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Innovations in Potato Seed Production

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Preface

Potato is an important component of the Indian diet. It is consumed throughout the year as a vegetable and in the form of processed or value-added products. Owing to the changing lifestyles, the consumption of processed and value-added potato products has been increasing steadily. The technological advances steered by the Indian Council of Agricultural Research have played an important role in increasing potato production in India. Yet, its yield remains low; less than half of that in the USA. It is primarily due to the non-availability of quality seed at an affordable prices. India is the second-largest producer of potatoes, hence its seed requirement is also huge. Keeping in view the rising demand for potato seed, the National Academy of Agricultural Sciences (NAAS) organized a strategy workshop on 27th October 2020 to explore prospects for the adoption of emerging innovations in seed production for higher and sustainable potato production.

This document provides a brief description of the traditional seed production system and its limitations, explores the changing paradigm in seed potato research, and discusses the prospects of integrating the emerging technologies with the existing seed production system. It also suggests an action plan along with the required institutional and policy support for the production of the required quantity of certified potato seed. I hope the recommendations contained in this document will be utilized by the stakeholders on the potato seed supply chain.

I, on behalf of the Academy, thank Drs S.K. Chakrabarti and Dr R.K. Singh, and the participants of this strategy workshop. My special thanks to Drs S. Mohanty, S.K. Pandey and N.K. Pandey for their critical comments on this paper. I also thank Drs P.S. Birthal and Malavika Dadlani for their editorial support.

(Trilochan Mohapatra)
President, NAAS

Innovations in Potato Seed Production

1. INTRODUCTION

Potato is an important commercial food crop in India, providing livelihood support to millions of smallholder farmers and supplementing the calorie and nutritional requirements, besides the culinary preferences of Indian consumers. Compared to the widely grown staple cereals and other crops, the cultivation of potatoes is labor intensive, but more remunerative and hence it suits the resource endowments and cash flow requirements of the smallholder farmers who have adequate labor resource in relation to the land they possess. Potatoes are available throughout the year and are consumed in several forms, as vegetable and value-added processed products. Approximately 8% of the potatoes harvested in India are transformed into value-added products, the demand for which has been growing at a faster rate than for staple foods.

India is the second-largest producer of potatoes in the world. It accounts for 11.3% of the global area and contributes 12.5% to global production. Driven by the growing demand and supported by technologies and innovations, potato production in India has been increasing fast. In 2018-19, India harvested more than 53 million tons of potatoes from 2.16 million hectares of cropped area with an average production of 24.54 tons per hectare. The growing demand and increasing consumer awareness about safe and healthy diets in the domestic as well as international markets are compelling potato farmers to adopt good agricultural practices (GAP). Planting certified good quality seed is a pre-requisite for the adoption of the IndGAP package as proposed by the Quality Council of India for the production of safe and hygienic food.

The Government of India is committed to ensure the timely availability of certified seeds to the farmers cultivating different crops. However, for the high-volume high-seed rate crops like potatoes, the production and supply of good quality certified seeds is a challenge. Annually India requires 5.4 million tons of potato tubers as seeds. The challenge becomes even more complex as the vegetative mode of propagation makes the seed vulnerable to several pathogens in its multiplication process and the seed multiplication ratio (SMR) of 1:6 is very low. Farmers, especially the marginal and small farmers, rarely store their harvests as seeds for the next growing season. Often, they buy seed potatoes every season, making the seed replacement rate (SRR) almost 100%. However, there is no institutional mechanism to monitor the quality of seed potatoes. Most often, degenerated produce is sold as seed, especially to small and marginal farmers who lack finances. The seed alone comprises over one-third of the total cost of production of potatoes.

