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Corresponding Author

Murlidhar J. Sadawarti

e-mail: murlidharsada@gmail.com

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Innovative Methods to Enhance Seed Potato Production

Murlidhar J. Sadawarti^{1*}, Tanuja Buckseth², S. P. Singh³, Vinod Kumar², Rajesh K. Singh⁴, Ashwani K. Sharma⁵, Subhash Katare¹, Pooja Jatav⁶, Deepanshi Deora⁶, Priyadarshani Khambalkar⁶, R. K. Samadhiya¹, S. K. Sharma¹, Surender Singh¹, Shyam Kumar Gupta¹ and Brajesh Singh²

Abstract

Ensuring the availability of high-quality potato seed at a reasonable price and at the appropriate time continues to be a significant issue for government seed-producing agencies globally. Traditional methods of seed potato production encounters numerous challenges such as a low multiplication rate (1:6), the buildup of degenerative diseases, perishability, bulkiness, and a sluggish process for generating 100% healthy seed stock. To tackle these issues, rapid multiplication techniques (RMTs) have become increasingly important. Among these, the aeroponic system has impressive multiplication rate (1:20–80) and apical rooted cuttings (ARC) and sprout cuttings has potential for large-scale seed multiplication, being both economical and beneficial for farmers. Each ARC cutting can yield 7–15 tubers, while a well-developed sprout cutting can produce 6–11 tubers per sprout and ongoing research is concentrating on optimizing them in terms of agronomic practices, fertilizer combinations, plant health management, cost-benefit ratios, and storage. These methods are also being actively encouraged for incorporation into formal seed potato production systems, with the goal of enhancing seed availability and accessibility for farmers.

1. Introduction

The production of potatoes in India has been experiencing significant growth, primarily fuelled by the increasing domestic demand for both fresh consumption and processing. This growth is further supported by the implementation of advanced technologies and innovative farming practices. On a global scale, India holds the position of the second-largest potato producer, contributing approximately 11.3% of the total global potato area and nearly 16.0% of the overall production. In the 2022–23 period, the nation

Author's Address

¹ICAR-Central Potato Research Institute, Regional Station, Gwalior, M.P (474 020), India

²ICAR-Central Potato Research Institute, Shimla, HP (171 001), India

³ICAR-Central Potato Research Institute, Regional Station, Patna, Bihar (801 506), India

⁴ICAR-Central Potato Research Institute, Regional Station, Modipuram Meerut, U.P (250 110), India

⁵ICAR-Central Potato Research Institute, Kufri Fagu Unit, Kufri, H.P (171 012), India

⁶Rajmata Vijaya Raje Scindia Krishi Vishwa Vidyalaya, Gwalior, M.P (474 020), India

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produced around 60.14 million tonnes of potatoes from an estimated 2.3 million hectares of cultivated land (Singh and Dutt, 2024). To maintain this level of production, it is estimated that 5.4 million tonnes of certified or quality seed potatoes will be necessary. However, generating such a large volume of high-quality seed through traditional methods is nearly impossible due to constraints related to multiplication rates, degeneration, and resource demands. This requirement for seed presents a significant challenge for the potato industry, as seed alone constitutes a substantial portion—approximately 40–50% of the total costs associated with potato production. The elevated costs and limited access to quality seed frequently create obstacles for small and marginal farmers, underscoring the pressing need for alternative and more effective seed multiplication systems. The deficiency of quality seed potatoes is acknowledged as one of the most critical hindrances in potato production, especially in developing countries where seed systems are often either underdeveloped or fragmented. It is estimated that globally, only about 11% of the world's potato crop is cultivated using certified and quality seed, while the remainder relies predominantly on farm-saved or informally exchanged seed stocks. This considerable disparity in seed availability often forces farmers to persist in cultivating with degenerated planting materials, which not only diminishes yield potential but also hastens the spread of seed-borne diseases.

