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Research Review Articles

A novel sustainable aeroponic system for healthy seed potato production in India – An update

TANUJA BUCKSETH[1], RAJESH K SINGH[2], JAGESH K TIWARI[3], ASHWANI K SHARMA[4], SUKHWINDER SINGH[5] and S K CHAKRABARTI[6]

ICAR-Central Potato Research Institute, Shimla, Himachal Pradesh 171 001, India

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ABSTRACT

High yielding varieties and sound planting materials are prerequisites for sound seed potato production. Low multiplication rate, high seed (tuber) rate, dynamic amassing of degenerative infections, perishability and massiveness are the inherent issues in seed potato production. This may result in non-accessibility/non-availability of sufficient amounts of value seeds at reasonable cost and seed cost alone reflects 40% which is half of the aggregate expenses of development in potato. To go around a portion of these issues, a few alterations, for example, tuber ordering for infection opportunity, seed increase stages and seed accreditation guidelines have been created and incorporated with regular potato seed generation programs. The advent of tissue culture, in which virus-free plants can be produced through meristem culture, maintained indefinitely under controlled conditions and multiplied in artificial media under sterile conditions in the laboratory throughout the year irrespective of growing season, has revolutionized seed production in potato world over. Recent developments in automation of minitubers production have further enhanced adaptability of these techniques in potato seed production. In addition to quality assurance through meristem culture, aeroponic technique of minitubers production ensures high multiplication rate at initial stages of quality seed potato production.

Key words: Aeroponic, Soil-less production, Virus-free seed potato

Potato (*Solanum tuberosum* L.) is the third most essential sustenance harvest of the world after rice and wheat. Being a vegetative harvest through tubers, it is exposed to substantial number of seed-borne ailments causing degeneration of seed stocks throughout the year (Buckseth *et al*. 2016, Singh *et al*. 2016). It's imperative to utilize great quality seed potatoes for monetary returns. Be that as it may, accessibility to value seed is a noteworthy limitation in potato production particularly in developing nations. Because of this, farmers are regularly compelled to utilize locally developed deteriorated seeds of earlier years in spite of extreme yield reductions up to about 40% (Singh *et al*. 2016). In India, one noteworthy reason for low potato profitability is the utilization of low quality seed and at present the state and central seed offices of the nation can meet just 20–25% prerequisite of aggregate quality seeds. For connecting this wide gap, large-scale integration of typical and speedy multiplication techniques like micropropagation and also hydroponics/aeroponics at business level, open new avenues for creating enough amount of healthy seeds tubers in short period (Buckseth *et al*. 2016).

Recently, hydroponic/aeroponic systems have been developed for production of minitubers by utilizing healthy *in vitro* plants (Buckseth *et al*. 2016, Otazu 2010, Pandey and Singh 2014, Singh *et al*. 2012). Additionally to reduce the cost of production, these systems facilitate round the year production and adoption of phytosanitary standards (Singh *et al*. 2016, Singh *et al*. 2012, Tierno *et al*. 2014). Hydroponically developed minitubers, like Technitubers[R] (size 10-15 mm in diameter) were created under strict hygienical conditions in high density plantings and harvested at intervals from plants growing in nutrient film. As reported, Technitubers[R] are ideal for storage, transportation and mechanized planting with the assistance of vacuum seeder (Naik and Buckseth 2018). Scientific agronomic packages were conjointly developed and field trials conducted over years in many countries and it's been incontestable that a healthy and vigorous potato crop can be raised from Technitubers[R]. Further, Quantum Tubers TM is another proprietary method during which minitubers were created from *in vitro* plants by M/S Quantum Tubers Corporation, USA. This technology has the advantage of short propagation time for harvestable minitubers (40-50 days) and high number of minitubers (10000 nos.) per square

Scientist (tanujagbpuat@gmail.com), [2]Principal Scientist & Head (rjan_1971@yahoo.co.in), [3]Senior Scientist (jageshtiwari@gmail.com), [6]Principal Scientist & Director (skc_cpri@yahoo.co.in), ICAR-CPRI, Shimla, HP; [4]Principal Scientist & Head (ashwanicpri@gmail.com), ICAR-CPRS Kufri, HP; [5]Senior Scientist (ss.cpri@gmail.com), ICAR-CPRS, Jalandhar, Punjab.

meter weighing 1-5 g (Naik and Buckseth 2018) in a year.

