Menoufia J. Plant Prod., Vol. 5 September (2020): 253 – 263 https://mjppf.journals.ekb.eg/

PRE-BASIC SEED POTATO PRODUCTION IN AEROPONIC CULTURES

M. M. Khalil[1] and A. H. Hamed[2]

(1) Potato and Vegetatively Propagated Vegetables Department, Horticulture Research Institute, Agricultural Research Centre, Giza, Egypt.

(2) Virus and Phytoplasma Research Department, Plant Pathology Research Institute, Agricultural Research Centre, Giza, Egypt.

Received: Aug. 23 , 2020 Accepted: Sep. 21 , 2020

ABSTRACT: The current study was carried out to investigate Pre-Basic Seed Potato Production in soilless cultures under Egyptian conditions. Furthermore, the study investigated the possibility of plantlets direct acclimatization of three potato varieties in Aeroponic culture system comparing with substrate culture system (peat moss and vermiculite 3:1 v/v). Also, the growth and the yield of three cultivars (Diamant, Lady Rosetta and Spunta) were compared. Aeroponics showed better survival rate and promising method for acclimatization of potato plantlets *ex vitro*. Moreover, Varietal differences were noticed between the three tested varieties. The best response as survival rate, stem length and leaf area were observed by Spunta followed by Lady Rosette while Diamant came in the last place. However, Diamant produced the highest plant dry matter. Aeroponic system gave higher minituber number per plant while substrates gave higher average minituber weight. The obtained results recommend the use of Aeroponic culture system in acclimatization of *in vitro* potato plantlets and minitubers to be introduced in pre-basic seed programs in Egypt.

Key words: Pre-basic Seed Potato, acclimatization, Aeroponic, Minituber.

INTRODUCTION

Potato is the fourth important food crop in the world after wheat, rice and corn. The global production in 2018 reached 368.2 million ton (FAO, 2020). Potato is propagated by vegetative means causing accumulation of diseases and degeneration (Struik and Wiersema, 2012). Modern seed potato production systems depend on production of nuclear stock of plants free from diseases specially virus diseases and multiplying it *in vitro* (Kawakami *et al*., 2015). Pre-basic seeds are produced after several subcultures *in vitro* then transferred to *semi-in vivo* conditions (greenhouses) for production of minitubers. Minitubers production in greenhouses is an intermediate step between multiplication *in vitro* and production in open field (Struik, 2007). The seed produced from minitubers are planted in screen houses or in open fields for next generation's production. Increasing multiplication rate and reducing number of generations in open fields is crucial point in reducing diseases accumulation in progeny tubers. Mohamed *et al.* (2018) stated the possibility of local seed tuber production pre-basic potato minitubers from tissue culture-in Egypt and limiting the high costs of importing such materials. The use of soilless culture provides an advantage for pre-basic seed potato production by avoiding soil porn diseases (Millam and Sharma, 2007). Hougland used solution culture in potato plant nutrition studies (Hougland, 1947; Hougland and Arnon, 1950). Also, solution culture was used in physiological studies of factors affecting tuberization in potato (Krauss and Marschner, 1982; Wan *et al*., 1994). Furthermore, NASA made a series of researches on potato cultivation as source of nutrition in life supporting systems in space using nutrient solution cultivation (Wheeler, 2006). Boersig and Wagner (1988) suggested the use of Aeroponics for seed potato production. In South Korea Studies (Kang *et al.,* 1996; Kim *et al*., 1997; Chang *et al.,* 2000) led to transformation to minituber production in solution culture either hydroponic or Aeroponic culture. Studies on potato hydroponics were conducted also in Spain (Farran and Mingo-Castel, 2006; Muro *et al*., 1997), Belgium (Rolot and Seutin, 1999), Brazil (Corrêa *et al*., 2009), 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). Furthermore, Tunio *et al.* (2020) stated that Aeroponics techniques could make potato production more efficient, can reduce the number of steps in the potato seed multiplication, and costs as well as plant health and quality of the first field. Also, the Aeroponics system increases potato tubers production, provides protection from pests, soil-borne diseases, good nutrition monitoring and fast seed production. In hydroponics and Aeroponics more minituber production than substrates (peat moss, perlite, sand…) was reported (Muro *et al*., 1997; Rolot and Seutin, 1999; Chang *et al*., 2012; Factor *et al*., 2012; Tierno *et al*., 2014; Rykaczewska, 2016). The plant material for seed potato production in Aeroponics is mainly acclimatized plantlet produced from tissue culture (Abdullateef *et al*., 2012) or rooted cuttings from plantlets produced *in vitro* after acclimatization for one week (Ritter *et al*., 2001); although Rolot and Seutin (1999) used sprouted microtubers. The present investigates potato plantlets direct acclimatization in Aeroponics. Also, study four cultivars pre-basic seed minituber production in Aeroponics under Egyptian conditions.