In the context of India, the challenges are even more pronounced. A significant factor contributing to the low profitability of potato farming is the prevalent use of inferior or degraded seed materials. Currently, the state and central seed corporations in the nation can fulfill only 20–25% of the national demand for quality seed potatoes, resulting in a large number of farmers relying on informal seed sources. This shortage continues to exist despite a well-organized seed multiplication chain, mainly due to the inherent limitations of the traditional system. The availability of high-yielding varieties, along with disease-free, physiologically young, and true-to-type planting materials, is essential for sustainable potato production. Nevertheless, the traditional seed potato production system faces numerous challenges. These challenges include a very low multiplication rate per cycle, the necessity for a high seed rate because of the bulky nature of tubers, the progressive accumulation of degenerative diseases, and the perishability of seed tubers during storage and transportation. Furthermore,

the conventional system necessitates multiple field generations to generate adequate seed stock, and the process of producing 100% healthy seed is both slow and resource-intensive (Buckseth et al., 2020).

While the ICAR-Central Potato Research Institute (CPRI) provides breeder seed to state seed agencies, it is seldom multiplied through all three recommended generations using the prescribed seed plot technique, mainly because of infrastructural constraints and insufficient monitoring. Each multiplication cycle in the traditional system lasts about one complete cropping season, which is nearly four months, thereby extending the timeline for seed availability. As a result, the failure to quickly multiply and distribute healthy seed material greatly hinders productivity improvements and presents a significant challenge to increasing potato profitability and sustainability in India (NASS, 2021).

2. The Necessity for Rapid Multiplication Systems (RMTs)

Currently, the ICAR-Central Potato Research Institute (CPRI) generates approximately 72% of breeder seed using the traditional seed plot method, while only 28% is produced through advanced technological systems. Nevertheless, due to the ongoing increase in potato cultivation area and the rising demand for both table and processing potatoes, the anticipated need for high-quality seed is projected to grow significantly. To meet this demand, it is crucial to not only enhance the multiplication rate of seed potatoes but also to expedite the entire seed production process. In this regard, alternative methods must be swift, economical, and capable of yielding disease-free seed potatoes of guaranteed quality. Therefore, it is essential to develop a seed production system that incorporates innovative propagation technologies, reduces the exposure of planting material to field conditions (where the risk of degeneration is elevated), and includes a strong mechanism for certification and quality assurance. Such a system should guarantee that the seed produced and distributed by both public institutions and private seed growers upholds genetic purity, physiological integrity, and phytosanitary standards (NASS, 2021).

A global transformation in potato seed production has already occurred. Leading potato-producing nations, including the Netherlands, China, and various European countries, have transitioned from traditional field-based

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multiplication to advanced seed production systems. These innovative systems have not only enhanced seed quality but also increased the multiplication rate, ensuring the timely provision of healthy planting material. In recent years, numerous rapid multiplication techniques (RMTs) have been developed and standardized for potatoes to expedite seed availability. Among these, the most commonly utilized methods, especially in developing nations, comprise: Micropropagation, which involves the generation of plantlets and microtubers in aseptic in vitro environments; Cuttings, which utilize various types of vegetative cuttings such as single-node, tuber sprout, axillary shoot, leaf-bud, and apical cuttings; Aeroponics, a soilless cultivation method where roots are suspended in air and periodically misted with nutrient solution; and Hydroponics, which involves cultivation in a nutrient solution medium devoid of soil. These techniques facilitate the indefinite maintenance of pathogen-free stocks in controlled laboratory settings and enable year-round multiplication in sterile artificial media, irrespective of the growing season. The implementation of such methods has transformed potato seed production worldwide by significantly decreasing reliance on traditional field generations, reducing disease exposure, and enhancing multiplication efficiency (Buckseth et al., 2022).

The advanced planting materials created using these techniques are later multiplied in insect-proof screen houses to produce disease-free seed tubers, which are classified as breeder seed (referred to as Generation-0 or G0 seeds). These G0 seeds establish the basis of the formal seed production chain and are subsequently multiplied through successive field generations while adhering to stringent phytosanitary and certification protocols. This comprehensive approach guarantees the rapid availability of healthy seed tubers, thus tackling one of the most significant challenges in potato cultivation (Naik and Karihaloo, 2007).