Aeroponic System

Aeroponics is the way toward developing plants in an air or fog condition without utilization of soil or a total media. The word aeroponic is derived from the Latin word 'air' (meaning air) and 'ponic' (meaning work) (Farran and Mingo-castel 2006). This is an elective strategy for soil-less culture in supplement arrangements under controlled conditions. Strategies of developing plants without soil were first created during the 1920s by botanists who utilized crude aeroponics to contemplate plant root structure; and the method has for quite some time been utilized as an examination apparatus in root physiology. In the early1940s, the innovation was to a great extent utilized as an exploration apparatus as opposed to a monetarily practical strategy for getting yield. Carter (1942) was the primary scientist to contemplate air culture and depicted a strategy for developing plants in water or fog to encourage examination of roots. Fifteen years after the investigation of Carter (1942), Went (1957) named this technology as "aeroponics". In current agriculture, diverse soil-less production procedures for example, Nutrient Film Techniques (NFT) and aeroponics have been developed (Singh *et al*. 2010). Prior works have indicated great outcomes with NFT for potato tuber production. Besides, tuber commencement was found poorer in nutrient solution without solid media, than in permeable media (e.g. perlite or vermiculite). The tuberization restraints of stolons immersed in a solution could be the outcome of mechanical resistance. The usage of aeroponic technique for potato seed production is extremely recent in Europe. Previously, the utilization of these advances was restricted virtually all over the world and just a few nations, for example, China or Korea were utilizing them for the generation of potato quality seeds (Kim *et al*. 1999). These days, aeroponics is being utilized effectively in South America (Mateus-Rodriguez *et al*. 2012) and endeavors are made to present this innovation additionally in some African nations (Otazu 2010). Taken together, aeroponic culture is a vital technique of soil-less culture under controlled conditions for healthy quality seed potato production.

Healthy seed potato production through aeroponics

Preparation of virus-free in-vitro planting material: Being a clonally propagated crop, potato is sensitive to viral diseases over the successive generations (Naik and Buckseth 2018). Therefore, quality seed potatoes can be produced under aeroponics using virus-free *in vitro* plants, which are regenerated through various tissue culture based techniques as described below (Buckseth *et al*. 2016, Naik and Buckseth 2018).

Meristem culture: This incorporates *in vitro* culture of meristematic arch (0.1–0.3 mm in size either from the apical (terminal) or axillary meristems) of actively dividing cells situated at the developing tip of the shoot, along with a part of the subjacent tissue containing a couple of leaf primordia. Since synthetic control isn't accessible for viral diseases, meristem culture is the main technique to take out infections from foundationally tainted potato cultivars. Although, most of the varieties under seed chain have been free from viruses using meristem culture, however its response varies from genotype to genotype and also upon nature of virus.

Thermotherapy: Growing plants under higher temperature (35–37°C) than the normal (18–20°C) for 4-6 weeks significantly reduces the growth of potato viruses. Hence, thermotherapy of infected plants followed by plant tissue culture of the extreme temperature treated plants permit additional success in production of virus free plants. Besides, low temperature treatment (4–7°C) is effective to cure potato spindle tuber viroid (PSTVd).

Chemotherapy: This method includes utilization of synthetics like antibiotics, plant development controllers, amino acids, purine and pyrimidine analogs to inactivate infections or restrain replication/development of infections in tissues. *In vitro* chemotherapy of meristematic explants with antiviral synthetic ribavirin (Virazole: 1-D-ribofuranosyl-1, 2, 4-triazole-3-3carboxamide) has been found to be most promising for elimination of major potato viruses.

Electrotherapy: Electrotherapy (15 mA current for 5 min) of *in vitro* plants has been found effective to some extent in some viruses like potato virus X (PVX) and resulted in 60-100% virus free plants.

