

Quality Planting Material of Grape: Need to Develop Plant Certification Standards for the Indian Grape and Wine Industry

Sharmistha Naik^{1*}, Kaushik Banerjee¹ and Sadanand A. Dhekney²

¹ICAR-National Research Centre for Grapes, P.B. No. 3, P.O. Manjari Farm, Solapur Road, Pune 412 307, Maharashtra, India.

²Department of Agriculture, Food and Resource Sciences, University of Maryland Eastern Shore, 1 College Backbone Road, Princess Anne MD 21853, USA.

*Corresponding author email id: naiksharmistha@gmail.com

Abstract – Asexual propagation of grapevines through cuttings and grafting has been followed for several centuries to maintain the genetic fidelity of cultivars that are valued for their fruit and enological characteristics. Grapevines are adversely affected by several biotic factors including fungal, viral and bacterial pathogens, insects and nematodes. Vineyards infected with viruses may exhibit a significant decrease in yield while also severely affecting quality parameters such as low sugars, poor color development and improper ripening. Grapevine viruses are primarily spread through infected propagation material. Thus, the use of clean, disease-free planting material is paramount for maintaining high vineyard productivity, fruit quality and value-added products for export purposes. Certified, disease-free propagation material is currently in high demand for new vineyards as well as replacement of vines in old vineyards. We propose the development of a three-stage system in order to ensure the generation and availability of certified, disease-free grapevine propagation material to growers. Stage I and II will consist of establishing a nucleus and foundation stock for grapevine cultivars and rootstocks. The nucleus stock will be developed by testing current germplasm for grapevine viruses and viroids followed by meristem tip culture and chemo-/thermo-therapy for the elimination of endophytic pathogens. The nucleus stock (G-1) will be propagated to develop foundation stocks (G-2), which will be maintained in the field under sanitary conditions and routinely tested for grapevine viruses. Propagation materials from the foundation stock will be distributed to nurseries in Stage III, which will be used for further propagation (G-3 and G-4) and distribution of certified materials (G-4) to growers. The system will be initiated and spearheaded by public research institutions and will be implemented with the involvement of registered nurseries in major grape producing regions. The successful implementation of this system will enable Indian growers maintain healthy vineyards while also helping to achieve high productivity in grape and wine production.

Keywords – Virus Testing, Meristem, Micropropagation, Vegetative Propagation, Nucleus Stock, Foundation Stock.

I. INTRODUCTION

Grapevine (*Vitis vinifera*) is one of the most important fruit crops in India and is widely cultivated in diverse agro climatic zones ranging from temperate in regions in Himachal Pradesh to tropical areas of South India. As per the 3rd advance estimate of DA & FW (2023), acreage under grapevine cultivation in India was 0.16 million ha with an annual production of 3.48 million tons of fruit in 2021-2022 (Table 1).

Maharashtra and Karnataka are major grape growing states contributing more than 95% acreage and production (DA&FW, 2023). India is also a major exporter of table grapes with an estimated export of 0.27 million tons fruit worth 2303 crores (US \$ 306 million) in 2021-22 (APEDA, 2023). During the last 22 years (2000-2021) the annual compound growth rate (ACGR) for grape export from India was 12.36% (FAOSTAT, 2023). The export of table Grapes has been accompanied by a steady increase in domestic consumption, which

necessitates an increase in area under grapevine cultivation to meet the increasing demand.

The increasing demand for fresh fruit in India can be achieved by expanding area under grapevine cultivation while simultaneously improving productivity in existing vineyards. However, the Annual Compound Growth Rates (ACGRs) for area, production and productivity of grapes in India during 2000-2021 were 6.35%, 5.07% and (-) 1.2%, respectively (FAOSTAT, 2023). This combined with a scarcity in the availability of land suitable for grapevine cultivation pose major challenges for increasing grape production in the country.

Table 1. Area, Production and Productivity of grape in India (2021-2022).

State	Area ('000 ha)	Production ('000 t)	Productivity (t/ha)
Andhra Pradesh	2.36	51.50	21.85
Arunachal Pradesh	0.00	0.01	3.33
Haryana	0.04	2.01	47.76
Himachal Pradesh	0.07	0.11	1.54
Jammu & Kashmir	0.32	1.73	5.45
Karnataka	35.68	871.79	24.43
Kerala	0.00	0.00	5.19
Madhya Pradesh	0.09	1.36	16.00
Maharashtra	118.41	2466.54	20.83
Manipur	0.02	0.22	12.94
Mizoram	2.33	17.30	7.41
Nagaland	0.11	0.20	1.77
Punjab	0.22	6.92	30.90
Rajasthan	0.00	0.01	5.00
Tamil Nadu	1.95	47.66	24.44
Telangana	0.30	9.64	31.72
Total	161.91	3477.00	21.48

[Source: DA & FW (2023)]

Grapevines are infected by about 86 different viruses, which can severely affect fruit yield and vineyard productivity (Fuchs, 2020). The availability of disease-free propagation material is one of the important factors influencing grapevine yield and quality, along with long-term vineyard health and productivity. In India, the current demand for propagation materials is met by private nurseries who utilize conventional methods such as cutting, budding and grafting. Commercial mother blocks in nurseries that are infected with viruses and other endophytic pathogens, may spread the diseases to new vineyards through infected propagation material. The use of infected planting materials can severely reduce yield and productivity while also causing long term degeneration in vineyards and loss of acreage under grape production.

