Certification of Quality Planting Material of Clonally Propagated Fruit Crops for Promoting Agricultural Diversification
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NATIONAL ACADEMY OF AGRICULTURAL SCIENCES, NEW DELHI
May 2022
Preface

Fruit crops such as apple, apricot, almond, cherry, pear, peach, plum and walnut are high-value clonally propagated crops and can contribute significantly towards enhancing farmers' income. However, the productivity of most of these crops is low. The non-availability of genuine certified planting material of improved / superior fruit varieties is a major bottleneck in increasing productivity. Further, a lack of awareness and technical know-how for production of certified quality planting material also hampers increasing their productivity. In fact, diseases of clonally propagated fruit crops caused by viruses, virus-like agents and bacterial pathogens severely affect yield, appearance and taste of fruits and also plant longevity. These pathogens are often difficult to detect in propagation material, such as rootstocks and budwood, and are inadvertently taken to fields where these were not present before.

The detailed guidelines are required to ensure production and supply of certified quality planting material (CQPM) of high-value fruits crops. Realizing the need for quality planting materials of clonally propagated fruit crops to promote agricultural diversification the National Academy of Agricultural Sciences (NAAS) organized a strategy workshop on “Certification of Quality Planting Material of Clonally Propagated Fruit Crops for Promoting Agricultural Diversification” on September 20, 2021. This policy paper is an outcome of the deliberations in this workshop.

On behalf of the Academy, I compliment Prof V.K. Baranwal in bringing out recommendations for strengthening research and extension systems on CQPM. I also take this opportunity to thank Dr Pratap Singh Birthal and Dr Malavika Dadlani for their editorial support. I hope this document will be useful to the policymakers and other stakeholders.

(Trilochan Mohapatra)
President, NAAS

May 2022
New Delhi
CERTIFICATION OF QUALITY PLANTING MATERIAL OF CLONALLY PROPAGATED FRUIT CROPS FOR PROMOTING AGRICULTURAL DIVERSIFICATION

1. INTRODUCTION

India has made remarkable progress in horticultural production, reaching 330 million tonnes in 2020-21. Demand for horticultural commodities, including fruits and vegetables, has been increasing continuously, offering considerable scope for further increase in their production. Growth in production comes from an increase in area or productivity or both. Scope for growth through area expansion is limited, and the growth has to come from productivity improvements. A key constraint in raising productivity is the lack of certified quality planting material (CQPM).

India enacted the Seed Act in 1966. It helped establish seed certification agencies by the states. Amongst horticultural crops, this Act provides for the certification of the clonally propagated potato but not for other clonally propagated crops. The availability of quality seed caused a revolution — potato production increased from 4.9 million tonnes in 1973-74 to 48.7 million tonnes in 2019-20. However, the yields of most clonally propagated fruit crops are low compared to their corresponding world highest productivity (Table 1). Banana is the only fruit crop supported by the certified quality planting material under the National Certification System for Tissue Culture Raised Plants (NCS-TCP).

Fruits can contribute significantly to India’s agricultural economy through exports. In 2020-21, India exported fruits, including fresh grapes, mango and walnut, worth Rs 4833.3 crores. Citrus and apple are grown in large areas throughout the country and have significant potential for exports. To harness the full potential of the clonally propagated fruit crops, efforts are needed to develop a robust system for the production of CQPM of their elite clones on indexed desirable rootstocks. This is expected to help diversify crop portfolio, conserve natural resources and increase farmers’ income.

Table 1. Area and yield of important clonally propagated fruit crops in India, 2019-20

