E-book

"SUSTAINABLE VITICULTURE: SOLUTIONS TO STRENGTHEN LOCAL AND GLOBAL TRADE"

Edited by, N A Deshmukh, P H Nikumbhe, S Naik, S K Holkar, K Banerjee and Dr. B Venkata Rao

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E-BOOK

ON

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Sustainable viticulture: Solutions to strengthen local and global trade

Editors: NA Deshmukh, PH Nikumbhe, S Naik, S K Holkar, K Banerjee and B Venkata Rao

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भाकृअनुप-राष्ट्रीय अंगूर अनुसंधान केन्द्र
ICAR-NATIONAL RESEARCH CENTRE FOR GRAPE

Preface

Grape cultivation is a vital sector of Indian agriculture, contributing significantly to both domestic and international trade. During the 2023-2024 season, India exported approximately 343,982.34 metric tonnes of grapes, generating revenue of ₹3,460.70 crores ($417.07 million USD). Europe remains India's primary export destination, with the UK, Lithuania, and the Netherlands being key markets. India competes in the global grape industry alongside leading exporters such as Peru, Chile, China, and the USA.

In India, grape production is largely concentrated in Maharashtra and Karnataka, accounting for nearly 95% of the total output. Unlike Western countries where a significant share of grapes is used for wine production, India's consumption pattern is different as 70% of grapes are consumed fresh, 28% are processed into raisins, and the remaining portion is used for wine and juice production.

Currently Indian grape industry faces challenges such as high production costs, environmental and biological stresses, quality management, and post-harvest losses. These factors directly impact growers profitability, making it essential to adopt sustainable and innovative solutions to enhance both local and global trade opportunities.

This e-book, titled “Sustainable Viticulture: Solutions to Strengthen Local and Global Trade,” provides insights into entrepreneurial opportunities in grape industry. Key topics covered include nursery establishment, cost-efficient production practices, market intelligence, value addition, residue management, formation of Farmer Producer Companies (FPCs) and Farmer Producer Organizations (FPOs). Additionally, the book explores emerging technologies such as decision support systems offering solutions to improve sustainability and profitability.

I hope that this publication serves as a valuable resource for farmers, entrepreneurs, researchers, and industry professionals, equipping them with the knowledge and strategies needed to drive innovation and long-term sustainability in the grape sector.

Kaushik Banerjee
Director

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Chapter-1

Pesticide residue monitoring strategies for nurturing sustainable grape production

Kaushik Banerjee

Director, ICAR- National Research Centre for Grapes, Pune

Introduction

Grapes are among the most widely grown fruits worldwide, consumed both fresh and in the processed forms (wines, raisins). In India Grape production is an essential agricultural activity. It contributing to both domestic consumption and export market, with significant economic and nutritional benefits. The world's population is predicted to reach over 10 billion by 2050. According to a recent evaluation by the Food and Agricultural Organisation (FAO) of the United Nations, the global food supply must increase by 70% in order to fulfil the rising demand of the world's population. Ultimately the ever-increasing population has given the burden on the current agricultural system to meet the food demands using the available resources such as land water and natural resources. At present crop output can be increases only by applying the herbicides, pesticides, insecticides, higher doses of fertilizers and soil amendments.

However, extensive use of pesticides to combat pests and diseases poses a significant challenge to the quality and safety of grapes. Pesticide residues in grapes can have negative impacts on human health and the environment, making it crucial to develop effective monitoring strategies. By understanding the number of important risk factors associated with pesticide accumulation in grapes, In India, Agricultural and Processed Food Products Export Development Authority (APEDA) has implemented a number of internal monitoring mechanisms for domestic and international control. As an export development organisation founded in 1985 by the Ministry of Commerce and Industry (under the APEDA Act of the Government of India), APEDA has developed and implemented analytical methods and quality control procedures to monitor pesticide levels in various food matrices, including grapes and to assess risks to human health for nearly two decades.

In agriculture large number of classes of pesticides is used, they are varying according to their nature, use and chemical structure. The mostly used classes of pesticides in grapes are given in the figure 1.