Grapevine yield, quality and vineyard productivity can be significantly improved by the use of disease-free planting material coupled with improved management techniques. In vitro culture techniques such as meristem

culture and micropropagation are routinely used for the rapid production of clean, disease-free planting material and their integration in producing quality planting material is critical for vegetative propagated crops (Naik and Khurana, 2003). In view of the advantages offered by in vitro culture techniques, the Department of Biotechnology (DBT), Govt. of India notified a unique “National Certification System for Tissue Culture Raised Plants (NCS-TCP)” system (<https://dbtncstep.nic.in/>) for quality management of vegetatively propagated crops under the Seeds Act 1966. NCP-TCP has been implemented by the DBT since 2006 and was successfully applied for potato propagation, which resulted in an increase in production from 28.6 million tons in 2007 to 54.3 million tons in 2021. The system is currently being used for apple, banana and Citrus, which has led to significant increase in production and economic returns to farmers (APPARI, 2019). Such technologies are critically needed in the grapevine industry in India for supplying disease-free planting material and improving long term yield and productivity.

II. DOMESTIC REQUIREMENT AND PRODUCTION OF GRAPE PLANTING MATERIAL IN INDIA

Grapevines grown for table purpose are planted at a spacing of 2.75 m X 1.5 m, which amounts to 2,400 plants per ha. At the current rate of 6.35% ACGR for acreage, it is estimated that approximately 24.7 million vines will be required to plant new vineyard acreage of 10,287 ha annually with the demand for clean planting material progressively increasing in the future. Additionally, 25.9 million new vines will also be required to replant old vineyards and ageing vineyards that are more than 15 years old. Thus, there exists a demand for more than 50 million new quality vines to meet the demand for existing and new acreage under grape cultivation.

Grape planting material in India is either produced by the nurseries or by farmers themselves using hardwood cuttings and grafting. Hardwood cuttings are obtained from 3-4 year old vigorous and high yielding vines after October pruning. About 30-45 cm long cuttings having 3-4 nodes are cut from the middle portion of the selected cane. A straight transverse cut is made 1 cm below the node at the lower end and a slanted cut is made at 2-3 cm above the top bud. The lower portion of the cutting (4-5 cm) is dipped in 1000-1500 ppm Indole-3-butyric acid (IBA) and then planted in the ground on raised beds or transferred to plastic bags for rooting and growth. After sufficient shoot growth, vines are then transplanted in the vineyard.

Grapevine grafting is accomplished by using high quality scion and abiotic and biotic stress tolerant rootstock material. Rootstocks including 110 Richter, 140 Ruggeri, 1103 Paulsen, SO4, St. George, Dogridge, 1613 and Ramsey impart drought and salinity tolerance while also providing some degree of nematode resistance. Dogridge is among the most popular rootstocks used for grafting in India. The grafting process consists of planting the rootstocks either in the field or in polythene bags in the nursery. V notch and chip bud grafting are commonly used techniques, which consist of using one-year old scion wood and 7-10-month-old rootstocks (Somkuwar and Adsule, 2004). The scion material is a wedge-shaped piece consisting of a bud and some attached wood, which is then inserted into the corresponding notch of the rootstocks at approximately 30-40 cm above ground level. The graft union is then wrapped with polythene strip while taking care to leave the bud unwrapped. Following growth of the bud and shoot development, the stem above the graft union is pruned while also removing any suckers that grow below the graft union. Successfully grafted vines in plastic bags are then planted in the vineyard at the recommended spacing.

The current demand for grapevine planting material is primarily met by private nurseries and farmers who pr-

-opagate vines from existing vineyards with no systems in place for the detection and elimination of pathogens in propagation materials. The Indian Minimum Seed Certification Standards Act enacted in 1966 describes detailed certification standards for seed propagated crops but very limited standards are provided for fruit crops (Trivedi and Gunasekaran, 2013). The National Horticulture Board (NHB) initiated a nursery accreditation process for different crops in India with a rating scale of 1 to 5. Most nurseries have a rating below 3 indicating that these do not fulfil all the requirements for producing clean planting material. Interestingly, there are only 4 accredited nurseries with very limited propagation capacity in non-grape growing regions of India (Table 2).

Table 2. NHB accredited nurseries for production of grape planting material.

