01

RESEARCH BRIEF

Apical Rooted Cuttings

Enabling Indian Smallholders to Be Self-Reliant in Potato Seeds

Background

Potato is the third most important food crop in India behind rice and wheat in terms of human consumption and it receives the tag of staple, vegetable, and cash crop. Despite witnessing significant growth in production and consumption in the past five decades (more than a fivefold increase in production from 8.3. million tons in 1980 to 50 million tons in 2020) and holding the rank of second largest producer and consumer of potato in the world, the sector continues to struggle with several constraints, particularly the lack of affordable and available quality planting material for smallholder producers.

Potato seed supply chain in India

The current seed supply chain in India is highly concentrated in and around Punjab, where potato seeds are produced by large companies using aeroponic technology and transported up to 2,000 kilometers to potato-growing states of Eastern and Southern India. The high transportation cost, accounting for 20-30 percent of the seed price, is borne by poor farmers. To make matters worse, the high price does not guarantee high quality, thus making it difficult for small and marginal farmers to invest such a large sum in seed purchases, which account for nearly half of the total cost of production. The spread of aeroponic technology has been limited to a few large seed companies in Punjab because of its high capital requirement and long gestation period. The high price of seeds in potato-growing states has kept the seed replacement rate much lower than the desirable replacement rate of 25 percent to obtain good growth in productivity and production.

Aeroponic technology involves planting tissue culture (TC) plantlets on Styrofoam sheets in grow boxes in a high-tech temperature-controlled facility where nutrient solution is sprayed on the roots and mini-tubers are harvested by lifting the base. Since these mini-tubers are sold to seed producers at INR 8-9 per tuber, they are multiplied several times in an open field to bring the unit cost down and then they are sold to potato farmers across the country as early-generation seeds. These early-generation seeds sold to potato farmers are regarded as "truthfully labeled seeds" because there is no independent monitoring mechanism to verify the seed production and multiplication practices followed by farmers in open fields and ascertain seed quality.

Apical rooted cutting seed production technology

Apical rooted cutting (ARC), a low-cost potato seed production technology, has been practiced in Vietnam for decades. In 2018, the International Potato Center (CIP), as documented at *https://www.outlookindia.com/website/story/apical-rooted-cuttings-could-revolutionize-potato-seed-production-in-india/331839*, introduced apical rooted cutting in Karnataka in collaboration with the University of Horticultural Sciences (UHS), Bagalkot. Since then, CIP, in partnership with the respective state agriculture/horticulture department, has introduced ARC in several potato-growing states, such as Haryana, Odisha, Assam, Meghalaya, and Tripura. The schematic of the ARC process is presented in Figure 1. Like aeroponics, the starting material for ARC is also TC mother culture, which then involves subculturing and multiplication in a tissue culture laboratory. But, unlike aeroponics, in which TC plantlets are planted in a high-tech facility, ARC involves planting of these TC plantlets in cocopeat in a polyhouse to establish a mother bed (Figure 1). The apical cuttings of these mother plants are taken every 15 days and replanted in cocopeat for rooting and taking further apical cuttings at two-week intervals. In three months, one TC

plantlet can produce 70-80 ARCs, with some plants producing more than one cutting in 15 days. As Figure 1 shows, these rooted cuttings are planted either in an open field or in a shade net (soilless or with soil) depending on the location. If aphid pressure is low, then ARCs can be planted in an open field for G0 production.