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Fruits</th>
<th>Area (000 ha)</th>
<th>Production (000 t)</th>
<th>Yield (t/ha)</th>
<th>Highest yield (t/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Mango</td>
<td>2301</td>
<td>20529</td>
<td>8.92</td>
<td>12.50 (Brazil)</td>
</tr>
<tr>
<td>2.</td>
<td>Citrus</td>
<td>1058</td>
<td>14032</td>
<td>13.26</td>
<td>27.93 (Brazil)</td>
</tr>
<tr>
<td>3.</td>
<td>Banana</td>
<td>877</td>
<td>31779</td>
<td>36.24</td>
<td>65.27 (Turkey)</td>
</tr>
<tr>
<td>4.</td>
<td>Apple</td>
<td>309</td>
<td>2783</td>
<td>9.01</td>
<td>60.05 (Switzerland)</td>
</tr>
<tr>
<td>5.</td>
<td>Grape</td>
<td>147</td>
<td>2939</td>
<td>19.99</td>
<td>32.64 (China)</td>
</tr>
<tr>
<td>6.</td>
<td>Walnut</td>
<td>108</td>
<td>287</td>
<td>2.66</td>
<td>35.20 (Romania)</td>
</tr>
<tr>
<td>7.</td>
<td>Pear</td>
<td>42</td>
<td>306</td>
<td>7.29</td>
<td>89.20 (Montenegro)</td>
</tr>
<tr>
<td>8.</td>
<td>Cherry</td>
<td>30</td>
<td>10.95</td>
<td>0.37</td>
<td>30.0 (Suriname)</td>
</tr>
<tr>
<td>9.</td>
<td>Peach</td>
<td>19</td>
<td>125</td>
<td>6.58</td>
<td>18.11 (Romania)</td>
</tr>
<tr>
<td>10.</td>
<td>Plum</td>
<td>23</td>
<td>90</td>
<td>3.91</td>
<td>49.0 (Montenegro)</td>
</tr>
<tr>
<td>11.</td>
<td>Almond</td>
<td>10</td>
<td>9</td>
<td>1.27</td>
<td>21.40 (Israel)</td>
</tr>
<tr>
<td>12.</td>
<td>Apricot</td>
<td>5.3</td>
<td>15.07</td>
<td>2.84</td>
<td>18.20 (Romania)</td>
</tr>
</tbody>
</table>


National Academy of Agricultural Sciences

1
2. VIRUSES AND VIRUS-LIKE PATHOGENS

Viruses and virus-like pathogens and the diseases caused by them are significant constraints in improving the productivity of clonally propagated fruit crops in India, especially apple, banana, citrus and grapes. Most of these crops are perennial in nature and harbour many viruses, viroids and phytoplasmas (Table 2). These pathogens severely affect the plants' yield, quality (appearance, taste and nutrients) and longevity, resulting in huge economic losses to their growers. Consumers are also affected by the price volatility and poor quality of fruits produced from the infected plants.

Viruses and virus-like pathogens are difficult to detect in propagation materials such as rootstocks and budwood. These are inadvertently introduced through the infected planting materials even in the areas that were earlier free from such pathogens. For example, the recent studies on virome profiling of exotic and indigenous grapevine cultivars showed many viruses not reported previously in India (Sidharthan et al., 2020). Similarly, the virome analysis of three apple cultivars has confirmed the presence of two viruses and one viroid that were not reported previously in India (Nabi et al., 2022). Such inadvertent introduction of infections can be best prevented through CQPM. Perhaps, this is the most critical factor that will contribute to raising the productivity of fruit crops and diversifying the crop portfolio. The certified superior quality materials of clonally propagated fruit crops are defined as ‘the production of uniform, healthy, disease-free planting material raised through vegetative methods with an overarching goal of improving the physiological and phytosanitary quality of plants’ (AP AARI, 2019). Achieving this needs establishment of a national certification system.

Table 2. Important viruses and virus-like pathogens infecting clonally propagated fruit crops