There is a huge gap between the requirement and supply of certified seed potatoes in India. The Central Potato Research Institute of the Indian Council of Agricultural Research produces about 3,000 tons of Breeder Seed every year and supplies 80% of it to the states and other agencies for its multiplication. If this stock were to multiply in three stages, *i.e.,* Foundation 1, Foundation 2, and Certified grades, we can produce only about 0.5 million tons of certified seed. On the assumption of 100% SRR it meets only 10% of the total seed requirement, leaving a deficit of about 4.9 million tons. It is virtually impossible to produce such a huge quantity of certified seeds using the traditional methods. Besides its low rate of multiplication in a longer span of 7-8 years, the traditional seed production system suffers from several other constraints like (i) requirement of a huge number of disease-free propagules in the initial stage, (ii) slower process of generating 100% healthy seed stock from the infected material, (iii) progressive accumulation of degenerative viral diseases in each field exposure, and (iv) field multiplications of initial disease-free material. It is further complicated by the fact that Breeder Seed supplied by ICAR-CPRI is seldom multiplied in all three generations by the State Seed Certification Agencies maintaining the recommended procedures. About 1.2 million tons of potato seed is sold by the private seed producers, especially those from Punjab, western Uttar Pradesh, West Bengal and Haryana, though there are no mechanisms and infrastructures for monitoring seed quality. It is, therefore, imperative to evolve a seed production system, encompassing the innovative techniques to improve the quality of seed and to reduce the field exposure, along with a robust system of certification and quality assurance of the seed produced and supplied by the private seed growers.

2. TRADITIONAL SYSTEM OF SEED PRODUCTION

In India, the process of production of healthy potato seed began in the hills during the 1930s. Hills were chosen for the purpose because of the slower rate of seed degeneration and low aphid infestation there. However, the organized system of potato seed production began during the 1960s. It was based on the clonal selection, tuber indexing and field multiplication of healthy indexed tubers. Given the low seed multiplication rate due to the vegetative mode of propagation, the traditional system recommended the multiplication of seed tubers in seven generations under a strict quality control regime for the production of a sufficient quantity of certified seed. The Breeder Seed production itself was taken up in four generations from the indexed tubers at the ICAR-Central Potato Research Institute (ICAR-CPRI), Shimla, initially in the Kufri and Fagu hills (near Shimla). However, with the standardization of the “Seed Plot Technique” in 1965, the disease-free seed production programme was extended to the plains. The procedure followed for seed production under the traditional system is briefly described below.

Nucleus and Breeder Seed: The Nucleus Seed (NS) is developed in the hills and plains under favourable growing conditions with temperatures ranging 8-28^{0}C.In the hills, it is produced during the long-day conditions at a temperature range of 12-28^{0}C and in the plains under the short-day condition at a temperature range of 8-28^{0}C. The NS is developed through clonal selection and tuber indexing. For the clonal selection, apparently, the healthy plants are marked in the field and four uniform tubers are selected from each plant and serially numbered. The health status of each tuber is checked by the tuber indexing and by growing their eye-plugs and testing the resulting plants for freedom from viruses. Every year a total of about 32,000 tubers are indexed at Modipuram (12,000), Gwalior (10,000), Jalandhar (4,000), Patna (2,000) and Kufri (4,000), of which about 26,000 –27,000 tubers are tested through ELISA due against all common viruses (PVX, PVS, PVA, PVY, PVM and PLRV). The disease-free indexed tubers are multiplied in the field in stage I, the produce of which is further multiplied in stage II. The seed produced at these stages is designated as Nucleus Seed. The produce of stage II is multiplied during the third year as the pre-breeder seed in stage III. This is further multiplied in the fourth year in stage IV. The produce of the fourth-year multiplication is called Breeder Seed (BS).

Stage-I multiplication: The healthy indexed tubers are planted in stage-I individually at a wider spacing of 1 x 1 m in the hills and 1.2 x 1.2 m in the plains, and tested individually through ELISA against six potato viruses and also inspected visually for mosaics and other abnormalities/ varietal mixture. The produce of only true-to-type healthy plants is planted during next year in the next stage.

Stage-II multiplication (clonal multiplication): The healthy produce of a single hill in stage-I is planted in a row as a clone at a wider inter-row spacing of 1 or 1.2 m and intra-row spacing of 20-40 cm as per the size of tubers. The crop in stage II is tested against viruses through ELISA and inspected visually for mosaics. The healthy produce of stage II of a variety is bulked and planted in the next stage.

*Stage III multiplication (bulk multiplication):*The bulked produce of stage II is planted in stage III for bulk multiplication at a normal spacing of 60 x 20 cm. The crop here is randomly checked (300 plants/ha) against viruses and the whole crop is visually inspected for variety purity and mosaics. The healthy produce is bulked for multiplication at the next stage to produce the breeder seed.

