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Local Seed Potato Production Through Rooted Apical Cutting (RAC) Technology

A compilation of two years of learning in

Karnataka

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LOCAL SEED POTATO PRODUCTION THROUGH ROOTED APICAL CUTTING (RAC) TECHNOLOGY

A compilation of two years of learning in Karnataka

Foreword from GIZ

The global programme "Green Innovation Centres for the Agriculture and Food Sector (GIC) India", commissioned by the German Ministry of Economic Development and Cooperation (BMZ), has been working on the integrated development of the tomato, potato and apple value chain by identifying and scaling innovations that enhance the productivity and income of smallholder farmers and small-scale farming enterprises while creating employment opportunities in up-stream and down-stream businesses.

In Karnataka, the GIC project has been working on the potato and tomato value chain in Hassan and Chikkamagaluru districts. This project is being implemented through a dedicated field team and in close cooperation with the Department of Horticulture (DoH), University of Horticultural Sciences Bagalkot (UHSB), Krishi Vigyana Kendra (KVK), Centre of Excellence for FPO, etc. The project has successfully demonstrated several innovations to achieve the key objectives.

In the potato value chain, the project is addressing the low yields which are caused primarily due to lack of quality and early generation seeds. Since 2019, the project has promoted the innovative rapid seed multiplication method "**Rooted Apical Cutting (RAC) Technology**" which was first developed by the International Potato Centre (CIP) and UHSB under Rashtriya Krishi Vikas Yojana (RKVY) in 2019.

Acknowledging the immense potential of this technology, the GIC project has built a strong network of partners such as CIP, DoH, UHSB, KVK and the private sector to introduce this technology to farmers in Hassan district. Over the last three years, the project has conducted various field trials on RAC and gathered farmers' and nursery owners' feedback.

In close cooperation with the Department of Horticulture, an action plan was prepared to scale up this technology in six major potato growing districts in Karnataka. For this, GIC project is continuing support through CIP and UHSB. In this journey of testing and scaling of the RAC technology, many learnings have been collected and documented in this publication to be used for replication in new areas of the country and to take up further research on this exciting technology.

This learning's document on RAC is a product of collaborative approach by DoH, CIP, UHSB and GIZ. I would like to sincerely thank the involved organisations for contributing their learnings, which will help to achieve a decentralised and farmer centric rapid potato seed production in Karnataka and beyond.

G. Qualitz

Mr Gerrit Qualitz
Project Director
Green Innovation Centres for the Agriculture and Food Sector – India

Message from University of Horticultural Sciences, Bagalkot

The major districts producing potato (an important vegetable crop) in the state are Hassan, Kolar, Belagavi, Chikkamagaluru, and Chikkaballapur, with comparatively lesser area and production in other districts like Bengaluru Rural, Dharwad and Chamrajnagar. In Hassan and Chickmagaluru districts potato is mainly cultivated as Kharif crop whereas in other districts it is mainly grown as a Rabi crop. The average productivity of the state is around 12 to 13 t/ha, which is much below the national average of 22 t/ha. One of the major reasons for low productivity in the state is non availability of quality seed tubers free from viral, bacterial and fungal diseases.

Strategy to address this issue is to produce the quality seed tubers locally in Karnataka with good, potential and adoptable, viable and low cost technology. In this direction, the University of Horticultural Sciences, Bagalkot (UHSB) in collaboration with International Potato Centre (CIP) & GIZ had carried out studies on development, adoption and suitability of apical rooted cuttings (ARC) Technology for rapid multiplication of seed tubers. The study has resulted in very convincing and promising results about the potentiality of this technology.

Later, during 2021 and 2022 with collaborative efforts of UHS, CIP, GIZ and KSDH the technology was taken to farmers field (mainly in Hassan region and very few locations in Kolar and Chikkballapur region) for pilot testing. The farmers appreciated the technology and gave their feedback that they are able to get more yields compared to their conventional practice and comparatively disease-free crop with minimum investment on crop care. Now more and more farmers are coming forward to adopt this new technology throughout Karnataka.

In this context the GIZ Karnataka compiled the research accomplishments and good agricultural practices of potato production in the form of manual. Also, they are bringing out manual of good agriculture production in tomato and other vegetables. I hope this manual will help all the stakeholders of the farming community to improve their income and sustainable development in horticulture sector.

My best wishes and congratulations to whole team.

K. M. Indiresh
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Message from Department of Horticulture, Karnataka

Potato is an essential crop in the State of Karnataka, primarily grown in districts such as Hassan, Chikmagaluru, Chikkaballapura, Kolar, Belagavi, and Dharwad. However, the lack of access to high-quality potato seeds has been a persistent issue in the State for many years, as the entire State relies on seeds from Jalandhar in Punjab. The supply chain for seed potatoes involves many private companies and traders, but the non-availability of required varieties is a major problem that hinders productivity, which falls below the national average.

Over the past three years, the Green Innovation Centre project of GIZ, in collaboration with the Department of Horticulture, International Potato Centre (CIP), and University of Horticultural Sciences, Bagalkot (UHSB), has introduced an innovative Rooted Apical Cutting (RAC) technology in Hassan district to produce seed potatoes involving private nurseries and farmers. The technology has been widely accepted among nursery owners and farmers, and the success of the pilot has prompted plans to scale up the technology in all major potato-growing districts in Karnataka. The Department of Horticulture has allocated a budget to start demonstration and training programs for farmers to adopt this technology with the goal of achieving self-sufficiency in potato seed tuber production within the next three years.

To support this effort, GIZ has produced a short learning document on RAC technology in collaboration with CIP, UHSB, and DoH. The booklet provides technical information about the innovative technology, as well as short case studies of farmers and a business plan for all levels, including tissue culture labs, nurseries, and farmers' fields. Overall, these initiatives represent a significant step towards addressing the issue of seed potato supply in Karnataka and increasing potato productivity in the state.

I wish this booklet will serve as a guiding book to spread this innovative technology in coming years.