MATERIALS AND METHODS

The source of plant materials was free virus *in vitro* plantlets of three potato varieties *i.e.* Diamant, Lady Rosetta and Spunta. Serological detection was carried out in Serological laboratory of Virus and Phytoplasma Research Department, Plant Pathology Research Institute, Agricultural Research Centre (ARC). Double antibody sandwich enzyme linked immunosorbent assay (DAS-ALISA) was used to test samples to virus against PVX, PVY, PLRV, TRV, AMV and PMTV according to Clark and Adams (1977) to estimate the relative viral load in potato leaves at starting culture *in vitro* and at different subsequent stages; after interacting the leaves extracts with polyclonal antisera from rabbit (LOEWE® Biochemica GmbH, Germany), the developed color was measured at 405 nm. The plantlets were multiplied *in vitro* at Potato Tissue Culture lab., Horticulture Research Institute. The multiplication media was MS (Murashige and Skoog, 1962) salts and vitamins supplemented with 30 g/l sucrose, 0.1 mg/l GA_3 solidified with 7 g/l agar with adjusted pH to 5.7 prior autoclaving at 1.05 Kg/cm^2 and 121°C for 20 min. In the last subculture 0.1 mg/l IBA was added to the medium.

Acclimatization Experiment: The treatments of the study were two factors i.e., varieties (Diamant, Lady Rosetta and Spunta) and the culture system (Substrate and Aeroponic). The substrate consisted of peat moss and vermiculite 3:1 v/v. The plantlets were cultured in styrofoam seedling trays.

Aeroponic system was designed from wooden box 2 m length, 1 m wide and 0.5 m depth; inner side was coated with styrofoam sheets then covered with black plastic sheets the uber side of the box was styrofoam 84 cell seedling trays. The boxes were connected to ½ hp motor connected to timer and contactor to supply the nutrient solution to the nozzles for 30 seconds each 5 minutes. The nutrient solution composed of half-strength potato solution (Chang *et al.*, 2000), containing N, P, K, Mg, Ca, and S at 100, 22, 146, 21, 55 and 28 mg/l, respectively as macro-nutrients, and Fe, Mn, B, Zn, Cu, and Mo at 3.0, 0.5, 0.5, 0.05, 0.02, and 0.01 mg/l. Solution electrical conductivity (EC) was adjusted to 1.0± 0.1 dS m^{-1} and 5.5- 6.0 pH The experiment was repeated twice its results were analogous hence data presented for the last one. Each treatment consisted of three replicate each replicate was represented by eighty-four plants (seedling tray). Data of leaf number, stem length, internode length (distance between fourth and fifth leaf), leaf area was determined using Easy leaf Area software and fresh weight. Three transplants of each replicate were dried in oven at 105° C tell constant weight and weighted for dry weight and dry matter.