Stage IV multiplication (Breeder Seed production): The healthy produce of stage III is planted in stage IV at a normal spacing to produce Breeder Seed. This crop is also tested for viruses (150 plants/ha) and visually inspected for varietal purity and diseases if any. The plants showing any symptoms of the virus in testing or mosaics/varietal mixture on visual inspection during all the stages are rouged out.

Foundation Seed (FS): The breeder seed produced at the ICAR-CPRI is supplied to the State Departments of Agriculture/Horticulture, National Seeds Corporation (NSC) and other institutional seed producing agencies for multiplication at Foundation Stage I and Foundation Stage II by following the package of practices of “Seed Plot Technique” suitable for quality seed production. The produce is certified at each stage by the State Seed Certification Agency.

Certified Seed (CS): The produce of Foundation Stage II is multiplied further by the registered growers to get the certified seed. The produce is certified by the State Seed Certification Agency. The certified seed is further multiplied in two stages (Certified Seed 1 and Certified Seed II) by the seed growers to meet their seed requirements and for the market. The quality of the Certified Seed I and II stages is monitored by the seed producers/farmers themselves. Ideally, at this stage, the seed production should also be monitored and certified by the State Seed CertificationAgencies.

3. INNOVATIONS IN SEED PRODUCTION

3.1. Tissue culture-based systems

Seed potato production involving micro-propagation (tissue culture) techniques can overcome many of the problems associated with the traditional seed production system. The important steps involved in a tissue culture-based seed production system are : (i) stem/sprout cuttings for culture initiation, (ii) meristem tip culture for virus freedom, and (iii) cyclical *in vitro* stem cuttings for the year-round multiplication.

The micro-plants derived from tissue culture are usually not directly used for commercial cultivation but are used for either micro-tuber production *in vitro* or mini-tuber production under greenhouse or aeroponic systems. The micro/mini-tubers thus obtained are multiplied for 3-4 successive generations before being used as seed for commercial cultivation.

Meristem culture for virus elimination:In this technique, a small growing point or meristem, approximately 0.1 - 0.3 mm in size, from a tuber sprout or stem of a potato plant is excised and placed in a test tube or any other vessel with a culture medium for obtaining virus-free stock. The meristem culture procedure is combined with thermotherapy and/or chemotherapy to increase the likelihood of obtaining virus-free plants. Even after taking all precautions for virus elimination, only a few virus-free mere clones are obtained. It is, therefore, essential that each mericlone is tested for virus using ELISA, ISEM and PCR techniques before it is used as a source plant in a large-scale micro propagation programme.

Micropropagation: Single-node cuttings of virus-free potato mericlones are grown in semi-solid or liquid culture media under aseptic conditions for obtaining new micro-plants. Murashige and Skoog's (MS) medium supplemented with 2.0 mg L^{-1} D-calcium pantothenate and 20 g L^{-1} sucrose is ideally suited for large-scale *in vitro* micropropagation of potatoes. Cultures are incubated under a 16 h photoperiod (60 µmol $m^{-2} s^{-1}$ PFD) at 20 ± 2 °C. Usually, three single-node cuttings with one or two leaves are planted into each culture tube (25×150 mm). Within three weeks, the axillary/ apical buds of these cuttings develop into full plants. These micro-plants are further sub-cultured up to ten times on fresh culture media at an interval of three weeks. Therefore, it has the potential to produce about 59,049 micro-plants from a single culture tube within 7 -8 months under controlled conditions.

Micro-tuber production from micro-plants: Micro-tubers are miniature tubers produced *in vitro* under tuber-inducing conditions. These small dormant tubers are particularly convenient for handling, storage and distribution. In general, 15-20 micro-tubers with an average size of about 100-200 mg, are obtained from each tissue culture flask. Micro-tubers are usually not used for raising commercial crops but utilized for the production of mini-tubers in greenhouses. The micro-tubers are planted in nursery beds under aphid-proof net houses (50 micro-tubers m^{-2}) to produce mini-tubers. This technology has not become very popular among farmers because of the poor survival of micro-tubers (60-65%)as well as the poor crop emergence (50-60%) in nursery beds.