Mr Rajender Kumar Katari
Principal Secretary of Government
Karnataka Government Secretariat
Horticulture & Sericulture Department

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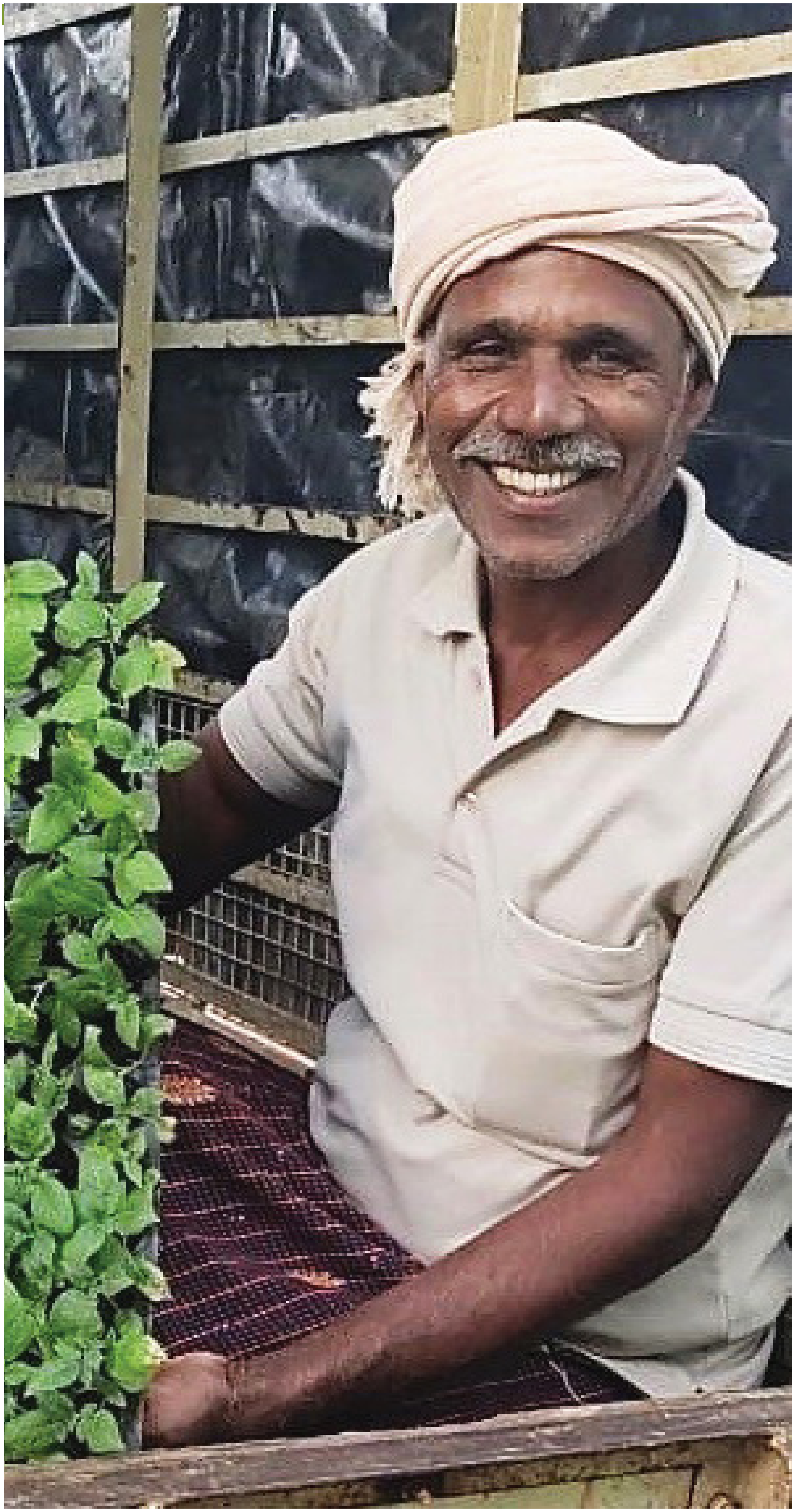

INTRODUCTION

01

In Karnataka, potato is being grown mainly in Hassan, Kolar, Chikkaballapura, Belagavi, Dharwad and Chikkmagaluru districts.

Over the past few years, the area under potato cultivation in the state has reduced drastically due to the outbreak of diseases and low returns, and farmers switching to other crops. In Hassan district alone, approximately 60,000 ha area was under potato cultivation only a few years ago and it now stands at 12,000 ha.

While the national average for productivity of potato production is about 22 t/ha, average productivity of potato production in Karnataka is about 12 t/ha (among the lowest in the country). The major issues related to seed potato which affect productivity include:

Poor quality of seed potatoes

Technically speaking, seed potatoes used by Karnataka farmers are not seeds. These uncertified seeds are grown in Punjab and sold in the state as seeds. High incidences of viral diseases in Punjab potato fields affect the quality of the seed potato with faster degeneration. There is also no information regarding which generation of seed the farmers are receiving. Unscientific storage of seeds at cold stores in Karnataka leading to seed problems such as poor sprouting.

Poor access to seeds by farmers

Seeds are not produced locally in Karnataka but are coming from Punjab (approximately 2,500 km away). This results in uncertainty of seed availability leaving farmers with no option but to entirely depend on local traders.

Higher price of seeds

Seed prices fluctuate greatly and are largely dependent on the situation at the time of planting rather than the production cost of seed. If there is demand, the prices are raised enormously by the traders.

In India, the seed potato production is largely confined to north India, especially Punjab. The seed growers in Punjab are entrepreneurial, skilled, and have captured India's seed market. Of late, conditions in Punjab are becoming less suitable for seed production which has resulted in a shift in the time of seed potato planting. The ideal time for planting is in October, however many farmers are not able to take up planting because of delayed paddy cultivation. As a result of this late planting, the crop is more prone to vectors which transmit viruses, resulting in faster degeneration, and therefore less reliable seed coming from Punjab. There is need to develop non-conventional areas for seed potato production. With ideal conditions for potato cultivation in both Kharif and Rabi, Karnataka offers the right conditions to develop the seed potato sector. Adopting the Rooted Apical Cutting (RAC*) technology, which is already quite popular in Vietnam, can be a game changer as it enables increased multiplication rate and more rapid seed potato multiplication at a lower price.

The Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH (German Agency for International Cooperation), is Germany's development agency. It provides services in the field of international development cooperation. In its projects, GIZ works with partners in national governments as well as actors from the private sector, civil society and research institutions. GIZ's main commissioning party is Germany's Federal Ministry for Economic Cooperation and Development (BMZ). Other commissioners include the European Union, the UN, the private sector, and governments of third countries. Since 2016, the GIZ global programme "Green Innovation Centres for the Agriculture and Food Sector (GIC)– India", financed by BMZ has been active in India.