Virus detection: In vitro plants produced by above techniques are utilized for quality seed generation after mass augmentation through tissue culture (Buckseth *et al*. 2016, Naik and Buckseth 2018). To accomplish this, identification of potato infections in the *in vitro* plants is basically essential. Even after taking all precautions to use meristematic tips followed by various treatments favouring virus elimination, finally a very few results in virus-free mericlones. Hence, meristem-originated plants are tested for virus freedom before using them as mother plants in micropropagation. Precise, delicate and fast identification of potato infections is basic for distinguishing infection free mother plants and their utilization in seed production programs (Singh *et al*. 2016). A few serological, nucleic acid and PCR (additionally constant quantitative PCR) - based examinations are accessible for precise diagnosis and conclusion of potato infections.

In serologic strategies, enzyme-linked immune sorbent assay (ELISA), dot immune binding assay (DIBA) and immune sorbent microscopy (ISEM) are most generally used strategies for detection of plant viruses. Over the years, numerous modifications were introduced in ELISA systems with increasing handiness of organism and polyclonal antibodies to cut back host matter background reactions Whereas, macromolecule conjugation relies on specific pairing between the one normal de-oxy ribonucleic acid or ribonucleic acid and a complementary macromolecule probe to make double stranded macromolecule (Naik and Buckseth 2018). Polymerase chain reaction (PCR) combined with reverse transcription (RT-PCR) and real-time quantitative PCR (RT-qPCR) has additionally been used for detection

of picogram quantities of infectious agent macromolecules in infected tissues. With its relative simplicity and high sensitivity, the PCR-based strategies are progressively being employed to observe and diagnose plant viruses (Tierno *et al*. 2014).

In vitro multiplication: Tissue culture (micropropagation) permits large-scale multiplication of virus-free potato microplants. Nodal cuttings of virus-free potato microplants are grown on solid or liquid medium under aseptic conditions for getting new microplants (Buckseth *et al*. 2016, Naik and Buckseth 2018). Murashige and Skoog's (MS) medium supplemented with 2.0 mgl^{-1} D-calcium pantothenate, 0.1 mg/l GA^3, 0.01 mg/l NAA and 30 g/l sucrose is best suited for propagation of potato microplants. Cultures are usually incubated under a 16 h photoperiod (50-60 µ mol/m^2/s light intensity) at 20 °C. Usually, three nodal cuttings (1.0–1.5 cm) are inoculated per culture tube (25 × 150 mm), and the tubes are closed with cotton plugs. Within 3 weeks the axillary/apical buds of these cuttings grow into full plants. These plants can be further sub-cultured on fresh medium. At an interval of every 25 days of sub-culturing, theoretically 315 (14.3 million) microplants can be obtained from a single virus-free microplant in a year.

Healthy plants can be used for direct transplanting after hardening, in the aeroponics growth chamber. Temperature and photoperiod are two important physical factors that affect potato microtuber induction *in vitro*. The optimum temperature for *in vitro* tuberization is 20°C, with a constant temperature being more effective than alternating day-night temperatures (Naik and Buckseth 2018). Temperatures below 12°C and above 28°C have been found to be inhibitory to potato microtuber production.

Aeroponic growth system: This innovation comprises plant development with encased root framework in dim chamber by showering supplement nutrient solution on roots with fog/splash gadgets that incorporate aeroponic chamber, siphon, showering cylinder, clock and solution stored tank (Pandey and Singh 2014, Singh *et al*. 2012, Buckseth *et al*. 2016). Potato development and use of minitubers utilizing aeroponics have been looked into by Buckseth (2016). A cylinder with a few spouts goes through the aeroponic chamber and splashes supplements on root zone of plants. The aeroponic chamber has a removable opening with gaps for holding potato plants (Fig1a). Front of the aeroponic chamber is set with pivots and can be opened to harvest minitubers of ideal size more than once at various time intervals. *In vitro* plantlets are planted in the openings and settled by wipe. The supplement arrangement is splashed for 30 seconds after each 3–5 minutes in beginning developing stages (Singh *et al*. 2012). After some weeks, root framework begins developing inside the development chamber. The supplement arrangement splashing interim is drawn out up to once in 15 min with dynamic development of the plants. Stolon and tuber arrangement starts at various interims depending on the assortment. Picking of the tubers begins following 45–50 days of planting when a portion of

