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AEROPONIC SEED POTATO PRODUCTION: A PROMISING AND SUSTAINABLE STRATEGY FOR SEED POTATO PRODUCTION IN PAKISTAN

Raja Mohib Muazzam Naz[1]*, Muhammad Hanif[1], Waqas Ahmed Dogar[1], Muhammad Umar[1], Qandeela Nigar[1], Uzma Arif[1], Saima Noor[2], Amber Imtiaz[2], Haider Ali[2], Kazim Ali[2], Aish Muhammad[3], Khalid Farooq[3], Rehmat Kabir[4]

[1]Horticultural Research Institute, National Agricultural Research Centre, Park Road, Islamabad 45500, Pakistan
[2]National Institute for Genomics & Advanced Biotechnology, National Agricultural Research Centre, Park Road, Islamabad 45500, Pakistan
[3]KOPIA, Pakistan Center, Islamabad
[4]Pakistan Agricultural Research Council, Mountain Agricultural Research Station, Chilas, Pakistan
*Corresponding Author's email address: mohibhortian@parc.gov.pk

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ABSTRACT

Potato is an important food and cash crop globally and faces many challenges in Pakistan. These challenges include issues with soil fertility, pest and disease pressure and shortages of high-quality seed potatoes. The scarcity of high-quality seeds is a massive hassle in Pakistan. Farmers in Pakistan, often reuse their seeds or obtain them from informal sources. This practice leads to increased seed quality deterioration and tuber-borne diseases, resulting in decreased yields. To address this situation, aeroponic techniques can effectively meet this challenge. Aeroponics is a novel technique for producing high-quality seed potato, aiming to address the challenge of seed production. Aeroponic techniques are commercially practised in many countries. Thus, in this review, we have highlighted the importance of aeroponic technology and how this technique can help uplift/boost up the seed potato production system in Pakistan. The overview concludes that aeroponic seed production offers numerous benefits, including improved yields, and resistance, even as keeping natural resources. Despite the challenges, the evaluation indicates that the implementation of aeroponic seed production technology in Pakistan may offers a promising and sustainable technique for seed potato production in Pakistan.

Keywords. Aeroponic, Soil-less technology, Nutrition, Virus-free seed potato, Seed Potato

INTRODUCTION

Potato is an important crop of Pakistan, with a lar ge cultivated area of 0.31 million hectares and an annual yield of 7.9 million tons (Economic Survey of Pakistan. 2021-2022). Potato is an important crop in Pakistan, both for food security and economic development. However, the conventional methods of seed potato production in Pakistan have several challenges, including low seed quality, susceptibility to disease and high-water usage. Aeroponic seed production has emerged as a potential solution to address these challenges and improve potato cultivation (Tunio *et al.*, 2020).

Traditional growing of potatoes involves considerable risk and uncertainty due to fundamental and abiotic factors such as strong winds, floods, drought and pest infestation. This is mainly because field farming requires extensive land use, substantial land preparation expenditures, labour and excessive water use. Given these challenges, researchers seek innovative agricultural methods. It has been suggested that a viable solution might be to employ currently available technologies when operating in a controlled environment. Among these technologies, soilless cultivation/aeroponic is a promising option in terms of seed potato production (Buckseth *et al.*, 2022).

Aeroponics supplies nutrients to plants via an aerosolized nutrient solution administered regularly within the root zone. The roots maintain constant exposure to unpolluted ambient air, fostering heightened respiration within root tissues and an accelerated metabolic rate. The outcome is a substantial increase in biomass production across both the root and shoot systems, encompassing the generation of mini-tubers (Andrade-Piedra *et al.*, 2019). Utilising aeroponic technology, a yield ranging from 30 to 40 mini-tubers per potato plant can be achieved. The distinct advantage of the aeroponic system lies in the ability to harvest tubers at the optimal size, consequently enhancing mini-tuber production (Ritter *et al.*, 2001). Applying aeroponics in potato multiplication can prevent a complete generation of seed potato multiplication as compared to field, leading to cost reduction and elevated plant health quality during the initial phase of field production (Čížek and Komárková, 2022).

