virus diseases, and multiply it *in vitro* (Kawakami et al., 2015). Pre-basic seeds are produced after several subcultures *in vitro* and then transferred to *semi-in vivo* conditions (greenhouses) for mini-tuber production as an intermediate step between multiplication *in vitro* and production in open fields (Struik, 2007; Adly et al., 2023). Mini-tubers are planted in isolated open fields for the next generations of production. Increasing the multiplication rate and reducing the number of generations in open fields is a crucial point in reducing disease accumulation in progeny tubers. Recently, the use of soilless culture has provided an advantage for pre-basic seed potato production by avoiding soil porn diseases (Millam & Sharma, 2007) and increasing the number of mini-tubers produced, which could reduce the number of generations, especially in countries lacking isolated cool area with a low population of virus-transmitting insects (peach aphids; *Myzus persicae*). Furthermore, Tierno et al. (2014) recommended aeroponic culture for a high-quality pre-basic seed potato production system under temperate conditions. Solution culture was used in plant nutrition and physiology studies of factors affecting tuberization in potatoes (Hougland, 1947; Hougland & Arnon, 1950; Krauss & Marschner, 1982; Wan et al., 1994). Furthermore, NASA conducted a series of studies on potato cultivation in life-supporting systems in space using nutrient solution cultivation (Wheeler, 2006). Boersig & Wagner (1988) suggested the use of aeroponics for

[#]Corresponding author emails: m.mohammad66@yahoo.com, mohammad.khalil@arc.sci.eg Phone: 01004482677
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seed potato production. South Korean studies (Kang et al., 1996; Kim et al., 1997; Chang et al., 2000) led to the transformation to mini-tuber production in solution culture. Studies were conducted in different countries, i.e., Spain (Muro et al., 1997; Farran & Mingo-Castel, 2006; Tierno et al., 2014), Belgium (Rolot & Seutin, 1999), Brazil (Corrêa et al., 2007), Peru (Mateus-Rodriguez et al., 2012), India (Bucksetha et al., 2016), and Kenya (Mbiyu et al., 2012). Moreover, CIP released a manual for seed potato production by aeroponics (Otazu, 2010; Andrade-Piedra et al., 2019). Recently, Khalil & Hamed (2020) recommended the use of an aeroponic culture system in the acclimatization of *in vitro* potato plantlets and mini-tuber production as a preliminary stage in pre-basic seed programs in Egypt.

The nutrient solution is one of the most important factors affecting potato mini-tuber production in aeroponics (Silva Filho et al., 2022). Nitrogen is one of the most important nutrients that control potato growth, and reducing nitrogen reduces the number of tubers produced while increasing nitrogen delays tuberization and extended vegetative growth (Souza et al., 2013; Oraby et al., 2015; Chang et al., 2016). However, Calori et al. (2022) suggested that each potato cultivar needs a specific nutrition management strategy for plants growing aeroponically.

The current study aims to evaluate aeroponic culture as a tool for local pre-basic seed potato production for varieties of major concern in the Egyptian potato industry. Three different nutrient solutions were used to study the potato mini-tuber production of five potato varieties in aeroponics. The selected five varieties represented 72% (104 thousand tons) of the imported seed potatoes (144 thousand tons) for Egypt's 2023 summer season.

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). The greenhouse was equipped with a fan and a bad cooling system. The aeroponic culture system consisted of concrete brick walls leaned with black polyethylene sheets; the upper side was covered with 120cm length and 60cm width styrofoam sheets (3cm thickness) with holes (15*20cm distance) for transplanting the plantlets. Three separate units were used; each unit consisted of a nutrient solution tank (500L) fertigate three modules (replicate) each one with 1.20m width and 5m length. The nutrient solution running in a closed circle was used by spraying the nutrient solution on plant roots inside the module through fine mist foggers; 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 7min for 30sec. The nutrient solution was substituted completely every 7 days. The pH (5.5-6.5) and EC (1.7- 2.1 mS/cm) were measured and followed during the growth period. *In vitro* produced plantlets derived from meristem culture and multiplied *in vitro* were acclimatized in the greenhouse for three weeks (Fig. 1), and then transplants were used as the plant material for culture in aeroponic modules (Fig. 2). The transplanting occurred in the two years 2021 and 2022 at 1st November.