<table>
<thead>
<tr>
<th>Crop</th>
<th>Viruses</th>
<th>Viroids</th>
<th>Phytoplasma &amp; Fastidious prokaryotes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Banana</td>
<td>Banana bunchy top virus (BBTV)<em>, banana streak viruses (BSV)</em>, banana bract mosaic virus (BBrMV)<em>, cucumber mosaic virus (CMV)</em>, banana mild mosaic virus (BanMMV), banana virus X (BVX) and abaca bunchy top virus (ABTV)</td>
<td>Candidatus Phytoplasma asteris, Candidatus Phytoplasma noviguieneense</td>
<td></td>
</tr>
<tr>
<td>Citrus</td>
<td>Indian citrus ringspot virus (ICRSV)<em>, citrus tristeza virus (CTV)</em>, citrus yellow vein clearing virus (CYVCV)<em>, citrus mosaic virus (CiMV)</em>, citrus leprosis virus (CiLV-C), citrus chlorotic dwarf-associated virus (CCDaV), citrus virus A (CiVA), citrus concave gum-associated virus (CCGaV), citrus psorosis ophiovirus (CPV), citrus vein enation virus (CVEV), citrus tatter leaf virus (CTLV), citrus leaf blotch virus (CLBV), satsuma dwarf virus (SDV), citrus variegation virus (CVV), citrus endogenous pararetrovirus (CitPRV) and gummy bark (GB)</td>
<td>Citrus exocortis viroid (CEVd), citrus cachexia viroid (CCaV), hop stunt viroid (HSVd)*, citrus bark cracking viroid (CBCVd), citrus dwarfing viroid (CDVd) and citrus bent leaf viroid (CBLVd)</td>
<td>Candidatus Phytoplasma cynodontis, Candidatus Liberibacter asiaticus, Candidatus Phytoplasma aurantifolia and Candidatus Phytoplasma asteris</td>
</tr>
<tr>
<td>Grape</td>
<td>Grapevine yellow speckle viroid (GYSVd1*,2*), hop stunt viroid (HSVd*), Australian grapevine viroid (AGVd*) and grapevine latent viroid (GLVd*)</td>
<td>Candidatus Phytoplasma asteris, Candidatus Phytoplasma solani and Candidatus Phytoplasma australiense</td>
<td></td>
</tr>
<tr>
<td>----------------</td>
<td>---------------------------------------------------------------------------------------------------------------------------------</td>
<td>------------------------------------------------------------------------------------------</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Grapevine fleck virus (GFkV)<em>, grapevine fan leaf virus (GFLV), grapevine red blotch virus (GRBV)</em>, grapevine rupestris vein feathering virus (GRVFV), grapevine leaf roll associated virus (GLRaV) 1*,2*,3*,4*,7, grapevine virus (GVA, B)<em>, grapevine rupestris stem pitting associated virus (GRSPaV)</em> and grapevine red globe virus (GRGV)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Apple</td>
<td>Apple mosaic virus (ApMV)<em>, apple necrotic mosaic virus (ApNMV), temperate fruit decay-associated virus (TFDaV), Apple chlorotic leaf spot virus (AcLSV)</em>, apple stem grooving virus (ASGV*), apple stem pitting virus (ASPV)<em>, apple green crinkle associated virus (AGCaV), cucumber mosaic virus (CMV), prunus necrotic ringspot virus (PNRSV)</em>, apricot latent virus (ApLV), apple ruberry wood virus (ARWW-1 &amp; 2) and citrus concave gum-associated virus (CCGaV)</td>
<td>Candidatus Phytoplasma mali and Candidatus Phytoplasma pruni</td>
<td></td>
</tr>
<tr>
<td>Almond</td>
<td>Apple mosaic virus (ApMV), apple chlorotic leaf spot virus (AcLSV), cherry mottle leaf virus (CMLV), prunus necrotic ringspot virus (PNRSV), and prune dwarf virus (PDV)</td>
<td>Candidatus Phytoplasma phoenicium</td>
<td></td>
</tr>
<tr>
<td>Cherry</td>
<td>Cherry necrotic rusty mottle virus (CNRMV), cherry leaf roll virus (CLRv), cherry green ring mottle virus (CGRMV), cherry mottle leaf virus (CMLV), prunus necrotic ringspot virus (PNRSV), cherry little leaf virus (CLV1 &amp; 2), cherry virus A (CVA)*, prune dwarf virus (PDV) and plum pox virus (PPv)</td>
<td>Candidatus Phytoplasma pruni and Candidatus Phytoplasma asteris</td>
<td></td>
</tr>
<tr>
<td>Peach</td>
<td>Apple chlorotic leaf spot virus (AcLSV)<em>, plum pox virus (PPV), peach leaf pitting-associated virus (PLPaV), prune dwarf virus (PDV), prunus necrotic ringspot virus (PNRSV)</em>, peach virus D (PeVD) and plum bark necrosis stem pitting-associated virus (PBNSPaV)</td>
<td>Candidatus Phytoplasma pruni, Candidatus Phytoplasma Phoenicium, Candidatus Phytoplasma ziziphi and Candidatus Phytoplasma pyri</td>
<td></td>
</tr>
</tbody>
</table>
Plum | Apple chlorotic leaf spot virus (AcLSV)*, plum pox virus (PPV)*, prune dwarf virus (PDV), prunus necrotic ringspot virus (PNRSV)* and plum bark necrosis stem pitting-associated virus (PBNSPaV) | Hop stunt viroid (HSVd) and peach latent mosaic viroid (PLMVd) | Candidatus Phytoplasma pruni, Candidatus Phytoplasma solani and Candidatus Phytoplasma prunorum

Pear | Apple mosaic virus (ApMV)*, temperate fruit decay-associated virus (TFDaV), apple chlorotic leaf spot virus (AcLSV)*, Apple stem grooving virus (ASGV*), apple stem pitting virus (ASPV)*, apple green crinkle associated virus (AGCaV), prunus necrotic ringspot virus (PNRSV)*, apricot latent virus (ApLV) and pear chlorotic leaf spot-associated virus (PCLSaV) | Pear blister canker viroid (PBCVd) and apple scar skin viroid (ASSVd)* | Candidatus Phytoplasma pyri and Candidatus Phytoplasma trifolii

*Pathogens reported in various vegetatively propagated fruit crops in India are marked with an asterisk

