

INDO-KENYAN COLLABORATIVE APPROACH AND POTENTIAL FOR COMMERCIALIZATION OF PLANT TISSUE CULTURE

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ABSTRACT

More than 75% of Kenyans make some part of their living from agriculture and the sector accounts for more than fourth of Kenya's gross domestic product (GDP). Agriculture employs about 2 million people, and has been increased up to 21% of all agricultural exports. Despite of continuous population growth, agricultural productivity has gradually become stagnated in recent years. Only about 20% of Kenyan land found suitable for farming, and in these areas maximum yields have not been achieved, leaving considerable potential for increase in productivity. Quality planting material is one of the most important components for increasing the productivity. Tissue culture is proven technology to produce disease free and true to type quality planting material derived from the superior clone. It is noteworthy facts that India has demonstrated significant success in the area of commercial plant tissue culture. Government of India decided to share experience of Indian plant tissue culture to African countries and build capacity of nationals through training organized by BCIL in different modules. In spite of significant development for commercialization of plant tissue culture in Kenya, cost and quality of tissue culture plants remain major constrains in Kenya. India's experience in implementing the quality management system might be replicated to address these constrains which will facilitate realization of potential for Kenyan plant tissue culture.

Keywords: Plant tissue culture; BCIL; commercialization; constrains; QMS; NCS-TCP.

BACKGROUND

Kenya, an East-African nation has the largest, most diversified economy in the region. Agriculture is the backbone of the Kenyan economy and has a major role in country's development strategy. Crop production plays an important role in Kenya's economic development as a major source of income, employment creation and saving on foreign exchange expenditure through import substitution. More than 75% of Kenyans make some part of their living in agriculture, and the sector accounts for more than a fourth of Kenya's gross domestic product (GDP) [1].

Kenya is a prominent producer of tea and coffee, as well as the third-leading exporter of fresh produce, such as cabbages, onions and mangoes. Small farms grow corn along with potatoes, bananas, beans and peas [2]. Although, farming is the most important economic sector in Kenya, less than 8% of the land only is used for crop and feed production. Crop diseases, pests and weeds greatly reduce the potential of crop in quality and quantity. Losses due to these constraints are estimated at 40%. Efforts to increase production and reduce these losses are necessary to conserve the agriculture sector.

The average annual growth rate of 20% in agricultural sub-sector underscores demand of Kenya's high quality produce in the world markets. The agriculture sector is mainly dominated by large-scale farmers and private sector with a presence of small percentage of small-scale farmers. It employs about 2 million people, and accounts for up to 21% of all agricultural exports. Agricultural productivity has gradually become stagnated in recent years. Moreover, only about 20% of Kenyan land is suitable for farming, and in these areas maximum yields have not been achieved, leaving considerable potential for increases in productivity [3].

Quality planting material is one of the most important components for increasing the productivity. Tissue culture is proven technology to produce disease free and true to type quality planting material derived from the superior clone. This technology has been widely applied in agriculture, horticulture and forestry to produce quality plants at commercial scale. Plant tissue culture techniques offer platform for mass multiplication of identified superior clones in limited time and space round the year [4].

India has demonstrated significant success in the area of commercial plant tissue culture. The gross installed capacity available is 500 million plants per annum. There are presence of around 200 companies ranging from installed capacity 0.5 million to 70 million plants per annum. National Certification System for Tissue Culture Plants (NCS-TCP), a unique quality management system for tissue culture sector being implemented in India has played very conducive role for growth of this industry by facilitating production and distribution of quality planting materials [5].

Government of India recently shared experience of Indian plant tissue culture to African countries and build capacity of nationals through training in different modules. Out of 198 candidates trained under programme, a largest number of participation (Total 36) received from Kenya out of 24 participating countries. This training supported by Ministry of External Affairs (MEA), Government of India acted as good platform for exchanging knowledge and sharing experience [6]. This comprehensive training programme organized by Indian government through Biotech Consortium India Limited (BCIL) to train and develop skills of Kenyans in the area of commercial plant tissue culture may become precursor for further collaborative work in the area of plant tissue culture.