SN	NHB Accredited Nursery	NHB Star Rating	Variety	No. of Mother Plants	Production Capacity
1	Centre of excellence for fruits (Citrus) Village: Phuglana, Distt.: Hoshiarpur (Punjab)	3	Star Ruby	20	1000
2	Grape Farm Village: Maralia, Bishnah, Distt.: Jammu (J&K)	1	F. Seedless Perlette Punjab Purple Pusa Navrang Pusa Trishar	332 172 91 244 43	2000 1000 800 25000 4500
3	Model Vine Yard Village & Tehsil: Lar, Distt.: Ganderbal (J&K)	1	Hussani Kishmish Sahibi	41 48 120	3500 3500 9200
4	VNR Nursery Pvt. Ltd. Village: Malpuri, Distt.: Raipur (Chhattisgarh)	3	VNR - Lali	49	7000

[Source: NHB (2023)]

III. PHYTOSANITARY ISSUES FOR GRAPEVINE PROPAGATION MATERIALS

Grape production is adversely influenced by fungal, bacterial and viral pathogens, insects and nematodes. Major fungal diseases in Indian vineyards are downy mildew caused by *Plasmopara viticola*, powdery mildew caused by *Erisiphae necator* and anthracnose caused by *Elsinoe ampelina*. Major insect pests affecting grapevines are mealybugs, flea beetles, thrips, leafhoppers, stem borers, scale insects and mites. Among the various nematodes infesting vineyards, root knot nematode (*Meloidogyne* spp), root lesion nematode (*Pratylenchus* spp) and dagger nematode (*Xiphinema* spp) cause major damage. Lack of management practices for biotic stresses can significantly impact vineyard yield and productivity. Foliar disease and insect management is effectively achieved using pesticides while rootstocks are used for the management of soil borne diseases and nematodes. (Adsule and Upadhyay, 2007; Mani et al., 2008).

Grapevines are infected by about 86 viruses and viroids, which have a debilitating effect on vineyard health and productivity. Viral infection of vines can result in poor bunch development, a severe reduction in berry sugars and colors, resulting in the production of poor quality fruit for table and wine purposes. In severe cases, vine death can occur thereby requiring the vineyard to be replanted (Basso et al. 2017). Among the different

viral pathogens, the *Grapevine leafroll associated viruses* (GLRA) are most severe having worldwide economic importance. The intensity of virus symptoms depends on cultivar, weather and crop management practices. Viruses may remain latent for long periods of time and manifest when vines are weakened due to other biotic/abiotic stress factors. Due to the confounding nature of virus symptoms along with their ability to stay latent, visual detection in vines can be very difficult. Viruses are primarily spread through infected propagation materials while existing infections in vineyards can spread from infected to healthy vines through insect vectors. Currently there are no control measures for viruses and infected vines are uprooted and burnt to prevent their spread to healthy vines in the vineyard.

Studies on the prevalence of grapevine viruses in India are limited. *Grapevine leafroll-associated virus* (GLRaV) 1 and GLRaV-3 were detected from ‘Shiraz and Pinot Noir in the Nashik and Pune grape growing regions by using double antibody sandwich (DAS)-ELISA (Kumar et al. 2012 a; b). ‘Thompson Seedless’ and ‘Anab-e-Shahi cultivars were found to be infected with grapevine yellow speckle viroid 1 (GYSVd-1, genus *Apscaviroid*) in vineyards of Bijapur, Doddaballapur and Kolar districts of Karnataka (Sahana et al., 2013). Grapevine leafroll disease caused by different ampeloviruses, their geographical distribution, characterization, diversity, management strategies have been discussed by Kumar et al. (2017). Sidharthan et al. (2020), carried out Next Generation Sequencing (NGS) based virome analyses of mRNA and sRNA of exotic and Indian grapevine cultivars to identify 23 viruses and viroids, some of which were identified for the first time in India. The whole genome sequences generated in this study can be used as a resource for reliable indexing of grapevine viruses and viroids in quarantine and certification programs. The viruses and virus-like agents reported from India and their mode of transmission is presented in Table 3.

Table 3. Grapevine viruses and virus-like pathogens reported from India.

Virus/Viroid Reported in India*	Known Modes of Transmission	Diagnostic Tool**
Grapevine fleck virus (GFkV)	Found in phloem and is mainly transmitted through planting material	<i>Vitis rupestris</i> St. George (Indicator plant), PCR
Grapevine red blotch virus (GRBV)	By hoppers and planting material	Visual, Quantitative PCR
Grapevine leaf roll associated virus (GLRaV) 1,3,4	Mealybugs, scale insects and planting material	Visual, <i>Vitis vinifera</i> cv. Cabernet Franc (Indicator plant for GLRa viruses), ELISA, PCR, NGS
Grapevine virus (GVA, B)	Mealybug and planting material	Kober 5BB- a cross between <i>Vitis berlandieri</i> × <i>V. riparia</i> (Indicator plant for GVA), LN33-a hybrid between Couderc 1613 × Thompson Seedless (Indicator plant for GVB), ELISA, PCR, NGS
Grapevine rupestris stem pitting associated virus (GRSPaV)	Planting material	NGS
Grapevine yellow speckle viroid (GYSVd 1, 2)	Planting material	NGS
Hop stunt viroid (HSVd)	Planting material and mechanical transmission	NGS
Grapevine viroid (AGVd)	Planting material	NGS

Virus/Viroid Reported in India*	Known Modes of Transmission	Diagnostic Tool**
Grapevine latent viroid (GLVd)	Planting material	NGS

* NAAS (2022).