There is no scientifically documented evidence of the actual economic losses caused by graft-transmissible pathogens in fruit crops in India. However, in the USA, it has been estimated that in wine grapes, the virus-induced leaf roll disease can cause losses in the range of $25,000 to $2,26,000 per hectare over a predicted life span of 25 years of a vineyard (Almeida et al., 2013). The impact of leafroll disease in California alone is estimated at $90 million a year (Fuchs et al., 2021). Mosaic and other viruses can reduce apple yield by up to 49%. Infections of viral diseases in cherry and peach can cause yield loss up to 30% (Cembali et al., 2003). In India, the decline in citrus production is attributed to the infection of citrus tristeza virus (CTV) and huanglongbing bacterium Candidatus Liberibacter asiaticus (CLas). The incidence of CTV in Khasi mandarin orchards in Northeastern states has been recorded at 42-69% (Singh et al., 2017).

3. CERTIFICATION OF QUALITY PLANTING MATERIAL

The availability of quality planting material is critical to the success of horticulture developmental initiatives and the overall diversification of agriculture. It is more significant in perennial horticultural crops with a long gestation period. The available varieties of many fruit crops yield poor quality, and therefore the growers depend on imported superior exotic varieties. However, the propagation of such exotic varieties is not regulated, causing the introduction of new pathogens, especially viruses.

Many nurseries of different crops in several states have been accredited by the National Horticulture Board (NHB). Most of these nurseries have a rating below 3 on a scale of 5 (as per the accreditation criteria available at that time), indicating that these do not fulfil the requirements of CQPM, including virus testing. Testing samples of budwood source plants collected from 11 Kinnow mandarin nurseries in Punjab (rated 2 to 4 stars by NHB) indicated the presence of citrus yellow vein clearing virus, Indian citrus ringspot virus and huanglongbing-associated CLas (Pant et al., 2018). This means that farmers do not have access to good quality certified disease-free
planting material of true to type varieties, resulting in poor orchard productivity and fruit quality. A recent study on seasonal dynamics of viruses in grapevine indicates a drastic decline in the copy number of viruses during December under the tropical conditions (Sidharthan, 2022), indicating criticality in the timing of virus indexing.

The unorganized private sector nurseries lack modern infrastructure, including an insect-proof greenhouse, mist chamber, efficient nursery tools, machinery and technical know-how to produce genetically-pure and pathogen-free quality planting material. Guaranteed performance in terms of higher yield and quality of crops could be achieved with reliable planting material and good management practices. There is no emphasis on monitoring quality planting material in terms of genetic makeup and trueness, varietal purity, robustness, transmissible pathogens and other pests.

3.1 CQPM: International Scenario

The citrus bud wood certification was first started in Brazil in 1921 for sweet oranges. Later, it was supported by a state decree in 1939 that established regulations for the sale of citrus trees wherein nurseries producing citrus plants were required to be obligatorily registered and periodically inspected. Since then, similar provisions have been implemented by other citrus-producing countries like Israel, France, South Africa, and the USA.

In the USA, the citrus budwood certification program was extended to all the clonally propagated crops in 2008 under the National Clean Plant Network (NCPN) to protect fruit trees, hops, grapes and other clonally propagated crops from the spread of economically harmful pests and diseases. Under NCPN, clean plant material is made available to states for the production of certified clean planting material by private nurseries and certified producers. The program is supported by a network of centers for diagnostic and pathogen elimination services to produce clean propagative plant material and maintain blocks of pathogen-tested plant material at sites across the United States. Network participation currently consists of 47 collaborating programs at 35 centres in 20 states (Fuchs et al., 2021). The centres dedicated to fruit trees are based at the Washington State University, Clemson University in South Carolina and the University of California, Davis. The centres collaborate to provide products and services needed for specialized fruit tree growing regions across the United States. Each scion or budwood source tree is identified for tracking purposes to maintain a history of test results for diseases of economic importance. Similar records are maintained for the clonally propagated rootstocks, which are tested on a random basis. To ensure that trees produced under the program remain free of virus diseases, registered scions and rootstocks are tested regularly. The intensive indexing of the scion orchards on a regular basis in the program has been instrumental in a low incidence of the diseases caused by viruses and virus-like pathogens.

South Africa has also established a similar certification program to develop seed sources for rootstocks and budwood sources to produce certified planting materials by nurseries under the ‘Superplant Scheme a (Von Broembsen and Lee, 1988).