Although progressive farmers have generally become familiar about tissue culture technology, its large scale successful adoption requires notable changes in cultivation practices, and enhanced wide spread awareness [7]. Plant tissue culture technology is found to be more knowledge intensive and requires proper irrigation facility than traditional banana cultivation. Simulation studies show that improving access to irrigation could lift tissue culture productivity gains to above 20% [8].

STATUS OF TISSUE CULTURE COMMERCIALIZATION IN KENYA

The Kenya Agricultural Research Institute (KARI) is mandated with relevant research in plant tissue culture. KARI had been the national institution bringing together research programmes in food crops, horticultural and industrial crops, livestock and range management, land and water management, and socio-economics. KARI promotes sound agricultural research, technology generation and dissemination to

ensure food security through improved productivity and environmental conservation [9]. By act of parliament the Kenya Agricultural & Livestock Research Organisation (KALRO) was established in 2013. [10] It merged with KARI, Coffee Research Foundation, Tea Research Foundation and the Kenya Sugar Research Foundation and has oversight of 18 research institutes [11].

Tissue culture technique is routinely applied in Kenya to rapidly multiply pathogen-free elite planting material for resource poor farmers who often cultivate inferior varieties because of limited access to elite varieties in crops such as banana, sweet potato and cassava which have low production rates. Production of virus free plants is particularly relevant in combating cassava brown streak disease (CBSD), Sweetpotato virus disease (SPVD) and Banana virus diseases. Tissue culture is also used to conserve germplasm of genetic stocks mainly for high value nonstable crops especially cut flowers. Genetic transformation is particularly applied in research where it is difficult to achieve desirable phenotypes through conventional breeding. Such cases include breeding for weevil resistance in sweet potato, brown streak virus resistance in cassava, and drought tolerance.

According to available data, tissue culture was established in Kenya in early 1980s to increase production of pyrethrum (*Chrysanthemum cinerariifolium*) and citrus under patronage of Kenya Agricultural and Livestock Research Organisation (KALRO) and University of Nairobi. Tissue culture applications by KARI now KALRO and other public and private institutions have expanded to cover other crops such as banana, cassava, sweetpotato wheat, maize, sugarcane and

ornamental plants. Kenya has developed a significant capacity for agricultural biotechnology compared to her counterparts in the East and Central African region.

Banana is the common fruits in Kenya. Bananas are cultivated as a staple food in Kenya. However, the main problem with banana farming remains to be that bananas in Kenya are easily prone to diseases that affect the yield. Fungal and bacterial diseases such as Sigatoka and Fusarium Wilt, and Bacterial Xanthomonas Wilt (BXW) respectively along with Nematodes and weevils are the major pests and diseases that affect banana farming in Kenya [12].

Plants are also affected by viruses that cause diseases such as the banana bunchy top disease and banana streak. Due to prevalent viral diseases affecting farming in Kenya, tissue culture has been used by Kenyan researchers to yield disease free stock materials. The tissue culture raised plants are uniform genetically, free from disease and high yielding. This contributes to improved economic benefits per unit area of land through use of tissue cultured plants for farming in Kenya [13]. The lack of clean planting material is a major constraint for banana production in East and Central Africa. When establishing new fields, tissue culture plantlets will reduce damage by banana pests and diseases [14].

Traditional cultural practices in banana production have been a major cause of the problems in banana production in Kenya in the recent past. Through such traditional cultural practices, the farmers transmit unknowingly most of the banana pests and diseases through banana suckers as these farmers search for and procure suckers as planting material from one farm to another. The spread of pests and disease through this practice can reduce banana yields by up

to 90%. Therefore, there is need to encourage the farmers to improve their cultural practices and use clean, disease-and-insect-free planting materials. Tissue-culture propagation techniques can provide such planting materials. When establishing new fields, tissue culture plantlets will reduce damage by banana pests and diseases [15].