The experimental design was a split-plot design with three replications; three separated tanks for nutrient solution (main plot). The three compared nutrient solution concentrations are shown in Table 1 (Silva Filho et al., 2020; Mateus-Rodriguez et al., 2014; Chang et al., 2000). Each tank was connected with three culture modules (1.2* 5m), and each module contained 24 plants of the five tested varieties, i.e., Cara, Diamant, Hermes, Lady Rosetta, and Spunta (subplot). Plants were spaced 15*20cm. Data on vegetative growth were recorded after 60 days, i.e., stem length, leaf number, root length, stolon number, fresh weight, and dry weight of stems, leaves, stolons, and roots. Dried leaf samples were used for nutrient determination. Leaf samples were wet-digested using sulphuric-perchloric acid mixtures (AOAC, 1990). Total nitrogen content was determined using the Kjeldahl method (AOAC,1990). Potassium and calcium were determined by a flame photometer (AOAC,1990). Phosphorus, magnesium, iron, manganese, zinc, boron, and copper were determined by Inductively Coupled Plasma Spectrometry (Utima 2 JY Plasma). Total chlorophyll content was determined in the terminal leaflet of the fourth leaf as SPAD using the TYS-B Chlorophyll meter (Kunshan Agritop Technology Co., Ltd.; China). Mini-tuber yield data (number and weight) were collected; beginning from the first week in January, tubers larger than 18 mm were harvested weekly (10 harvests), while in the last harvest, mini-tubers were divided into large (>18mm) and small (<18mm) mini-tubers. Data were subjected to an ANOVA using Statistix 10 software. Means were compared using Tukey's test for at least a significant difference ($P \leq 0.05$).