In Europe, a unified certification system for healthy planting material of fruits was implemented in 2017 to ensure that the planting material is free from viruses and has varietal identity and homogeneity. The certification system is operated by the European & Mediterranean Plant Protection Organization (EPPO), and it is (a) based on a three-stage certification system (pre-
basic, basic and certified material), (b) voluntary addition to the legally prescribed plant passport, and (c) open to all interested fruit tree nurseries. The nurseries are authorized to label the plant material with a unique quality label (https://www.eppo.int/).

In the UK, Fruit Propagation Certification Scheme (FPCS) (www.gov.uk) encourages the production and use of healthy planting stock. Commercial growers (‘propagators’) must join the FPCS to sell certified plants. The scheme covers soft fruits (strawberries, berry fruit and currants); tree fruits (apples, pears, cherries and plums); and Vaccinium shrub berries. The tissue culture raised plants of these crops are also included in FPCS. The Nuclear Stock Association (NSA) accepts varieties (candidates) from the industry for virus, disease and pest testing to meet the requirements for Pre-Basic (PB) stock as specified by the FPCS regulations. The viral pathogen, if present, is eliminated by heat treatment only after renewed testing for the viruses and a true-to-type test of the plants to be planted in the nuclear stock and used as parent material for the propagation of certified fruit trees.

3.2 Production of CQPM of Clonally Propagated Fruit Crops in India

The need to produce CQPM of clonally propagated fruit crops, particularly citrus, has been felt in India for a long (Raychaudhury and Verma, 1992). Efforts are on, but so far, these have remained in infancy. The ICAR-Central Citrus Research Institute (ICAR-CCRI) maintains mother blocks of different citrus varieties and supplies about 0.3 million indexed CQPM of Nagpur mandarin (Santara), mosambi and acid lime plant, to the growers and selected nurseries in citrus-growing states. Similarly, 1 to 4 lakhs virus-free budwood of Sathgudi sweet orange were supplied to the growers by Citrus Research Station at Tirupati from 1996 to 1999. Approximately 7-8 lakhs of planting material of Kinnow mandarin are provided every year to farmers in Punjab. Only one-fourth of it is produced and supplied by the State Agricultural University and the nurseries of the state’s horticulture department. Private nurseries provide the bulk of the planting material of Kinnow mandarin to the farmers. However, there are no defined standard operating procedures for supplying certified quality planting material at any of these centres.

In pome-fruits also, there is a shortage of CQPM, as there is a huge demand to develop or convert the traditional orchards to high density under the high-density and medium-density planting schemes of the government (https://hpuniv.ac.in). The government-owned nurseries and the ICAR-Central Institute of Temperate Horticulture in Jammu and Kashmir are producing CQPM for medium-density plantations, but to a limited extent. Currently, the plants imported from Italy and other countries on M9 rootstock are being used for developing high-density apple orchards.

India has an annual requirement of nearly 200 million CQPM of clonally propagated crops; in citrus alone, almost 20 million CQPM is required (ICAR-CCRI, Nagpur). There is an urgent need to develop an efficient regulatory system to produce CQPM of clonally propagated crops. The National Horticulture Board (NHB) has put a step in this direction by accrediting many nurseries supplying plants of different fruit crops. These nurseries have to fulfil various requirements of CQPM, including virus testing (http://nhb.gov.in). But there is no organised mechanism to undertake certification of CQPM supplied by the accredited nurseries.

The country has developed a model certification system for tissue-culture plants under the Seed Act 1966. The NCS-TCP was established by the Department of Biotechnology, Government of
India, in 2006 to promote the growth of the tissue culture (TC) industry in India (Fig. 1). The main objective of the NCS-TCP is to provide certified virus-free, and true-to-type tissue culture raised plants for growers to improve the productivity of the identified crops. The program includes the fruit banana. The CQPM of bananas provided a boost to the banana industry. Banana production increased from 14.2 to 31.5 million tonnes, making India the world’s largest banana producer, and raising farmers’ income 5 to 6 times (APAARI, 2019).

Fig. 1. Organization structure of NCS-TCP (Source: https://dbtn catastcp.nic.in/)

The NHB regulates the accreditation of nurseries to produce planting materials for different horticultural crops, including clonally propagated fruit crops. To ensure true to type quality planting material, the NHB has set standards in terms of infrastructure, quality of seed and planting materials and adoption of nursery management practices. Based on the set guidelines for accreditation and
rating of nurseries, a total of 688 nurseries across the country are accredited and rated in star ratings (1 to 3 star, as per recent guidelines) (Fig. 2).