Working in Hassan and Chikkmagaluru districts, the GIC project identified, tested and introduced various

*In India, RAC Technology is called as Apical Rooted Cutting (ARC) Technolgoy. They are used synonymously.

innovations in potato cultivation in a participatory manner involving the farmers. Under the GIC project, the testing of the RAC technology involving farmers was taken up from 2020 by involving the International Potato Centre (CIP) as technical agency. The project adopted a collaborative approach and involved the University of Horticultural Sciences, Bagalkot (UHSB), the local Department of Horticulture (DoH), private nurseries and farmers to carry out various trials to standardise this innovative technology for rapid and decentralised potato seed production.

This report is the compilation of learnings gained by conducting trials under the project and field level implementation since 2020. While preparing this document, inputs from the University of Horticultural Sciences, Bagalkot and the Department of Horticulture were taken. Involving the scientists and officers from university and department, three days write-shop was organised to prepare this report.

Following are the broad sections of this report :

- Introduction to Rooted Apical Cutting (RAC) Technology
- Tissue Culture Lab
- Multiplication in Nursery
- Field production of tubers
- Economics of RAC technology at Tissue Culture lab, Nursery, Satellite nursery and Field level
- Case studies
- New Innovations in RAC technology

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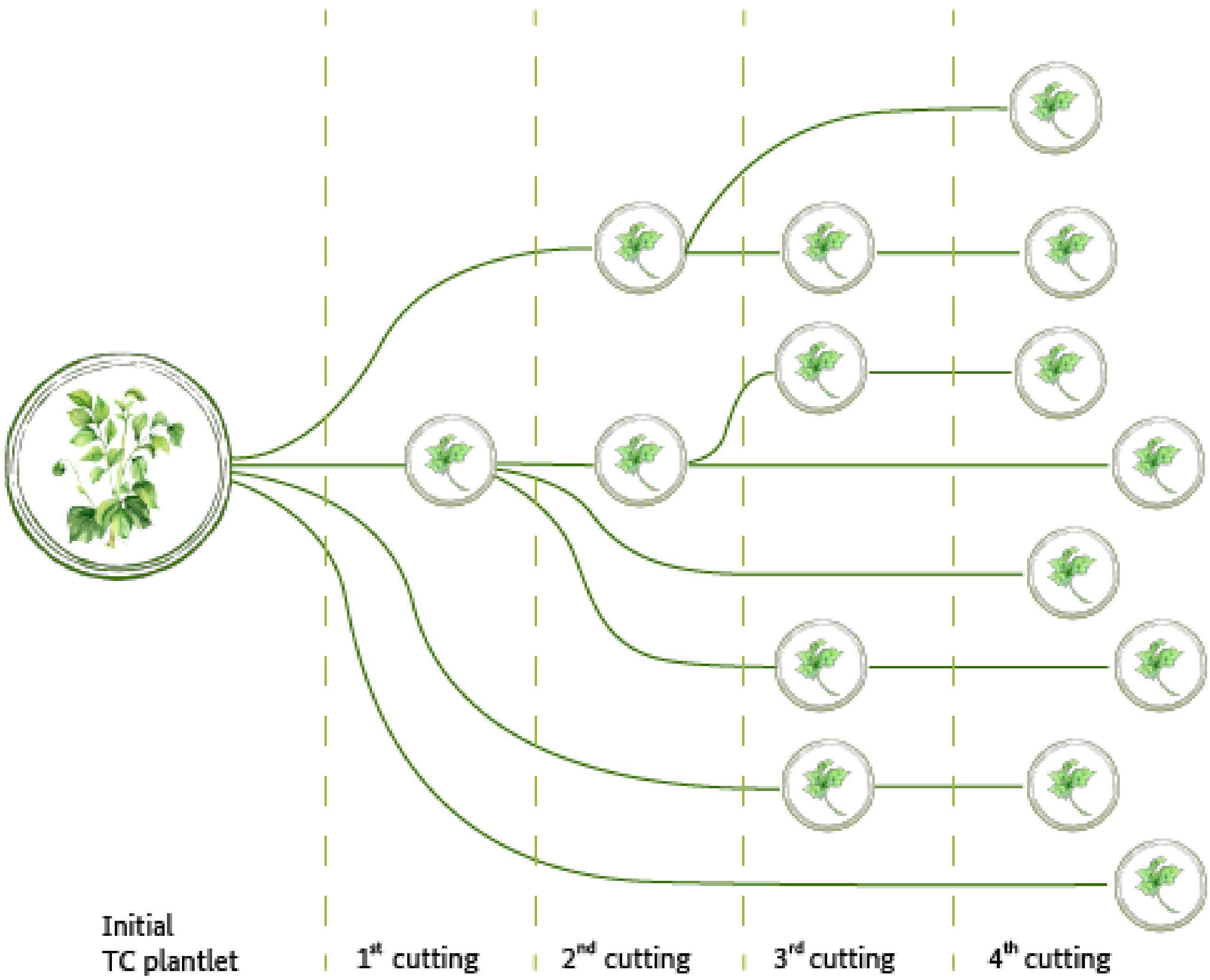
THE ROOTED APICAL CUTTING (RAC) TECHNOLOGY

02

The Rooted Apical Cutting (RAC*) technology is a low-cost potato seed production technology.

It is a form of vegetative propagations in which rooted transplants are produced in a polyhouse from tissue culture plantlets, which allow the rapid multiplication of seed potatoes. Rather than letting tissue culture plantlets mature and produce minitubers, cuttings are produced from the plantlets. Once rooted, these cuttings are transplanted in a temporary nethouse or open field to produce new minitubers. Through the technology's rapid multiplication, large numbers of seedlings can be produced in 12-14 weeks.



The first rounds of cuttings expand parent material in the first months of production. The remaining months dedicated to commercial production of rooted cuttings. Adjacent diagram is a simplified demonstration of cuttings from one mother plant over the six-week period. Mother plants are produced up to appr. 3 - 4 weeks until the first cuttings will be planted in the field. Thus, any new shoots forming after this, will be placed into plugs for transplanting – the commercial product which will continue to be produced over a 2 - 4-month period. Thus, apical cuttings involve: i) production of rooted cuttings (transplants) originating from tissue culture plantlets in the screenhouse and ii) production of seed tubers in the field from transplants.

*In India, RAC Technology is called as Apical Rooted Cutting (ARC) Technolgoy. They are used synonymously.