Growth and Yield Experiment: The plantlets were cultured in 4 Aeroponic module wooden boxes (2 m length, 1 m wide and 0.5 m depth) as described in acclimatization experiment. The nutrient solution sprayed for 30 seconds each 5 minutes. The nutrient solution composed of half-strength potato solution (Chang *et al.*, 2000) tell 45 days after transplanting then, N concentration was lowered to 75 mg/l and increased K concentration to 200 mg/l this solution was used tell the end of harvest after 100 days from transplanting. Solution electrical conductivity (EC) was adjusted to 1.0± 0.1 dS m^{-1} and 5.5- 6.0 pH the experiment was repeated twice, its results were analogous hence data presented for the last run. Each treatment consisted of three replicates each replicate was represented by 21 plants. After 90 days from transplant tubers number and tubers weight were recorded.

Statistical analysis and design:

Statistix 10 software was used for data analysis. A factorial complete randomize blocks design was used; separation between means was performed by the L.S.D at 5 % level (Snedecor and Cochran, 1980).

Results

Acclimatization Experiment: Plantlets grown acclimatized in Aeroponic cultures showed higher percentage of survival than plantlets in substrate cultures (Fig 1a). Furthermore, varietal differences were noticed in survival rate with the highest values for Spunta followed by Diamant while Lady Rosetta came in the last rank (Fig. 1 b). Moreover, data presented in Table 1 show higher significant values of stem length and leaf area for Aeroponic culture system than substrate culture. Also, Spunta and Lady Rosetta gave higher stem length than Diamant. However, no significant differences were recorded between varieties and culture system (substrate or Aeroponics) in leaves number after one month from transplanting. Alternatively, Spunta gave the highest significant value for Internode length this could interpret the highest values of stem length recorded by Spunta plants. Nevertheless, the interactions between varieties and culture system did not record any significant differences for the studied parameters except for plant fresh weight (Table 1). Although dry matter was higher in substrate culture than in Aeroponic culture system (Fig.2).

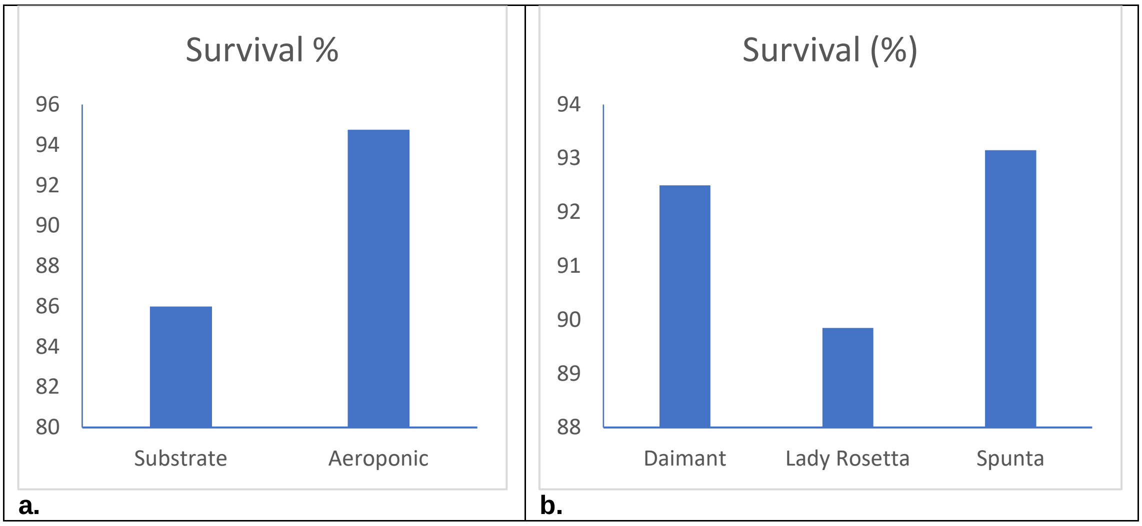

Fig. 1: Survival rate after one month from transplanting.

Table 1: Growth parameters of transplants after one month from transplanting of plantlets in greenhouse.