The evaluation criteria are focussed on infrastructure for accreditation and rating of nurseries are based on different parameters like location, mother plant block attributes, propagation techniques, infrastructure, irrigation facilities, operation manuals, staff and quality, trade relations, bio-security, and disease-free conditions. Under the bio-security and disease-free conditions, the adoption of plant protection measures, condition of plants being free from disease/insect infestation, adoption of biological control and bio-safety protocol and facility/out-sourcing for virus testing are not strictly implemented for accreditation.

Fig. 2. Spread of NHB accredited nurseries (star rated) PAN India

A total of 31 fruit crops are covered for accreditation of nurseries (Table 3). In the set criteria for nursery accreditation, although the biosecurity and disease-free condition are mentioned, the regular indexing or testing for the clonally propagated viruses and virus-like pathogens has not
been considered. It is also worth noting that out of the total 688 of the star rated nurseries across the country, only 1.31% are three-star rated, 10.61% are two-star rated, and the majority (88.08%) are one-star rated (Table 4).

Table 3. List of vegetative fruit crops and states where NHB accredited nurseries (star rated) are located

<table>
<thead>
<tr>
<th>Crop</th>
<th>States where certified nurseries are located</th>
</tr>
</thead>
<tbody>
<tr>
<td>Apple</td>
<td>Jammu &amp; Kashmir, Uttarakhand, Himachal Pradesh, Gujarat</td>
</tr>
<tr>
<td>Acid lime</td>
<td>Maharashtra, Gujarat, Madhya Pradesh, West Bengal, Karnataka</td>
</tr>
<tr>
<td>Almond</td>
<td>Jammu &amp; Kashmir</td>
</tr>
<tr>
<td>Propagated Apricot</td>
<td>Jammu &amp; Kashmir, Uttarakhand, Himachal Pradesh</td>
</tr>
<tr>
<td>Banana</td>
<td>Jharkhand</td>
</tr>
<tr>
<td>Cherry</td>
<td>Jammu &amp; Kashmir</td>
</tr>
<tr>
<td>Citrus</td>
<td>Punjab, Haryana, Maharashtra, Himachal Pradesh, West Bengal, Jammu &amp; Kashmir, Uttarakhand, Rajasthan</td>
</tr>
<tr>
<td>Date palm</td>
<td>Gujarat</td>
</tr>
<tr>
<td>Dragon fruit</td>
<td>Gujarat, West Bengal</td>
</tr>
<tr>
<td>Fig</td>
<td>Maharashtra, Jammu and Kashmir, Chhattisgarh, Karnataka, Rajasthan</td>
</tr>
<tr>
<td>Grapes</td>
<td>Jammu and Kashmir</td>
</tr>
<tr>
<td>Kinnow</td>
<td>Uttar Pradesh, Punjab</td>
</tr>
<tr>
<td>Kiwi</td>
<td>Uttar Pradesh, Punjab</td>
</tr>
<tr>
<td>Orange</td>
<td>Maharashtra</td>
</tr>
<tr>
<td>Papaya</td>
<td>Rajasthan, Madhya Pradesh</td>
</tr>
<tr>
<td>Peach</td>
<td>Uttarakhand, Jammu &amp; Kashmir, Uttar Pradesh, Punjab, Himachal Pradesh, Haryana</td>
</tr>
<tr>
<td>Pear</td>
<td>Jammu &amp; Kashmir, Himachal Pradesh, Punjab, Chhattisgarh, Uttar Pradesh, Uttarakhand</td>
</tr>
<tr>
<td>Pecan</td>
<td>Jammu &amp; Kashmir</td>
</tr>
<tr>
<td>Plum</td>
<td>Jammu &amp; Kashmir, Uttarakhand, Uttar Pradesh, Punjab, Himachal Pradesh, Haryana</td>
</tr>
<tr>
<td>Pomegranate</td>
<td>Bihar, Jammu &amp; Kashmir, Haryana, Chhattisgarh, Himachal Pradesh, Uttarakhand, Karnataka, Madhya Pradesh, West Bengal, Himachal Pradesh, Gujarat, Andhra Pradesh, Uttar Pradesh, Rajasthan, Kerala, Maharashtra</td>
</tr>
<tr>
<td>Sapota</td>
<td>Maharashtra, West Bengal, Karnataka, Orissa, Gujarat, Madhya Pradesh, Chhattisgarh, Kerala, Rajasthan, Jharkhand</td>
</tr>
<tr>
<td>Sweet Lime</td>
<td>Maharashtra, Chhattisgarh</td>
</tr>
<tr>
<td>Sweet Orange</td>
<td>Maharashtra, Punjab, West Bengal, Rajasthan, Madhya Pradesh, Haryana, Himachal Pradesh, Uttarakhand</td>
</tr>
<tr>
<td>Walnut</td>
<td>Jammu and Kashmir, Uttarakhand</td>
</tr>
</tbody>
</table>
Table 4 State-wise distribution of star rated nurseries as accredited by the National Horticulture Board (NHB) (as of April 2022)