Shortage of good quality seed potato is one of the most important factors limiting potato production in Kenya [14]. Due to limited supply, the certified potato seeds are highly priced and the cost of seeds account for 42% of the total production costs. [16] As a result, farmers depend on seed from informal sources which include farm-saved (self-supply), local markets, and neighbours [17]. This informal system leads to the use of poor quality seeds and could produce infected plants.

Domestic demand for tissue culture materials is high even though various challenges have hindered growth of plants. These include poor distribution of rainfall in the recent past years, lack of irrigation facilities to supplement water requirements, limited extension/dissemination support to farmers and others. If these challenges can be handled, the uptake of tissue culture plants, particularly bananas can increase to over 80% of estimated potential of over 10 million seedlings per season.

In Kenya, farmers were introduced to tissue culture banana in 1997 through a partnership between the Kenyan Agricultural Research Institute (KARI) (now known as Kenya Agriculture and Livestock Research Organization) and the International Service for the Acquisition of AgriBiotech Applications (ISAAA). The initial two phases of tissue culture banana introduction were conducted between 1997–2003, during

which the feasibility and appropriateness of the technology were tested and systems of production and distribution of the tissue culture banana were piloted.

STAKEHOLDERS OF PLANT TISSUE CULTURE IN KENYA

Key institutions presently involved in tissue culture activities in Kenya include: Government institutions (KALRO), Universities (Jomo Kenyatta University of Agriculture and Technology (JKUAT) and University of Nairobi (UoN), Private companies (Mimea International Limited, Stockman Rozen limited, Oserian TC Lab and not for profit Organisations (Africa Harvest; and the International Services for the Acquisition of Agric-biotech Applications (ISAAA).

National Research Organisations

KALRO is the main national organization involved in tissue culture through its centers and institutes scattered across all the 47 counties of Kenya and working on a diverse number of crops. KALRO first established tissue culture in the late 1980s, to propagate elite pyrethrum and potato planting materials. In successive years, the Organisation has expanded its tissue culture program to include other crops such as cassava (*Manihot esculenta*); sweet potato (*Ipomoea batatas*); sugarcane (*Saccharum officinarum*), coffee (*Coffea Arabica*), citrus fruits, oil palm (*Elaeis guineensis*), fruit trees and medicinal plants. KALRO continues to work with public research institutions and private companies in Kenya through partnerships, technology transfer and capacity building.

Several KALRO centers are involved in tissue culture activities, notable of which include: KALRO-Thika (working on banana,

Musa spp; *Macadamia spp*; sweet potato and flowers); KALRO-Biotechnology Centre (developing protocols for cassava and sweet potato transformation and micropropagation of virus-free planting materials of oil palm, banana and vanilla); KALRO -Kakamega (cassava and sweet potatoes); KALRO - Njoro (sweetpotato, banana, cassava, oil palm, potato and wheat double haploids) KALRO - Molo (pyrethrum); and KALRO-Tigoni (potato pre basic seed).

KALRO institutes specialize on individual crops and they have employed tissue culture in breeding, bulking and disease elimination in their elite varieties. The institutes include KALRO – Tea

Research Institute, Coffee Research institute and Sugar research institute (SRI). Tea Research Institute that focuses on the application of *in vitro* micropropagation of tea and eucalyptus clones showing fast growth. The Coffee Research Institute (CRI) is a center of excellence for coffee research in Kenya. CRI has optimized tissue culture techniques for rapid multiplication and dissemination of one of its elite variety (Ruiru II) and coffee intercropping companion crops such vanilla, banana and pineapples. The sugar research institute has recently established tissue culture laboratory to enable them meet the rising demand for disease free sugarcane planting material in the country (Fig. 1).