** Rowhani et al. (2005) (for indicator plants) and Anatoly et al. (2018) (for serological and molecular diagnostics).

No studies have been conducted on the economic impacts of virus infections in vineyards in India. However, in the USA, it was estimated that leaf roll disease incurred losses between \$25,000 to \$226,000 per ha 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). Such huge losses can primarily be mitigated by using virus-free planting material and adopting strict sanitary and cultural practices. Although viruses are difficult to detect in rootstocks/ budwood/ planting material, diagnostic tools such as serological Enzyme Linked Immunosorbent Assay (ELISA) and nucleic acid based Polymerase Chain Reaction (PCR) are available methods to test virus status of plant samples. Secondly, since viruses move in a systemic fashion throughout the vine and there are no chemical control measures, it is not possible to cure infected plants using conventional methods. There are some reports of virus elimination from infected grapevines through heat treatment (Over de Linden and Chamberlain, 1970). However, meristem tip culture in combination with chemotherapy and/or thermotherapy is the only proven method for elimination of viruses and production of clean plants (Wang et al., 2018; Klimenko et al., 2020). These techniques have been successfully applied for the propagation of disease-free plants in vegetatively propagated crops in India (Naik and Karihaloo, 2007; APAARI, 2019). Thus, there exists a critical need for the integration of this technology in grapevines for large-scale propagation of virus-free plant materials.

IV. QUALITY PLANTING MATERIAL OF GRAPE: INTERNATIONAL SCENARIO

Until recently, there have been few comprehensive standards or assessment criteria for grapevine planting material by nurseries and grape growers. As a result, inferior material has sometimes been planted and there have been numerous reports of vineyard failure or underperforming vineyards worldwide that need replanting within 5-10 years of establishment (Smart et al., 2012). Major grape growing regions around the world have established and implemented stringent phytosanitary measures in grapevines and other perennial crops to restrict the entry and spread of viral pathogens.

Certification procedures with the characteristics of clean stock programs were established in Argentina in 2001 and in Chile in 2007. In both countries, nuclear stocks are certified, if they are free from some important viruses. In Argentina, these viruses are GFLV, Grapevine leafroll associated viruses (GLRaV-1, GLRaV-2, and GLRaV-3), GFkV, rugose wood, vein mosaic, and vein necrosis. In Chile, they are GFLV, GLRaV-1, GLRaV-2, GLRaV-3, GVA and Grapevine virus B (GVB) (Golino et al., 2015).

The New Zealand Winegrowers Board developed Grafted Grapevine Standards and an associated certification program with the objective of minimizing the probability of infected material being released to the industry. As per these standards, certified mother plants are true-to-type at the varietal level and free from GLRaV-3 at the time of testing. Specific physical specifications and the related management systems are also described in these standards.

In European Union, the first Directive 68/193 (issued on 9 April 1968) on the “Marketing of Vegetatively Pr-

-opagated Material of Grapevines” categorized propagative materials as “basic”, “certified”, “standard” and defined the sanitary characteristics of mother vineyards destined for their production. Additional directives were then issued to harmonize quality standards with member countries and currently directive 2002/11/CE is in force. The certification system is operated by the European & Mediterranean Plant Protection Organization (EPPO), and it is based on a three-stage certification system viz., pre-basic, basic and certified material (<https://www.eppo.int/>).

In Canada, the production of quality planting material is managed by the Canadian Food Inspection Agency (CFIA) under Directive D-15-02. A systems approach for producing virus-tested grapevines for export to the USA and domestic use is outlined in this directive. The standards involve virus testing, field inspection, isolation distance, and vector control for minimizing the presence and spread of viruses. Plants produced under the scheme must originate from first-generation (G1) stock produced by the CFIA or approved facilities, and these original mother plants are tested for viruses and virus-like pathogens of concern as determined by the North American Plant Protection Organization (NAPPO) Standard No. 35.

The provisions of citrus bud wood certification established in Brazil in 1921 and state decreed in 1939 were adopted with certain modifications by other citrus producing countries including the USA. In the USA, the citrus budwood certification program was extended to 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 this programme, a Strategic Plan and Program 2021-2025 containing implementation guidelines for citrus, grapes, fruit trees, hops, rose, sweet potato and berries was developed by the Animal and Plant Health Inspection Service, US Department of Agriculture. As of 2021, the Network funded 47 collaborating programs with 34 Centres or locations in 20 States and territories (Fuchs et al., 2021). Under NCPN, clean plant material is made available to states for the production of certified clean planting material by private nurseries and certified producers. For grapevine, University of California, Cornell University, Wisconsin State University, Florida A & M University, Missouri State University and North Carolina State University have been identified as cooperating service centres for imports, diagnostics, pathogen elimination to produce clean propagation material and maintain blocks of pathogen-tested mother plants, and supply of basic clean material. These centres collaborate to provide products and services needed for specialized grape 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. In the USA, certified grapevine nuclear stocks are produced and maintained at Foundation Plant Services (FPS) of different universities. These certified nuclear stocks are then made available to nurseries and grape growers for further multiplication to produce quality planting material of grapevine. Grape Clean Plant network (CPN) in conjunction with members of core working group developed a grapevine testing scheme designated as “PROTOCOL 2010” (Rowhani and Golino, 2010). To qualify as Protocol 2010 plant material, the FPS source vines need to be generated using microshoot tip tissue culture techniques (0.5 mm or smaller meristematic dome) and these generated vines must test negative for more than 38 pathogens (viruses, phytoplasma and Pierce's Disease caused by *Xylella fastidiosa*).