Mini-tuber production in soil: Mini-tubers can be produced using either micro-plants as planting material. In this system, the hardened and virus-free micro-plants or micro-tubers are transplanted inside a net-house for the production of mini-tubers. Approximately 2,000 mini-tubers can be produced per m^2inside a net house. The mini-tubers so obtained are multiplied usually in three subsequent generations (Generation 1, 2, and 3) before supplying to farmers as seed.

The main advantages of micro-tubers over micro-plants are that these are hardier, easy to handle and transport, and require less care during planting and post-planting operations. However, it takes 2-3 months' additional time in the laboratory for the production of micro-tubers, followed by storage for breaking dormancy. Further, the yield from micro-tubers is less than that of micro-plants, thus use of micro plants directly for the production of mini tubers is preferred over micro tubers.

Soil-less aeroponic system: In this system, micro-plants are planted on top of a chamber, and the developing root zone inside the chamber is fogged with nutrient solution (Tierno et al., 2014, Buckseth et al., 2016). The chambers are installed inside an insect-proof net-house. The aeroponic chamber has a removable opening at the top with gaps for holding potato plants. The front of the aeroponic chamber is set with pivots and can be opened to harvest mini-tubers of ideal size at different time intervals. Picking of tubers begins after 45–50 days of planting when they attain a size of approximately 15–17mm diameter. Picking of mini-tubers is done every week, and around 10–12 harvests are taken. Normally 45-50 mini-tubers can be gathered from a single plant as against 8–10 mini-tubers under the net-house system. The harvested mini-tubers are stored at 2–4°Cto be utilized for planting in the following season.

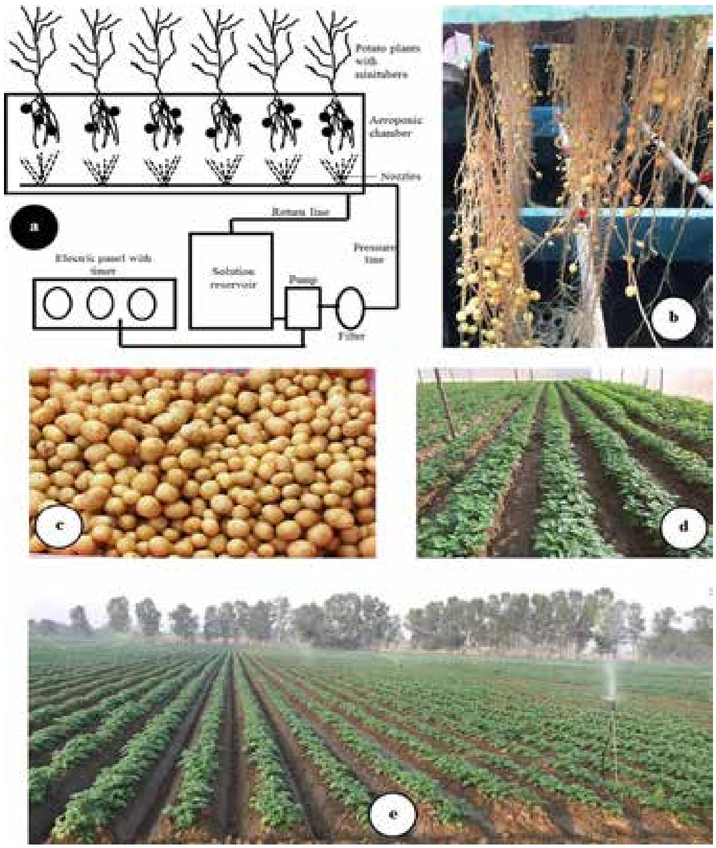

Fig.1. Aeroponics in potato. (a) Diagrammatic presentation of the aeroponic system. (b) Mini-tubers developed in the aeroponic chamber. (c) Harvested mini-tubers. (d) Mini-tuber crop in net-house, and (e) Mini-tuber crop in the field.

Since the requirements of different potato varieties differ in their nutritional compositions and photo periods, it is important to standardize variety-specific nutrient solutions and growing conditions under an aeroponic system (Millam and Sharma, 2007; Otazu, 2008). In an aeroponic system, it is possible to produce 2,094 mini-tubers in one square meter compared to 771 in soil/ substrate-based nursery beds. This system requires a high level of specialization in planning, operational expenses and standardization of genotype-responsive nutrient solutions, but it offers quality seeds. This technology is widely accepted by seed potato producing organizations globally (Kim et al., 1999; Otazu, 2008), but its adoption in India is largely limited to private companies and big seed growers.