Fig. 1. a) Tissue culture banana images; b) Sweetpotato nuclear material germplasm conservation; c) Tissue culture cassava (Source: Manfred Miheso, KALRO-NJORO tissue culture lab)

African Development Corporation (ADC)

ADC is a Government Parastatal that produces and supplies of quality seed to farmers at affordable prices. ADC-Molo center is the leading producer and supplier of tissue culture potato seed (Mini-tubers and seedlings) in Kenya. ADC maintains and multiplies over 18 potato varieties in their tissue culture laboratory and produce breeders seed under a hydroponics, aeroponics, and on-farm systems.

Universities

Jomo Kenyatta University of Agriculture and Technology (JKUAT)

Jomo Kenyatta University of Agriculture and Technology (JKUAT), is involved in applying tissue culture techniques for producing disease-free seedlings mainly of banana, sweet potato, Aloe vera and other plants such as *Jatropha*. In addition, the university offers BSc programs that have courses in plant tissue culture and biotechnology. The University also undertakes M.Sc. and PhD training in biotechnology and also provides short courses in plant tissue and organ culture. In terms of human and infrastructure capacity, JKUAT has modern laboratory with well trained and skilled researchers and support staff.

University of Nairobi (UoN)

The Department of Plant Science and Crop Protection at the University of Nairobi initiated tissue culture work in 1983 with focus on citrus, cassava, sugarcane and pyrethrum. The Department is also involved in development of tissue culture protocols for ornamental plants and training of

graduate and postgraduate students in tissue culture.

Private Sector

Mimea International Limited

Mimea International Limited is a private tissue culture facility established in Kenya in 2004 for production of quality planting materials of: Banana, vanilla, horticultural crops (passion, citrus, mangoes papaya) and tree species (*Jatropha*, *Moringa oleifera*, *Azadirachta indica*, *Prunus africana*) and flowers (Table 1). The company currently produces between 50,000 to 70,000 banana seedlings and about 100,000 eucalyptus seedlings per year.

Oserian TC Lab

The Oserian TC lab is a private tissue culture laboratory in Kenya that was established in 1992 in response to the expanded demand for high quality cut flower production. Currently, the laboratory produces *Statice*, *Gypsophila*, *Gerbera* and *Lilies*, which are meant for either local or foreign markets. Recently, the Oserian TC lab has also engaged in production of banana, sweetpotato and potato plantlets.

Asepsis Limited

Asepsis Limited is one of the biggest privately owned tissue culture laboratory operating in East Africa. The company is involved in micro-propagation of plantation crops (potatoes, sugar cane and bamboo), ornamentals (vera and bixa), medicinal (limonium, anthurrium, gerbera, cycad) and horticulture (banana and strawberry) plants. The plantation crops include. The ornamental plants include many types of cut flowers and garden plants.

Table 1. List of Research Institutes, Universities, Companies private laboratories involved in plant tissue culture of various crops

Name of institution	Plants grown	Remarks
Public research institution		
Kenya Agriculture and Livestock research Organization	Bananas, Sweet potatoes, Cassava, Potato, Pyrethrum Coffee	There are many research centres in Nairobi, Thika, Njoro, Kakamega and Ruiru
Tea research Foundation	Tea	It is at the research level not yet available to the farmers.
Public universities		
Jomo Kenyatta University of Science and Technology	Bananas	Sweet potatoes and Aloe vera are at research level
University of Nairobi	Citrus, Bananas, Ornamental Crops, Sugarcane and Pyrethrum	Pyrethrum and sugarcane are at the research level
Institute for Biotechnology Research (IBR) Jomo Kenyatta University of Agriculture & Technology	Bananas, coconut and sweet sorghum	Commercial seedling supply/ Research
Private and Commercial Institutions		
Asepsis Limited [18]	Cut flowers, bamboo, garden plants, bananas strawberry and medicinal plants	They produce crops on contract for government and Nongovernmental institutions, as well as individuals
Genetics Technology International Limited	Bananas, potatoes, sweet potatoes, cassava, vanilla, bamboo ornamental and medicinal plants.	It has a capacity of producing 20 million plantlets per year.
Oserian Tissue Culture	Cut flowers	They produce plants only for their farm.
Africa Harvest Limited	Banana	Commercial seedling supply/ research
Stokman Rozen Kenya Limited	Banana, potatoes and strawberries	Commercial seedling supply/ research
Aberdare Technologies Limited	Banana	Commercial seedling supply/ research
Private laboratories		
Agro plant technology	Bananas	The laboratory is situated in Kisii and is a small scale
China Kenya Laboratory	Bananas	Small scale situated in Nakuru
Bonprix limited	Bananas	Small scale started in 2015 in Muranga
Track Green Multi-Purpose Company Limited [19]	Bananas	-