Local seed production through the RAC technology involves the following major steps:

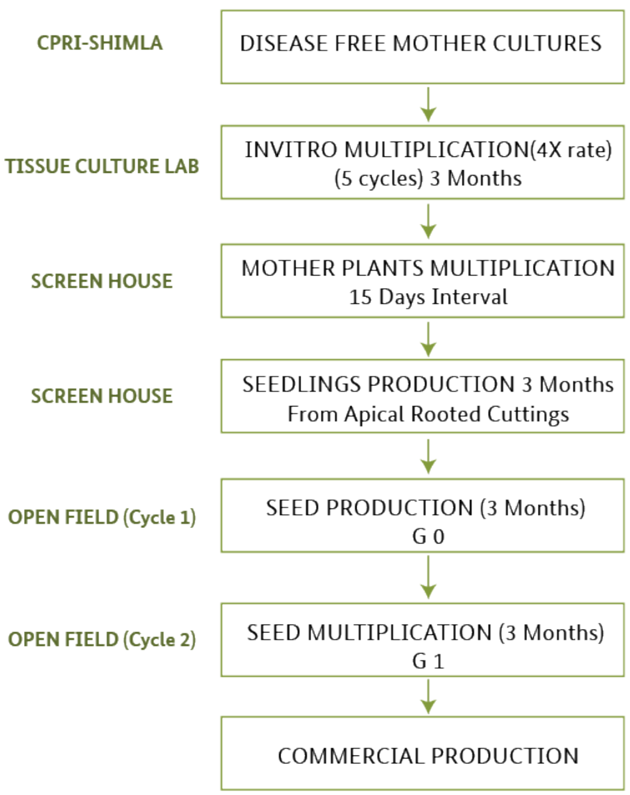
- In-vitro multiplication of potato plantlets in a tissue culture lab
- Production of RACs in private nurseries
- Planting of RACs by farmers (G0 production)
- Storing of G0 seeds in cold stores
- Planting G0 seeds the following season for further multiplication (G1)
- Again, storing seeds in cold stores and planting the following season

This cycle continues for the next one or two seasons (depending on the quality) for multiplication then the seed is subsequently used for ware potato production.

Advantages of RAC technology

- Production of Early generation seeds.
- Decentralised seed production system where farmers can produce their own seeds.
- Short period for seed multiplication compared to conventional seed production.
- Low cost of seed production and less complex compared to aeroponic.
- Karnataka has the advantage of two seasons which enables to speed up seed production cycles.
- Availability of a large number of local nurseries which can produce the cuttings. Distribution of cuttings becomes easy as the production of cuttings can be planned in different locations.

Flow Diagram of Apical Rooted Cutting Technology



THE THREE PARTS OF THE RAC TECHNOLOGY

03

The RAC technology involves three major parts:

I Potato tissue culture
II Production of RACs in nurseries, and
III Seed potato production

The process and learnings gained in each of these parts is deliberated in the following pages.

3.1 Potato Tissue Culture

3.1.1 In-vitro multiplication of potato plants

Tissue culture is the first step in RAC. Standard potato tissue culture procedure is followed to get disease free tissue culture plantlets. Mother culture is obtained from CPRI (Central Potato Research Institute) and used for further multiplication.

The basic concept behind tissue culture is totipotency, which means that every cell has a capacity to grow into an entire new plant. There are three main steps in potato tissue culture. 1. Media preparation, 2. Culture transfer, and 3. Incubation

3.1.2 Media Preparation

Plants normally grow in natural media, the soil. But for tissue culture propagation artificial media is used which has all the nutrients required for plant growth. A standard full-strength MS media (Murashige and Skoog invented MS medium in 1962 and developed a standard protocol) is used. The procedure is as follows

Components	Concentration
Stock solution A (MS-A): Macronutrients (10x concentration, enough to prepare	
10 l of MS media, dissolved in 1 l of MilliporeTM water)	
Supplement for MS medium (NH4NO3 + KNO3)	35.5 g
Calcium chloride dehydrate, CaCl2 .2H2O	4.4 g
Magnesium Sulphate heptahydrate, MgSO4. 7H2O	3.7 g
Potassium dihydrogen Phosphate (KH2PO4)	1.7 g
Stock solution B (MS-B): Micronutrients (100 x concentration, sufficient to prepare 100 l of MS media, dissolved in 1 l of MilliporeTM water)	
Manganese Sulphate tetrahydrate, MnSO4.4H2O	2230 mg
Zinc Sulphate tetrahydrate, ZnSO4.4H2O	860 mg
Boric Acid (H3BO3)	620 mg
Potassium Iodide (KI)	83 mg
Sodium Molybdate dehydrate, Na2MoOH.2H2O	2.5 mg
Copper Sulphate pentahydrate, CuSO4.5H2O	2.5 mg
Cobaltous Chloride hexahydrate, CoCl2.6H2O	2.5 mg

Components	Concentration
Stock solution C (MS-C): Fe-EDTA (100 x concentration, sufficient to prepare 10 l of MS media, dissolved in 100 ml of MilliporeTM water)	
Ferrous Sulphate heptahydrate, $FeSO_4.7H_2O$	278 mg
Disodium ethylenediaminetetraacetate dehydrate, $Na_2EDTA.2H_2O$	373 mg
Stock solution D (MS-D): Vitamins (100x concentration, sufficient to prepare 10 l of MS media, dissolved in 100 ml of Double distilled water)	
Glycine	20 mg
Nicotinic acid	5 mg
Pyridoxine Hydrocloride (HCl)	5 mg
Thiamine Hydrochloride (HCl)	1 mg
Myo-Inositol	1000 mg

3.1.3 Culture transfer

To a small quantity of double distilled water, desired quantities of all the four stock solutions are integrated and dissolved properly using a hot plate cum magnetic stirrer with the avail of a magnetic flea. The quantity of each stock solutions, the amount of carbon source (sucrose) and different additives to be integrated to prepare 1 litre of full-strength MS media is given in the table below. Also, pH is maintained at 5.7.

This media is poured into autoclaved glass bottles (300 ml capacity) at the rate of 30 ml/bottle. After autoclaving, these bottles with media are used for subculturing after 3 - 4 days.

Culturing:

Disease-free stock plants obtained through meristem culture are used as starter material for further multiplication.