<table>
<thead>
<tr>
<th>S.N.</th>
<th>State/UT</th>
<th>Total Number of Nurseries</th>
<th>Single Star Nurseries (number)</th>
<th>Two Star Nurseries (number)</th>
<th>Three Star Nurseries (number)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Punjab</td>
<td>18</td>
<td>12</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>2</td>
<td>Jammu and Kashmir</td>
<td>110</td>
<td>102</td>
<td>6</td>
<td>2</td>
</tr>
<tr>
<td>3</td>
<td>Maharashtra</td>
<td>87</td>
<td>79</td>
<td>8</td>
<td>0</td>
</tr>
<tr>
<td>4</td>
<td>Uttar Pradesh</td>
<td>81</td>
<td>77</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
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4. ROADMAP FOR PRODUCTION OF CPQM

The availability of genuine CQPM of fruit crops is a significant hindrance to raising production and exports. The lack of awareness and technical know-how for producing certified quality planting material and its potential discourage its adoption in the field. Farmers even purchase the planting material without considering its quality.

To achieve this, a National System on ‘Certification of Quality Planting Materials – Clonally Propagated Crops’ (CQPM-CPC) may be established along the lines of the NCPN of the USA.

The key component in CQPM is the production and maintenance of virus-free source plants and their further propagation for the production of clean, healthy planting material of high quality for
distribution to growers. Therefore, standard operating procedures (SOPs) need to be developed and implemented at the national level for production of clean stocks of fruit crops. The pathogen-free mother plants with good horticultural traits need to be registered with a unique identification number. Budwood should be derived from the mother plants and distributed to stakeholders such as accredited nurseries and other agencies involved in the propagation and distribution of planting material. The state of art pathogen testing laboratories at crop-based research Institutes/ universities need to be established and accredited for pathogen testing. These laboratories should be networked under the umbrella of the ‘Plant Pathogen Diagnostic Network’ (PPDN), which should be controlled by the Indian Council of Agricultural Research (ICAR). On the lines similar to the NCS-TCP, a coordinating cell needs to be established to accredit diagnostic laboratories under the proposed PPDN. The coordinating cell may be housed at the national research institutes like ICAR-Indian Agricultural Research Institute, New Delhi. The training programs on capacity building in pathogen testing should be organised regularly for the personnel engaged in pathogen testing (viruses, virus-like pathogens, bacteria, fungi, as well as pests like scales and mites). The pathogen testing laboratories should use a standardized diagnostic protocol for selected elite planting material. In case pathogens are detected, their eradication through thermotherapy coupled with tissue culture mediated protocols or shoot-tip grafting should be undertaken, and the plants should be released only after being retested for freedom from pathogens. The program on certification of quality planting material of clonally propagated fruit crops should be funded by the Central Government to produce certified virus-free nucleus material, which can then be made available to private nurseries for propagation. The basic lab set-up of PPDN is illustrated in Fig. 3.

**Fig. 3. The basic framework for ‘Plant Pathogen Diagnostic Network’ centre**

The initial plant materials to be taken in CQPM-CPC could be either exotic elite materials imported through a quarantine system or domestic materials, which are extensively tested using robust standard diagnostic tools (Fig. 4). The imported exotic plant materials need to be maintained in a post-entry quarantine facility and tested through robust tools by the PPDN periodically. For testing of these materials, high-throughput sequencing (HTS by mRNAome or sRNAome) should be initially employed to detect the probable infection of any identified or unidentified virus or virus-like pathogens. The HTS will enable detecting the probable infection of all viruses and virus-like pathogens in a single limited sample without running multiple detection assays. For the HTS based virus detection, standard crop-wise assays on sampling, template preparation, HTS pipeline and *in silico* analysis pipeline should be developed and put in place. The tissues to be used for HTS analysis (targeting both RNA and DNA pathogens) are most crucial here. For this, a gold standard procedure should be developed and followed. For instance, to detect all viruses and virus-like pathogens in citrus, the mixed sample (leaf lamina and phloem tissues) could be ideal. Once HTS
based testing is done, it is to be followed by standard molecular/serological tests, if required. If the plant material is tested positive, it needs to be sanitized by an appropriate method (thermotherapy, tissue culture and shoot-tip grafting) to eliminate the infection. After sanitization, the materials are to be retested for freedom from pathogens. If the planting materials are tested free from infection, they must be maintained as clean pathogen-tested certified nucleus material in the foundation block. The first stage of nucleus stock materials will be the first block (S1), which may comprise only a small number of plants, usually five to ten of each clean accession depending on the plant species. Plants in the S1 block may be maintained on an open site (only if the viruses and virus-like pathogens are not prevalent in that zone) or contained in controlled setups (greenhouses, screen houses or tissue culture). To further propagate the clean nucleus foundation plants, the plant materials from the S1 block are to be established further in fields, referred to as the S2 block, to scale up the propagating materials, which are to be taken to the growers/farmers. Depending on the bulk of clean propagating materials required, it may be further propagated in S3 and subsequently in S4 blocks (Fig. 4). The materials in the S1 block need to be maintained as ‘Certified Clean Foundation Plant Stocks’ at CQPM-CPC centres and the State Department of Horticulture/Agriculture. The plant materials in S2 to S4 stages may be established and maintained by the nurseries (public or private), and registration-cum-certification of these materials can be done by the State Department of Horticulture/Agriculture in collaboration with PPDN laboratories under the umbrella of CQPM-CPC (Fig. 4).

