International Journal of Chemical Studies

P-ISSN: 2349–8528
E-ISSN: 2321–4902
www.chemijournal.com
IJCS 2020; 8(5): 1151-1157

Received: 08-08-2020
Accepted: 13-09-2020

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In vivo performance of hi-tech planting materials for seed potato production: A review

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DOI: https://doi.org/10.22271/chemi.2020.v8.i5p.10450

Abstract
The production of healthy seed is very crucial to sustain the production and productivity of potato. Traditionally used conventional seed potato production system leads to lower multiplication rate, have bulkiness of seed tubers and encourages accumulation of tuber borne viruses, fungi and bacteria in subsequent seasons leading to significant losses in quality and tuber yield over seasons. Hi-tech seed production systems based on micro-propagation technologies improves the quality of breeder seed, enhance seed multiplication rate and reduce field exposure of seed crop. Under this system, there are three different type of seed production systems *viz* micropant, microtuber and aeroponic based. The major components of hi-tech seed production include development of healthy mother plants, followed by mass multiplication of healthy mericlones through *in vitro* micropropagation which is used for microtuber/aeroponic production, minituber production from microtubers/aeroponic tubers or directly from micro-plants under protected conditions (G-0) followed by two field multiplication for production of prebasic and basic seed potatoes. Growth (emergence, plant height, compound leaves and stems) and yield parameters (mean tuber weight and yield by number and weight) varied as per hi-tech planting materials *viz* microplant, microtuber and aeroponic tuber, crop husbandry, genetic background/cultivar and size of planting materials used for minituber production under *in vivo* (G-0) in different agro climatic systems.

Keywords: Hi-tech, microplant, microtuber, aeroponic, growth parameters, yield parameters, potato

Introduction

Importance of quality seed in potato

High yields of potato (*Solanum tuberosum* L.) in the field can be ensured by use of high-quality seed potato (Calori *et al*., 2017) [7]. Thus quality seed tuber is an extremely important factor in potato production. Since potato is a vegetatively propagated plant, fungal, bacterial and especially viral disease agents are easily transmitted through seed tubers (Truta and Detec, 1997) [59]. Viral diseases are responsible for degeneration of seed tubers, which decrease their vigor and productivity (Sangar *et al*., 1988) [48]. The availability of quality planting material of improved potato varieties in adequate quantities is the major issue that needs to be attended (Sadawarti *et al*., 2018b) [46]. At present the country has an area of approximately 1.96 million ha under potato and requires about 4.9 million tones of quality seed at the seed rate of 3.0-3.5 t/ha. In potato cultivation, potato seed is most expensive input accounting for 40 to 50 percent of the production cost (Buckseth and Singh, 2018) [5].

Need of hi-tech systems for seed production

The production of healthy seed is very crucial to sustain the production and productivity of potato. Currently, the common method of commercially important potato cultivars propagation is through tubers. However, this propagation encourages accumulation of tuber borne viruses, fungi and bacteria in subsequent seasons. This has led to significant losses in quality and tuber yield over seasons (Badoni and Chauhan, 2010 [3]; El-Komy *et al*., 2010 [11], Tsoka *et al*., 2012 [60], Naik *et al*., 2000 [30], Chindi *et al*., 2014 [8] and Muthuraj *et al*., 2016 [26]). The lower multiplication rate and bulkiness of seed tubers of conventional potato seed production did not attract private and public seed companies to engage in potato seed business.

This study seeks to review and assess the various options available for healthy seed tuber production and to suggest the way forward for Rapid Multiplication Techniques (RMTs) such as Tissue Culture (TC), aeroponics etc. It is estimated that use of healthy potato seed tubers/planting material leads to about 30% increase in potato yield.

Hi-tech methods of seed potato production

Use of tissue culture technique in seed production has resulted in mass production of potato in a very short period of time. The system is characterized by very flexible and rapid multiplication giving a higher planting propogules (Beukema and Van de Zaag 1990 [4] and Pruski, 2001 [36], Muthuraj *et al*., 2016 [26]). Slowly, micro propagation is replacing conventional propagation of potatoes (Naik and Karihaloo, 2007[29], Moeini *et al*., 2011 [25]).