Variety	Culture Systems	Stem length (cm)	Leaves area (cm^2/plant)	Leave No./plant	Internode length (cm)	Fresh weight (g./plant)	Dry weight (g./plant)
Diamant	Substrate	10.3	2.02	8.3	1.0	1.5	0.14
	Aeroponic	11.7	2.35	7.7	1.1	1.5	0.09
Lady Rosetta	Substrate	12.7	3.69	9.7	1.2	1.3	0.10
	Aeroponic	19.3	4.76	8.7	1.9	1.8	0.09
Spunta	Substrate	14.0	2.32	9.3	1.7	2.1	0.14
	Aeroponic	22.0	2.51	8.3	2.8	1.1	0.04
LSD at 5%		NS	NS	NS	NS	0.4	NS
Diamant		11.0	2.19	8.0	1.1	1.5	0.11
Lady Rosetta		16.0	4.23	9.2	1.5	1.5	0.09
Spunta		18.0	2.42	8.8	2.3	1.6	0.09
LSD at 5%		2.7	0.37	NS	0.8	NS	NS
	Substrate	12.3	2.68	9.1	1.3	1.6	0.12
	Aeroponic	16.3	3.07	8.4	1.8	1.5	0.08
LSD at 5%		2.3	0.30	NS	NS	NS	0.03

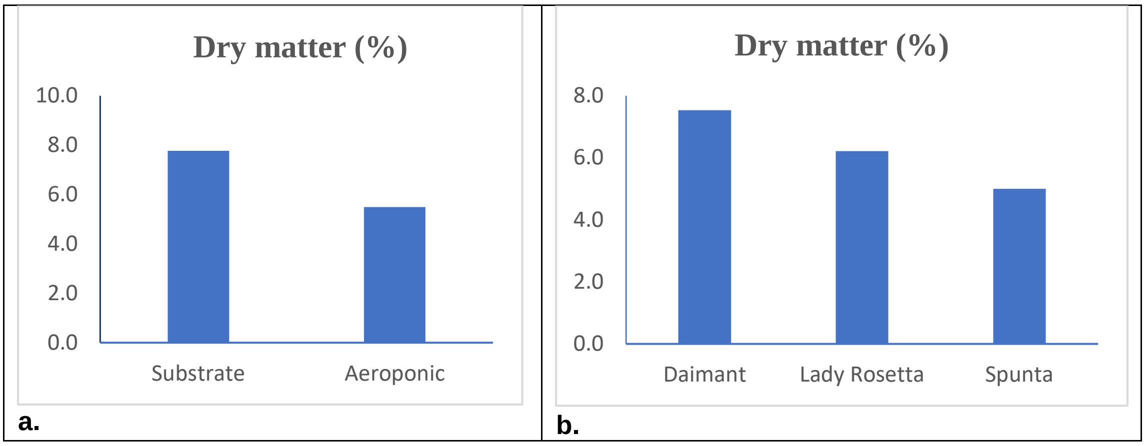

Fig. 2: Dry matter (%) after one month from transplanting

Growth and Yield Experiment: Varietal differences were noticed between verities in vegetative growth phase (Fig. 3). Furthermore, Data presented in Table 2 reveal that significant differences were observed between the three tested varieties in tuber number, tuber weight per plant and average tuber weight. Lady Rosetta (Fig. 4) gave the highest number of minitubers per plant followed by Diamant while Spunta came in the last rank. The two varieties Diamant and Lady Rosetta gave higher minituber weight per plant than Spunta. However, Spunta and Diamant produced higher average tubers weight than Lady Rosetta. Concerning the difference between culture systems (Substrate or Aeroponic) the superiority in minitubers number per plant was for Aeroponic with 37 minituber per plant, whereas substrates gave average minitubers of 5 only. Also, Aeroponic produced tubers weight per plant than substrate. Alternatively, Substrates produced higher average minituber of tuber weight than minitubers produced in Aeroponics.

The effect of the interactions between the varieties and the culture systems on tubers number and weight per plant was significant while the effect of interaction on average tuber weight was not significant. The uppermost tubers number produced by Lady Rosetta in Aeroponic (57) while the lowermost tubers number per plant produced by the three varieties cultured in the substrates (Table 2). The highest tubers weight per plant produced by Lady Rosetta or Diamant in Aeroponic, while the lowest one produced in substrate culture with any of the tested varieties.