Apical rooted cuttings (ARC): Unlike aeroponic technology which requires high capital requirement and a long gestation period of nearly four years, the apical rooted cutting (ARC) is a low-cost technology with simple steps that can be easily adopted by progressive farmers, farmer producer organizations (FPOs), and other small entrepreneurs in the potato production belts to produce quality seed at affordable prices. Similar to aeroponic, the ARC starts with tissue cultured micro-plants which are planted in the nursery to establish a mother bed. The apical cutting (2-3 cm) with two leaves are taken from the mother plants every 12-15 days either to replant in the mother bed for further cutting or plant in pro-trays filled with coco peat for rooting. In around 45 days, one micro plant can produce eight rooted cuttings. These rooted cuttings of 15-20 days old are planted either in temporary net houses or open fields for first-generation (G0) seed production.

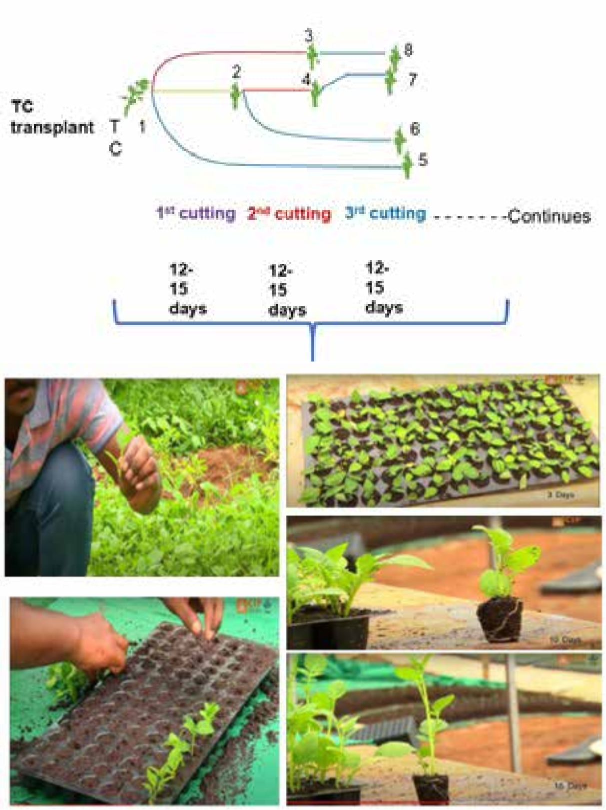

Fig. 2. Apical cuttings from mother bed planted in pro trays for rooting (Photos taken at ARC facility established by CIP & UHS Bagalkot)

In the last few years, the International Potato Center (CIP) in collaboration with Central Potato Research Institute (CPRI), University of Horticultural Sciences, Bagalkot and the Directorate of Horticulture, Government of Odisha has evaluated the performance and economic viability of this technology in different parts of India. Based on the data collected from different pilot sites in Karnataka, Assam, Odisha and Haryana, the average number of G0 tubers produced from each cutting is around 10 with significant variation among different varieties. Kufri Himalini is the best performing variety with average G0 tubers of 18, followed by KufriChipsona1 with 11 tubers. The most popular variety among farmers, Kufri Jyoti, produces an average of 10 tubers per cutting.

Fig.3. ARC production in a private nursery at Hassan, Karnataka (Photo taken by CIP Karnataka team)

So far, several nurseries in Hassan, Karnataka have taken up ARC production for selling it to farmers in the state. In addition, they have been able to ship cuttings to other states, including Maharashtra, Odisha, Assam and Haryana. As the demand for cutting increases in different parts of India, there will be an opportunity for nurseries with tissue culture laboratories to start producing cuttings. Table 1 provides the cost and returns of producing cuttings from tissue culture plantlets (Mohanty et al., 2020). The investment in infrastructure, which includes a tissue culture laboratory and two 500-square-meter polyhouses, is around INR 35 lakhs, with INR 15 lakhs for the tissue culture laboratory and INR 20 lakhs for two polyhouses. Assuming a 10-year useful life for the tissue culture laboratory and polyhouses, the annual amortized amount is estimated to be INR 3.5 lakhs. The cost of producing 20 lakhs ARCs from tissue culture plantlets is estimated to be INR 14.1 lakhs. Reasonably pricing each cutting at INR 1, the profit is found to be INR 5.9 lakhs.