Pathogen testing is done using PCR, ELISA, herbaceous and woody indexing.

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

V. PROPOSAL FOR PRODUCING CERTIFIED QUALITY GRAPEVINE PLANTING MATERIAL

The Department of Biotechnology, Govt. of India has notified a model certification system for tissue-culture plants under the Seeds Act 1966. The NCS-TCP was established in 2006 to promote the growth of the tissue culture industry in India and provide certified virus-free, and true-to-type tissue culture raised plants for growers to improve the productivity of the identified crops. Major components for production of certified virus-free grape planting material involve production and maintenance of virus-free source plants (rootstocks and varieties); and their further propagation for supply of healthy rootstocks, scion and plant material to growers. Therefore, standard operating procedures (SOPs) in accordance to Seeds Act 1966 and NCS-TCP need to be developed with the involvement of several stakeholders. Some components of the United States NCPN can also be integrated in the certification of grape planting material program in India.

A suggested operating procedure in India may start with quarantine cleared imported grapevine genotypes, identified domestic varieties/rootstocks and newly developed improved varieties/rootstocks. Highest level of genetic purity of the starting material shall be ascertained using important morphological characters and DNA fingerprinting. The selected grapevine genotypes then undergo a series of diagnostic procedures to ensure their disease freedom. If a genotype tests positive for any targeted pathogen, the pathogen is eliminated using meristem culture technique. The resulting mericlones are re-tested for their freedom from targeted pathogens. Once grapevines are free from target pathogens, they qualify as Nucleus Stock [Generation-1 (G-1)] grapevines. This Nucleus Stock material is maintained in double doored net houses following best management practices to avoid pest incidence and mechanical and vector mediated transmission of pathogens. G-1 grapevines are regularly visually inspected and continuously monitored and tested for target pathogens. Region specific G-1 varieties/rootstocks are further multiplied as foundation stock (G-2) by research institutions located in different regions following requirements as stipulated under Seeds Act 1966 and best sanitary and agricultural practices. G-2 material is annually inspected by the seed certification agencies of respective states to issue certification label. Registered nurseries purchase G-2 materials to establish their own mother blocks, from which they can produce G-3 and G-4 grapevines under best management practices as stipulated under Seeds Act 1966. The G-3 and G-4 grapevines undergo the certification process and the certified G-4 material is supplied to the grape growers. The proposed scheme is outlined in Table 4 and depicted in Figures 1 and 2.

Table 4. Proposed outline for producing certified virus-free grapevine planting materials in India.

Activity	Stakeholders	Responsibilities
Import	Indian Council of Agricultural Research- National Bureau of Plant Genetic Resources (ICAR-NBPGR), New Delhi	Strict quarantine clearance using traditional and modern diagnostic techniques such as ELISA, PCR and NGS
Training	Advance Centre for Virology, Indian Agricultural Research Institute (IARI), New	Training in grape virus testing Training in grape meristem culture and micropropagation

Activity	Stakeholders	Responsibilities
	Delhi ICAR Institute /University / Private firm having expertise in meristem culture/ Expertise from the United States	
Nucleus Stock (G-1)	ICAR-National Research Centre for Grapes (ICAR-NRCG), Pune Advance Centre for Virology, IARI, New Delhi (referral laboratory for virus testing)	<p>Production of true-to-type and disease-free nucleus rootstocks and varieties. Use of morphological characters and DNA fingerprinting for varietal purity; available methods for testing freedom from bacterial, fungal, insect and nematode pests; indicator plants, ELISA, PCR, NGS etc. for diagnosis of all viruses and viroids as given in Table-3; and meristem culture technique for eliminating viruses/viroids.</p> <ul style="list-style-type: none"> • Maintenance of “Nucleus Blocks” in double doored net houses following best management practices to avoid pest incidence and mechanical and vector mediated transmission of viruses. • Testing of all nucleus plants for freedom from diseases/pests/nematodes and viruses after every 5 years. • Record keeping and traceability of nucleus material through Bar Coding. • Supply of nucleus material (rootstocks and varieties) to produce foundation stock.
Foundation Stock (G-2)	<p>ICAR-IARI, New Delhi (for rootstocks and varieties grown in North India)</p> <p>ICAR-NRCG, Pune (for rootstocks and varieties grown in Central India)</p> <p>ICAR-Indian Institute of Horticultural Research (ICAR-IIHR), Bangalore (for rootstocks and varieties grown in South India)</p>	<ul style="list-style-type: none"> • Multiplication of nucleus stocks to produce foundation stock following requirements as stipulated under Seeds Act 1966 and best sanitary and agricultural practices. • Visual inspection of all multiplied plants for freedom from diseases, insect pests, nematodes and viruses. • About 5% randomly selected plants to be tested for freedom from leaf roll associated viruses. • Testing of maintained foundation stock for freedom from diseases/pests/nematodes and leaf roll associated viruses after every 5 years. • Annual inspection of multiplied material by seed certification agency of respective state and issue certification label. • Record keeping and traceability of registered stock material through Bar Coding • Supply of certified foundation stock material (rootstocks and varieties) to participating registered nurseries for production of Certified Planting Material.
Certified Planting Material	Voluntary registration by National Horticulture Board (NHB)-rated nurseries	<ul style="list-style-type: none"> • Multiplication of foundation stocks to produce certified planting material following requirements as stipulated under