Discussion

The results could be interpreted in the light of that growth in Aeroponics allow more aeration for root system also higher availability of nutrients with concentration within the ideal range for growth of roots and tubers. Furthermore, the minitubers production in the greenhouse required good husbandry for the delicate plantlets, microtubers, or the lack of the nutrition supply which restrict the growth comparing with normal seed tubers (Ewing, 1997). Therefore, the manipulation of nutrition after the in vitro phase in greenhouse could improve minitubers yield and characteristics (Lommen and Struik 1992; Ranalli, 1997; and Struik and Lommen, 1999). Also, the obtained results could be related to the ability of Aeroponic culture system to enhance fast, large root growth (Fig. 5). In according with the obtained results potato plants in aeroponics show extended vegetative growth and delayed in tuber production with higher minituber yield than substrates but with lower minituber weight (Ritter et al., 2001). Also, higher multiplication rates (47 tubers per plant) were obtained in Aeroponics whereas average tubers weight was higher in pots (Factor et al., 2012). Supporting our results on varietal differences, Monalisa and Zorba varieties grown in Aeroponics produce higher minitubers number with better size and weight distribution, while Agria tuber weight declined (Tierno et al., 2014). Aeroponics produced two to three folds number of tuber than in soil substrates (Rykaczewska, 2016). As a general conclusion minitubers production in solution cultures give larger number of smaller minitubers than in soil substrates. Furthermore, minitubers production in solution cultures (Aeroponics or hydroponics) give larger numbers of smaller minitubers than in soil substrates (Muro et al., 1997; Rolot and Seutin, 1999; and Rykaczewska, 2016). Also, Potato plants in Aeroponics show extended vegetative growth and delayed in tubers production with higher minitubers yield than hydroponics and beds but with lower minituber weight (Ritter et al., 2001).

Fig. 3: Growth in Aeroponic after 75 days from planting

Table 2: Varieties response to different culture systems at harvest time.

Variety	Culture system	Tubers No. /plant	Tubers weight /plant (g)	Average tuber weight (g)
Diamant		20.3	69.9	4.8
Lady Rosetta		31.4	65.8	3.4
Spunta		11.5	44.4	5.5
LSD at 5%		2.1	9.7	1.1
	Substrate	5.1	32.2	6.5
	Aeroponic	37.1	87.9	2.6
LSD at 5%		1.7	7.9	0.9
Diamant	Substrate	5.3	35.1	6.6
	Aeroponic	35.3	104.8	3.0
Lady Rosetta	Substrate	5.4	24.5	4.8
	Aeroponic	57.3	107.1	1.9
Spunta	Substrate	4.6	36.9	8.2
	Aeroponic	18.3	51.79	2.8
LSD at 5%		2.95	13.7	NS

Fig. 4: Minitubers of Lady Rosetta produced in Aeroponics at harvest time.