The export of Indian grapes to EU countries was severely restricted in 2003–04, due to pesticide residues found in Indian grapes that were found to be over the EU-MRLs,

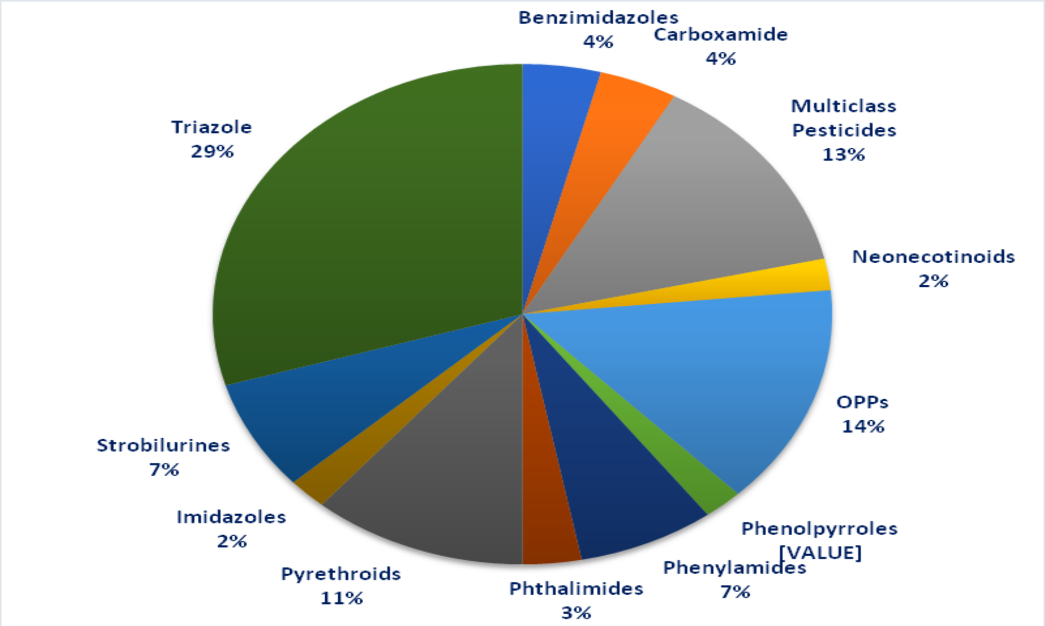

Fig 1. Classes of pesticides (Foods, 2022, 11, 1623.)

particularly in Monocrotophos and methomyl. As a corrective measure, EU authorities advised the Indian government to establish a food safety traceability system for monitoring pesticide residues in grapes before resuming exports in the following (2004-05) harvest season. Being a crop-specialised institution, ICAR's NRCG was designated as the National Referral Laboratory (NRL) to set up a system for tracking, managing and testing pesticide residues in grapes for export in 2004. Under this system, the NRL facilitates the development of various guidance documents for monitoring pesticide residue by farmers at the farm, along with other activities related to sample collection, until the residue analysis test reports are released by commercial food testing laboratories. Additionally, it finalises the list of pesticides to be monitored in consultation with various stakeholders.

Besides, NRL aims to develop protocols for the sampling and multi residue analysis of targeted pesticides. It helps all commercial testing laboratories building capacity by harmonising testing protocols, training their personnel and organising proficiency testing throughout the year. To promote stakeholders' awareness, NRL issues internal alerts as and when any grape sample fails to meet EU-MRL standards. The process of internal alert automatically blocks the next steps of A-Mark Grading and Phytosanitary certification, without which customs clearance is impossible. This way, the system allows the export of only MRL-complaint consignments, as evidenced by the low number of rapid alerts for grape consignments over the last decade.

The NRL-NRCG has been contributory in the development of multiple innovative high-throughput analytical methods for the analysis of multiclass pesticides in grapes. The institute has enhanced numerous existing AOAC Official Methods to meet the specific requirements of Indian food matrices prior to implementing them for routine analysis following appropriate validation. The methods involve optimisation of effective sample preparation workflows, followed by confirmatory analysis using advanced mass spectrometry (e.g. GCMS/MS and LC-MS/MS). A system like this one not only regulates the quality of grapes but also reduces the risk of commercial failure. Numerous food testing laboratories across the nation have successfully adopted these procedures for their straightforward workflow, selectivity, sensitivity, robustness, throughput and cost-effectiveness. By utilising readily available NRL proposed methods that are suitable for supporting domestic and international trade, these laboratories can also save time and money. Efforts are also being made to introduce automated workflows not only for superior precision in analysis but also to support human health. These cutting-edge testing technologies have seen widespread implementation all over the country in laboratories that analyse food.