3. Aeroponic Technique

Aeroponics is a relatively new technology that enhances plant tissue culture for the production of potato seeds. In addition to developed countries, nations such as China, Korea, and Vietnam have already implemented commercial aeroponic seed potato production, showcasing its significant potential to alleviate the seed potato bottleneck in developing areas (Chiipanthenga et al, 2012). The aeroponic system is especially effective for

generating pre-basic potato seed in temperate climates, and optimizing this system is a strategic investment aimed at achieving efficient and sustainable production of high-quality minitubers. Due to the rising demand for advanced seed production techniques, aeroponics has emerged as a well-established technology (Figure 1). It minimizes the number of multiplication stages, boosts plant health, and enhances the quality of the initial field generation.



Figure 1: A. Stepwise aeroponic seed production system, B. Aeroponic minitubers raised seed crop under insect proof net house

In aeroponics, the roots of plants are held in a dark, enclosed chamber and are intermittently misted with nutrient solutions. This cutting-edge method allows for the swift multiplication of generation-0 (G0) seed potato material, thereby aiding agricultural advancement and enhancing commercial seed systems. Aeroponics supports year-round production while maintaining compliance with phytosanitary regulations. The production of G0 aeroponic potatoes is more lucrative due to increased productivity, superior-quality tubers that are devoid of pests and diseases, and the ability to plant at any time.

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Consequently, aeroponics offers a practical technological solution for mini-tuber production within the potato seed system. Its benefits encompass precise nutrient management, rapid multiplication, elevated survival rates, effective space utilization, continuous air circulation, and an environmentally friendly operational mode—attributes that have the potential to revolutionize the potato seed industry. In India, aeroponics has already transformed seed potato production by providing high-quality seeds, although it necessitates meticulous planning, investment in infrastructure, and standardized nutrient formulations (Buckseth et al., 2022).

4. Apical Rooted Cutting (ARC)

Apical cuttings are rooted transplants obtained from tissue culture plantlets in a screenhouse. Instead of allowing tissue culture plantlets to grow and produce minitubers, cuttings are excised and rooted; once established, these cuttings are transplanted into the field to produce seed tubers. A novel, low-cost, and farmer-friendly technology known as Apical Rooted Cuttings (ARC) has recently been standardized following seed plot technique by ICAR-Central Potato Research Institute (CPRI), Shimla, for hi-tech seed potato production (Figure 2). In this system, *in vitro* plantlets are raised in a nursery, and rooted cuttings are subsequently transplanted in glasshouse or nethouse conditions. ARC offers a cost-effective approach for producing quality planting material, particularly in seed-deficit regions, and helps overcome the persistent shortage of seed potatoes through its faster multiplication rate. The technology is simple, adoptable, and suitable for progressive farmers, farmer producer organizations (FPOs), and small entrepreneurs in potato-growing regions, thereby enabling the production of quality seed at affordable prices. Moreover, ARC presents a profitable business opportunity for smallholders due to its potential for significantly increasing the supply of

quality seed.

Apical rooted cuttings have been extensively utilized for many years in Southeast Asia, especially in Vietnam, where approximately 5 million rooted apical cuttings (RACs) are generated each year, resulting in an average yield of 20–25 t/ha. A similar level of success has been noted in Kenya and Uganda, where the adoption of ARC by seed producers, smallholders, and rural youth has fostered opportunities for prosperity in resource-limited highland communities. In India, ARC has been effectively incorporated into the breeder seed production program, providing an advantage over aeroponic technology due to its simplicity, shorter production cycle, and reduced capital requirements. Each apical cutting generally yields 7–10 seed tubers, with instances of producing 15 or more under optimal conditions. These tubers can be further multiplied for one or two seasons, after which the harvest is marketed as high-quality seed, comparable to basic or certified seed within formal certification systems. This guarantees that farmers have access to superior quality seed, leading to increased crop yields and promoting repeat adoption. Preliminary findings at ICAR-CPRI Shimla have shown the viability of ARC for low-cost quality seed production, leading to its commercialization to 7–8 firms to improve seed availability. It is crucial to note that ARC necessitates strict compliance with standard operating procedures to ensure seed health (Buckseth et al., 2024).