Stockman Rozen Kenya Limited

Stockman Rozen Kenya Limited was established in 1994 and is the largest producer of rose topgrafts in Africa. The company has harnessed tissue culture for conservation of high value germplasm and rapid multiplication of cut flowers. The company also produces tissue culture banana, potato and strawberry.

Non-Government Organization (NGO)

Even though NGOs working in Kenya are not directly involved in tissue culture application, some have developed technical programs that are relevant to tissue culture. The interventions include; provision of factual and relevant information to stakeholders, introduction of tissue culture banana to the resource poor farmers, assisting in establishment of farmer-based tissue culture companies such as Tissue Culture Banana Enterprise Ltd. The NGOs also provide training and mentorship for dissemination of tissue culture technology, assist in development, promotion and dissemination of tissue culture plantlets and provide information and access to the market. Most significant NGOs include;

Africa harvest

Africa Harvest Foundation International is a non-profit organization established in 2002 to promote use of advanced science and technology products to improve agricultural productivity in Africa.

International Services for the Acquisition of Agric-biotech Applications (ISAAA)

The International Services for the Acquisition of Agric-biotech Applications (ISAAA) is a not-for-profit international organization. ISAAA's core mandate is to share benefits of crop biotechnology to

smallholder farmers in resource poor developing countries, through knowledge sharing and transfer of proprietary biotechnology applications. ISAAA aims to achieve its mandate in Kenya by supporting micropropagation and distribution of banana and multipurpose trees. Table 1 summarizes the stakeholders engaged in commercial plant tissue culture in Kenya.

KENYAN SCENARIO WITH REFERENCE TO QUALITY MANAGEMENT SYSTEM AND COST OF TISSUE CULTURE BANANA

Constraints to Commercialization of Tissue Culture in Kenya

Limited, delayed and inaccessible markets have slowed down commercialization of tissue culture in Kenya. Weak and ineffective research-oriented-farmer linkages inhibit setting up of private tissue culture laboratories because most farmers only trust government organisations and find it hard to contract private producers. The cost of tissue culture raised banana varieties is 100 KSH (Rs. 70 approx) in the region which is five times higher as per the feedback provided by Kenyan Candidates during training (Fig. 2).

Potential for Accelerated Commercialisation

Kenya has established several initiatives in the agriculture sector that can be further exploited for commercialization of tissue culture in the country. Devolution of Agriculture to Counties has been very instrumental in ensuring increased productivity of food. The ministry of agriculture at county levels has mapped counties into Agri Ecological zones and is promoting climate smart agriculture. One area of intervention has been purchase of tissue culture plantlets mainly (Cassava,

sweetpotato, banana and tree seedlings) for smallholder farmers.

County governments have also established farmer managed secondary nurseries across the country with involvement of vulnerable groups (women, youth and the disabled) in hardening and marketing of tissue culture plants.

The Kenyan government has also through the county governments embarked on establishment of county centers of excellence in Agriculture where farmers can be trained on adoption of modern farming technologies. Tissue culture is key in this endeavor.

Economic exploitation by small, medium and large scale entrepreneurs is well

established in the flower industry. As such, Kenya is the leading exporter of cut flowers to Europe and USA in the region. The potential for use of tissue culture for conservation of endangered plant species and medicinal plants is still in its infancy and it is one avenue that can be lucratively exploited for commercialization.