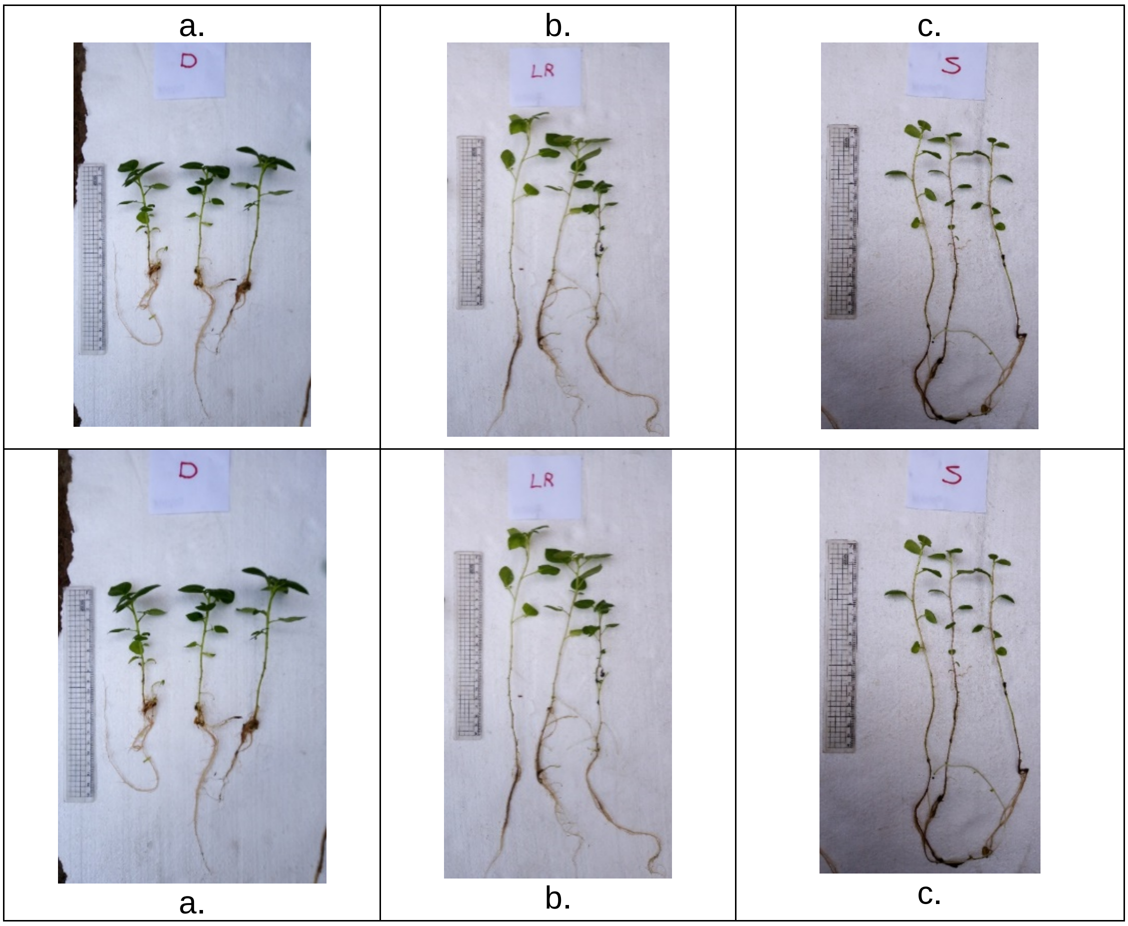

Fig. 5: Root growth after 13 days from transplanting, in Aeroponics (top) and in substrate (bottom) a: Diamant, b: Lady Rosetta, c: Spunta.

Conclusion

The current study illustrates the possibility of direct acclimatization of potato plantlets in Aeroponics. Moreover, recommend the use of Aeroponics for pre-basic seed potato production for maximizing the number of minitubers and reduce the number of generations needed for certified seeds production which could enhance and reinforce Egyptian seed potato production. For efficient local application of Aeroponic system in pre-basic seed potato production factors of seasons nutrient solution should also be considered further studies.

REFERENCES

Boersig, M.R. and S.A. Wagner (1988). Hydroponic systems for production of seed tubers. Am. Potato J., 65:471 (abstract).

Bucksetha, T., A.K. Sharma, K.K. Pandey, B.P. Singh and R. Muthuraj (2016). Methods of pre-basic seed potato production with special reference to Aeroponics—A review. Scientia Hortic., 204: 79–87.

Chang, D.C., S.Y. Kim, K.Y. Shin, Y.R. Cho and Y.B. Lee (2000). Development of a nutrient solution for potato (*Solanum tuberosum* L.) seed tuber production in a closed hydroponic system. Korean J. Hortic. Sci. Tec., 18: 334–341.

Chang, D.C., C.S. Park, S.Y. Kim and Y.B. Lee. (2012). Growth and tuberization of hydroponically grown potatoes. Potato Res., 55: 69- 81.

Clark, M. F. and A. N. Adams (1977). Characteristics of the Microplate Method of Enzyme-Linked Immunosorbent Assay for the Detection of Plant Viruses. J. Gen. Virol,. 34: 475-483.