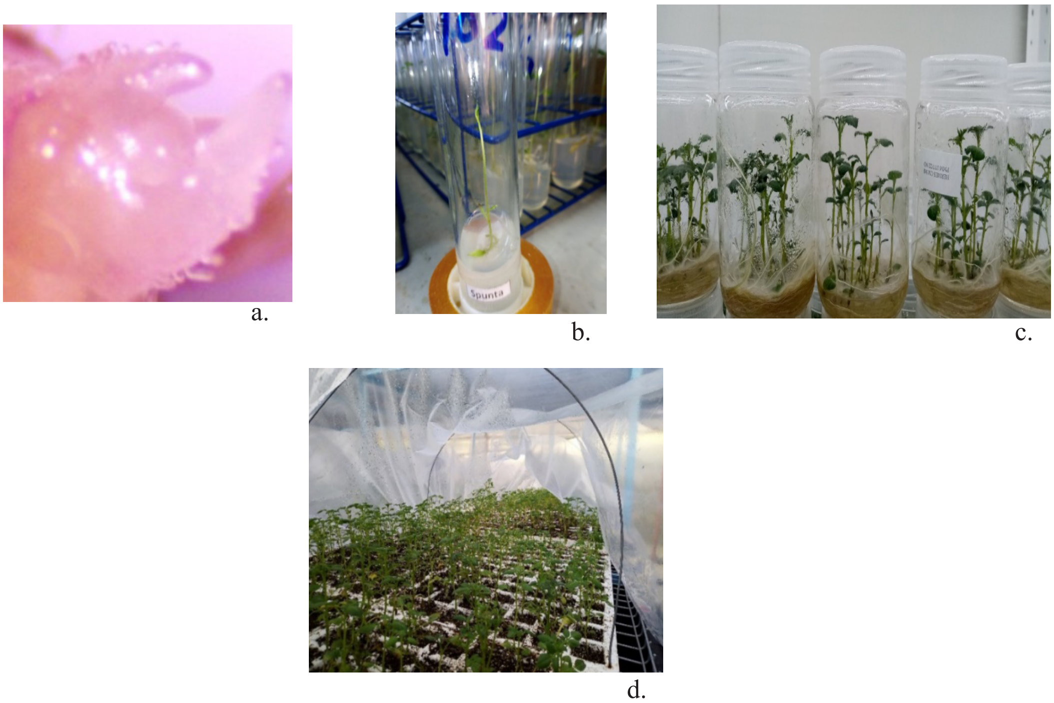

Fig. 1. ***In vitro*** **plantlets produced from meristem culture [(a.); succeeded plantlets free from viruses multiplied** ***in vitro*** **(b. and c.); acclimatization in seedling trays in greenhouses under plastic tunnels (d.)]**

Fig. 2. Mini-tuber production in aeroponics [a: transplants ready for transplanting; b and c: after one month from transplanting; d.: growth of min-tubers; e and f: after 60 days of supporting the plants with strings; f and g: growth of mini-tubers; h and i: harvested min-tubers]

TABLE 1. Composition of the nutrient solution used in the study

Nutrients	Concentration (ppm)					
	Nutrient solution 1 (N1)*		Nutrient solution 2 (N2)*		Nutrient solution 3 (N3)*	
	Stage 1**	Stage 2***	Stage 1**	Stage 2***	Stage 1**	Stage 2***
N	198.00	158.00	198.10	84.00	199.70	203.00
P	39.00	49.00	35.00	35.00	43.40	41.00
K	183.00	229.00	220.00	275.00	293.00	332.00
Ca	142.00	142.00	150.00	150.00	110.00	130.00
Mg	38.00	38.00	58.00	49.00	43.00	36.00
S	52.00	65.00	70.00	70.00	56.00	64.00
Fe	2.00	2.00	1.00	1.00	3.00	3.00
B	0.30	0.30	0.50	0.50	0.50	0.50
Cu	0.02	0.02	0.10	0.10	0.02	0.02
Zn	0.06	0.06	0.15	0.15	0.05	0.05
Mn	0.40	0.40	0.50	0.50	0.5	0.5
Mo	0.06	0.06	0.05	0.05	0.01	0.01
EC (mS/cm)	1.7	1.9	2.0	2.1	1.9	2.1

* Nutrient solution 1 (N1): after Silva Filho et al. (2020); Nutrient solution 2 (N2): after Mateus-Rodriguez et al. (2012); Nutrient solution 3 (N3): after Chang et al. (2000).

** Stage 1: vegetative growth stage from transplanting until 60 days.

*** Stage 2: Tuberization stage after 60 days from transplanting.

Results

The performance of potato plants established in the aeroponic system (Figs. 1 & 2) was measured using vegetative growth and mini-tuber yield parameters. The vegetative growth data presented in Table 2 show that in aeroponic culture, the third nutrient solution (N3; Chang et al., 2000) and the second nutrient solution (N2; Mateus-Rodriguez et al., 2012) resulted in significantly higher values of vegetative growth than the first nutrient solution (N1; Silva Filho et al., 2022) in both seasons. Furthermore, Table 3 revealed the leaf's content of nutrients, with a higher content of P and Fe in N3. Moreover, N2 recorded the highest Mg and Cu concentrations in leaves.

The five tested varieties exhibited significant differences in vegetative growth characteristics (Table 4). Cara and Lady Rosetta varieties produced the highest number of leaves. The Cara, Hermes, and Lady Rosetta gave the highest leaf fresh weight. However, the Hermes variety formed the tallest roots. Moreover, the Spunta and Cara varieties recorded the tallest stems and the highest tuber number after 60 days. Lady Rosetta and Hermes produced the highest leaf dry weight. However, the Daimant variety recorded the shortest stems with the lowest values of leave leaf number, leaf fresh weight, leaf dry weight, and stem fresh and dry weight. However, Diamant recorded the highest value for stolon number, fresh and dry weight.