The Kenyan government has recognized the importance capacity building in the area of tissue culture in addressing food insecurity and poverty and as such it has made efforts to integrate tissue culture programs in agricultural research and industry. It is noteworthy and significant milestone that the Kenya benefitted by Indian government through BCIL to train and develop skills of Kenyans in the area of commercial plant tissue culture.

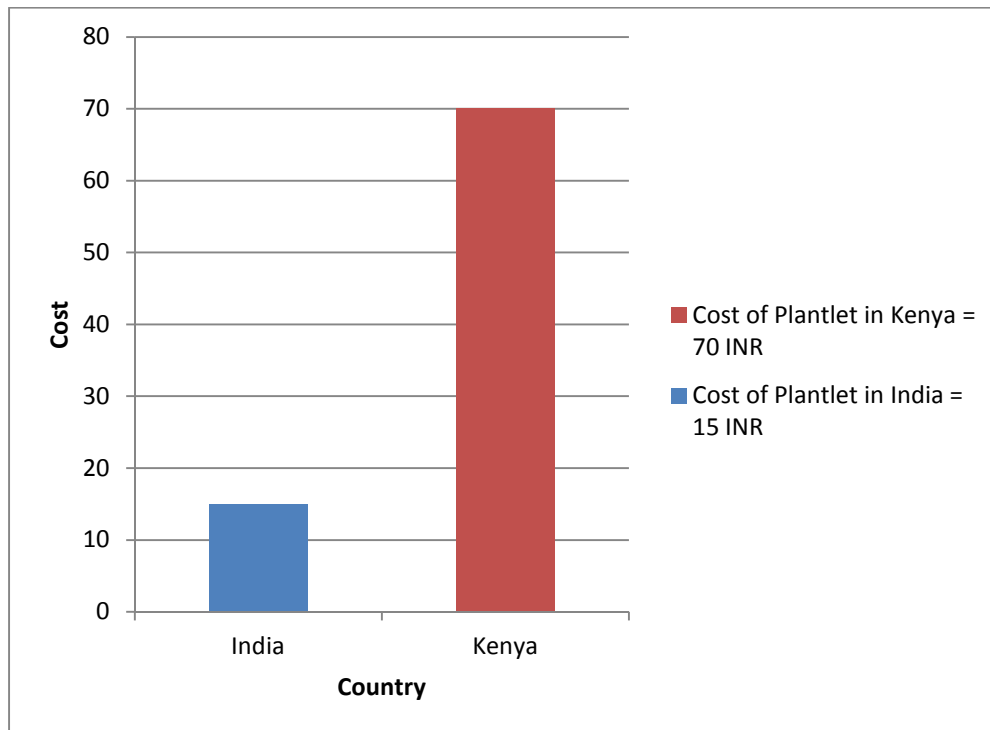


Fig. 2. Comparison of cost of one tissue culture banana plantlet in India v/s Kenya

BRIDGING THE QUALITY GAPS THROUGH INDIAN EXPERIENCE OF QMS

High cost of tissue culture plants due to contamination in *in-vitro* cultures and mortality in tissue culture is one of the major constraints. Ensuring quality of tissue culture plants is another challenge for rapid commercialization of tissue culture technology. These aspects can be addressed through learning experience of India for implementing the National Certification System for Tissue Culture Plants (NCS-TCP).

Approximate one and half decade before, Government of India realized need to support plant tissue culture sector in ensuring quality of tissue culture plants through a well-defined quality management system. Accordingly, NCS-TCP was initiated by Department of Biotechnology (DBT), Government of India aimed at certification of the tissue culture-raised propagules up to laboratory level. Various components of NCS-TCP namely Management Cell, Accredited Test Laboratories and Referral Centres were identified and operationalized.