Pesticide Residue Monitoring in Grape Export involved following steps:

i) Sampling and Testing: Regulatory authorities and export promotion councils may conduct sampling and testing of grape samples to monitor pesticide residues. Samples are collected from farms, packing houses, or export consignments and analyzed for pesticide residues using accredited laboratories.

ii) Certification and Documentation: Exporters are required to provide certificates of analysis certifying compliance with MRLs and other regulatory requirements. Documentation may include details of pesticide use, application practices, and pre-harvest intervals.

iii) Export Inspection and Control: Export consignments of grapes may undergo inspection and testing by designated authorities to verify compliance with regulatory standards. Non-compliant shipments may be rejected, detained, or subject to corrective actions.

Advanced Analytical Methods for Pesticide Residue Monitoring

Advanced analytical methods, such as Quick, Easy, Cheap, Effective, Rugged, and Safe (QuEChERS), Solid-Phase Micro-Extraction (SPME), pressurized liquid extraction (PLE), dispersive liquid-liquid micro extraction (dLLME), and assisted dispersive liquid-liquid micro extraction method (ADLL-ME), have been developed for the detection and quantification of pesticide residues in grapes. These methods offer several advantages, including reduced sample preparation time, lower solvent consumption, and increased sensitivity and accuracy. However, the implementation of these methods in India requires further research and investment.

Sample Preparation Methods for Pesticide Residue Monitoring

Sample preparation is a critical step in pesticide residue monitoring. The QuEChERS method has become widely used due to its micro-scale extraction procedure, which requires less time and less organic solvent. This method involves acetonitrile in the extraction process for effective extraction, which can be separated from salt before final purification. However, the method requires further optimization for the analysis of pesticide residues in grapes.

Separation and Identification Methods for Pesticide Residue Monitoring

The most used methods for separation and identification of pesticides in grapes include gas chromatography (GC), liquid chromatography (LC), and mass spectrometry (MS). These methods offer high sensitivity and selectivity, enabling the detection of multiple pesticides in a single sample. However, the implementation of these methods in India requires further research and investment.

Pesticide Residue Monitoring using Gas Chromatography:

In the realm of agricultural productivity and food safety, the monitoring and control of pesticide residues in food products play a pivotal role. Pesticides are essential for crop protection, but their residues in food can pose serious health risks if they exceed safe levels. Gas Chromatography-Mass Spectrometry/Mass Spectrometry (GC-MS/MS) has emerged as a powerful analytical technique for the separation and identification of pesticide residues in food samples due to its sensitivity, selectivity, and accuracy. This paragraph explores the advancements in separation and identification methods within GC-MS/MS for pesticide residue monitoring.

A popular separation method for analysing pesticide residue is gas chromatography (GC). Based on their volatility and affinity for the stationary phase inside the chromatographic column, pesticide compounds are separated using this method. The study of complex pesticide combinations is made possible by improved column technologies, such as capillary columns with distinct stationary phases, which have improved peak separation and resolution.

Pesticide residues can be identified and quantified with great effectiveness using mass spectrometry. In GC-MS/MS, analytes are fragmented and ionised in the mass spectrometer subsequent to GC separation. The resultant mass spectra offer distinct fingerprints for every chemical, making precise identification possible even in intricate matrices.

Tandem Mass Spectrometry (MS/MS): When compared to single-stage MS, GC-MS/MS provides improved selectivity and sensitivity. In tandem MS, particular product ions are chosen for additional examination in the second step after precursor ions are initially chosen and fragmented. This increases the accuracy of results by making it possible to identify low-level pesticide residues in the midst of loud background noise.

Fig 2: LC MS/MS instrument

Because GC-MS/MS offers extremely sensitive and selective separation and identification techniques, it has completely transformed the field of pesticide residue monitoring. New sample preparation methods combined with instrumentation advancements keep pushing the frontiers of analytical accuracy and detection limits. In an agricultural environment that is becoming more complicated, these developments are essential for guaranteeing food safety and regulatory compliance. GC-MS/MS will continue to lead the way in pesticide residue analysis as technology advances, preserving environmental sustainability and public health.

Pesticide Residue Monitoring using Liquid Chromatography:

The monitoring of pesticide residues in food products is paramount for ensuring food safety and protecting public health. Liquid Chromatography-Mass Spectrometry/Mass Spectrometry (LC-MS/MS) has emerged as a cornerstone analytical technique for the separation and identification of pesticide residues in various food matrices. This article delves into the advancements in separation and identification methods within LC-MS/MS for pesticide residue monitoring.