Importance of basic planting material

The basic planting material has to be true to type, free from viruses and other diseases and has to be maintained during micropropagation and its subsequent seed production system. The microplants are channelized to respective seed production systems where they subsequently form minitubers Minitubers are then utilized for field multiplication to produce breeder seed. For hi-tech based planting system, the basic techniques of tissue culture is utilized in all the seed production systems for development of planting material at the earliest stage (Kaur, 2018[17]) fig 2. Hi-tech system has been started by ICAR-Central Potato Research Institute Shimla in the recent past. Under this system, there are three different types of seed production systems (fig 1):

i) Microplant based

Three to four weeks old healthy microplants are transferred to protrays filled with sterilized peat moss for hardening. The hardened plantlets should be removed along with peat moss and transplanted in nursery beds prepared with soil, sand and FYM (2:1:1 ratio respectively). Microplants should be planted in 30 x 10 cm spacing under insect proof net house condition.

ii) Microtuber based

The microplants are tested for virus freedom before initiating microtuber production. The virus-free plants are mass multiplied through nodal cuttings on semisolid MS medium in culture tubes (25 x 150 mm) following the standard procedure up to 10 cycles and further multiplied in net house.

iii) Aeroponic based

Aeroponics is the process of growing plants in an air mist environment without the use of soil or an aggregate medium since water is used in aeroponics to transmit nutrients to the plants. In aeroponics, plants growth is facilitated by suspending them in air, in an enclosed environment, and providing necessary nutrients by spraying on roots. The nutrient solution is continuously circulated as per need through the system and monitored for pH and EC and amended whenever necessary (Buckseth and Singh, 2018 [5], Farran and Mingo-Castel, 2006 [12])). The harvest technique in aeroponics is convenient, and repeated harvesting offers the possibility of obtaining tubers of a desired size and comparatively higher in number (Ritter *et al*., 2001 [40]). There is a tremendous scope to increase healthy seed production vertically by adopting aeroponic technology of seed system where increase in multiplication rate from 5:1 to 50:1 can be achieved (Buckseth and Singh, 2018[5]).

Microplant Microtuber Aeroponic

Fig 1: Hi-tech seed production systems

The major components of hi-tech seed production include development of healthy mother plants, followed by mass multiplication of healthy mericlones through *in vitro* micropropagation, used for microtuber/aeroponic production, minituber production from microtubers/aeroponic tubers or directly from micro-plants under protected conditions followed by two field multiplication for production of prebasic and basic seed potatoes (Otroshy, 2006 [32], Buckseth and Singh, 2018 [5], Venkataselam *et al*., 2011 [61]). Mini-tuber is an intermediate step of potato seed production between laboratory micropropagation and field multiplication (Naik and Khurana, 2003 [8]). Mini-tubers can be obtained on *in vitro* plantlets under *ex vivo* condition or under *in vivo* condition after planting them in soil (Naik and Karihaloo, 2007 [28]; Otroshy and Struik, 2008 [33]). Minitubers are used in breeding programmes and in the seed production industry because many tubers can be generated in a small space (Hosseni *et al*., 2011 [14]).

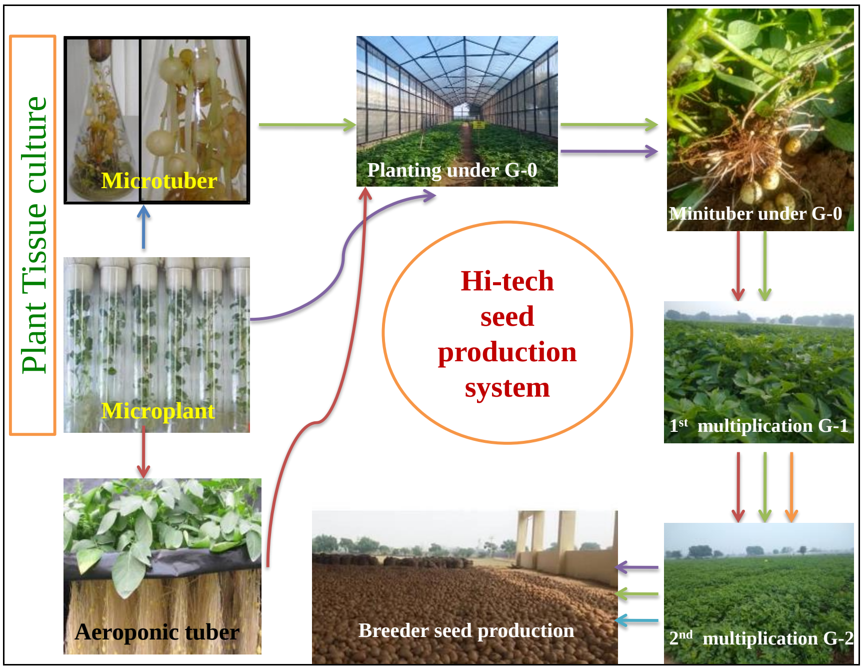

Fig 2: Inter-relationships between the three hi tech seed potato production systems

Agronomy of mini-tuber production

Crop husbandry techniques greatly affect mini-tuber production. An ideal combination of plant population, row width, and in-row seed spacing for a particular variety are the major factors for optimizing tuber size and grower's revenue (Rex and Mazza 1989 [39]). This is most important for ware as well as seed potato production to get higher yield (Kaur *et al*., 2019 [18]) which affects the seed cost, plant development, yield and quality of tubers (Bussan *et al*., 2007 [6]). It also varies depending on the environmental conditions and cultivars (Al Mamun, 2016 [1]).