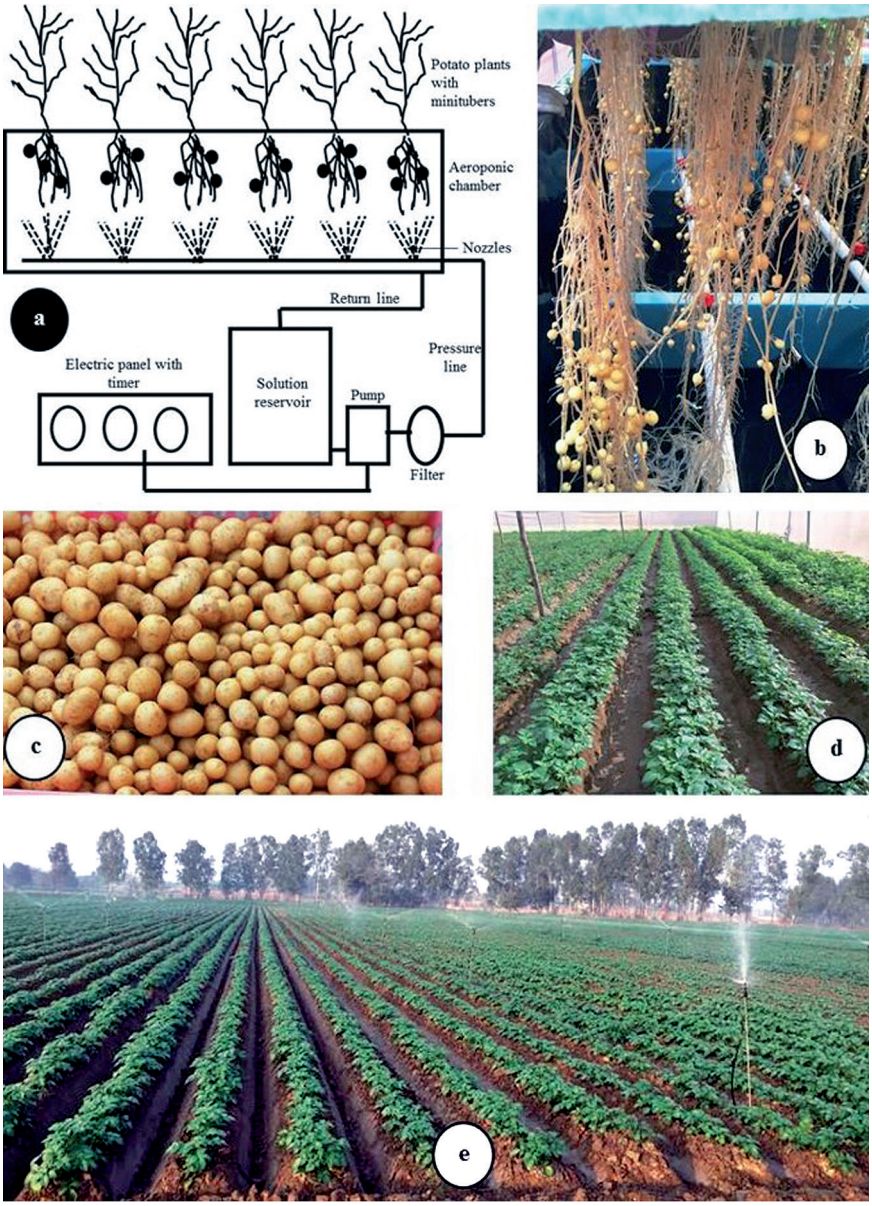

Fig 1 Diagrammatic representation of aeroponic framework. (a) Aeroponic system, (b) Potato minitubers developed in dark aeroponic chamber, (c) Harvested aeroponic minitubers, (d) Successive generation of aeroponic minitubers crop in net house and (e) in the field.