The propagation of plantlets through single-node stem cuttings over five to six cycles in controlled environments can yield between 100 and 1000 virus-free plants from a single plantlet. Mechanical cutting does not significantly enhance the spread of Potato virus in field production, indicating that the physical process of cutting does not introduce or worsen the virus in the field. Consequently, apical stem cuttings obtained from G0 and G1 plants can act as a reliable planting stock to increase the foundation (G1) and commercial (G2) seed supply. On average, G0 cuttings generate approximately 10 tubers, although performance may differ by variety (Nikmatullah et al, 2021).

5. Sprout Cutting

The practice of utilizing sprouts for the rapid multiplication of seed potatoes has been in place in India since the mid-1940s. This technique, referred to as sprout cutting or sprout culture, entails the separation of sprouts from seed tubers and their subsequent direct planting. It stands as



Figure 2: Stepwise Apical Rooted Cutting (ARC) seed potato production system

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one of the most straightforward and swift multiplication methods within the traditional seed system, offering an effective alternative for farmers and seed producers who may not have access to advanced technologies. Sprout cutting guarantees high multiplication rates while preserving seed health. This method is particularly advantageous for generating virus-free seed potatoes, facilitating the rapid multiplication of substantial quantities of quality seed in a brief timeframe. Once the sprouts are detached, the mother tubers remain viable for seed production, thus optimizing efficiency. Notably, sprout cutting does not diminish the productive capacity of mother tubers, rendering it a sustainable approach for the supply of seed potatoes. By ensuring the timely provision of quality seed at a reduced cost, this technique aids in alleviating shortages and stabilizing prices for farmers. Additionally, it lessens reliance on imports and new minituber production, with reports indicating productivity enhancements of up to 200% per unit of imported seed potato. Sprouts obtained from G0-class seed potatoes are regarded as an ideal foundation for national seed production initiatives (SouzaDias and Feldmann, 2024).

Over the past forty years, Brazilian farmers have progressively embraced sprout cutting, influenced by experimental findings from the mid-1990s. This technique entails the removal of vigorous apical sprouts from mother tubers, which are then utilized as planting material. Each tuber can yield a minimum of three sprouts, and since each sprout can generate approximately three minitubers, the multiplication rate nearly doubles in comparison to traditional planting methods (from 10–20 daughter tubers per tuber/seed potato). Alternatively, when large seed potatoes (greater than 55 mm) are stored in cold conditions (4 °C, 82% relative humidity) for more than six months and subsequently transferred to dark rooms (15–20 °C, 85% relative humidity), they can produce up to three successive sprout flushes, although the performance is contingent upon the cultivar. This advancement has been recognized as a promising solution for low-income farmers, with the potential to alleviate food scarcity by improving seed availability.

Sprouts may be planted in substrates that are recommended for vegetable seedlings, with fertilizer application guided by soil analysis (Figure 3). Alternatively, they can be directly sown in aerated, solarized soil. Consistent irrigation throughout the multiplication cycle is crucial. After planting, sprouts develop into standard potato

plants, yielding tubers that are comparable in size (2–4 per plant, ranging from 3–6 cm in diameter) and characteristics to those produced from conventional seed tubers, while maintaining varietal integrity (Devaux et al., 2020).



Figure 3: Stepwise Sprout cutting based seed potato production system

6. Conclusion

RMTs are being increasingly embraced and advocated by seed potato entrepreneurs and private sector stakeholders globally due to quicker and more efficient multiplication rates, preserving disease-free conditions and reduce the frequency of field exposures as compared to traditional seed potato systems. Their incorporation into seed systems not only hastens the spread of enhanced varieties but also fortifies the entire seed value chain, ensuring that high-quality planting materials. Adoption of these technologies, along with supportive policy frameworks, and capacity development, will be crucial for sustainable seed potato production.

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