Number of mini-tubers, tuber yield per plant and average tuber weight are reported to be higher at low plant population, whereas, total number of tubers as well as total tuber yield per m^2 is higher at higher plant populations (Gupta *et al*., 2003 [13]). Planting of micro-plants at a spacing of 45 cm x10cm resulted in maximum number and yield of mini-tubers per plant, whereas, yield per unit area were higher at 30 cm x 10cm planting density (Kumar *et al*., 2012 [21]). Similarly significantly higher tuber weight was reported at 45cm x10cm (26.11 t/ha) for aeroponic minituber multiplication under G-0 (Sadawarti *et al*., 2019 [47]). Maximum average tuber weight was observed for treatment combinations of 30 cm spacing and 150 kg N ha^{-1} and low average tuber weight was recorded at 10 cm intra row spacing with no nitrogen application (Negero, 2017 [31]). Per plant higher yield was obtained at wider spacing due to increased competition for nutrients, space, sunlight etc. leading to an increase in number of tubers per plant (Srivastava *et al*., 2016 [56], Hui *et al*., 2013 [16]). Different varieties respond differently due, to changes in spacing and population (Creamer *et al*., 1999[9]). Increase in number of tubers per unit area with increasing plant population may be due to more number of plants or stems per unit area as tuber number is known to be directly related to stem number (Sharma *et al*, 2014a [49] and Zamil *et al*., 2010 [63] and Diengdoh *et al*., 2012 [10]).

Growth behavior of hi-tech planting materials

Emergence/establishment

The *per cent* survival/establishment significantly differed in different potato cultivars, type of planting material and their interaction under *in vivo* conditions (Gupta *et al*., 2003 [13], Kumar *et al*., 2007 [20] and Venkatasalam, 2011 [61]). Establishment of micro-plants was 99.1% in furrow and 98.4% in the flat bed planting methods (Sharma *et al*., 2010 [52]). More than 70% *in vivo* plantlets were survived in direct transplanting under Modipuram (UP) conditions of India (Kumar *et al*., 2011 [22]). The establishment (%) of micro-plants was very less which ranged from 51.41% to 40.57% in different cultivars under Gwalior conditions of North-Central India (Sadawarti *et al*., 2018b [46]). This might be due to higher atmospheric temperature and lower humidity at planting time under Gwalior conditions. Variation in microplant establishment was also reported among different cultivars in other agro climatic conditions *viz* Modipuram, Gwalior, shimla and Kufri of India (Kumar *et al*., 2012 [21], Venkataselam *et al*., 2011 [61], Kumar *et al*., 2007 [20], Sharma *et al*., 2014a [49], Muthuraj and Ravichandran, 2015[27] Sadawarti *et al*., 2015 [42]). It shows the variability of different potato cultivar for establishment of microplants in different agro climatic regions.

Somani and Venkatasalam (2012) [55] reported size and genotype exert effect on microtuber emergence (%) and their survival. Srivastava *et al*. 2015 [57] observed that micro-tuber survival was very good in the bigger sized micro-tubers (*i.e.* in the grade of 4-8 mm and >8 mm) and as the size grade decreases to <4 mm, the potential of the micro-tuber survival decreased significantly. Microtuber emergence showed decreasing trend with decrease in size i.e. 97 % in 3-5g and lowest 82.0% in 0.3-0.5g microtubers (Kawakami and Iwama, 2012 [19]). Leclerc *et al*. (1995 [23]) reported that, the growth and survival/ vigor of potato tubers is supported by the food material stored in the tubers particularly carbohydrates and could thus be conducive to plant development and hence relatively bigger micro-tubers had distinct advantage. Alsadon *et al*. (1988 [2]) reported that functionality of plants glands produced by small micro tubers is less than larger microtubers. Larger sizes give better emergence and a better early vigor and produced higher yield and more tubers per plant (Struik and Wiersema, 1999 [58]). Differences in micro-tuber survival due to genetic background/cultivars were reported under NE conditions (Gupta *et al*., 2003 [13];

Srivastava *et al*., 2015 [57]) and under plains of India (Singh *et al*., 2007 [54], Sadawarti *et al*., 2017b [44], 2018a [45]) and under Bangladesh conditions (Hoassain *et al*., 2017 [15]). Similar trend was reported in case of minituber multiplication with respect to size and genetic background (Singh *et al*., 2007 [54], Sadawarti *et al*., 2017a [44]). Sadawarti *et al* (2018a [45]) reported among micro-propagated material mean establishment/emergence (%) was highest in mini-tuber (81.91) followed by micro-tuber (50.42) and micro-plant (45.67) under Gwalior conditions of central India. Field emergence of 100% has been reported in the harvested aeroponic mini tubers (Farran and Mingo-castel 2006 [12]).