DBT, Government of India ensures successful implementation of NCSTCP in the country. DBT Recognizes to tissue culture companies and accredits Test Laboratories based on the conformity with NCS-TCP guidelines. BCIL assists DBT in implementation and overall coordination of NCSTCP as the Management Cell. Referral laboratories are responsible for developing protocols and providing technical guidance to Accredited Test Laboratories. Accredited Test Laboratories (ATLs) test and certify tissue culture plants of recognized tissue culture production facilities. Recognized Tissue Culture Companies under NCS-TCP have the responsibility to adopt the NCS-

TCP guidelines and Standard Operating Procedures (SOPs) in order to produce and distribute quality tissue culture plants to the farmers (Fig. 3) [20].

NCS-TCP and Its Impact in Indian Tissue Culture Sector

NCS-TCP has strengthened capability of tissue culture industry. The process of Recognition of the Tissue Culture Production Facilities helps the tissue culture companies to improve their facility and adopt good manufacturing practices. Once Tissue Culture Company is recognized by NCS-TCP, it helps in increasing the visibility of organization resulting into increased market reach. Farmers get certified plants which instils high level of confidence for adopting the tissue culture technology and thereby helps in growth of tissue culture sector.

Resource Pool in Kenya through Training in India

Biotech Consortium India Limited (BCIL) under the sponsorship of Ministry of External Affairs (MEA), Government of India organized a series of programmes on plant tissue culture during year 2017-19. Kenya has been one of the most active participants in the plant tissue culture training programme, total 36 participants have represent Kenya in these programmes. This covered various stakeholders in the plant tissue culture sector i.e. scientists, agricultural officers, entrepreneurs, laboratory technicians, senior officials such as directors amongst others. The participants represented various institutes such as KALRO- associated institutes and regional centres, officers from county governments, officers from department of agriculture, officers of ministry agriculture, livestock and fisheries, other companies and agriculture based development institute. These candidates have provided a very

positive feedback towards the programme. They believed that the learning will be very helpful for working towards using the knowledge & experience gained through the programme to promote tissue culture sector in the country.