Corrêa, R.M., J.E. Pinto, V. Faquin, C.A. Pinto and É.S. Reis. (2009). The production of seed potatoes by hydroponic methods in Brazil. Fruit Veg. Cereal Sci. Biotech., 3: 133-139.

Ewing, E.E. (1997). Potato. In: The physiology of vegetable crops (H.C. Wien, ed). CAB International

Factor, T.L., S. Lima Júnior, H.S. Miranda Filho and J.A.C. de Araújo (2012). Potential hydroponics systems for seed potato production in tropical conditions. Acta Hortic., 927: 905-911.

FAO (2020). Food and Agriculture Organization Database. Retrieved from www.fao.org/faostat.

Farran, I. and A.M. Mingo-Castel (2006). Potato minituber production using Aeroponics: effects of plant density and harvesting intervals. Am. J. Potato Res., 83: 47–53.

Hougland, D.R. and D.I. Arnon (1950). The water culture method for growing plants without soils. Calif. Agr. Exp. Sta. Circ., 347.

Hougland, G. (1947). Minimum phosphate requirement of potato plants grown in solution cultures. J. Agr. Res., 75: 1-18.

Kang, J.G., S.Y. Kim, H.J. Kim, Y.H. Om and J.K. Kim. (1996). Growth and tuberization of potato (Solarium tuberosum L.) cultivars in Aeroponic, deep flow technique and nutrient film technique culture systems. Korean Soc. Hortic. Sci., 37: 24-27.

Kim, K.T., S. B. Kim, S.B. Ko and Y.B. Park. (1997). Effects of minituber picking intervals on the yield and tuber weight of potato grown in Aeroponics. RDA J. Hortic. Sci., 39: 65-69.

Krauss, A. and H. Marschner (1982). Influence of nitrogen nutrition, daylength and tempreture on contents of gibberellic and abscisic acid and on tuberization in potato plants. Potato. Res., 25:13-21.

Kawakami, T., H. Oohori and K. Tajima (2015). Seed potato production system in Japan, starting from foundation seed of potato. Breeding Sci., 65(1):17-25.

Lommen, W. J. M. and P. C. Struik (1992) Production of potato minitubers by repeated harvesting: Effect of crop husbandry on yield parameters. Potato Res., 35: 419- 432.

Mateus-Rodriguez, J., S. de Haan, I. Barker, C. Chuquillanqui and A. Rodriguez-Delfin (2012). Response of three potato cultivars growth in a novel Aeroponics system for minituber seed production. Acta Hortic., 947, 361–368.

Mbiyu, M.W., J. Muthoni, J. Kabira, G. Elmar, C. Muchira, P. Pwaipwai, J. Ngaruiya, S. Otieno and J. Onditi (2012). Use of Aeroponics technique for potato (*Solanum tuberosum*) minitubers production in Kenya. J. Hort. For., 4:172-177.

Millam, S. and S.K. Sharma (2007). Soil free techniques. In V. D., Potato biology and biotechnology advances and prospective. Elsevier Pub.

Mohamed, F., G. Omar, K. Abd El-Hamed and B. El-Safty (2018). Influence of Plant Density and Genotype on Potato Minituber Production from Microshoots and Microtubers. Egy. Soc. Environ. Sci., 17: 77-84.

Murashige, T. and F. Skoog (1962). A revised medium for rapid growth and bio assays with tobacco tissue cultures. Physiol. Plant., 15: 473–479.

Muro, J., V. Díaz, J.L. Goñi and C. Lamsfus (1997). Comparison of hydroponic culture and culture in a peat/sand mixture and the influence of nutrient solution and plant density on seed potato yields. Potato Res., 40: 431–438.

Otazu, V. (2010). Manual on quality seed potato production using Aeroponics. International Potato Centre (CIP), Lima, Peru.

Ranalli, P. (1997). Innovative propagation methods in seed tuber multiplication programmes. Potato Res., 40(4): 439-453.