Plant height

Variation in plant height was reported for genetic background (cultivar) and type of planting materials used in different studies. For microplant multiplication, highest plant height was reported in Kufri Sadabahar, Kufri Chipsona-1, Kufri Anand and Kufri Badshah under Modiouran UP (Kumar *et al*., 2007 [20], 2011 [22] and 2012 [21]) and Kufri Himalini and Kufri Giriraj under Kufri, Shimla conditions (Sharma *et al*., 2010 [52], 2014a [49]). Plant height was maximum in Kufri Chipsona-2 (63.7 cm) after 60 days of planting followed by Kufri Chipsona-1 (51.3 cm) and shortest height at this stage was recorded in Kufri Bahar (36.4 cm) which was at par with Kufri Pukhraj (38.6 cm) under microtuber multiplication (Singh *et al*., 2007 [54]). Plant height was significantly lowest in >4-6mm size microtubers (5.1cm) over >6-8mm size (8.1cm) and >8mm size microtubers (11.1 cm) at 50 days after planting. Increase in plant height with increase in microtuber size is due to higher vigour in the microtuber of large size (Sadawarti *et al*., 2017b [44]). Plant height was significantly higher in 3-10 g minitubers at 50 days (32 cm) and 75 days (35 cm) over <3g minitubers (22 and 26 cm, respectively) under G-0 Sadawarti *et al*., 2017a [41].

Stem/plant

Variation in stem number was reported in microplants, microtubers and minitubes due to to genetic background. Significantly highest number of stems 3.3 and 3.0 respectively were recorded in cv. Kufri Chipsona-3 and Kufri Sadabahar under microplant at Modipuram UP (Kumar *et al*., 2012[21]). The number of shoots per plant varied significantly between the cultivars with more shoots in Kufri Giriraj (2.14) than Kufri Kanchan (1.88) under microplant multiplication (Sharma *et al*., 2014a [49]). Significantly higher stems per plant was recorded in <3 g minitubers (1.2) over other two types of micropropagated materials *viz* microplant and microtuber which recorded single stem per plant under Gwalior condition of North central India (Sadawarti *et al*, 2017b [44]). Sadawarti *et al* (2018a [45]) reported significantly higher stem/ plant in >8mm size microtubers (1.9) followed by >6-8mm size (1.3) over >4-6mm size microtubers (1.2). Single stem/plant were reported in both the <3g and 3-10g grade of aeroponic minituber multiplication under Gwalior conditions (Sadawarti *et al*., 2017a [43]).

Compound leaves/plant

Canopy cover at 45 days was highest in Kufri Bahar, Kufri Anand and Kufri Pukhraj and in Kufri Chipsona-1 and Kufri Chipsona-2 at 60 days of planting (Kumar *et al*., 2007 [20]) and leaf area index in Kufri Chipsona-1 at Modipuram UP (Kumar *et al*., 2012 [21]) and higher compound leaves in Kufri Sindhuri under Gwalior (MP) conditions of India (Sadawarti *et al*., 2017b [44]). Compound leaves/plant was significantly higher in 3-10g of minituber (13) over <3g (9) of aeroponic minitubers multiplication under G-0 (Sadawarti *et al*., 2017 a[43]). The Microtubers had high means for the plant height, the branch number as compared to *in vitro* plants (Öztürk and Yildirim, 2010 [35]).

Yield parameters of hi-tech planting materials

Mean tuber weight

From microplants, significantly highest mean tuber weight was observed in cv. Kufri Sadabahar (15 g) followed by cvs. Kufri Bahar and Kufri Surya under Modipuram and Gwalior conditions which could be due to cultivars having lesser number of mini-tubers per plant (Kumar *et al*., 2007 [20], 2011 [22], 2012 [21] and Sadawarti *et al*., 2018a [45]). Mean tuber number/plant was significantly higher in micro-plant (14.61) over microtuber (12.59) multiplication in three varieties under Bangladesh conditions (Hossain *et al*., 2017 [15]). In micro-tuber, mean tuber weight ranged from 26.50 to 7.77 g and was highest in Kufri Surya (26.50 g) (Sadawarti *et al*., 2018a [45]). Cultivar Kufri Giriraj produced maximum average weight of mini-tubers (14.3 g) followed by Kufri Chipsona-2 (13.9 g) under micro-tuber multiplication study (Somani and Venkatasalam, 2012 [55]). Singh *et al*. 2007 [20] reported mean tuber weight of 9.0 g in all the varieties except Kufri Chipsona-2 (6.4g). Among micro-propagated material mean tuber weight was highest in mini-tuber (22.46 g) followed by micro-plant (15.59 g) and micro-tuber (14.62 g) (Sadawarti *et al*., 2018a [45]).