Activity	Stakeholders	Responsibilities
(G-3 and G-4)	(above 2-star rating) in major grape producing districts as given below. Andhra Pradesh: Anantapur Karnataka: Bangalore, Kolar and Bijapur Maharashtra: Nashik, Sangli, Ahmednagar, Pune, Satara, Solapur and Osmanabad Mizoram: Champhai Tamil Nadu: Dindigul and Theni Telangana: Rangareddy and Medak	Seeds Act 1966 and best sanitary and agricultural practices. • Visual inspection of all plants for freedom from diseases, insect pests, nematodes and viruses. • Annual inspection of multiplied material by seed certification agency of respective state and issue certification label. • Record keeping and traceability of certified planting material through Bar Coding • Sell of certified rootstocks, budwood and/or rooted/grafted planting material to grape growers.

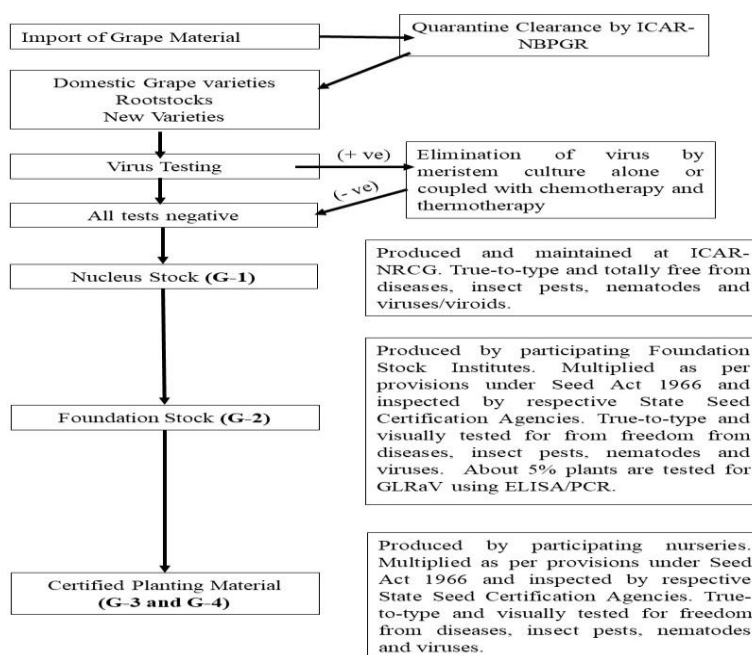


Fig. 1. Proposed scheme for production of certified quality planting material of grape in India.

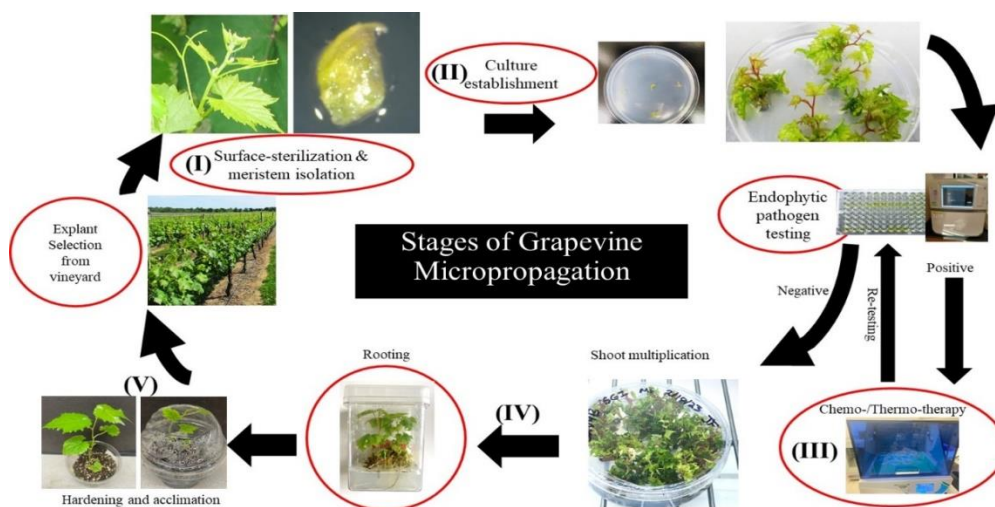


Fig. 2. Flow-chart for virus-freedom of grapevine using meristem culture and micropropagation.

VI. CONCLUSION

In addition to the development of a three-phase system for virus-free grapevine plant materials, it is paramount to develop extension and outreach programs that provide growers with education and awareness about virus prevalence in vineyards and management practices to mitigate their effects. Generation of an awareness and education among farmers and nurseries about benefits of production and use of quality planting material in vegetatively propagated crops like grape is likely to bridge the gap between demand and supply of grape planting material and also increase production, quality and productivity of grapes in India.