- 3 - 4 weeks old in-vitro plants are used for culturing.
- Sub-culturing operations are performed under laminar flow to maintain aseptic conditions. A standard procedure is followed for operating laminar air flow
- In-vitro plantlets are carefully removed from the glass container inside the laminar airflow.
- Each plant is cut into different pieces at the internodal region. The root part is discarded.
- These 15 - 20 nodal cuttings are placed in each of the glass jar with media for incubation in the growth chamber.
- For better growth, wide mouthed plastic containers are preferred over standard glass jars.

3.1.4 Incubation

- The containers with nodal cuttings are placed in the growth chamber. The room temperature is maintained at 22 - 25 °C. Using cool white fluorescent lights, 16 hours light and 8 hours darkness is maintained for better growth. It is recommended to use an automatic timer to set the photoperiod.
- These nodal cuttings grow into an individual plant in 3 - 4 weeks. The procedure is repeated for further multiplication of in-vitro plants or these plants are used for producing RACs.
- Large number of in-vitro plants can be produced in short period because of short cycle of 3 - 4 weeks.

Key learnings: Potato tissue culture

- Use of sugar instead of sucrose to minimise the cost. Sucrose is one of the costliest carbon sources used in TC. Instead of this sugar is used on trial basis and observed that there is no difference in the growth of plants. A systematic study can be taken up on this observation.
- Normally in TC labs, double distilled water is used for media preparation. Double distilled water contains no salts, and the TDS (Total Dissolved Solids) of that water is 0. However, the project successfully tried reverse osmosis (RO)-purified water instead of double distilled water. TDS of the RO water ranges between 30 and 40. Though double distilled water is preferred, RO water with low TDS can also be used. Cost of RO water is less compared to double distilled water.
- Commercial-grade agar also gave similar results as those of lab grade, which is expensive.
- Instead of test tubes, glass bottles/jars are preferred as they are more economical.
- 15 - 20 nodal cuttings per each bottle is more optimal for growth and economic point of view.
- Results showed that 30 - 35 ml media per bottle (300 ml capacity) is optimum.
- The standard practice has been to place the nodal cuttings vertically for culturing in the container. However, trials indicated that horizontal placing of nodal cuttings can also give similar results. Horizontal placement is preferred as it takes less time.
- There is a varietal response for tissue culture multiplication. Observed varieties K. Himalini and K. Chipsona-4 have more vigorous growth than K. Jyoti. On average, four or five nodal cuttings are possible in three weeks in K. Himalini and K. Chipsona-4, whereas it is three or four nodes in K. Jyoti. Also, more branching is seen K. Himalini.
- If we use the apical portion of the tissue culture mother plant for subculturing, then the growth is faster compared to the basal portion of the mother plant.
- Light with a 16-hour daylength and an intensity of 50 - 60 µEm-2s-1 (cool white fluorescent light) is required, otherwise plantlets develop a pale colour and become very thin.
- Tissue culture multiplication of K. Lima shows the slowest growth, whereas K. Mohan grows quickly compared to other varieties such as K. Himalini, K. Sangam and K. Jyoti.

- During the rainy season, the percentage of tissue culture contamination is high compared to the summer season.
- Tissue culture plantlets contaminated with bacteria can still be used for nursery activity if the growth of the plantlets is good.
- The apical portion of the plantlets will not generally carry bacteria thus we can use bacterial contaminated bottles for subculturing in special circumstances, although it should be avoided in general for multiplication. However, it is not possible to use plantlets with fungal contaminants as the spores spread more quickly.

3.2 Production of RACs in nurseries

3.2.1 Multiplication of mother plants in mother beds

Preparation of mother beds :

- Mother bed structures are formed by using bricks or nylon rope and 1-ft iron rods. The bed should be 4 ft width, which helps easy access from both the sides. The bed height should be of 4 inches which enables better root growth; and bed length can be decided based on requirements.
- After the basic structure is ready place antiweed mat on the bed to hold the coir pith.
- Use good quality, well decomposed enriched coir pith as the medium. Check the quality of the coir pith for pH (ideally, 6.5 - 7) and electrical conductivity (EC) before using. The EC should be less than 1.
- Evenly water the bed before planting. Quality of irrigation water is important; check it periodically.
- After watering the bed, make holes at spacing of 4x4 inches and 2 inches depth.

Planting of in-vitro plants :

- Carefully remove the in-vitro plantlets from the bottles without damaging the root and wash it carefully to remove the excess media. TC plantlets that are 20 - 25 days old are more ideal for planting, as we observed better establishment compared with old plantlets.
- Carefully place a single TC plantlet – two in case of small plantlets – in each hole and gently press the coirpith to cover the hole.
- Do not water immediately after planting as it may damage the tender TC plants.
- As a general practice, irrigate the bed daily once based on the weather conditions. Thumb rule is to not allow the bed to dry. Excess watering also affects the growth and establishment of plants.
- Providing additional shade after in-vitro planting improves the survival rate.

Mother plants multiplication :

- In two or three weeks, these in-vitro plantlets are established and ready for first apical cutting. Normally, cold climate in winter requires more time (3 - 5 days more) for cuttings compared to warm temperatures in summer.
- Cut the apical portion of these mother plants at about 2 inches high, having two nodes and about four leaves.
- Dip these apical cuttings in water for two - three seconds, and then plant them in the bed (4 inches apart).
- These newly planted cuttings start rooting in five or six days and will be ready for next cutting in about 12 - 15 days. Meantime the in-vitro plantlets also produce new apicals and are also cut for further planting in the beds.
- This cycle continues and the mother plants multiplication happens in geometric proportion. Every 15 days, the mother plants are doubled. Technically, each in-vitro plantlet has a potential to give 250 cuttings in four months.

Production of RACs for field planting :

- Once enough mother plants are produced and when the season is favourable for field planting, the apical cuttings from the mother beds are planted in protrays (98-cavity) for rooting.
- In 15 - 20 days, these cuttings are ready for field transplantation, either in a nethouse or in open field.
- Three or four days before field transplantation, reduce the quantity of water and increase the light intensity by managing shade. This ensures better hardening of plants.
- On the day of transplanting, these well-rooted cuttings are transported to the main field by using crates or by carefully folding the trays and arranging in a vehicle. Before transporting to main field, it is advisable to take up one prophylactic spray for sucking pest in the nursery which provides protection for initial period in main field.
- The RACs can also be transported long distances by air cargo using thermocol boxes. The best field establishment can be expected if the planting is done before 24 hours.