Aeroponics generates a substantial yield of consistently uniform potato mini-tubers concurrently. The pivotal factor underpinning successful tuber production within the aeroponic framework is the precise regulation of tuber initiation processes. This advanced cultivation technique provides a controlled environment that promotes optimal conditions for the potatoes to initiate and develop tubers, resulting in a synchronised and homogeneous yield of mini-tubers (Singh *et al.,* 2019). The controlled environment in aeroponics allows for manipulating factors such as nutrient availability, light exposure, and humidity, collectively contributing to orchestrating the tuber initiation phase. As a result, aeroponics emerges as a cutting-edge approach to achieving a bountiful harvest of standardised mini-tubers with enhanced predictability and consistency (Christie and Nichols, 2004).

In Pakistan, using potato aeroponic technology offers a promising avenue for agricultural advancement. This innovative approach presents a range of perspectives that warrant exploration. The current status of potato aeroponics in the country reflects its nascent stage and potential to revolutionise potato cultivation practices. However, as with any emerging technology, there are inherent challenges, including adapting the technology to local agro-climatic conditions, ensuring scalability, and optimising resource efficiency. Despite these challenges, significant opportunities exist to integrate potato aeroponic systems within Pakistan's agricultural landscape. The convergence of technological innovation, research, and sustainable practices could propel the potato industry towards higher yields, enhanced quality, and improved food security. This review delves into the multifaceted dimensions of potato aeroponic technology, aiming to shed light on its current landscape while envisioning its future trajectory within Pakistan's agricultural framework.

Constraints in Seed Potato Production in Pakistan: Pakistan has been a significant challenge for the agricultural sector. Issues such as limited access to high-quality planting material, inadequate disease management practices, and lack of proper storage facilities have hindered the potential for efficient and sustainable seed potato production. Additionally, variable climate conditions and resource limitations further complicate the process. Addressing these constraints requires a comprehensive approach involving research, technology dissemination, and policy support to enhance seed potato quality, disease resistance, and overall production in the country (Devaux *et al.,* 2021)**.**

From the perspective of Pakistan, it has been observed that there are 25.2 tons per hectare potato yield, that is despite the fact that the average yield is higher than the world average but comparatively low as examine the potential of the country because of several reasons. Availability of diseases free, healthy and true to type seeds and contemporary production technology are the essential constraints to achieve the better potato production targets. It's very alarming that in spite of good ranked in potato producing countries, but we are not able to produce high quality seed. Pakistan has the capacity to meet good quality certified seed requirement only 1% against 0.5-0.7 million tons per annum demand and mostly depend on imported seed that is about 15000-20000 tons per annum from different countries (Muhammad *et al.,* 2022).

Opportunities: Seed potato production has gained widespread adoption globally as a reliable practice. It is crucial for the increasing population and the climatic changing scenario to embrace the latest technologies in potato production for sustainable and profitable farming (Waaswa *et al.,* 2021). This will contribute to the growth and development of potato production in Pakistan. The commercial application of aeroponic strategies for seed potato production, precise management, and plant safety measures can offer indigenous high-yield capacity and excessive vigour of seed potato. The Pakistan Agricultural Research Council, in partnership with the Korean Government, Rural Development Administration (RDA) - Korea Program on International Agriculture (KOPIA) Pakistan, has established an aeroponic seed potato production facility at the National Agricultural Research Centre (Dogar *et al.,* 2023). Through tissue culture and aeroponics facilities improvement in Pakistan, more than 200,000 nucleus mini tubers were harvested from the fall of 2021 and spring of 2022 plantation. This is an impressive and successful venture of KOPIA in Pakistan for seed potato production and self-sufficiency to ensure food safety in the country (Dogar *et al.,* 2023).

History of Aeroponic Technology: Aeroponic research has a rich history that dates back to the 1920s when it was first introduced as a soilless growing technique. While it initially served as a study tool in the early 1940s, it was in 1942 that W. Carter developed a water vapour method to supply nutrients to plant roots for root examination. This marked the first research in air culture. In 1944, L.J. Klotz discovered a way to use vapour misting to study diseases of citrus and avocado roots (Mir *et al.,* 2022a). In 1952, G.F. Trowel successfully grew apple trees in a spray culture. The Genesis Rooting System, also known as the Genesis Machine, was the first commercial aeroponics setup that used a microchip to control the process. It was quickly connected to an electrical outlet and a water faucet and was developed by GTI in 1983. In the 1990s, NASA conducted a series of tests on earth and in space to produce biomass without soil and with minimal water, which proved highly efficient. NASA research has shown that aeroponically grown plants have an 80% growth in dry-weight biomass (essential minerals) compared to hydroponically grown plants. NASA has given special attention to aeroponic methods because mist is easier to control than liquid in zero-gravity conditions (Kumari and Kumar, 2019).