Because pesticide chemicals have different affinity for the stationary phase in the chromatographic column, LC separates them. Ultra-high-performance liquid chromatography (UHPLC), one of the most recent developments in LC technology, has greatly increased the speed, resolution, and efficiency of separation. Furthermore, selectivity is improved by the creation of specific stationary phases designed for pesticide analysis, enabling the separation of intricate combinations of pesticide residues.

SPE, or solid-phase extraction: Sample preparation is frequently carried out utilising SPE to extract and concentrate pesticide residues from food samples prior to analysis by LC-MS/MS. The sensitivity and dependability of pesticide residue analysis are increased by advances in SPE techniques, which expedite the procedure, increase extraction efficiency, and reduce matrix effects. Examples of these advancements include the use of innovative sorbents and automated sample preparation systems.

In LC-MS/MS, after separation by LC, analytes are ionized and fragmented in the mass spectrometer. The resulting mass spectra provide characteristic fragmentation patterns for each compound, enabling accurate identification and quantification of pesticide residues in complex matrices. LC-MS/MS offers enhanced selectivity and sensitivity compared to single-stage MS. In tandem MS, precursor ions are selected in the first stage, fragmented, and specific product ions are selected for further analysis in the second stage. This allows for the detection and quantification of pesticide residues at trace levels, even in the presence of interfering matrix components, ensuring reliable results for regulatory compliance.

Pesticide residue monitoring has been entirely changed by LC-MS/MS, which provides extremely sensitive, effective, and efficient separation and identification techniques. The limitations of detection limits and analytical capabilities are constantly being pushed by developments in instrumentation, sample preparation methods, and data analysis procedures. These developments are crucial for safeguarding the integrity and safety of the world's food supply chain as well as shielding the general public's health from the dangers posed by pesticide residues. LC-MS/MS will continue to be a vital analytical technique in the analysis of pesticide residues as technology develops, propelling continued improvements in the regulation and enforcement of food safety.

Regulation of Pesticide Residue Monitoring in Indian Grape Export

The regulation of pesticide residue monitoring in grape export is crucial for ensuring the safety and quality of grapes. By adhering to international standards, implementing effective monitoring programs, and fostering collaboration between exporting and importing countries, the grape industry can uphold regulatory compliance, protect consumer health, and sustain global trade relationships. Continued vigilance and investment in monitoring and regulatory infrastructure are crucial to address emerging challenges and maintain the integrity of the grape export market. The Agricultural and Processed Food Products Export Development Authority (APEDA) has developed a regulation for the control of pesticide residues in the export of fresh grapes to the European Union. The regulation includes a procedure for monitoring pesticide residues in water at grape farms and pack houses, as well as a surveillance system for controlling residues of pesticides allowed/recommended by National Research Centre for Grapes for cultivation of grapes. However, the regulation requires further enforcement and monitoring to ensure compliance.

Regulatory Authorities in India:

a) Food Safety and Standards Authority of India (FSSAI) is the apex regulatory body responsible for regulating and supervising food safety and standards in India. It formulates regulations, standards, and guidelines related to pesticide residues in food products, including grapes.

b) Ministry of Agriculture and Farmers Welfare: The Ministry of Agriculture oversees agricultural production, including pesticide use regulations and registration of pesticides. It collaborates with FSSAI to ensure that pesticides used in grape cultivation comply with safety standards.

Regulatory Framework in India:

i) Maximum Residue Limits (MRLs): FSSAI establishes MRLs for pesticide residues in grapes and other food commodities based on scientific risk assessments. These MRLs specify the maximum allowable concentrations of pesticide residues that are deemed safe for human consumption.

ii) Pesticide Registration: Before pesticides can be used in grape cultivation, they must be registered with the Central Insecticides Board and Registration Committee (CIBRC) under the Ministry of Agriculture. Registration involves evaluation of pesticide efficacy, safety, and environmental impact.

iii) Good Agricultural Practices (GAP): FSSAI promotes the adoption of GAP by grape growers to minimize pesticide residues in produce. GAP encompasses practices such as integrated pest management, judicious pesticide use, adherence to application guidelines, and pre-harvest intervals.