Mother beds produce minitubers, which can also be used for planting. After the season is over, maintain the mother beds for 2-3 weeks. Mother plants also produce minitubers which can also be used as G0 planting material. Each plant has a potential to produce at least one tuber.

General nutrient management practices in mother nurseries

- For better root growth and healthy plantlets production in nurseries, use 1 g of humic acid and 5 g of Trichoderma per kg of coir pith used.
- Spray water soluble NPK (19:19:19) 3 g/l and micronutrients 3 ml/l at 10 days' interval to mother plants.
- At 15 days' interval, spray 5 g/l of potassium Schoenite and 5 g/l of calcium nitrate.

General pest and disease management in nurseries

- It is expected that there should be no pests inside the nurseries. However, as a precaution, use yellow and blue sticky traps to control sucking-pest damage in nurseries.
- As a precautionary measure to control pest incidence, spray neem oil 3 ml/l or Sperotetramat (e.g. Movento OD) 1 ml/l or Safidopyropen (e.g. Sefina) 2 ml/l or Spinosad (Tracer/Spintor) 0.3 ml/l of water.
- To control blight, spray Mancozeb 3 g/l; if disease appears spray cymoxanil + Mancozeb 3 g/l, and if there is more incidence of disease, spray Dimethomorph 1 g/l + Mancozeb 3 g/l of water.
- For seedling rotting, drench Fosytyl AI (e.g. Aliette) 2 g/l of water.

Key learnings: RAC Nurseries

- Shallow planting of TC plants in beds resulted poor root establishment. Hence in-vitro plantlets need to be planted at least one inch deep.
- Coirpith in nursery beds should not be compacted otherwise it results in poor root penetration
- For every 10 - 15 days, a combination spray of NPK, micro-nutrients and humic acid gives good results for both shoot and root growth.
- Abiotic stress such as temperature fluctuations (decrease or increase in temperature) can induce aerial tuber formation with very poor root development.
- In grading of mother bed tubers, 2 g, 5 g and 10 g tubers are obtained, with a greater proportion of medium-sized tubers.
- Establishment of the mother bed with in-vitro plantlets requires intensive care and maintenance. The project's experience shows not all nurseries are capable of handling in-vitro plantlets. So, it is better to establish mother beds with in-vitro plantlets in one or two nurseries with all the care and the apicals can be shared with large number of nurseries for further multiplication.

Suggestions for good nursery management

- Polyhouse is more suitable compared to nethouse.
- Use 40 mesh insect proof net and make sure that it is not damaged.
- Use double door system in nursery and both the doors should be closed always.
- Surrounding areas of nursery should be clean and plants related to potato family should not be there in the nursery (tomato, brinjal, chilli and other weed plants).
- Use white net to control light intensity, if its more use green net.
- Do not enter the nursery after having visited the fields, this may lead to the entry of various pest and disease from the clothes and footwear
- Proper phytosanitary measures should be followed.
- Use antiweed mat on the floor to control the weeds in the nurseries. Do not use plastic sheet since this will affect the drainage of water.

3.3 Seed Potato Production

3.3.1 Field selection

- The area selected should be free from serious soil borne pests particularly of wart, Bacterial wilt, Black scurf, common scab and cyst nematode
- Choose a field which was not used for growing potato, tomato, chilli, brinjal and tobacco for last two years.
- Field should not be adjacent to the above crops or a minimum isolation distance of 5 meter should be provided.
- Choose a field with proper irrigation and drainage

Soil

Wide range of soils e.g. sandy loam, silt loam, loam and clay soil are suitable. Well drained sandy loam and medium loam sols, rich in humus are most suitable for potato production. Potatoes are well suited to acidic soils (pH 5.0 - 6.5). Alkaline or saline soils are not suitable for seed production as it may cause bacterial scab issues.

Climate Requirement

- The vegetative growth of the plant is best at a temperature of 24 °C while tuber development is favoured at 17 - 19 °C. Hence, potato is grown as a summer crop in the hills and as a winter crop in the tropical and subtropical regions.
- The minimum and maximum temperature should be within 8 - 28°C during crop season.
- In Hassan, both the seasons (Kharif and Rabi) are congenial for potato cultivation.

3.3.2 Field management practices

Land preparation

- One deep ploughing followed by 2 - 3 shallow cultivations are practiced to obtain fine tilth. The soil should have higher pore space and offer least resistance to tuber development
- Ridges and furrows are opened at a distance of 60 - 70 cm before planting.

Planting method

- 2 – 3-weeks old saplings are planted 17 - 20 cm apart on the side walls of the ridge, 2 inches above the furrow level. Like this, water logging can be avoided and proper ridging at later stages will be made possible.
- Planting is done at a depth of 5 - 8 cm and covered with soil.
- As RAC plants have a greater number of haulms per plant, spacing of 20 - 25 cm plant to plant and row to row distance of about 70 cm can reduce high humidity, thereby incidence of late blight, especially in Kharif season.

Earthing up

- The main objective of earthing up is to keep the soil loose and destroy weeds.
- A minimum of 2-3 times of earthing up is required at an interval of 15 - 20 days to prevent the greening of tubers and to get a greater number of tubers.
- The first earthing-up should be done when the plants are about 20 - 25 days old. The second and third earthing up is often done to cover up the tubers which will form in the upper layer of soil, especially in case of K. Himalini.

Manures and fertilizers

- Apply well decomposed farmyard manure at 7 - 8 t /acre. If green manure crop is grown, then the manure dose can be reduced to 4 - 5 t /acre.
- For green manuring, it is recommended to grow sunhemp and daincha for 6 - 7 weeks and incorporate it into the soil.
- Application of 50 kg of DAP, 100 kg of potash

and 50 kg of secondary macro nutrients which contains CaMgS (15:3:5) per acre are recommended to use before making ridges and furrows.

- A solution which contains 1 kg of humic acid (98 %) and 5 kg of multi micronutrinet mix (Zn:Fe:Mn:B = 10:5:2:0.3) in 200 litres of water is preferred to drench 5 days after planting.
- Spray 1: 3 g of 6:12:36 grade N:P:K (Opifol) and Multi Micronutrient mix (Brexil plus) at 1 g/ lit followed by second spray after 5 days
- Spray 2: Potassium schoenite (KMS) 5g + Calcium nitrate at 5 g/ lit
- Application of 25 kg Urea at 20 - 25 days and 50 - 55 days after planting

Plant protection

One preventive spray for sucking pest and fungal diseases should be given in the nursery itself which protects the plants in the main field for about 10 - 15 days.