How does it work?: Aeroponic development is a soilless approach in which plants are grown, supported at the top, with their roots placed into a container. A nutrient mixed in water is periodically pumped into the container and misted onto the putting roots. The nutrient solution is sprayed in the form of a nice particulate mist of 50-60 microns. The roots stay hydrated and absorb their nutrients without staying suspended in soil or water. Full access to oxygen in the air promotes the boom rate of roots and vegetative parts. Such an environment additionally gives plant full right of entry to carbon dioxide inside in the range of 450 to 780 ppm for photosynthesis so that grow within the aeroponic environment develop quicker and absorb more nutrients than ordinary hydroponic plants (Mir *et al.,* 2022b).

Instead of using soil for growing plants, enriched water solution, within the proper dosage and within the proper time, is used for growing plants,

- Grow speedy and robust.
- High rate of tuber production.
- Uniform, healthy, higher growth rate and vigorous potato tubers.
- Production of uniform size of mini-tubers.
- Remain in balance and stay longer.
- Provide greater comparable phenolic, flavonoid, and antioxidant properties.
- Have longer shelf life.
- More efficiently potato production.
- Eliminate many steps involved in seed potato multiplication.
- Have higher nutritional value over traditionally grown fruits, vegetables or even flowers.
- Environment friendly approach due to less amounts of water input per unit of planted area.

Greenhouses are used for aeroponics manufacturing. Any things that can be grown in soil may be grown aeroponically. The most famous crops are potato, ginger, lettuce, tomato, basil, parsley, cherry tomato, squash, bell pepper, crimson kale, cucumber and decorative vegetation.

Table 1: General comparison of aeroponic and conventional methods of seed potato production

Aspects	Aeroponic Method	Conventional Method
Seed Quality	Generally, produces high-quality seeds	Quality can vary based on conditions
Space Efficiency	Requires less space	Requires more space for planting
Water Usage	Uses less water	Uses more water for soil irrigation
Nutrient Management	Precise control over nutrient delivery	Nutrient distribution in the soil varies
Disease and Pest Control	Easier to control diseases and pests	It may require more pesticides/fungicides
Labour Intensity	It can be automated, reducing labour needs	Manual labour for planting and upkeep
Environmental Impact	Potentially lower environmental impact	More soil erosion and runoff are possible
Harvest Efficiency	Easier harvest process	Digging required for tuber retrieval
Initial Investment	Higher setup costs for aeroponic systems	Lower initial costs for conventional
Yield Potential	High yield potential	Yield may vary based on soil quality
Growth Rate	Faster growth in aeroponic conditions	Growth rate influenced by soil health

Maintenance of System: Maintaining an aeroponics device is easy, requiring a minimum amount of time. Daily maintenance includes checking pH stages, Electrical conductivity (EC) level and ensuring the nutrient reservoir continues to be crowned off. Every couple of weeks, nutrient solution should be replaced with a fresh batch. The old solution can be used to water house plants or landscape plants around the home (Kumari and Kumar, 2019).

Attributes of Aeroponics: Aeroponics production allows crops to be grown intensively. This method consumes only $1/30^{th}$ the amount of water needed to produce the same product, grown traditionally outdoors. Crop rotation is unnecessary because there is no soil depletion of nutrients as in the case of soil used as a medium. Growth is not controlled or limited by seasonal variations; therefore, it can be produced continuously whole year, Table 1. There is little to no risk of weeds or parasites in greenhouses because of substantial barriers to the entry of insects (Čížek and Komárková, 2022). Through aeroponic system a single potato plant can produce 30-50 mini-tubers as compared to soil 6-10 tubers (Tengli *et al.,* 2022).