Concerning the mini-tuber yield data, the main effects of the three tested nutrient formulas tested did not enhance significant differences in mini-tuber yield (number, weight, large or small mini-tubers). Significant differences between the tested varieties were obtained (Table 5). Cara gave the highest yield of larger than 18 mm size mini-tubers in both seasons (20.5 and 27, respectively). Also, Cara recorded the highest total mini-tubers in the second season (39.1). In contrast, in the first season, Cara and Hermes gave the highest significant total mini-tuber yield per plant (29.1 and 28.5, respectively). Also, Cara and Hermes recorded the highest significant number and weight of small mini-tubers (less than 18mm) in both seasons. On the other hand, the lowest number of total mini-tubers, large mini-tubers, and small mini-tubers was recorded by the Diamant variety. The interaction between nutrient solution composition and varieties gave significant differences (Table 6). The interaction between the second nutrient solution (N2; Mateus-Rodriguez et al., 2012) and Cara resulted in the highest number and weight of large mini-tubers in both seasons. Furthermore, Cara gave the highest total mini-tubers number and weight in the second nutrient solution in the second season. Hermes came in second place for total mini-tuber number and weight. Concerning the differences in small mini-tubers (< 18mm) number and weight, were significant only in the second season, with the highest values for the third nutrient solution with Diamant.

TABLE 2. Main effects of three nutrient solutions on vegetative growth after 60 days of transplanting

Nutrient Solution*	Leaf No.	Leaf FW (gm)	Leaf DW (gm)	Stem length (cm)	Root length (cm)	Tuber No.	Stolon No.	Chlorophyll (SPAD)
				First season				
N1	18.9	31.1	2.1	54.3	67.4	17.5	18.5	34.8
N2	20.4	43.5	3.1	50.9	78.0	16.9	28.0	33.6
N3	23.4	34.1	2.6	56.8	77.6	17.5	19.8	36.1
Tukey HSD at 0.05	3.1	9.8	0.5	NS	NS	NS	4.4	1.3
				Second season				
N1	20.7	31.6	2.1	55.5	69.9	19.8	21.0	35.0
N2	24.2	46.3	3.2	58.5	82.5	20.1	30.9	33.4
N3	26.5	37.5	2.6	59.6	82.2	19.9	22.2	36.1
Tukey HSD at 0.05	1.1	3.1	0.5	2.2	3.4	NS	3.7	1.3

* Nutrient solution 1 (N1): after Silva Filho et al. (2022); Nutrient solution 2 (N2): after Mateus-Rodriguez et al. (2012); Nutrient solution 3 (N3): after Chang et al. (2000).

TABLE 3. Main effects of three nutrient solutions on leaf content of nutrients after 60 days of transplanting

Nutrient Solution*	N%	P%	K%	Ca%	Mg%	Fe (mg/kg)	B (mg/kg)	Zn (mg/kg)	Mn (mg/kg)	Cu (mg/kg)
						First season				
N1	3.89	0.33	2.14	2.25	0.44	552	34	148	493	40
N2	3.97	0.31	2.15	1.90	0.81	557	40	137	398	47
N3	4.02	0.36	1.87	2.10	0.65	685	23	112	322	40
Tukey HSD at 0.05	NS	0.01	0.22	NS	0.04	103	4	12	83.9	2
						Second season				
N1	4.01	0.33	2.56	2.32	0.44	560	37	153	464	39
N2	4.05	0.35	2.76	2.00	0.81	547	44	142	416	48
N3	4.06	0.40	3.42	2.17	0.65	714	26	131	362	39
Tukey HSD at 0.05	NS	0.03	0.41	NS	0.04	67	3	5	93	2

*Nutrient solution 1 (N1): after Silva Filho et al. (2022); Nutrient solution 2 (N2): after Mateus-Rodriguez et al. (2012); Nutrient solution 3 (N3): after Chang et al. (2000).