the tubers achieve approximately 15–17 mm width. When the principal flush is gathered, arrangement of extra tubers is activated coming about into more minitubers/plant (Fig 1b). In this framework, picking of minitubers is done after everyone week, and around 10–12 harvests are taken. Normally 45-50 minitubers can be gathered from a solitary plant as against 8–10 minitubers under the net-house. These harvested minitubers (Fig 1c) are stored at 2–4ºC and are utilized for planting in the following season (Fig 1d and 1e). There are different reactions of assortments and day lengths on development of *in vitro* plants. Therefore, there is a need to work out nutritional and plant management (bower system under long day conditions) requirements for varieties and growing conditions (Millam and Sharma 2007, Otazu, 2008, Pandey and Singh 2014). It is essential to maintain the pH (6-7) of the nutrient solution at the desired levels all through the harvest time frame and its change at week by week intervals (Otazu 2010). In aeroponic framework, it is conceivable to create 2094 minitubers for every square meter, compared with 771 minitubers for every square meter in soil/ substrate-based nursery beds. Along these lines, aeroponic procedure offers numerous advantages for creating upgraded seed potato generation frameworks, mostly for minitubers. In spite of the fact that this system requires a high level of specialized ability in plan, foundation and running expenses and institutionalization of genotype-responsive supplement arrangements, the advantages offered are very high while delivering solid quality seeds. Consequently this innovation offers overall extensive scale reception by seed potato producing organizations (Kim *et al*. 1999, Otazu 2008).

Benefits of the technology

- Aeroponics stands out amongst the quickest strategies for proliferation for seed potato utilizing *in vitro* plants (Tierno *et al*. 2014). The method permits creation of huge quantities of healthy minitubers in one go, hence disposing of the requirement for more field, subsequently decreasing expenses and sparing time (Buckseth *et al*. 2016).
- An individual plant can deliver more than 100 minitubers in a solitary rather than ordinary strategy that make around 8 tubers just over the span of a year while just 5 to 6 tubers for every plant are created utilizing soil in the nursery in 90 days (Tierno *et al*. 2014).
- In the perspective of great outcomes acquired by Lommen (1995) concerning continued harvesting and considering the qualities of aeroponic culture, the blend of the two strategies is by all accounts especially valuable for minitubers production in potato.
- Production of potato through aeroponic enhances accessibility of seed potatoes. Likewise, aeroponics permit roguing of unhealthy plants (Nicholas 2007). Moreover, potato seed delivered through this strategy could show quickened development because of enhanced air circulation of the roots and ideal supplement take-up from an atomized supplement arrangement (Lemma *et al*. 2017).
- Aeroponic based potato minituber generation is expanding in India because of more number of minituber production per unit area and time (Fig 2) with controlled conditions round the year (Barak *et al*. 1996, Nicholas 2007).
- The aeroponics framework utilizes supplement arrangement distribution; henceforth, a constrained measure of water is utilized (Lommen 1995, Tierno *et al*. 2014).

Impact of the technology

Since 2011, this aeroponics system has been commercialized by many firms through the Indian Council of Agricultural Research (ICAR)-Central Potato Research Institute (CPRI), Shimla. Shortening the span of potato stock breeder seed production by just about a pair of years and production of fresh material are the most important advantages of aeroponic system that might revolutionize the potato seed trade within the country. Presently, CPRI produces 3186.82 tonnes of nucleus and breeder seed of twenty five potato varieties, out of which 70% is through conventional system whereas, 30% is through advanced (tissue culture-based aeroponic) system, that is merely adequate to fulfil the demand of healthy seed potato within the country. As there is limited scope to increase quantity of breeder seed at ICAR-CPRI farms, due to limitation of additional availability of land for seed production therefore, possibilities are being explored with the help of State Agricultural Universities (SAUs)/Krishi Vigyan Kendras