Aeroponic Scenario in Pakistan: The aeroponic situation for seed potato production in Pakistan remains in its early stages, with restrained adoption and studies in this generation. However, a few initiatives and studies display aeroponics' capacity for seed production in the country. Aeroponic technology for seed potato production changed into standardised and commercialised through the Pakistan Agricultural Research Council (PARC) in 2020. An aeroponic seed potato production technology project has been established in Pakistan by the Technical Cooperation Project (TCP) among RDA-KOPIA and PARC. It has been observed that Pakistan has established three aeroponic greenhouses at the National Agricultural Research Centre, Islamabad (Dogar *et al.,* 2023). Scientists have used this experiment to generate high quality seed, virus-free seeds that yield the best. The leftover seeds could be exported to other countries. The aims of the project are to establish additional greenhouses at the NARC to produce 400,000 nucleus seed potatoes and in this way produce 160,000 tonne of high quality fourth-generation (G4) seeds within five years (Muhammad *et al.,* 2022).

The autumn 2022 plantation at KOPIA screen houses yielded significant and remarkable results. A total of 8,400 tissue culture plants across Greenhouses 1, 2, and 3. Out of these, an impressive 8,107 plantlets not only survived but thrived. The total number of tubers harvested reached an impressive 386,247, with an average of 47.64 tubers per plant and an average tuber weight of 5.56 g. These outcomes underscore the success and productivity of autumn planting efforts at KOPIA screen houses in 2022.

Strategies to Develop a Sustainable Potato Seed Production System: Developing a sustainable seed potato production system in Pakistan through aeroponic techniques necessitates a multifaceted approach. Varied strategies are essential, encompassing careful varietal selection for adaptability to aeroponics, stringent pathogen management practices to mitigate disease proliferation, precise nutrient delivery systems for optimal growth, advanced environmental control mechanisms to ensure ideal conditions and focused root zone management to sustain root health (Estrada-Flores and Intelligence, 2009). Genetic purity preservation, data-driven decision-making, capacity building for stakeholders, economic viability assessments, collaborative research efforts, and supportive policy frameworks further contribute to the establishment of a robust and environmentally conscious seed potato production system. Integration of these strategies presents a comprehensive pathway to harness the potential of aeroponics, enhancing potato crop yield, quality, and sustainability in Pakistan's agricultural landscape.

Future Outlooks of Aeroponics: Compared to other farming methods, aeroponics has significant advantages in increasing plant growth and yield. However, these benefits come with associated costs, including high initial installation costs and the need for technical expertise in managing pH levels and nutrient concentration ratios. If you are new to hydroponics, it is recommended that you evaluate the pros and cons of aeroponics and other methods before choosing the method that best suits your current needs.

Although its implementation is intricate, aeroponic technology is promising for advancing agricultural practices. Many countries lack widespread familiarity with this innovative method among growers and horticulturists, necessitating well-trained personnel. Additionally, numerous substrates are globally marketed, rendering them costly. Exploring cost-effective local substrate options becomes imperative. Growers can customise aeroponic systems to suit their requirements, spatial limitations, and financial capacities. Vigilant attention to essential growth parameters such as nutrient levels, light, oxygen availability at the root zone, water quality, pH, sterilisation, and solution temperature is imperative. With its water, land, and nutrient efficiency, Aeroponics emerges as a forward-looking solution, positioning it as the future pathway for simplified crop cultivation.

CONCLUSION

In conclusion, this review paper underscores the immense promise of employing aeroponic techniques as a sustainable and innovative strategy for seed potato production in Pakistan. The strategies examined, ranging from varietal selection and disease management to environmental control and policy support, collectively emphasise the potential of aeroponics to revolutionise the agricultural landscape. By adopting these strategies, Pakistan could foster increased potato yield, improved crop resilience, and reduced environmental impact. The future is bright with the continued advancement of aeroponic technologies and practices. However, this potential must be harnessed through rigorous research, collaborative partnerships, and adaptive policies. The ongoing development of aeroponic seed production could address food security challenges and establish Pakistan as a pioneer in sustainable agricultural practices on the global stage.

ABBREVIATIONS

KOPIA: Korea Program on International Agriculture
NARC: National Agricultural Research Centre
NASA: National Aeronautics and Space Administration
PARC: Pakistan Agricultural Research Council
RDA: Rural Development Administration
TCP: Technical Cooperation Project

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