Number of minitubers

Minituber number varied depending on cultivar and emergence %. In microplant study, highest minituber/m^2 was reported in Kufri Anand followed by Kufri Bahar, Kufri Chipsona-1, Kufri Surya, Kufri Sutlej and Kufri Pukhraj under Modipuram, UP (Kumar *et al*., 2007 [20] and Kumar *et al*., 2011 [22]), in Kufri Sindhuri in Gwalior MP (Sadawarti *et al*., 2015 [42]) and Kufri Himalini and Kufri Kanchan in Kufri shimla HP conditions (Sharma *et al*., 2010 [52], Sharma *et al*., 2014a [49]). Lommen and Struik (1992) [24] also reported that number of progeny tubers depend on cultivars. *In vitro* plantlet group had higher tuber number (9.9) than the microtuber group (9.5) in 2007 but had lower mean in 2008, confirming variation in performance of potato plantlets between years, planting seasons, growing conditions, plant densities and potato cultivars (Özakaynak and Samanci, 2004 [34])

Somani and venkataselam (2012 [55]) reported maximum multiplication rate by number and weight in cultivar Kufri Chipsona-1 (15.4 and 2143g) and the minimum by Kufri Jyoti (3.9 and 314g) under 10 years study of microtuber multiplication. Variation in multiplication rate seems to be genetic trait (Singh *et al*., 2007 [54]) where crop raised from micro-tuber recorded higher multiplication rate than microplant raised crop. Lower production potential of micro-tubers has also been reported earlier (Wiersema, 1987[62]). The rate of multiplication of micro-plants and micro-tubers was almost similar in the cultivars under Shimla condition (Venkataselam *et al*., 2011 [61]). Total tuber number/m^2 was highest in Kufri Sindhuri (222 and 128) in microplant and micro-tuber and in Kufri Bahar (204) under minituber multiplication (Sadawarti *et al*., 2018a [45]). Total number of tubers per m^2 was also affected and, as mean of the two spacings, ranged from 107.8 with microtubers, 122.1 with minitubers, to 142.9 with normal tubers (Ranalli *et al*., 1994 [38]).

Yield by weight

Within cultivars, yield of minitubers was more in Kufri Giriraj (2.61 kg /m^2) than Kufri Kanchan (1.63 kg /m^2) under microplant study at Kufri Shimla (Sharma *et al*., 2014c[51]). The highest yield (2.7 Kg/m^2) of minitubers per unit area was observed in Kufri Bahar followed by Kufri Anand, which was at par with Kufri Sutlej and Kufri Badshah. Due to poor establishment, Kufri Pukhraj produced the lowest yield (1.69 Kg/m^2) of minitubers per unit area under microplant study at Modipuram UP (Kumar *et al*., 2007 [20]). Srivastava *et al* (2015 [57]) reported that large sized micro-tubers out yielded the smaller sized and differences in the production potential can be attributed to the variable genetic base of the varieties evaluated as well as to the corresponding growth vigour. Varietal differences on genetic background was also reported by Singh *et al*, 2007 [54] and Somani and venkataselam, 2012 [55]. For yield characteristics the *in vitro* plant group had higher means than those of the microtuber group. This superiority could be due to the longer growing time at the *in vitro* group plants after the transfer to seedbeds. Therefore the *in vitro* plant group plantlets had early rooting and leaf development as compared to the microtuber group tubers. Thus the *in vitro* plant group had longer period for tuber bulking so heavier tubers were produced (Öztürk and Yildirim, 2010 [35]).

Kufri Surya (2.67 and 2.92 Kg/m^2) in microplant, Kufri Bahar (1.65 and 1.78 Kg/m^2) in micro-tuber and Kufri Chipsona-1 (4.64 and 4.98 Kg/m2) in mini-tuber recorded significantly higher total tuber yield (Sadawarti *et al*., 2018a [45]). Total tuber yield was higher in mini-tuber (3.10 Kg/m^2) followed by microplant (1.74 Kg/m^2) and micro-tuber (1.16 Kg/m^2) Sadawarti *et al*, 2018a [45]. In aeroponic tuber multiplication, yield and number of tubers were dependent on the physiological age of minitubers harvested on successive dates (Rykaczewska, 2016 [41]). At close and wide spacings between rows, microtubers yielded 27.3 and 6.7 t/ha, and minitubers 38.9 to 24.4 t/ha respectively (Ranalli *et al*., 1994 [38]).

Conclusion

ICAR-CPRI, Shimla has standardized a number of hi-tech seed production systems based on tissue culture and micropropagation technologies. Adoption of those systems of seed production will improve the quality of breeder seed, enhance seed multiplication rate and reduce field exposure of seed crop by at least 2 years. Growth and yield parameters varied as per hi-tech seed production material, agronomy, genetic background and size of planting materials used for minituber production in different agro climatic systems. Aeroponic technology is promising due to higher seed multiplication rate.