Ritter, E., B. Angulo, P. Riga, C. Herran, J. Relloso and M. San Jose (2001). Comparison of hydroponic and Aeroponic cultivation systems for the production of potato minitubers. Potato Res., 44: 127–135.

Rolot, J.L. and H. Seutin (1999). Soilless production of potato minitubers using a hydroponic technique. Potato Res., 42: 457–469.

Rykaczewska, K. (2016). The potato minituber production from microtubers in Aeroponic culture. Plant Soil Environ., 62: 210–214.

Snedecor, G.W. and W.G. Cochran (1980). “Statistical Methods”, 7th ed., Iowa state Univ., Press, Iowa, U. S. A.

Struik, P. (2007). The canon of potato science: 25. Minitubers. Potato Res., 50:305–308.

Struik, P. C. and W. J. M. Lommen (1999). Improving the field performance of micro and minitubers. Potato Res., 42:559–568.

Struik, P. and S. Wiersema (2012). Seed Potato Technology. Wageningen Academic Publishers.

Tierno, R., A. Carrasco, E. Ritter and J. Galarreta (2014). Differential growth response and minituber production of three potato cultivars under Aeroponics and greenhouse bed culture. . Amer.J. Potato Res., 91: 346–353.

Tunio, M., J. Gao, S. Shaikh, I. Lakhiar, W. Qureshi., K. Solangi and F. Chandio (2020). Potato production in Aeroponics: An emerging food growing system in sustainable agriculture for food security. Chilean J. of Agric. Res. 80: 118-132.

Wan, W.Y., W. Cao and T.W. Tibbitts (1994). Tuber initiation in hydroponically grown potatoes by alteration of solution pH. HortSci., 29: 621–623.

Wheeler, R. (2006). Potato and human exploration of space: some observations from NASA-sponsored controlled environment studies. Potato Res. 49: 67–90.

انتاج تقاوي البطاطس ما قبل الأساس في المزارع الهوائية

محمد مصطفى خليل[1] ، على حسن حامد[2]

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

[2] قسم بحوث الفيروس والفيتوبلازما– معهد بحوث أمراض النبات– مركز البحوث الزراعية – الجيزة – مصر

الملخص العربى

أجريت الدراسة الحالية بغرض بحث انتاج تقاوي البطاطس ما قبل الأساس في المزارع اللاأرضية تحت الظروف المصرية. أيضا تم دراسة مدى إمكانية الأقلمة المباشرة في المزارع الهوائية لثلاث أصناف بطاطس مقارنة بألأقلمة في نظام مزارع مخاليط التربة (بيتموس وفيرميكيوليت 3 :1 نسبة حجمية). كما تم مقارنة محصول الثلاثة أصناف المختبرة (دايمونت وليدي روزيتا وسبونتا). أظهرت المزارع الهوائية تفوق في معدل بقاء النباتات وكانت وسيلة واعدة لأقلمة نباتات البطاطس خارج المعمل. لوحظت اختلافات بين الثلاثة أصناف المختبرة ونتجت أفضل استجابة كنسبة بقاء وطول أفرع ومساحة ورقية بواسطة صنف سبونتا وتلاه صنف ليدي روزيتا وجاء صنف دايمونت في المرتبة الأخيرة والذي أعطى أعلى مادة جافة للنبات. أعطى نظام المزارع الهوائية أعلى عدد للدرنات للنبات بينما أعطى نظام الزراعة في مخاليط التربة أعلى متوسط وزن للدرنة. ترجح النتائج المتحصل عليها استخدام نظام الزراعة الهوائية في أقلمة النباتات الناتجة من زراعة الأنسجة وإنتاج الدرينات (الميني تيوبر) التي يتم إدخالها في برامج انتاج تقاوي البطاطس ما قبل الأساس في مصر.

السادة المحكمين

أ.د/ محمد سيد أحمـــــد كلية الزراعة – جامعة طنطا

أ.د/ فتوح أبو اليزيد على كلية الزراعة – جامعة المنوفية