REFERENCES

- [1] P.G. Adsule and A. Upadhyay, 2004. *Package of practices for managing major diseases and insect pests on grapes*. Technical Bulletin No. 8. National Research Centre for Grapes, Pune. 21 p.
- [2] R.P.P. Almeida, K.M. Daane, V.A. Bell, G.K. Blaisdell, M.L. Cooper, E. Herrbach and G. Pietersen, 2013. Ecology and management of grapevine leafroll disease. *Front. Microbiol.* 4:94.
- [3] V.Z. Anatoly, V.V. Svetlana, A.B. Nadezhda, V.P. Elena, M.K. Anastasia and B.D. Boris, 2018. Methods for the Diagnosis of Grapevine Viral Infections: A Review. *Agriculture* 8:195. Available: <https://doi.org/10.3390/agriculture8120195>
- [4] APAARI, 2019. *Banana tissue culture in India: A Success Story*. Asia pacific association of Agricultural Research Institutions, Bangkok, Thailand. xvi+43 p.
- [5] APEDA, (2023, February). The agricultural and processed food products export development authority. Available: https://agriexchan-ge.apeda.gov.in/index/Product_description_32headChart.aspx?gcode=0205
- [6] M.F. Basso, T.V.M. Fajardo and P. Saldarelli, 2017. Grapevine virus diseases: Economic impact and current advances in viral prospect-ion and management. *Revista Brasileira de Fruticultura* 39(1). <https://doi.org/10.1590/0100-29452017411>
- [7] DA&FW, (2023, February). Department of Agriculture and Farmer's Welfare, Govt. of India. Available: <https://agricoop.nic.in/en/Stat HortEst#gsc.tab=0>.
- [8] DBT, (2023, July). Department of Biotechnology, Govt. of India. Available: <https://dbtncstcp.nic.in/>
- [9] FAOSTAT, (2023, February). FAO Web Page. Available: <http://www.fao.org/faostat>.
- [10] M. Fuchs, C.V. Almeyda, M.A.I. Rwahni, S.S. Atallah, E.J. Cieniewicz, K. Farrar, W.R. Foote, D.A. Golino, M.I. Gomez, S.J. Harper, M.K. Kelly, R.R. Martin, T. Martinson, F.M. Osman, K. Park, V. Scharlau, R. Smith, I.E. Tzanetakis, G. Vidalakis and R. Welliver, 2021. Economic studies reinforce efforts to safeguard specialty crops in the United States. *Plant Dis.* 105:14–26. Available: <https://doi.org/10.1094/PDIS-05-20-1061-FE>
- [11] M. Fuchs, 2020. Grapevine viruses: a multitude of diverse species with simple but overall poorly adopted management solutions in the vineyard. *J Plant Pathology* 102:643–653.
- [12] D.A. Golino, V. Savino, G.P. Martelli and M. Fuchs, 2015. Certification and international regulation of planting materials. In: *Compendium of Grapevine Diseases*. St Paul, APS Press.
- [13] V. Klimenko, I. Pavlova, V. Volodin and S. Gorislavets, 2020. Production of diseases - free plant materials of grapevine from phytopl-asma in vitro. *BIO Web of Conferences* 25: 05004. Available: <https://doi.org/10.1051/bioconf/20202505004>
- [14] S. Kumar, V.K. Baranwal, P. Singh, R.K. Jain, S.D. Sawant and S.K. Singh, 2012b. Letter to the Editor: Characterization of a Grapevine leafroll-associated virus 3 from India showing incongruence in its phylogeny. *Virus Genes* 45:195–200. Available: <https://doi.org/10.1007/s11262-012-0752-7>.
- [15] S. Kumar, S. D. Sawant, I. S. Sawant, K. Prabha, R. K. Jain and V. K. Baranwal, 2012a. First Report of Grapevine leafroll-associated virus 1 Infecting Grapevines in India. *Disease Notes*. Available: <https://doi.org/10.1094/PDIS-07-12-0647-PDN>
- [16] S. Kumar, R. Rai and V. K. Baranwal, 2017. Ampeloviruses Associated with Grapevine Leafroll Disease: A New Group of Viruses in India. In: Mandal, B., Rao, G., Baranwal, V., Jain, R. (eds) *A Century of Plant Virology in India*. Springer, Singapore. 9-26 pp. Available: https://doi.org/10.1007/978-981-10-5672-7_2.
- [17] M. Mani, N. S. Kulkarni, K. Banerjee and P. G. Adsule, 2008. *Pest management in grapes*. Extension Bulletin No. 2. National Research Centre for Grapes, Pune. 44 p.
- [18] NAAS, 2022. *Certification of Quality Planting Material of Clonally Propagated Fruit Crops for Promoting Agricultural Diversification, Policy Paper No. 107*, National Academy of Agricultural Sciences, New Delhi, 16 p.
- [19] P. S. Naik, and J. L. Karihaloo, 2007. *Micropropagation for Production of Quality Potato Seed in Asia-Pacific*. Asia-Pacific Consortium on Agricultural Biotechnology, New Delhi, India. 54 P
- [20] P. S. Naik, and S. M. P. Khurana, 2003. Micropropagation in potato seed production: need to revise seed certification standards. *J. Indian Potato Assoc.* 30: 267-273.
- [21] NHB (2023, March), National Horticulture Board, Government of India. Available: <https://nhb.gov.in/nursery/report/nurseryreport.aspx?enc=JFg4M7VAmRWST8gU62nUMw==>
- [22] A. J. Over de Linden, and E. E. Chamberlain, 1970. Production of virus-free grapevines in New Zealand. *New Zealand Journal of Agricultural Research* 13:991-1000.
- [23] A. Rowhani and D. A. Golino, 2010. Grapevine disease testing protocol-2010. Foundation Plant Services, FPS Grape Program Newsletter, October 2010. Pp 10-11.
- [24] A. Rowhani, J. K. Uyemoto, D.A. Golino and G.P. Martelli, 2005. Pathogen testing and certification of *Vitis* and *Prunus* species. *Annual Review of Phytopathology* 43: 261–278.
- [25] A. B. Sahana, C. R. Adkar-Purshothama, G. Chennappa, Z. Zang, M. Y. Sreenivasa and T. Sano, 2013. First report of Grapevine yellow speckle viroid-1 and Hop stunt viroid infecting grapevines (*Vitis vinifera*) in India. *Plant Disease* 97(11). Available: <https://doi.org/10.1094/PDIS-05-13-0494>
- [26] V. K. Sidharthan, A. M. Sevanthi, S. Jaiswal and V. K. Baranwal, 2020. Robust Virome Profiling and Whole Genome Reconstruction of viruses and viroids enabled by Use of Available mRNA and sRNA-Seq Datasets in Grapevine (*Vitis vinifera* L.). *Front. Microbiol* 11:1232. Available: <https://doi.org/10.3389/fmicb.2020.01232>
- [27] R. Smart, L. Mugnai and C. Lane, 2012. International viticultural consultant's view of grapevine trunk diseases and their impact on clients. *Phytopathologia Mediterranea* 51: 433–43.
- [28] R.G. Somakuwar, and P.G. Adsule, 2004. *Grape cultivation on rootstock*. Technical Bulletin No. 5. National Research Centre for gra-