Harvested tubers from the RAC will be G0 seeds and this needs to be keep in cold storage for 45 – 60 days to break dormancy. Then these tubers will be ready for taking up G1 seed tuber production

The agronomic practices will be similar to regular potato cultivation.

Some of the key practices to be followed for tuber planting are :

- Never plant the tubers immediately after removing them from the cold storage. At least 15 days will be required to get proper sprouting.
- Spread the seed tubers thinly under shade with diffused light.
- Sort-out the diseased, rotten tubers as well as with abnormal sprouts.
- Spray Mancozeb at 4 g/l of water on the cut potato tuber or moisten the potatoes by spraying water and then sprinkle Mancozeb at 4 g/kg seed over it. Mix the seed and fungicide properly.

Seed rate

30000 - 35000 saplings/acre depending on the spacing.

Spacing

As the spacing between plants decreases, the size of the tuber decreases, whereas the number of tubers increases. As the aim is to produce seed potatoes, a spacing of 60 cm row to row and 17 - 20 cm plant to plant distance is recommended

Water management

- One irrigation before land preparation and after planting
- Irrigation immediately after planting
- Irrigation after top dressing and earthing up
- Irrigate as per the crop requirement to avoid any drought stress. Soil must be kept always moist but hardening or too wet conditions of soil should not be allowed. Ensure that water level should not be more than 2/3 part of the ridge to avoid the over flooding of ridges.
- Stop irrigation at least one week before dehaulming.

Dehaulming and harvesting

- Crop should be harvested when haulms start yellowing and falling on the ground.
- At this stage haulms should be removed at ground level.
- From the point of seed production, dehaulming at 75 days after planting is recommended to produce quality and small sized tubers.
- Haulms must be destroyed as close to the ground as possible on the prescribed date and re growth of the haulms should be checked.
- The crop should be harvested about 10 - 15 days after dehaulming when the skin is suitably mature.
- There should be optimum moisture in the soil at the time of harvest.
- At the time of harvesting, farmers should collect all the tubers irrespective of size.
- Even the small tubers can also be used as seed.
- After digging, the tubers may be allowed to dry on the ground for some time in shade.

Grading and storage

- Potatoes should be graded in three grades like large (> 45 mm), medium (35 - 45 mm) and small (10 - 35 mm).
- After washing in water, treat only the seed potatoes in 3 % boric acid solution for 25 - 30 minutes.
- Proper grading should be done after harvest by removing disease-affected tubers.
- Dry in shade and pack grade wise in gunny bags.
- Store in cool and dark place.
- Around 45 - 50 days are required to break the dormancy in cold storage.

THE ECONOMICS OF THE RAC COMPONENTS

04

RAC technology involves three important commercial components.

These parts are tissue-culture multiplication, production of RACs in the nursery and production of seed potatoes from RACs in the field. Based on the project's experience over the last two years, a business plan has been worked out for each component, which is presented in below tables.

a) Potato tissue-culture economics (INR)

Cost category	To produce 500,000 plantlets (INR)	To produce 250,000 plantlets (INR)
Chemicals	34,216	17,108
Electricity	48,000	24,000
Lab establishment*	100,000	100,000
Personnel	883,100	441,900
Other	57,625	28,813
Mother culture	50,000	50,000
Service and maintenance	24,000	12,000
Rent	180,000	90,000
Grand Total	**1,376,941**	**763,821**
Cost of production per plantlet	2.75	3.06
Returns (at Rs.5/plantlet)	2,500,000	1,250,000
Profit	1,123,059	486,179

*** Total establishment cost is Rs.1,000,000, assuming it is for 10 years, 100,000 is considered per year**

b) RAC mother nursery economics (INR)

Mother nurseries procure tissue-culture plantlets from labs and establish the mother beds

Particulars	Unit	# Units	Unit Rate	Amount
Cost (For multiplication of 100,000 mother plant, 1000 m^2)				
Cost of tissue-culture plantlets (purchased)	Number	2,000	5	10,000
Bed preparation (1000 m2)	m2	1,000	30	30,000
Cocopith	tons	25	7,000	175,000
Plant nutrition and protection	L/S			25,000
Labor: cutting (3000 cuttings/day)	Number	33	400	13,333
Maintenance				20,000
Total Cost				**273,333**
Returns				
# apicals (6 batches, 200,000 each)	Numbers	1,200,000	0.3	360,000
# minitubers (at least two minitubers/plant)	Numbers	200,000	1.5	300,000
Total Returns				**660,000**
Profit				**386,667**

c) RAC satellite-nursery economics (INR)

Satellite nurseries purchase apicals from mother nurseries and produce RACs in batches.

Particulars	Unit	# Units	Unit Rate	Amount (INR)
Cost (For 600,000 RACs)				
Cost of apicals	Numbers	600,000	0.4	240,000
Protrays (98 cavity)	Trays	6,000	7	42,000
Cocopith (1 kg/tray)	Kg	6,000	7	42,000
Plant nutrition and protection	l/s			12,000
Labour (2000 cuttings/ day)	Numbers	300	400	120,000
Maintenance (watering, spraying, etc.)	l/s			12,000
Cost (600,000 RACs)	**Tray**	**6,000**		**468,000**
Returns				
Sale of RACs	Trays	6,000	100	600,000
Profit				**132,000**

d) RAC potato field-seed-production economics (INR)

S.No	Particulars	Unit	# Units	Unit cost	Total INR
	G0 Production (RAC planting)				
1	RACs	No.	40,000	1	40,000
2	Production cost	Acre	1	30,000	30,000
3	Cold storage	kg	7,000	2	14,000
	Total cost (per acre)				**84,000**
	Returns	kg	7,000	30	210,000
	Profit per acre				**126,000**
	G1 Production				
1	Seeds	kg	800	30.0	24,000
2	Production cost	Acre	1	30,000	30,000
3	Cold storage	kg	7,000	2	14,000
	Total Cost (per acre)				**68,000**
	Returns	kg	7,000	25	175,000
	Profit per acre				**107,000**
	Ware Potato				
1	Seeds	kg	800	25.0	20,000
2	Production cost	Acre	1	30,000	30,000
	Total cost (per acre)	**50,000**			
	Returns	**kg**	**7,000**	**15**	**105,000**
	Profit per acre				**55,000**