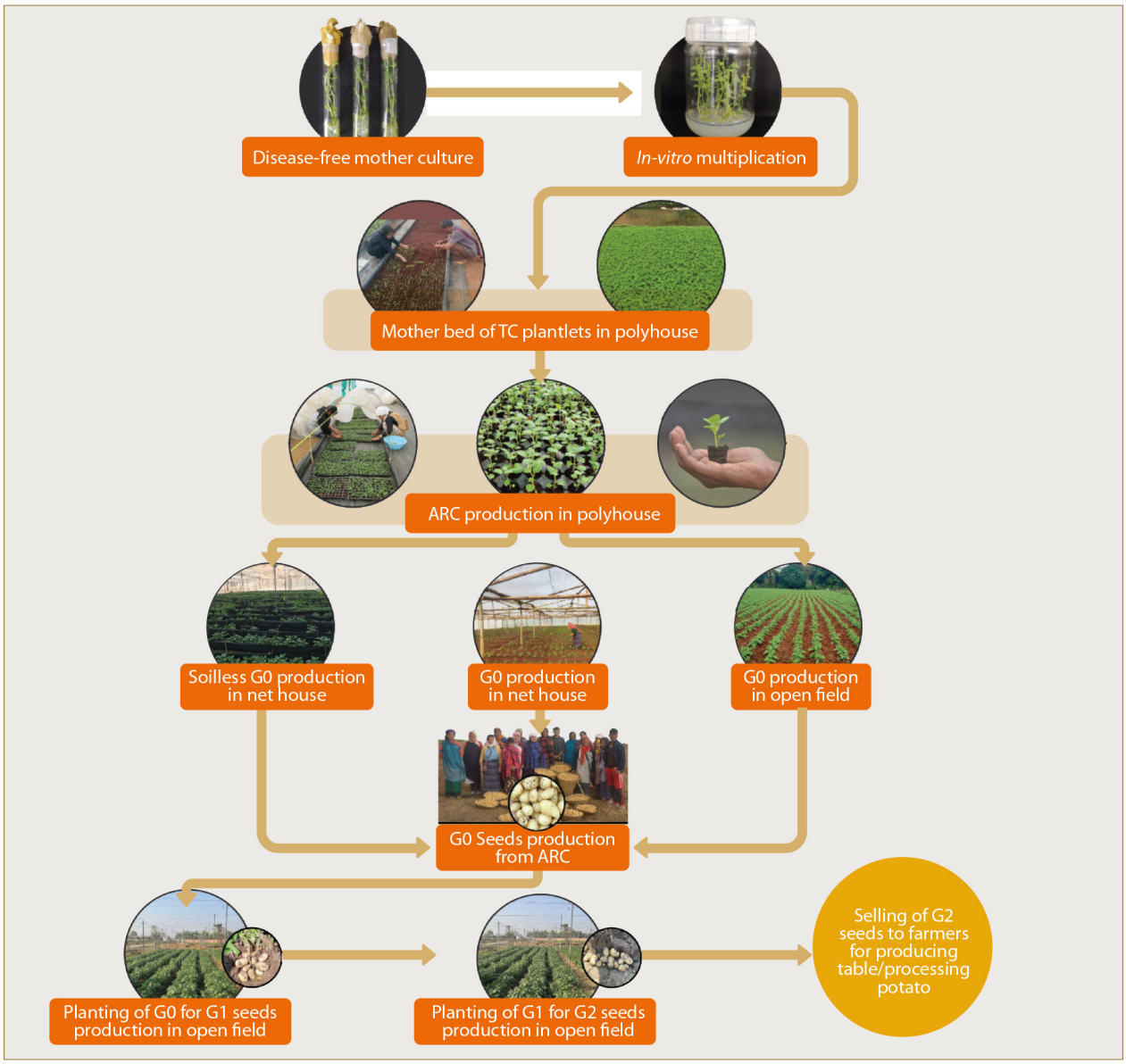

Figure 1. The schematic of the apical rooted cutting (ARC) potato seed production process

There is absolutely no doubt that the mini-tubers produced from aeroponics are disease-free, but the same cannot be said about ARC G0 seeds as they are planted in the net house either in cocopeat or in soil and some are even planted in open field. This has been the argument of many opponents of ARC: that G0 seeds from ARC cannot be guaranteed to be disease-free. But the comparison should be between the seed quality that reaches farmers through these two approaches rather than starting materials. Since the cost of production of mini-tubers is significantly higher than that of ARCs (INR 4-5 per mini-tuber vs INR 0.50 per ARC), seed producers need to multiply mini-tubers three to five times or even more in an open field for them to be economically viable as compared to one or two multiplications for ARCs. In other words, seeds sold to farmers from mini-tubers touch soil a lot more than seeds from ARCs and, every time the seeds touch soil, they are expected to pick up some virus. Based on this argument, the quality of seeds sold to farmers through ARC is likely to be better than that of seeds from aeroponics.