TABLE 4. Vegetative growth response of five potato varieties after 60 days of transplanting

Variety	Leaf No.	Leaf FW (gm)	Leaf DW (gm)	Stem length (cm)	Root length (cm)	Tuber No.	Stolon No.	Chlorophyll (SPAD)
	First season							
Cara	27.0	40.3	2.7	63.2	71.3	23.9	26.2	33.0
Diamant	12.4	29.8	2.0	37.6	66.8	11.2	25.3	39.8
Hermes	18.8	41.3	3.0	56.1	90.4	12.2	17.3	34.1
Lady Rosetta	25.8	36.6	3.0	46.7	82.7	14.6	18.3	33.7
Spunta	20.4	33.0	2.3	66.7	60.5	24.7	23.3	33.8
Tukey HSD at 0.05	5.9	11.8	NS	8.3	18.6	5.7	7.0	2.5
	Second season							
Cara	28.7	37.1	2.3	67.8	74.9	25.1	28.1	32.9
Diamant	15.9	30.6	2.1	43.8	69.2	14.6	29.2	39.6
Hermes	21.1	43.1	3.1	57.3	90.2	14.2	20.1	34.2
Lady Rosetta	31.4	45.7	3.2	51.0	87.9	19.9	21.7	33.6
Spunta	21.9	36.0	2.5	69.6	68.8	25.9	24.4	33.8
Tukey HSD at 0.05	2.1	3.9	0.7	5.0	4.5	2.1	2.8	2.9

TABLE 5. Mini-tubers harvest data of five potato varieties growing in aeroponic culture

Variety	Mini-tuber No.	Mini-tuber Weight (gm)	Large Mini-tuber No.	Large Mini-tuber Weight (gm)	Small Mini-tuber No.	Small Mini-tuber Weight (gm)
	First season					
Cara	29.1	144.6	20.5	132.3	10.0	22.8
Diamant	20.0	82.8	12.1	63.0	7.9	19.8
Hermes	28.5	134.4	17.0	110.2	11.6	24.2
Lady Rosetta	22.1	123.5	15.9	109.3	6.2	14.2
Spunta	23.7	124.8	16.4	108.2	7.2	16.6
Tukey HSD at 0.05	5.5	34.3	3.1	25.6	2.9	5.9
	Second season					
Cara	39.1	199.7	27.0	172.3	12.1	27.5
Diamant	22.4	106.5	14.4	86.8	7.9	19.7
Hermes	31.8	155.1	19.5	128.5	12.3	26.6
Lady Rosetta	29.4	152.1	21.4	133.5	8.0	18.6
Spunta	27.4	150.1	19.3	131.3	8.2	18.7
Tukey HSD at 0.05	2.1	20.2	1.7	21.1	0.9	5.4

TABLE 6. The effect of the interaction between nutrient solution composition and varieties in mini-tubers yield characteristics

Nutrient* solution	Variety	Mini-tuber No.	Mini-tuber weight (gm)	Large mini-tuber No.	Large mini-tuber weight (gm)	Small mini-tuber No.	Small mini-tuber weight (gm)
		First season					
N1	Cara	30.9	154.9	20.8	133.5	10.1	21.4
	Diamant	18.2	72.2	10.2	51.8	7.9	20.5
	Hermes	29.3	135.5	16.4	108.9	12.9	26.6
	Lady Rosetta	24.0	131.4	17.0	115.0	7.0	16.5
	Spunta	24.1	120.1	15.8	103.1	8.3	17.0
N2	Cara	31.6	166.8	25.4	172.8	10.6	25.2
	Diamant	21.6	96.7	13.8	77.2	7.8	19.5
	Hermes	23.7	107.9	14.1	89.2	9.6	18.7
	Lady Rosetta	21.6	121.4	15.3	108.3	6.2	13.2
	Spunta	21.1	109.5	14.6	94.7	6.5	14.8
N3	Cara	24.8	112.1	15.5	90.4	9.4	21.7
	Diamant	20.3	79.5	12.4	60.1	7.9	19.4
	Hermes	32.6	159.8	20.4	132.5	12.2	27.2
	Lady Rosetta	20.8	117.6	15.5	104.6	5.3	13.0
	Spunta	25.8	144.7	18.9	126.7	6.9	18.0
Tukey HSD at 0.05		NS	76.7	7.0	60.5	NS	NS
		Second season					
1	Cara	38.4	195.5	26.0	168.9	12.4	26.6
	Diamant	19.8	83.8	13.1	67.0	6.7	16.8
	Hermes	28.4	138.9	17.0	115.6	11.4	23.3
	Lady Rosetta	33.6	143.9	24.5	121.8	9.1	22.2
	Spunta	25.9	129.8	17.0	111.9	8.9	17.9
2	Cara	45.3	250.6	33.4	222.3	11.9	28.2
	Diamant	21.5	93.1	12.8	71.5	8.7	21.6
	Hermes	29.0	134.1	17.6	111.3	11.4	22.8
	Lady Rosetta	27.6	153.5	19.4	136.0	8.2	17.4
	Spunta	25.8	138.2	17.4	118.6	8.3	19.6
3	Cara	33.5	153.1	21.6	125.6	12.0	27.5
	Diamant	25.9	142.5	17.4	121.8	8.5	20.7
	Hermes	37.9	192.3	23.8	158.6	14.1	33.7
	Lady Rosetta	27.0	159.0	20.4	142.8	6.6	16.2
	Spunta	30.6	182.3	23.4	163.6	7.2	18.7
Tukey HSD at 0.05		5.3	67.1	4.4	60.8	2.0	14.2