References

1. Al-Mamun MA, Al-Mahmud A, Zakaria M, Hossain MM, Hossain MT. Effects of planting times and plant densities of top-shoot cuttings onmultiplication of breeder seed potato. Agriculture and Natural Resources. 2016; 30:1-6.
2. Alsadon AA, Knustson KW, Wilkinson JC Relationship between micro-tuber and mini-tuber production and yield characteristics of six potato cultivars. (Abst.). American Potato Journal. 1988; 65:468.
3. Badoni A, Chauhan JS. Conventional *vis-a-vis* biotechnological methods of propagation in potato: A review. Stem Cell. 2010; 1:1-6.
4. Beukema van der Zaag DE Introduction to Potato Production.-2nd edition, Center for Agriculture. Agriculture publishing and documentation Wageningen: Prdoc The Netherland, 1990, 1-208.
5. Buckseth T, Singh RK. Hi-tech seed production system-Training on Seed Potato Production (04th April – 13th April, 2018) ICAR-Central Potato Research Institute Shimla-171001, H.P, 2018, 8-13.
6. Bussan AJ, Mitchell PD, Copas ME, Drilias MJ. Evaluation of the Effect of Density on Potato Yield and Tuber Size Distribution. Crop science. 2007; 47:2462-2472.
7. Calori AH, Factor TL, Feltran JC, Watanabe EY, Moraes, CC, Purquerio LFV. Electrical conductivity of the nutrient solution and plant density in aeroponic production of seed potato under tropical conditions (winter/spring). Bragantia Campinas. 2017; 76(1):23-32.
8. Chindi A, Gebremedhin W, Giorgis, Atsede S, Lemma T, Kassaye N. Rapid Multiplication Techniques (RMTs): A Tool for the Production of Quality Seed Potato (*Solanum tuberosum* L.) in Ethiopia. Asian Journal of Crop Science. 2014; 6:176-185.
9. Creamer NG, Crozier CR, Cubeta MA. Influence of seed piece spacing and population on yield, internal quality and economic performance of Atlantic, Superior and Snowden potato varieties in eastern North Carolina. American Journal of Potato Research. 1999; 76(5):257-261.
10. Diengdoh LC, Rai R, Srivastava AK, Bag TK. Optimizing crop geometry for potato mini-tuber multiplication in net-house. International Journal of Agriculture Environmental Biotechnology. 2012; 5(2):113-15.
11. El-Komy MH, Abou-Taleb EM, Aboshosha SM, El-Sherif EM. Differential expression of potato pathogenesis-related proteins upon infection with late blight pathogen: A case study expression of potato osmotin- like protein. International Journal of Agricultural Biology. 2010; 12:179-186.
12. Farran I, Mingo-Castel AM. Potato Minituber Production Using Aeroponics: Effect of Plant Density and Harvesting Intervals. American Journal of Potato Research. 2006; 83:47-53.
13. Gupta VK, Kumar S, Baishya LK, Kumar M. Effect of planting density on mini-tuber production from micro-propagated plants. Potato Journal. 2003; 30:43-44.
14. Hosseini MB, Afshari RT, Salimi K. Breaking dormancy of potato Minitubers with thiourea. Potato Journal. 2011; 38(1):9-12.
15. Hossain MS, Hossain MM, Hossain T, Haque MM, Zakaria M, Sarkar MD. Varietal performance of potato on induction and development of microtuber in response to sucrose Ann. Agric. Sci. 2017; 62:75-78.
16. Hui J, Liu J, Song B, Xie C. Impact of Plant Density on the Formation of Potato Mimitubers Derived from Microtubers and Tip-Cuttings in Plastic Houses. Journal of Integrative Agriculture. 2013; 12(6):1008-1017.
17. Kaur RP. Agro-techniques for production of Hi-tech based planting material (microplants/minitubers) Training on Seed Potato Production (04th April – 13th April, 2018) ICAR-Central Potato Research Institute Shimla-171001, H.P., 2018, 69-73.
18. Kaur RP, Minhas JS, Singh S, Singh AK, Singh RK. High density planting of potato (*Solanum tuberosum* L)