Table 1. Cost and Returns of Establishing Tissue Culture Laboratory and Polyhouses to Multiply Tissue Culture Plantlets and Apical rooted cuttings.

Infrastructure development cost	One-time investment for 10 years (in INR)		Annual amortization cost (in INR)
Tissue culture laboratory	1,500,000		
Two polyhouses of 500-sq.-meter size	2,000,000		
Total upfront investment	3,500,000		350,000
Operating cost	**Number**	**Unit cost (in INR)**	**Cost/revenue/profit (in INR)**
Tissue culture plantlet production	20,000	3	60,000
Production of cuttings (including labour, coir pith, and tray)	2,000,000	0.50	1,000,000
Total cost			1,410,000
Gross revenue by selling cuttings	2,000,000	1.00	2,000,000
Net profit			590,000

The above operation of the tissue culture laboratory for producing tissue culture plantlets and of the polyhouses for producing cuttings, which requires an upfront investment of INR 35 lakhs and an operating budget of INR 14 lakhs, could be expensive for small entrepreneurs. In that case, an entrepreneur/nursery/farmer can take up ARCs by purchasing tissue culture plantlets from a tissue culture laboratory and operate on a smaller scale. As shown in Table 2, the upfront cost of setting up one polyhouse will be INR 10 lakhs and the operating budget for producing 10 lakhs cuttings will be approximately INR 5.3 lakhs (Mohanty et al., 2020). Selling at INR 1 per cutting, the operation will generate a net profit of INR 3.7 lakhs within 4–6 months.

Table 2. Cost and Returns of Establishing Polyhouses to Produce Apical Rooted Cuttings from Tissue Culture Plantlets.

Infrastructure development cost	One-time investment for 10 years (in INR)		Annual amortization cost (in INR)
One polyhouse of 500-sq.-meter size	1,000,000		
Total upfront investment	1,000,000		100,000
Operating cost	**Number**	**Unit cost (in INR)**	**Cost/revenue/profit (in INR)**
Tissue culture plantlet production	10,000	3	30,000
Production of cuttings (including labour, coir pith, and tray)	1,000,000	0.50	500,000
Total cost			630,000
Gross revenue by selling cuttings	1,000,000	1.00	1,000,000
Net profit			370,000

The cuttings are planted in either an open field or temporary net house for producing first-generation seed (G0) and in an open field for the second-and third-generation seed. The cuttings planted in the open field can be sold to farmers after the second generation, whereas cuttings planted in the net house can be multiplied one more round before selling to farmers to make them economically viable.

Table 3 provides the cost and returns of producing first- and second-generation seeds from ARCs in an open field and selling them to farmers as seeds (Mohanty et al., 2020). As shown in Table 3, one acre will require 40,000 cuttings that will produce around 4 lakh seed tubers with an average of 10 tubers per cutting.

Fig.4. G0 seed tubers from Himalini ARC in Morigaon, Assam (Photos taken by Dr S. Mohanty and CIP Assam team)

Table 3. Cost and returns of producing first-generation seed potato from apical rooted cuttings.

Operating cost	**Number**	**Unit cost (in INR)**	**Cost (in INR)**
Apical rooted cuttings	1 acre (40,000 cuttings)	1	40,000
Cost of production	1 Acre	60,000	60,000
Cold storage	4 lakhs	5,000	20,000
Multiplication from First- to Second-Generation Seeds			
Cost of production	10 acres	60,000	600,000
Cold storage	80 tons	2,000	160,000
Total Cost			880,000
Gross Revenue	80 tons	20,000	1,600,000
Net Profit			740,000

In the next season, 4 lakh first-generation tubers can be planted on 10 acres to produce 80 tons of second-generation seeds. These second-generation seeds can be sold to farmers in the following season at Rs. 20 per kilogram to generate a net profit of Rs. 7.4 lakhs.