Future Possibilities and Trends in Pesticide Residue Monitoring

Monitoring for pesticide residues is crucial to global efforts to ensure food safety and regulatory compliance. New methods and technology are desperately needed to improve monitoring capacities as concerns about pesticide levels in food keep growing. This article examines potential developments that could completely transform the field of pesticide residue monitoring, as well as emerging trends in the sector.

The future of pesticide residue monitoring in grape production in India lies in the development of more comprehensive and effective monitoring strategies. This includes the adoption of rapid and high-throughput techniques, advancements in analytical instrumentation such as UHPLC and HRMS, development of multi-analyte and multi-matrix methods, block chain technology for traceability and transparency, implementation of advanced analytical methods, the optimization of sample preparation methods, and the strengthening of regulatory frameworks for pesticide residue monitoring in grape export. Additionally, there is a need for increased awareness and education among farmers and consumers about the risks and impacts of pesticide residues in grapes.

Summary:

Pesticide residue monitoring is crucial for ensuring the safety and quality of grape production in India. The implementation of advanced analytical methods, the optimization of sample preparation methods, and the strengthening of regulatory frameworks for pesticide residue monitoring in grape export can contribute to sustainable and safe grape production. However, further research and investment are required to develop more comprehensive and effective monitoring strategies. Additionally, increased awareness and education among farmers and consumers about the risks and impacts of pesticide residues in grapes are essential for promoting sustainable and safe grape production in India. Recent studies have examined pesticide residue levels in grapes, revealing challenges with current analysis equipment. Typically, these tools demand large sample volumes, come with hefty price tags, require various organic solvents, and entail lengthy analysis times. Various solvents like acetonitrile, ethyl acetate, and acetone have been utilized in these analyses. However, among the prevalent sample preparation methods for grape analysis, QuEChERS, SPME, and SPE stand out. SPME, being eco-friendly, avoids organic solvents altogether.

Analytically, LC and GC are commonly employed for separation, often coupled with MS or MS/MS (QqQ) for highly sensitive identification and quantification. GC coupled with MS offers rapid detection, efficient separation, and user-friendly operation, making it particularly suitable for pesticide analysis in grapes. Detectors like MS/MS and QqQ excel in sensitivity, capable of detecting low pesticide concentrations. However, their widespread use is hindered by their high cost. Currently, there is no widely accepted method for assessing pesticide residues in grapes. This is a challenging task due to the large number of pesticides from diverse chemical classes, as well as the fact that these analytical approaches should apply in several countries with different opportunities. The future development of analytical methods requires enabling the rapid, sensitive, cheaper and easy to use analysis of pesticides in grape.

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Chapter-2

Quality planting material production in grape

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Introduction

India's grape industry has shown significant growth, with 1.6 lakhs hectares of cultivation area and an annual production of 34.80 lakh tons, averaging 21.75 tons per hectare. Over the past two decades, from 2000 to 2021, the annual compound growth rates (ACGRs) for grape cultivation area, production, and productivity have been 6.35%, 5.07%, and -1.2% respectively, indicating robust expansion in cultivation area and production, despite a concerning decline in productivity. Factors such as domestic demand, export opportunities, and technological advancements have been key drivers of this growth. However, challenges like climate vulnerabilities, quality standards, and sustainability issues persist.

Maharashtra and Karnataka are pivotal grape-growing states in India, collectively contributing over 95% of the total acreage and production. India's status as a major exporter of table grapes further highlights the sector's importance, with approximately 0.27 million tons of grapes exported in 2021-22, valued at 2303 crores. The export growth trajectory has been impressive, with an ACGR of 12.36%. This expansion in grape exports has been accompanied by a rise in domestic consumption, necessitating an increase in grapevine cultivation area to meet growing demand.

Maharashtra and Karnataka's dominance in grape production, along with India's flourishing export market and rising domestic consumption, highlight the dynamic evolution and significance of the grape industry in the country. Continued investment in research, innovation, and sustainable farming practices is crucial for enhancing the resilience and competitiveness of India's grape industry and ensuring its continued contribution to the agricultural economy.

Theoretical Requirement of Grapevine Planting Material in India is 50 crore Plants Per Annum

- The grape industry in India faces the ongoing challenge of replanting old and senile vineyards to maintain productivity and quality.