minitubers for increased seed productivity. Indian Journal of Agricultural Sciences. 2019; 89(6):989-993.
19. Kawakami J, Iwama K. Effect of Potato Microtuber Size on the Growth and Yield Performance of Field Grown Plants.-Plant Production Science. 2012; 15(2):144-148.
20. Kumar D, Singh V, Singh RP, Singh BP, Naik PS. Performance of *in vitro* plantlets for production of mini-tubers in vector free environment. Potato Journal. 2007; 34:131-132.
21. Kumar D, Singh OP, Lal SS, Singh BP, Singh V. Optimizing planting geometry of *in vitro* potato plants for growth and minitubers production in nethouse. Potato Journal. 2012; 39(1):69-74.
22. Kumar D, Singh V, Singh, BP. Growth and yield of potato plants developed from *in vitro* plantlets in nethouse. Potato Journal. 2011; 38(2):143-148.
23. Leclerc Y, Donnely DJ, Coleman WK, King RR. Microtuber dormancy in three potato cultivars. American Potato Journal. 1995; 72:215-223.
24. Lommen WJM, Struik PC Influence of a single non-destructive harvest on potato plantlets grown for mini-tuber production. Netherland Journal of Agricultural Sciences. 1992; 40:21-41.
25. Moeini MJ, Armin M, Asgharipour MR, Yazdi SK. Effects of Different Plant Growth Regulators and Potting Mixes on Micro-propagation and Mini-tuberization of Potato Plantlets. Advances in Environmental Biology. 2011; 5(4):631-638.
26. Muthuraj R, Singh BP, Buckseth T, Singh RK, Singh S, Sharma AK. Effect of micro-plants hardening on aeroponic potato seed production. -Potato Journal. 2016; 43(2):214-219.
27. Muthuraj R, Ravichandran G. Effect of inter row spacing on the Production of mini-tubers of potato. Annals of Horticulture. 2015; 8(1):65-68.
28. Naik PS, Khurana S. Micropropagation in potato seed production: Need to revise seed certification standards. Potato Journal. 2003; 30:267-273.
29. Naik PS, Karihaloo JL. Micropropagation for production of quality seed in Asia-Pacific.-Malhotra Publshing House. New Delhi, India, 2007, 1-15.
30. Naik PS, Chakrabarti SK, Sarkar D, Birman RK. Potato biotechnology: Indian perspective. Potato, global research & development. -Proceedings of the Global Conference on Potato, New Delhi, 6–11 December (1999) In: Khurana, S.M.P., Shekhawat, G.S., Singh, B.P., Pandey, S.K. (Eds.), Potato, Global Research and Development, 2000, 194-211.
31. Negero FW. Yield and yield components of potato (*Solanum tuberosum* L.) as influenced by planting density and rate of nitrogen application at Holeta, West Oromia region of Ethiopia. African Journal of Agriculture Research. 2017; 12(26):2242-54.
32. Otroshy M. Utilization of tissue culture techniques in a seed potato tuber production Scheme.-Doctoral thesis, Wageningen University, Wageningen, The Netherlands, 2006, 1-230.
33. Otroshy M, Struik PC. Effects of Size of Normal Seed Tubers and Growth Regulator Application on Dormancy, Sprout Behaviour, Growth Vigour and Quality of Normal Seed Tubers of Different Potato Cultivars. Research Journal of Seed Science. 2008; 1(1):41-50.
34. Ozkaynak EB, Samanci. Relationships between yield and yield components in potato (*Solanum tuberosum* L.) Cultivars with different minituber sizes. Akdeniz University. 2004; 17(2):127-133.
35. Öztürk G, Yildirim ZA. comparison of field performances of minitubers and microtubers used in seed potato production. Turkish Journal of Field Crops. 2010; 15(2):141-147.
36. Pruski K. Micropropagation technology in early phases of commercial seed potato production. PhD Thesis, Wageningen University, Wageningen, The Netherlands, 2001, 166.
37. Ranalli P, Bizarri M, Borghi L, Mari M. Genotypic influence on *in vitro* induction, dormancy length, advancing age and agronomical performance of potato micro-tubers (*Solanum tuberosum* L.). Annals of Applied Biology. 1994; 125:93-101.
38. Ranalli PF, Bassi G, Ruaro P, Del R, Candilo D, Mandolino G. Microtuber and minituber production and field performance compared with normal tubers. Potato Research. 1994; 37(4):383-391.
39. Rex BL, Mazza G. Cause, control and detection of hollow heart in potatoes: A review. American Potato Journal. 1989; 66:165-183.
40. Ritter E, Angulo B, Riga P, Herran C, Relloso J, San Jose M. Comparison of hydroponic and aeroponic cultivation systems for the production of potato minitubers. Potato Research. 2001; 44(2):127-135.
41. Rykaczewska K. The potato minituber production from microtubers in aeroponic culture. Plant Soil Environment. 2016; 62(5):210-214.
42. Sadawarti MJ, Pandey KK, Singh SP, Singh YP. Generational performance of microplant based seed potato production in Gwalior region. Environment and Ecology. 2015; 33(1A):275-278.
43. Sadawarti MJ, Pandey KK, Samadhiya RK, Singh RK, Singh SP, Roy S. Performance of Aeroponically Produced Potato Minitubers under Insect Proof Net House Conditions. Seed Research. 2017a; 45(2):175-178.
44. Sadawarti M, Pandey KK, Somani AK, Venkatasalam EP. Minituber Production Potential of Different Micro Propagated Material Under *In Vivo* Conditions of North Central India. Environment and Ecology. 2017b; 35(2A):820-823.
45. Sadawarti MJ, Samadhiya RK, Kumar V, Singh SP, Roy S, Venkatasalam EP *et al*. Hi-tech planting materials performance under *in vivo* conditions for potato breeder seed production. International Journal of Chemical Studies. 2018a; 6(3):817-22.
46. Sadawarti M, Singh SP, Roy S, Singh RK, Chakrabarti SK. Quality seed Potato production. Agriculture world. 2018b; 4(2):74-81.
47. Sadawarti MJ, Samadhiya RK, Singh RK, Singh SP, Buckseth T, Rawal S, Singh V *et al*. Standardization of agro-techniques for aeroponically produced potato minitubers under protected cultivation in North Central India-Indian Journal of Agriculture Sciences. 2019; 93(3):616-620.
48. Sangar RBS, Agrawal HO, Nagaich BB. Studies on the translocation of potato viruses X and Y in potatoes. Indian Phytopathology. 1988; 41:327-331.
49. Sharma AK, Kumar V, Venkatasalam EP. Effect of varying levels of nitrogen and plant density on the Production behavior of undersize seed tubers of potato (*Solanum tuberosum* L) in north-western hills of India. Indian Journal of Agricultural Sciences. 2014a; 84(3):407-410.