CASE STUDIES

05

5.1 Nursery

My name is Manjegowda, and I am from Kodihalli village in Hassan district. I own a nursery where I produce seedlings of various crops. With an intention to promote low-cost local potato seed production, last year they had given me 4 tissue culture bottles for trials. With that few tissue culture plants, we could able to multiply 16,000 plants. We gave these plants to neighbouring farmers for planting. I too planted 500 plants. After seeing the success, this rabi season with 100 tissue bottles (about 2,000 plants), I was able to multiply 200,00 plants, with repeated apical cuttings. I have given these plants to many farmers, and they are growing potatoes successfully. I also request all the nursery owners to take this nursery activity and help the farmers. I plan to produce 1,000,000 cuttings for kharif season. Last kharif season I had grown 500 'K. Himalini' RAC plants in my polyhouse and got 75–80 kg (about 6 tons/acre). Now, again I have planted these RAC seed tubers in about 16 rows. The crop is very good. Compared with other seeds, here there are fewer diseases and I am expecting double the yield. Normally, in Punjab seeds we get about four or five tubers, but here we are getting 8–12. We can multiply and use the same seeds for a couple of seasons, and there is no need to depend on the Punjab seeds. Initially, people were laughing at me when I planted cuttings. But now after seeing the success, they are also asking for cuttings.

5.2 Farmers

I am Devaraj from Tejur village, Hassan. We have been growing potatoes for a long time, but we are not getting quality seeds nowadays. Earlier, we used to get seeds from Chikkaballapur and later from Punjab. Initially, we were getting good seeds from Punjab, but now the quality is not good. We thought of quitting potato production itself. In the last season CIP introduced local seed production and had given me cuttings of ‘K. Himalini” variety for trials. I had a good crop. I had stored tubers in cold storage, and I have planted those tubers now. Here there is good demand for ‘K. Himalini’ variety. This season again I had planted 5,000 cuttings of ‘K. Jyoti’ variety, and received 14–15 bags of G1 seed. Many farmers have visited and appreciated my farm. We discussed the idea of producing our own seeds. About 10 farmers have asked me to give seeds. Once we are self-sufficient, we plan to sell seeds even to other states.

My name is Lavanya, I am from Tejur village, Hassan district, Karnataka. We have been growing potatoes for the past 15 - 20 years. I am a member in women farmers’ potato group which was formed three years ago. The GIC project is building our capacities in potato farming. We have been facing problems in sourcing and procuring quality potato seeds. Now we have another project in which CIP has introduced RAC technology and we have learned how to grow potatoes from plantlets. This is unique. From this technology we are learning how to produce potato seeds on our own, store it, and use it for next season. When we have excess, we would like to also sell it to neighbouring farmers.

NEW INNOVATIONS

06

6.1 Plastic containers instead of glass bottles

Normally, 300 ml capacity glass bottles are used in most of the tissue culture labs. A small study was successfully conducted to replace the glass bottle with plastic container (1000 ml) in tissue culture multiplication. The advantages of the plastic containers are as follows:

- Easy to transport to nurseries.
- No risk of breaking.
- Cheaper to transport because of reduced weight.
- Increased efficiency as it can accommodate more nodes (20 in a bottle compared to 60 in a plastic container).
- Observed better growth of tissue-culture plants, compared to glass bottle, which may be because of wider spacing and consequent better light penetration.
- The only disadvantage is that a plastic container cannot be reused more than three times, whereas a glass bottle can be used several times.
- The cost of each plastic container is Rs. 8 and glass container is Rs.18.

6.2 Fifty-cavity portrays for mother plants

Normally, coirpith beds are used to establish mother plants for RAC production. The costs involved are higher because a huge quantity of coirpith is required. Therefore, a few nurseries expressed concern about the initial investment. In order to find alternative, 50-cavity protrays have been used to establish mother plants instead of beds. Following are the advantages and disadvantages are the same :

Advantages

- Drastic reduction in cost
- Maintenance is easy
- More attractive to new nurseries
- Can be easily shifted from one nursery to another
- More plants can be accommodated in less area
- More suitable for areas with a shorter window of time for nursery activity

Disadvantages

- Fewer apicals/plant due to restricted space
- Potential for reduced yield of mother bed tubers

6.3 RACs for ware potato production

Farmers are also showing interest in planting RACs for ware potato production as they have observed following advantages:

- Due to heavy rains, the seed tubers planted by the farmers became rotten whereas RACs survived. Many farmers have lost their entire crop due to rains and incurred huge losses. There are instances where farmers have replanted the tubers and again lost the crop.
- Uniform sprouting of seed tubers is always an issue that affects field operations and hence the yield. With RAC planting, one can get uniform growth and crop stand.
- With tuber planting, it always challenging to maintain 100 % of the plant population. Many farms have only 80 - 85% population for various reasons. Unlike other crops, gap filling is not possible in potato. However, with RAC planting, more than 95 % population can be maintained, even if there is some mortality that can be compensated by replanting the gaps. By maintaining the optimal plant population, 10 - 15% more yield can be obtained.
- Large-size tubers are marketed as ware potato and seed-size potatoes can be used for planting.
- For ware potato, 25,000 plants are sufficient per acre. RACs cost Rs. 25,000. If tubers are planted, about 700k g are required which costs about Rs. 21,000 at Rs. 30/kg. Although it costs more for RACs, there are clear advantages.

6.4 Effect of defoliation on apical production

Each plant has the natural ability to compensate for the loss of vegetation and it recovers fast without affecting the normal production. A small study was conducted wherein 0 %, 25 %, 50 % and 75 % of the leaves were removed from the mother plants by cutting the leaves. Initial observations indicate that there is a slightly higher percentage of apicals produced in 50 % defoliated plants. This study will be replicated one more time to establish the results. If there is no impact on the apical production ability of the plant, even with the defoliation, then one can remove a certain number of leaves as it helps with pest and disease management.

List of Abbreviations

BMZ	German Federal Ministry for Economic Cooperation and Development
CIP	International Potato Centre
CPRI	Central Potato Research Institute
DoH	Department of Horticulture
EC	Electrical Conductivity
GIC	Green Innovation Centres for the Agriculture and Food Sector
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit
pH	Power of Hydrogen
PTD	Participatory Technology Development
RAC	Rooted Apical Cutting
RO	Reverse Osmosis
TC	Tissue Culture
TDS	Total Dissolved Solids
UHSB	University of Horticultural Sciences

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