Fig. 4. Standard operating procedure for the production of quality clonally propagated fruit crop plants under the National Network on ‘Certification of Quality Planting Materials – Clonally Propagated Crops’ (CQPM-CPC)
All the nucleus planting materials under the ‘Certified Clean Foundation Plant Stocks’ should be maintained in an insect-free environment and be tested for important clonally transmissible and vector-transmitted pathogens at regular intervals by the PPDN laboratories. It should be mandatory to register and get the certification of S1-S4 plants for these to be free from pathogen infections. The PPDN will be responsible for developing and updating the standard testing protocol and SOP for the battery of viruses/viroids/bacteria/phytoplasma/other pathogens for each crop under the CQPM-CPC. All the foundation blocks (S1 to S4) are to be under a rigorous approach to mitigate the influx of viral pathogens through vectors to keep it clean and infection-free. As per the proposed SOP, the plants of foundation block S1 in the contained set-up after the initial rigorous testing may then be indexed once a year in case of the high prevalence of vector-transmitted viruses in the area and two years in case of the absence of vector-transmitted viruses in the area. Further, the plants of certified clean registered nursery plant stocks (S2 to S4) needs to be indexed through random stratified sampling at the rate of 0.01% in case of 100 to 10000 plant population. If tested positive at any point in time, the infected plants should be immediately removed to check the spread of pathogens. This, in addition to ensuring the healthy, clean materials in foundation blocks, will also minimize the chances of introducing regulated pathogens in S1 to S4 blocks. Before taking these fields, it must be mandatory to index the plant for all known viruses and viroids at the latest multiplication stages (S2 to S4) fields. All the certified clean plant lots produced through CQPM-CPC should be labelled with a unique bar/QR code containing information about the mother stock, quality testing attributes and genetic trueness.

5. RECOMMENDATIONS

- Farmers and growers need to be sensitized through concerned central/state government departments / institutes and extension agencies about the benefits of using certified quality planting material from registered nurseries.
- To bridge the gap between demand and availability of certified quality planting material (CQPM), an institutional mechanism needs to be developed through the entrepreneurship model supported by research institutes/universities.
- Research institutes / universities need to be supported to provide the mother stock of quality planting material and train entrepreneurs who can undertake large scale multiplication and or grafting for making CQPM available to farmers and growers.
- The foundation plant stock and subsequent clean registered plant stocks under the CQPM-CPC should be labelled with a unique identification number (bar/QR code) containing information about the mother stock, quality testing attributes and genetic trueness.
- The accreditation system of nurseries by National Horticulture Board (NHB) needs revisiting to ensure the supply of certified disease-free and true to the type planting materials.
- To ensure the production and supply of CQPM to growers, a National System on ‘Certification of Quality Planting Materials – Clonally Propagated Crops’ (CQPM-CPC) may be established as the nodal agency to oversee the planning and execution of overall certification program of all clonally propagated plants in the country.
- A ‘Plant Pathogen Diagnostic Network’ (PPDN) should be established under the aegis of CQPM-CPC by pooling the established research institutes and state agricultural universities. Crop-wise working groups may be constituted to develop guidelines for certification of pre-basic/basic material and its entire workflow in CQPM-CPC. The standard testing protocol and SOP need to be framed for economically important viruses, viroids, bacteria, phytoplasma, fungi and other pathogens/pests (scales, mites) for each fruit species.

- All the imported planting material should be adequately tested for freedom from viruses through high-throughput sequencing under post-entry quarantine (PEQ) set-up. This shall enable detection of the probable infection of any identified or unidentified viruses in a short time.

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