Overall, the entire seed supply chain for ARCs can be taken up by one organization from setting up a tissue culture laboratory to producing second-generation seed tubers or it can be broken up into different components and can be taken up by different entities. In addition, some nurseries have started selling apical cutting to farmers in other states at Rs. 1,000 per kilogram (around 2,200 saplings) which can be shipped at a much lower transportation cost instead of selling rooted cutting at Rs. 1 per piece.

Fig.5. Shipping of fresh apical cuttings from Hassan Nursery
(Photos taken by CIP Karnataka team and put together by Dr S. Mohanty)

CIP and CPRI are working together to introduce ARC in other potato-growing states in the next few seasons. As the volume increases, the per unit cost of ARC will go down making seed cost even cheaper. As the ARC supply chain develops, it may be economical for farmers to directly use ARC as the planting material rather than seed tubers. Anticipating its potential, CPRI has started formulating standard operating procedures regarding the ARC plant health to ensure that seed quality from ARC remains virus-free.

Quality control of tissue culture-derived potato seed: A national certification system for tissue culture raised plants *(*NCSTCP*)*is being implemented by the Department of Biotechnology (DBT), Government of India.For its successful implementation, the DBT has created NCSTCP Management Cell (NMC), Referral Centers (RCs) and Accredited Test Laboratories (ATLs). Tissue culture production facilities get recognition under this quality management system based on compliance with recommended protocols, technical capabilities, infrastructure, a package of practices and documentation/record keeping. Once the tissue culture production facility is recognized, they become eligible to get their tissue culture raised planting material certified by ATL. The scheme is being used for the production of Potato Tissue Culture Raised Mini-tuber (PTCMT) that can be used as breeder seed for further production of certified classes of seed as prescribed in the Indian Minimum Seed Certification Standards (IMSCS). It is implicit in this scheme that the mini-tuber produced from micro-plants under either net-house/poly-house or aeroponic system can be multiplied a maximum of three times (Foundation 1 and 2, and Certified) for certified seed production. The private seed growers, however, are appealing for multiplication of mini-tubers at least for five generations before labeling as a certified class, to make such ventures commercially viable.

3.2. True potato seed

True potato seed (TPS) is a botanical seed produced as a result of sexual reproduction. Like all other botanical seeds, TPS has the potential to grow into a full plant but every plant is genetically different, thus making TPS population heterogeneous. Efforts were made at ICAR-CPRI to develop uniform TPS populations to get uniform crop stand, disease resistance and tuber yields. TPS populations have many advantages over seed tuber based crops. The major ones are disease- and pest-free planting material, easy transport and storage, and highly reduced seed rate. Three TPS populations viz., HPS-I/13, TPS-C-3 and 92-PT-27 were released by ICAR-CPRI during the 1980s. Quality control parameters for TPS production have been well prescribed in the Indian Minimum Seed Certification Standards. However, it has been mentioned that the hybrid TPS will be designated as a certified class seed to be planted for any use, except seed production. On the contrary, tuberlets produced in nurseries from TPS are usually used as commercial seeds by farmers. Since TPS is not much popular, it is not necessary to make major changes to its certification system. However, it will be necessary to develop an appropriate production and certification system of diploid hybrid TPS once the technology becomes available.

3.3. Diploid hybrid TPS

Being an autotetraploid and highly heterozygous crop, the selfing of potato results in severe inbreeding depression. Bringing down the ploidy to diploid level and selfing thereafter through the incorporation of a self-compatibility gene can result in homozygosity at a much faster rate than at tetraploid level. This approach has been demonstrated by Lindhout et al. (2011). Many public and private organizations, including ICAR-CPRI, are working on the development of diploid inbred lines and exploiting heterosis in potatoes at the diploid level.

4. ACTION PLAN FOR ADOPTION OF EMERGING INNOVATIONS

Since apical rooted cuttings (ARC) and diploid hybrid TPS technologies are yet to be commercialized, the proposed action plan for streamlining seed production in certified seed potato production system is exclusively based on well-adopted potato tissue culture raised mini tuber (PTCMT) technology.