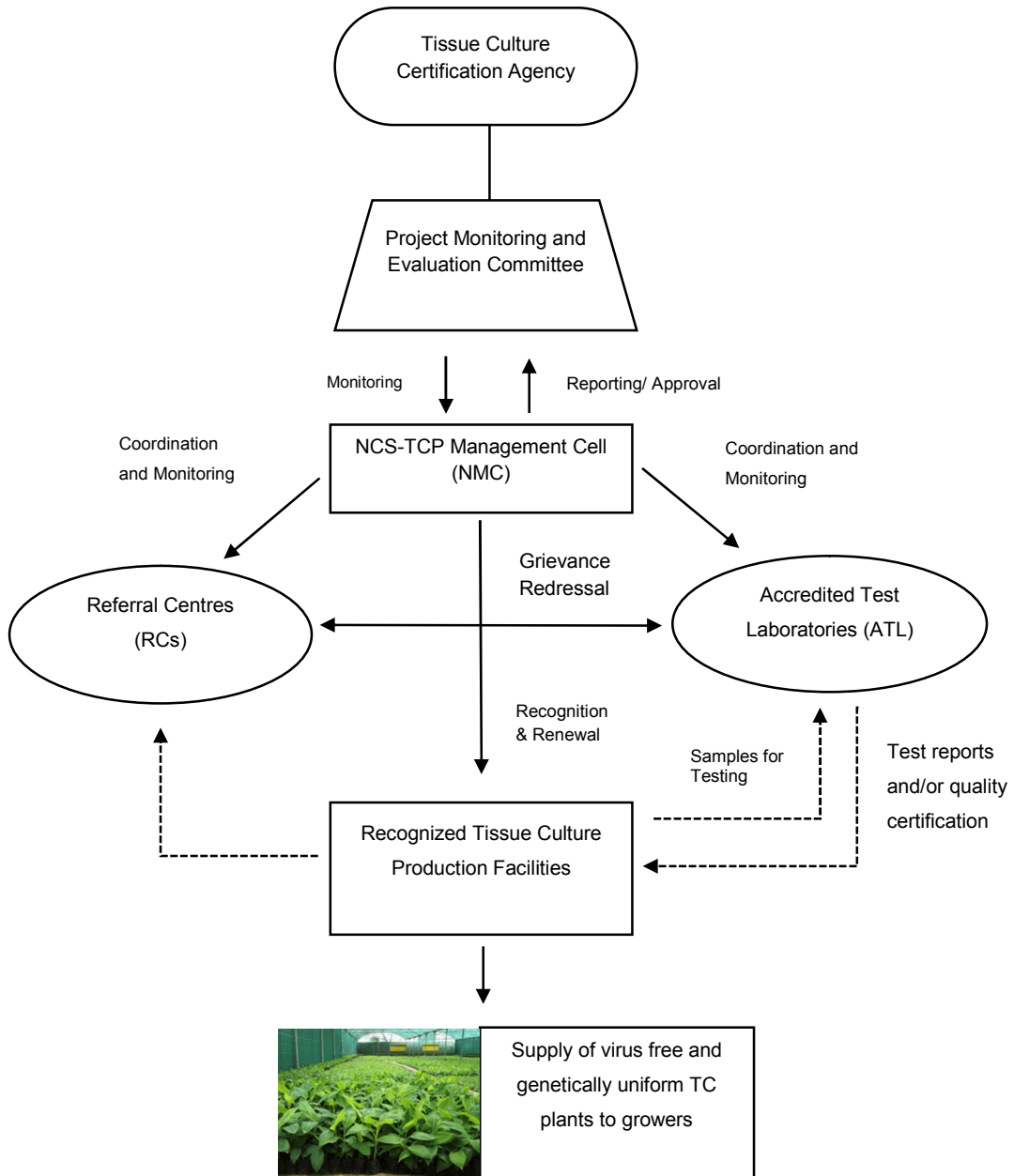


Fig. 3. Organization structure of NCS-TCP

It is felt that Tissue Culture Technology Platform should be established at any suitable University/Institute in Kenya. Existing tissue culture set-up might be strengthened so that it can be used for training, incubation of technology, organizing entrepreneurship programmes. Gradually, Govt of Kenya may move towards establishing the National Level Certification Programme for supporting tissue culture sectors by facilitating production and distribution of quality tissue culture plants among Kenyan framers. Certification Agency/Management Unit, Referral Centres and Testing Laboratory will provide a robust platform similar to NCS-TCP and in long terms it will provide an effective platform for promoting the plant tissue culture and realizing it full potential. NCS-TCP resulted in tremendous impact of banana tissue culture industries and directly to farming on profitability and improvement in livelihood of banana producers as well as growers of India. This certification programme has enabled to increase in the income of the farmers by 5-6 fold and with further development in post-harvest facilities and cold storage infrastructure, there is huge scope to bring more area under banana cultivation for export purposes [21].

CONCLUSION

There is a scope of Indo – Kenyan collaborative approach and good potential for growth of Kenyan tissue culture industry for production and distribution of disease free planting materials through technical support of BCIL and both Indo-Kenyan Govt. initiative. Since banana plants produced in the region are found to be affected by viruses and other bacterial and fungal diseases. Sterilization plays a very important role in to combat with these kind of infections [22]. Tissue culture plants provide a solution for production of virus free plants

however cost of these plants is higher as compared to that in India. It is noteworthy fact that there has been no major virus outbreak since the inception of the NCS-TCP in the country [23,24]. Although there are few laboratories in Kenya producing tissue culture raised crops, most of them are at a small scale. The planting material is generally sold locally within the country, Technical guidance for such small scale units will help them to expand their production capacity. Suggested initiatives for Tissue culture technology platform and certification programme would facilitate rapid commercialization of tissue culture technology and addressing the need of farmers for cultivation of quality tissue culture plants.

DISCLAIMER

The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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