- The average lifespan of a vineyard is estimated at 15 years, necessitating approximately 6.7% of old vineyards, equivalent to about 10,700 hectares, to be replanted annually.
- To accomplish this, a significant quantity of quality planting material is essential.
- At a planting density of 2400 plants per hectare, approximately 25 crore high-quality plants are needed annually to effectively rejuvenate these aging vineyards.
- Additionally, to accommodate the expansion of grape cultivation, spurred by the current annual compound growth rate (ACGR) of 6.35% for the area under grape cultivation, an estimated 10,300 hectares of new vineyard area are expected to be established.
- This expansion would necessitate an additional 25 crore high-quality planting materials.
- Ensuring a sufficient supply of quality planting material is critical to sustain and support both the rejuvenation of existing vineyards and the establishment of new ones.
- This is crucial for fostering the growth and vitality of India's grape industry.

Methods of Planting Material Production in India

Primarily sourced from specialized nurseries or propagated by farmers through hardwood cuttings and grafting.

Hardwood cuttings

- Hardwood cuttings are obtained from vigorous and high-yielding vines aged 3 to 4 years.
- Cuttings are typically 30-45 cm long with 3-4 nodes, selected from the middle portion of the cane.
- Precision in preparation is crucial, with straight transverse cuts made below the node and slanted cuts above the top bud.
- Lower portion of the cutting is treated with a solution containing 1000-1500 ppm Indole-3-butyric acid (IBA) to enhance rooting.
- Cuttings are planted directly in the ground on raised beds or transferred into plastic bags for rooting and further development.

Grapevine Grafting:

- Utilizes high-quality scion and rootstock material.

- Various rootstocks like 110 Richter, 140 Ruggeri, 1103 Paulsen, SO4, St. George, Dogridge, 1613, and Ramsey are preferred for their tolerance to drought and salinity.
- Dogridge is particularly popular for grafting in India.
- Techniques such as V-notch and chip bud grafting are commonly employed, using one-year-old scion wood and 7-10-month-old rootstocks.

Issues in Production of Quality Planting Material in Grapevine

- Current demand for planting material met largely by private nurseries and farmers propagating vines from existing vineyards.
- Lack of systems for detecting and eliminating pathogens in propagation materials poses a risk to vineyard health and productivity.
- Improved practices and regulations needed to ensure quality and disease-free nature of grapevine planting material in India.

Current Scenario of Grapevine Planting Material Production in India

The process is primarily facilitated by only five National Horticulture Board (NHB) accredited nurseries, indicating a limited number of sources for grape planting material in India.

These accredited nurseries include:

1. Centre of Excellence for Fruits in Punjab (production capacity: 1000 plants per year)
2. Grape Farm in Maralia, Jammu & Kashmir (production capacity: 33500 plants per year)
3. Model Vineyard in Lar,Jammu & Kashmir (production capacity: 16200 plants per year)
4. VNR Nursery Pvt. Ltd in Malpuri, Chhattisgarh (production capacity: 7000 plants per year)
5. ICAR National Research Centre for Grapes (NRCG)

Despite accreditation, the total combined capacity of nurseries in the region remains relatively low, amounting to just 57,700 plants per year. This limitation is exacerbated by the geographic distance from grape-growing areas, presenting a significant challenge to accessibility and distribution of planting material. Consequently, a considerable portion of grape planting material is sourced from local nurseries lacking accreditation from the National Horticulture Board (NHB), or directly propagated by farmers themselves. This reliance on non-accredited nurseries and farmer propagation underscores a gap in the availability and distribution of accredited planting material, hindering the overall efficiency and quality of grape cultivation in the region.

Losses due to Virus in Grapes

Absence of Economic Studies on Virus Infections in Indian Vineyards:

- Lack of studies examining the economic impact of virus infections in Indian vineyards.
- Contrastingly, research from the United States highlights significant financial losses caused by viruses like Grape leaf roll associated virus (GLRaV).

Financial loss due to Virus Infections:

- Almeida et al. (2013) reveal substantial losses ranging from Rs. 20.50 lakh to Rs. 2.0 crores per hectare over a 25-year vineyard lifespan due to GLRaV.
- Fuchs et al. (2021) report staggering annual losses of Rs. 738 crores in California attributed to leafroll disease.

Mitigation Strategies:

- Utilization of virus-free planting material crucial in reducing the risk of virus spread.
- Strict sanitary measures, including regular inspection and removal of infected vines, essential for controlling virus spread.
- Cultural practices aimed at minimizing vector populations also contribute to virus control efforts.