* Nutrient solution 1 (N1): after Silva Filho et al. (2022); Nutrient solution 2 (N2): after Mateus-Rodriguez et al. (2012); Nutrient solution 3 (N3): after Chang et al. (2000).

Discussion

Our study established a reliable system for growing potatoes in an aeroponic system for local seed potato production. Furthermore, three nutrient formulas tested were found reliable in mini-tuber production under Egyptian conditions. Superiority in vegetative growth parameters for the second and third nutrient solutions (N2 &N3) could be attributed to the higher EC of N2 and N3 (2.0 and 1.9 dS/m, respectively) than the first nutrient solution, N1 (1.7 dS/m). Also, N3 contained higher P, K, and Fe, while N2 contained higher Mg, Cu, and Zn (Table 1). Increasing electric conductivity resulted in increased shoot growth and reduced nutrient (nitrogen, phosphorus, calcium, and magnesium) absorption due to the transpiration rate decline (Chang et al., 2005). Previous studies stated that phosphorus plays a positive role in increasing tuber numbers in solution cultures (Rolot & Seutin 1999; Rolot et al., 2002). Furthermore, the non-significant differences in leaf nitrogen content between the three nutrient formulas are related to the close concentrations of nitrogen in the first stage of the three tested formulas (Table 1).

The obtained results of a high number of mini-tubers in aeroponics are in line with previous studies (Rykaczewska, 2016; Bucksetha et al., 2016; Khalil & Hamed, 2020; Silva Filho et al., 2022). Furthermore, aeroponics produced up to three times more tubers than soil substrates (Rykaczewska, 2016). The high number of tubers in aeroponics is related to the availability of nutrients and the fact that sequential harvests eliminate the dominant tubers, allowing the development of small tubers and new tubers production (Lommen, 1995). However, all three tested formulas gave a good growth and mini-tuber yield without significant differences for the nutrient solution composition main effects, which could be related to nitrogen, phosphorus, and magnesium concentrations in the three tested formulas being very close in the first stage (Table 1). Concerning the differences between varieties, this could be attributed to the genetic background mentioned by Broćić et al. (2022); the specific requirements of particular potato genotypes regarding aeroponic cultivation should be considered. The superiority of interaction between Cara and the second nutrition solution (N2) in the production of the highest number of large mini-tubers number in both seasons can be explained by the large decrease in nitrogen concentration in the N2 formula in the second stage (Table 1). In this respect, previous reports recommend lowering nitrogen concentration in the tuberization stage (Rolot & Seutin, 1999; Rolot et al., 2002). Delayed tuberization in aeroponics was related to extended vegetative growth enhanced by a relatively unlimited nitrogen supply (Ritter et al., 2001; Farran & Mingo-Castel, 2006). Nutrient interruptions should be conducted after sufficient haulm development to enhance tuberization (Chang et al., 2008; Chang et al., 2016; Oraby et al., 2015). Furthermore, Cara plants cultured in N2 produced the highest yield of total mini-tuber number, which could be attributed to the higher EC in N2 (2.1 dS/m). On the other side, Silva Filho et al. (2022) obtained a higher mini-tuber yield on the nutrient solution with a lower EC. However, Chang et al. (2005) reported that high EC reduces potato tuber growth in the late-maturing variety Jasim, while tuber growth increases in Superior, the medium-early variety. Also, it was reported that sufficient potassium content in potatoes enhanced higher levels of antioxidant enzymes under relatively high salt stress (Hassanein & Salem, 2017). One of the limitations of our study is that the studied varieties have different maturity categories, i.e., Cara is a late variety, and Diamant, Hermes, Lady Rosetta, and Spunta are medium early. The obtained results demonstrated the production of a large number of pre-basic seed mini-tubers in aeroponics. Four varieties (Cara, Hermes, Spunta, and Lady Rosetta) of the five tested varieties produced more than 150g mini-tubers/plant and can be categorized as high-yielding varieties under aeroponic culture (Tiwari et al., 2022).