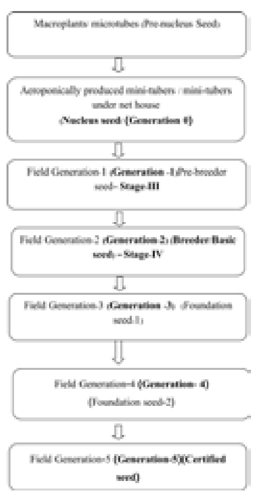

Fig. 6. Proposed seed potato production scheme through tissue culture

To produce 3.7 million tonnes of certified grade seed starting from mini-tubers, 26 new aeroponic units (ICAR-CPRI design) need to be established in 10 states. The mini-tubers so produced from the G0 crop are to be planted in greenhouses. Approximately 26 million mini-tubers will be produced from 26 aeroponic facilities @ 1 million /facility. Greenhouses covering a total area of 130 hectares will be required for planting mini-tubers thus produced from the aeroponic units to grow the G1 crop. It will not be possible to grow the G1 crop in such a large area by public sector organizations, and therefore, effective public-private partnership is to be developed for the purpose. The produce of the G1 will be grown in open fields following the IMSCS. With a seed multiplication ratio of 1:6, about 780 hectares of land will be required for the G2 crop. The produce of the G2 will be equivalent to the grade of Breeder Seed. The breeder seed will be multiplied by different agencies following the existing system.

We propose the creation of a National Seed Potato Certification Board **(**NSPCB**)** as an autonomous body under the DAC&FW, Ministry of Agriculture and Farmer Welfare, Govt. of India for monitoring and certification of potato seed. The Board of Management of NSPCB should have representatives from the DARE, AUs (from concerned states), State Agriculture Departments and Private Seed Growers. The Board should have a Central Testing Laboratory that takes care of seed testing needs of the existing as well as emerging seed production systems. Cost estimates for operationalizing this scheme is given below.

Table 4. Estimated cost for implementation of the plan

Fixed cost	
G0	₹ 44,65,50,000
G1	₹ 45,50,00,000
G2	Nil
Diagnostics	₹ 6,15,80,000
Total fixed cost	₹ 96,31,30,000
Manpower cost (annual)	
Diagnostic lab	₹ 2,93,52,000
Field inspection	₹ 9,12,00,000
Total manpower cost	₹ 12,05,52,000
Annual operational cost	
G0	₹ 28,25,000
G1	₹ 361478000
G2	₹ 673643100
Diagnostic	₹ 87540000
Total operational cost	₹ 112,54,86,100
Grand total	₹ 220,91,68,100

Note: G3, G4 and G5 will be certified by the National Potato Seed Certification Agency under NSPCB.

6. RECOMMENDATIONS

- An autonomous National Seed Potato Certification Board **(**NSPCB**)** be created under the DA&FW, Ministry of Agriculture and Farmers Welfare, Government of India for monitoring and certification of potato seed. The Board of Management of NSPCB should have representation from DARE, Agricultural Universities (AU)s (from concerned states), State Agriculture Departments and Private Seed Growers.
- State-wise suitable areas for certified seed production need to be identified in collaboration with the Agricultural Universities and private seed growers.
- A National Potato Seed Certification Agency under the NSPCB needs to be integrated with the National Seed Certification system.
- The research on novel technologies like Apical Rooted Cutting (ARC) and diploid hybrid seed needs to be supported and these should be gradually incorporated in the seed system as and when these are ready for commercialization for quality seed production in non-traditional areas.
- The indigenous varieties grown in different states need to be cleaned of viruses and a mechanism should be developed to get these registered/notified and bring them under a formal seed production system.
- The quality of truthfully labelled (TFL) potato seed should be checked diligently by the state agencies as per the provisions under Seed Control Order, 1983 and penalty should be imposed for selling sub-standard potato seed.
- An autonomous system like the NAK of The Netherlands should be created under the Ministry of Agriculture and Farmers' Welfare for providing single-window services to the stakeholders on the potato seed supply chain. A committee consisting of members from the ICAR, DA&FW, AUs, State Departments, independent experts and private seed producing agencies should be constituted as a national body for monitoring seed quality testing and certification, exclusively for potatoes.
- Develop public-private partnership for efficient and sustainable seed production systems, and support these financially.

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