Importance of Proactive Measures:

- Proactive measures vital for preventing and controlling viral infections to safeguard economic viability and sustainability of grape cultivation in India and globally.
- Emphasis on certified virus-free planting material and rigorous sanitary practices crucial for mitigating economic losses associated with viral infections in vineyards.

Factors needed to produce quality planting material

➢ **True-to-Type Scion and Rootstock Genotypes:**

- Verification of genetic integrity is crucial in grapevine propagation.
- Major ampelographic descriptors and a core set of 6 SSR markers recommended by the International Organisation of Vine and Wine (OIV) are utilized for this purpose.
- These tools help ensure the authenticity and purity of scion and rootstock genotypes, maintaining desired cultivar characteristics.

➢ **Disease Freedom:**

- Chemical pesticides are commonly used to combat fungal/bacterial diseases and insect pests on mother plants.

- These pesticides help eliminate pathogens and pests, safeguarding the health and quality of grapevine planting material.
- Despite pesticide usage, grapevines remain susceptible to viral and viroid infections.

➢ **Viral and Viroid Infections**

Viruses are difficult to detect visually. Their presence is detected using ELISA, PCR and indicator plantGrapevines are susceptible to a wide array of viruses and viroids globally, with over 86 identified strains posing potential threats. In India specifically, 15 viruses and viroids have been documented in grapevines, indicating a significant presence of these pathogens in local cultivation. Among the most concerning are infections caused by Grape leaf roll associated viruses (GLRaV), which can severely impact grape yields and quality. To mitigate these risks, stringent measures are imperative, including the adoption of virus-free planting material and the implementation of rigorous sanitary practices throughout vineyard management. Such proactive steps are essential to safeguarding grape cultivation from the detrimental effects of viral infections and ensuring the long-term sustainability of the industry.

Virus Testing and Elimination

Meristem Culture for Virus Elimination:

- The meristem, a metabolically active and rapidly growing tissue in plants, lacks vascular bundles within its dome, typically measuring between 0.1 to 0.2 mm.
- Plants developed from meristematic domes in tissue culture are generally devoid of viruses, as the absence of vascular bundles hinders viral movement.
- Meristem culture, when combined with thermotherapy and chemotherapy, further enhances the elimination of viruses from plant tissues.

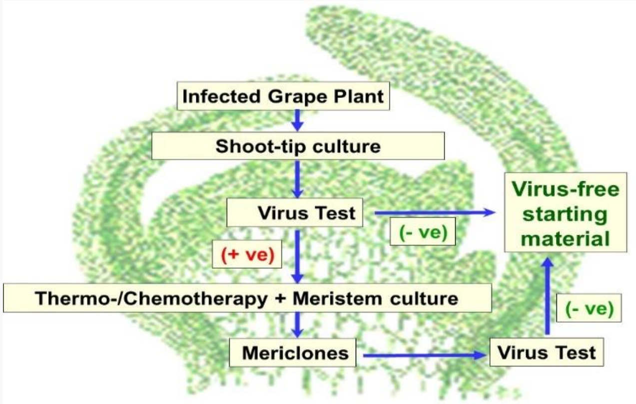

Fig 1. Virus testing and elimination

- Thermotherapy involves subjecting plant tissues to elevated temperatures to deactivate viruses, while chemotherapy entails treating tissues with antiviral chemicals.

Enhancing Virus-Freedom:

- The combination of meristem culture, thermotherapy, and chemotherapy offers an effective means of ensuring the production of virus-free plants.
- By eliminating viruses from the initial plant material, subsequent generations of plants derived from meristem culture are inherently virus-free.