Conclusions

The results of the current study support the use of aeroponic culture for Egyptian pre-basic seed potato production as a substitute for importing mini-tubers or producing in substrates. Furthermore, the study proved the possibility of high mini-tubers production in an aeroponic culture system (more than 30 mini-tubers/plant) from four major potato varieties. Further studies for aeroponic mini-tuber production under Egyptian conditions need to study the production seasons; summer, autumn, and winter.

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إنتاج تقاوي البطاطس ما قبل الأساس في مصر: دراسات مقارنة على تغذية البطاطس في المزارع الهوائية

محمد مصطفى خليل[1]، محمود محمد سامي[1]، مصطفى كمال عبدالحليم[1]، محمد سعد إمام[2]

[1]قسم بحوث البطاطس والخضر خضرية التكاثر – معهد بحوث البساتين - مركز البحوث الزراعية – الجيزة – مصر،

[2]المعمل المركزي للمناخ الزراعي - مركز البحوث الزراعية – الجيزة – مصر.

قيمت دراسة مقارنة باستخدام ثلاثة محاليل مغذية إنتاج تقاوي البطاطس ما قبل الأساس في المزارع . سُجلت اختلافات معنوية بين المحاليل المغذية المختبرة في مواصفات النمو الخضري ومحتوى الأوراق من العناصر (الفوسفور والبوتاسيوم والماغنسيوم والحديد والبورون والمنجنيز والزنك) ولم تسجل اختلافات معنوية في النيتروجين والكالسيوم. لم تصل الاختلافات بين التأثيرات الرئيسية للمحاليل المغذية لمستوى المعنوية. اختلفت الأصناف معنويا في مواصفات النمو الخضري ومحتوى الأوراق من العناصر ومحصول المينى تيوبر. أعطى الصنف كارا أعلى محصول للنبات من الميني تيوبر الكبيرة (أكبر من 18 مم) في الموسمين (20.5 و27 على الترتيب). كما أنتج الصنف كارا أعلى محصول ميني تيوبر كلى للنبات في الموسم الثاني (39.1) بينما في الموسم الأول أعطى الصنفين كارا وهرمس أعلى محصول الميني تيوبر الكلى للنبات (29.1 و28.5 على الترتيب). سجل الصنف دايمونت أقل قيم لعدد ووزن الدرنات للنبات. نتج عن التفاعل بين الصنف كارا والمحلول المغذى الثاني أعلى محصول ميني تيوبر للنبات في كلا الموسمين (25.4 و33.4 على الترتيب). تعضد النتائج الانتاج المحلى لتقاوي البطاطس ما قبل الأساس الميني تيوبر باستخدام المزارع الهوائية.