50. Sharma AK, Kumar V, Venkatasalam EP. Effect of method of planting and plantlet density on potato minituber production. Potato Journal. 2014b; 41(1):52-57.
51. Sharma AK, Venkatasalam EP, Kumar V. Effect of plant growth promoting bio-agents (Bacillus sp) on the production of potato (*Solanum tuberosum* L) mini-tubers in north-western Himalaya. Indian Journal of Agricultural Sciences. 2014c; 84(4):473-478.
52. Sharma AK, Venkatasalam EP, Singh RK, Singh S. Effect of variety and planting method of micro-plants on potato mini-tuber production during off-season in north-western Himalaya. Potato Journal. 2010; 37(1-2):28-32.
53. Sharma AK, Venkatasalam EP, Singh RK. Micro-tuber production behavior of some commercially important potato (*Solanum tuberosum* L) cultivars. Indian Journal of Agricultural Sciences. 2011; 81(11):1008-1013.
54. Singh V, Kumar D, Singh RP, Singh BP, Singh S. Performance of microtubers of various potato cultivars in net house. Potato Journal. 2007; 34(1-2):133-134.
55. Somani AK, Venkatasalam EP. Microtuber propagation for breeder's seed production of potato. Potato Journal. 2012; 39(1):98-100.
56. Srivastava AK, Yadav SK, Diengdoh LC, Rai R, Bag TK. Effect of plant density on mini-tuber production potential of potato varieties through micro-plants under net-house in North Eastern Himalayan region. Journal of Applied Horticulture. 2016; 18(1):61-63.
57. Srivastava AK, Yadav SK, Diengdoh LC, Rai R, Bag TK. Effect of cultivars and seed size on field performance of potato micro-tubers in North Eastern Himalayan region in India. Journal of Applied and Natural Science. 2015; 7(1):335-338.
58. Struik PC, Wiersema SG. Seed Potato Technology. - Wageningen Perss, Wageningen, 1999, 175-216.
59. Truta AAC, Detec Simult A. Nea de VìrusEmBatata (*Solanum tuberosum* L.) por DAS-ELISA e determinaÁ„o do material vegetal ideal a serutiliza dono sprogramas de indexaÁ„o. Lavras: UFV. (DissertaÁ„o ñ Mestrado), 1997, 59.
60. Tsoka O, Demo P, Nyende AB, Ngamau K. Potato seed tuber production from *in vitro* and apical stem cutting under aeroponic system. African Journal of Biotechnology. 2012; 11:12612-12618.
61. Venkatasalam EP, Latawa J, Sharma S, Sharma S, Sharma AK, Sharma PR *et al*. *In vitro* and *in vivo* performance of potato cultivars for different seed seed production systems. Potato Journal. 2011; 38:149-154.
62. Wiersema SG, Cabello R, Tovar P, Dodds JH. Rapid seed multiplication by planting into beds micro tubers and *in vitro* plants. Potato Research. 1987; 30:117-120.
63. Zamil MF, Rahman MM, Rabbani MG, Khatun T. Combined effect of nitrogen and plant spacing on the growth and yield of potato with economic performance. Bangladesh Research Publication Journal. 2010; 3(3):1062-1070.