The performance of ARCs in terms of number of tubers (G0 seeds) is the key to determining the economic viability of this technology. Based on the performance of ARCs in farmers' fields in several states, the number of G0 tubers from ARCs varies quite a bit depending on variety, but ranges from 10 to 20. Kufri Himalini, Kufri Uday (a recently released CIP line), Kufri Chipsona-3, Kufri Thar 2 (also a recently released CIP line), Kufri Karan, and Kufri Mohan produce on average 15-20 G0 tubers, whereas some varieties (such as Kufri Jyoti) produce on average 8-10 G0 tubers per plant.

The evolving ARC seed supply chain in India

In 2021-2022, both public and private sector organizations in different states produced more than 60 lakhs ARCs. Private nurseries (trained by CIP in partnership with GIZ) from Hassan District of Karnataka have led the way in producing 70-80 percent of these ARCs both for farmers in the state and for supplying to other potato-growing states, including Haryana, Odisha, and Maharashtra. In our recent survey conducted in Hassan, Karnataka, we found that participating nurseries dedicated on average 150 square meters for ARCs, nearly a tenth of their total net house space, and made a net profit of INR 126,291 in five months, with a benefit-cost ratio of 1.76. Similarly, farmers who purchased ARCs from nurseries and planted them in open fields to produce G0 seeds sold more than three-quarters (76.4 percent) of their G0 production at INR 2,400 per ton to other farmers and kept the remaining 23.6 percent to multiply in the next season. Farmers who planted stored G0 seeds in the next season had significantly less cost of production because of no seed purchase. The net return from selling G1 tubers was significantly higher than the net return received from G0 because of no seed cost in G1 production. Like G0 seeds, 16 percent of G1 production was retained by the farmers for seed use in the next season, which implies higher profit for those farmers next season when they plant stored G1 seeds. Overall, a farmer with one acre of ARC planting can make a net profit of INR 129,764 in two years by selling G0 and G1 seed tubers. But more importantly, ARC allows farmers to produce their own seeds and provide quality seeds to other farmers at a reasonable price. Apart from their profit, the availability of ARC seeds locally will have a spillover effect of higher yield and lower cost of production for other farmers who purchase G0 and G1 ARC seeds at reasonable prices.

Figure 2. ARCs produced in private nurseries by Hassan District farmers/entrepreneurs. Credit. Sampriti Baruah.

Similarly, in Haryana, large seed farmers in the plains purchased ARCs from Morni, where CIP in partnership with the Potato Technology Center (PTC), Department of Horticulture, had begun ARC production with 17 farmers in 2022 because of conducive weather in September and October. Since the availability of ARCs in Morni was not sufficient, some Haryana farmers purchased ARCs from Karnataka nurseries and airlifted them to Karnal for planting. One seed farmer in Haryana has set up his own tissue culture laboratory and has started producing his own ARCs. This is exactly what we had witnessed in Dalat, Vietnam, where many farmers have a small tissue culture laboratory in the backside of their house. Haryana farmers planted their own ARCs in a net house for G0 seed production. In Assam, where we had introduced ARC three years ago with a handful of farmers, they continued to multiply these seeds. One farmer has even sold his G0 seeds to a Punjab seed producer for multiplication.

In Odisha, CIP, in partnership with the Directorate of Horticulture (DoH), has started developing a supply chain consisting of FPOs, farmers' groups, young entrepreneurs, private nurseries, and tissue culture laboratories to begin producing a pipeline of 20-30 lakhs (2-3 million) ARCs annually. The objective is to develop an ARC supply chain that produces 75,000 tons of G2 seeds annually. One Odisha youth was so convinced by ARC last year that he bought nearly two lakhs ARCs from Karnataka private nurseries and planted them on 6.5 acres in Angul District of Odisha.