- pes, Pune. 23 P.
- [29] R. K. Trivedi and M. Gunasekaran, 2013. *Indian Minimum Seed Certification Standards*. The Central Seed Certification Board, DAC, MoA, Govt. of India. 605 P.
- [30] L.A. Von Broembsen and A.T.C. Lee, 1988. South Africa's citrus improvement programme. *International Organization of Citrus Virologists Conference Proceedings (1957-2010)*, 10. Available: <https://doi.org/10.5070/C516N4C38Q>
- [31] M.R. Wang, Z.H. Cui, J.W. Li, J.W. Hao, X.Y. Zhao, L. Zhao and Q.C. Wang, 2018. In vitro thermotherapy-based methods for plant virus eradication. *Plant Methods* 14:87. Available: <https://doi.org/10.1186/s13007-018-0355-y>

AUTHOR'S PROFILE



First Author

Dr Sharmistha Naik, is Scientist (Fruit Sciences) at ICAR-National Research Centre for Grapes, Pune. Her areas of research had been collection, documentation, geotagging and morphogenetic characterization of grape genotypes from Himachal Pradesh, grape biotechnology, grapevine tissue culture and grapevine improvement through mutagenesis She is recipient of Merit Certificates for B.Sc. and M.Sc. from Dr. YS Parmar University of Horticulture & Forestry, Nauni, Solan and Young Scientist Award (2020-2021) from Agro Environmental Development Society, Rampur (UP), India.



Second Author

Dr Kaushik Banerjee is the Director of ICAR-National Research Centre for Grapes, Pune. His area of research focuses on the development of efficient analytical methods for the sensitive and confirmatory estimation of pesticide residues and mycotoxins in agricultural and food matrices, and risk assessment studies for fixation of crop-specific MRLs. Being a member of the Scientific Panels of FSSAI, he regularly contributes to the development and implementation of food safety standards in India. He is also the Chairman of the India section of AOAC International. Dr Banerjee's extensive contributions to science and community have earned him numerous national and international laurels, and fellowships of the Royal Society of Chemistry, the National Academy of Agricultural Sciences, ICAR, and West Bengal Academy of Science & Technology.



Third Author

Dr. Sadanand A. Dhekney, is a Professor of Plant Biotechnology in the Department of Agriculture, University of Maryland Eastern Shore. Dr. Dhekney's research is focused in the area of grapevine biotechnology for the past 18 years with expertise in genetic improvement using precision breeding and genome editing. Dr. Dhekney has developed several protocols in grapevine tissue culture and transformation. Dr. Dhekney has received the 2013 Young Scientist Award from the Society for in Vitro Biology, the 2016 Early Career Research Achievement Award from the University of Wyoming and the 2017 Excellence in Research and Teaching award from the National Agricultural Honor Society, Gama Sigma Delta.