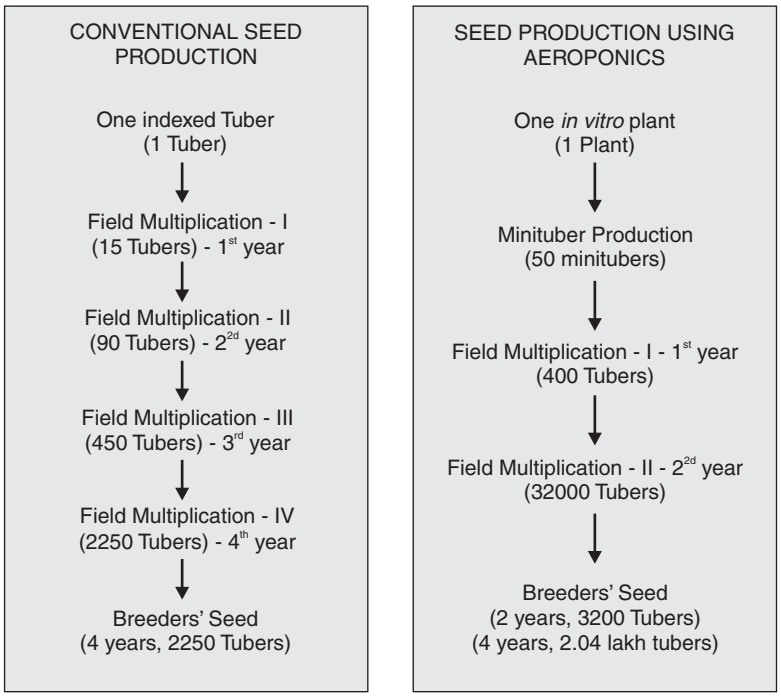

Fig 2 Comparison of conventional and aeroponic seed potato production system.

(KVKs)/Private farmers to identify the new areas of seed production, multiplication of breeder seed into Foundation Seed (FS)-I, FS-II and Certified Seed under Memorandum of Understanding (MoU) and to produce seed through hi-tech system with the help of entrepreneurs/private companies. The institute has generated revenue of ₹ 100 lakh as licensing fee by commercialization of this technology to these firms. Each firm was licensed to produce 10 lakh minitubers by aeroponic system. Even if each firm is operating at half of it potential, about 6.5 million minitubers will be produced. At an average rate of productivity of 25 tonnes/ha, it will produce 70500 tonnes of seed potato. This had generated revenue of worth ₹ 2500 million in the Indian economy.

What we know and what remains to be known in aeroponics?

Aeroponics was first used for vegetable production. It is a relatively new technique, especially for seed potato production (Buckseth *et al*. 2016). Initial tests provide us with the following information:

- Potato cultivars respond to aeroponics.
- Aeroponic production is especially sensitive to climate.
- Sequential harvests are required.
- Vegetative growth of plants is enhanced by 1–2 months.
- Aeroponic seed yields are similar as typical seed within the field.
- Initial investment will be recovered speedily.
- Bacterial contamination to nutrient solution looks promising in increasing seed production exploiting aeroponics.
- Aeroponics will considerably increase financial gain or cut back the assembly prices of quality potato seed and make it accessible to many growers.
- Non-conventional energy sources (solar, wind) seem good for aeroponics.

Optimization of seed potato production at ICAR-CPRI, Shimla by aeroponics

New varieties/genotypes should be tried and tested. Artificial conditions such as extra lights, humidity can be easily supplied in the greenhouse as per the requirement of the cultivars grown in different latitudes.

Distinctive cultivars may require diverse ideal supplement nutrient arrangements. Ideal grouping of chemical composition of nurients should be researched for every single cultivar. This is under current examination at CPRI, Shimla.

In vitro plants have demonstrated to yield well in aeroponics. We additionally need to decide and think about other plant materials, for example, cuttings and sprouts etc.

The excessive vegetative growth is a problem which needs investigation to increase overall yield. Dwarf cultivars should be bred especially for aeroponics.

Conclusion

In relieving the issue of non-availability of good quality seeds, methodologies to speedily multiply the seed tubers such as tissue culture in conjunction with aeroponic technology have been attempted. These advances should be given due consideration and ought to be advanced in most potato producing nations in order to expand potato yields. These technologies should be promoted in most developing countries so as to increase potato yields. In areas having high disease pressure, the new system of seed potato production based on soil-less system has the advantage of better health status of seed stocks due to the reduced number of field multiplications over the conventional (clonal multiplication) system.

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