In Meghalaya, CIP started working with the Meghalaya Basin Management Agency (MBMA), the DoH, and Central Potato Research Institute (CPRI) a little over 15 months ago. Now, the state has two fully functional tissue culture laboratories with trained personnel and upgraded infrastructure with production capacity of 150,000 TC plantlets annually. Two polyhouses have been established for mother beds and ARC multiplication, along with 14 net houses, to

produce G0 seeds. Meghalaya has the advantage of ARC production during August to November in East Khasi District with planting in Ri Bhoi District and selling ARCs to Assam and other potato-growing states. The state was able to sell some ARCs to Assam and Tripura in 2022 but could not supply enough because of its own demand. As ARC production expands in Meghalaya, it could become an ARC supplier for other northeastern states where the climate is not suitable for ARC production. Last season, we also introduced ARC in Tripura, where ARC production will be ramped up this year with training and development of ARC infrastructure. This year (in 2023), ARC production is expected to almost triple from 60 lakhs to 150 lakhs or more as its demand grows in potato-growing states and farmers become aware of this technology. A total of 150 lakhs ARCs may not sound like much for a country such as India, the world's second largest producer of potato with 2.2 million hectares of potato area (Ministry Of Agriculture and Farmer's Welfare, Second Advance Estimates (2021-22), but the effect of 150 lakhs (15 million) seeds on the seed supply chain is illustrated in Figure 3.

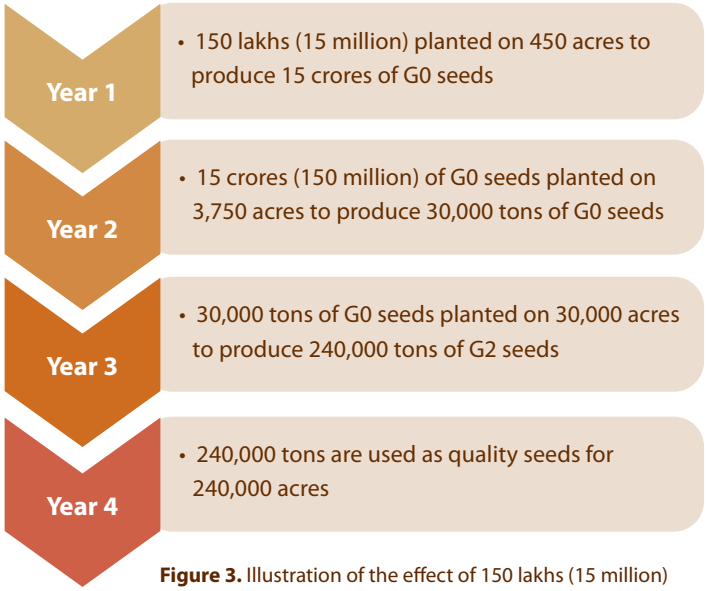

Figure 3. Illustration of the effect of 150 lakhs (15 million) ARCs on the seed supply chain.

As shown in Figure 3, 150 lakhs ARCs in 2023 will produce 240,000 tons of G2 seeds at the end of the third year. This is sufficient seeds for 240,000 acres in 2024.

Our target is to develop a pipeline of five crores (50 million) ARCs in the country by 2028, primarily led by private tissue culture laboratories, nurseries, and FPOs/farmers' groups/individual progressive farmers, which will be sufficient to produce enough G2 seeds to raise the current seed replacement rate from 10 to 25 percent. As the ARC supply chain develops and the unit cost of production of ARCs declines, it will be possible for farmers to directly use ARCs as planting materials for producing table and processing potatoes for the market.

A women-friendly technology

ARC is turning out to be a women-friendly technology. Women farmers and field technicians are able to engage at all stages of ARC production: tissue culture plantlet creation, cutting creation in nurseries and polyhouses, and even backyard/homestead open-field G0 production.

Figure 4. Tissue culture plantlet creation. Credit. Samarendu Mohanty

Figure 5. ARC field workers from Meghalaya. Credit. CIP team Meghalaya

Figure 6. Working inside polyhouse in filling up cocopeat protrays in East Khashi Hills, Meghalaya. Credit. CIP team Meghalaya

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