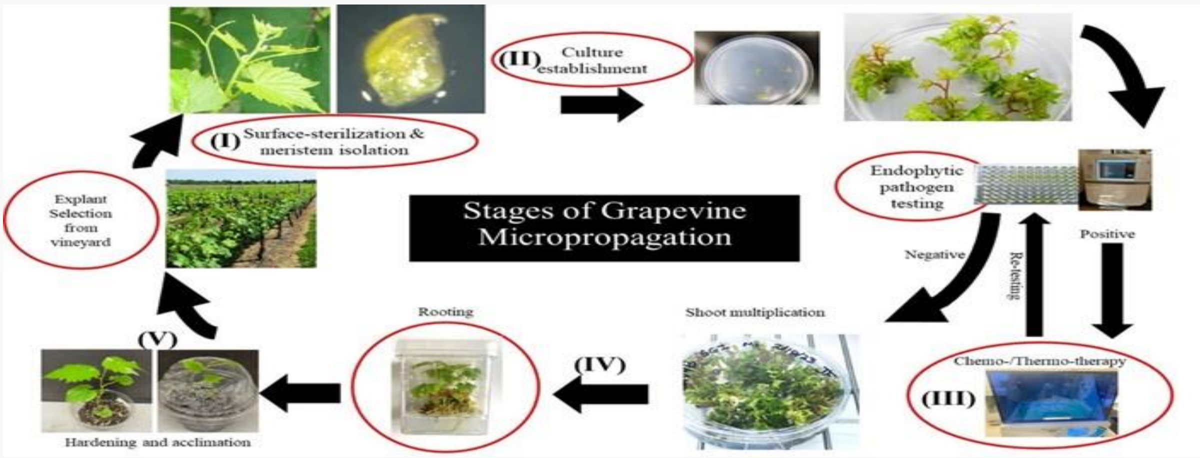

Fig 2. Flow-chart for virus-freedom of grapevine using meristem culture and micro-propagation

Micro-propagation in Tissue Culture:

- Virus-free plants obtained from meristem culture can be further multiplied through micro-propagation in tissue culture.
- Tissue culture techniques involve culturing small plant tissue samples in a nutrient-rich medium under controlled conditions, allowing for rapid multiplication of plant material.
- Micro-propagation enables the efficient production of large numbers of genetically identical, virus-free plants, providing growers with a reliable source of healthy planting material.

Certification Standards for Planting Material in India:

In India, the Indian Minimum Seed Certification Standards established in 1966 provided basic guidelines for grape cultivation, focusing on aspects like land requirements and field inspection. However, specific standards for grapevine were limited. In 2006, the National Certification System for Tissue Culture Raised Plants (NCS-TCP) was introduced, aiming to improve plant material quality through accrediting tissue culture facilities and implementing virus testing protocols. While elaborate standards were established for crops like potato, banana, sugarcane, apple, and citrus under NCS-TCP, grapevine lacked specific standards.

This gap underscores the need for tailored certification standards to ensure high-quality grapevine planting material and enhance the sustainability of the grape industry in India.

QUALITY PLANTING MATERIAL OF GRAPE: INTERNATIONAL SCENARIO

Major grape growing regions of world have established and implemented stringent phytosanitary measures in grapevines and to restrict the entry and spread of viral pathogens.

Argentina and Chile:

- Certification procedures established in Argentina in 2001 and in Chile in 2007.
- Nuclear stocks are certified in countries, ensuring quality and authenticity of planting material.

New Zealand:

- Developed Grafted Grapevine Standards and associated certification program.
- Standards aim to maintain high quality and integrity of grafted grapevines.

European Union:

- First Directive 68/193 issued in April 1968 on the "Marketing of Vegetatively Propagated Material of Grapevines".
- Propagative materials categorized as "basic", "certified", "standard", with defined sanitary characteristics of mother vineyards.

Canada:

- Canadian Food Inspection Agency (CFIA) manages production of quality planting material.
- Implements systems approach for producing virus-tested grapevines, ensuring quality for export to the USA and domestic use.

South Africa:

- Established certification program under the "Superplant Scheme" to develop certified planting materials by nurseries, focusing on rootstocks and budwoods.

USA:

National Clean Plant Network (NCPN) safeguards fruit trees, hops, grapes, and other clonally propagated crops from economically harmful pests and diseases.

- National Clean Plant Network (NCPN) established in the USA for protection against economically harmful pests and diseases.
- NCPN provides clean plant material to states for certified planting material production.
- Universities serve as cooperating service centres for grapevine under NCPN.
- Functions include imports, diagnostics, pathogen elimination, maintenance of pathogen-tested mother plants, and supply of clean material.

- Each scion or budwood source tree is identified for tracking purposes.
- Regular testing ensures freedom from virus diseases for registered scions and rootstocks.
- Certified nuclear stocks available to nurseries for further multiplication.

Proposed Certification Standards for Grapevine Planting Material in India

Nucleus Stock:

- Operated by ICAR-NRCG following NSC-TCP (2006) guidelines.
- Fidelity testing conducted using morphological characters and SSR markers to ensure genetic purity.
- Comprehensive virus testing performed against all reported viruses in India.
- Meristem culture and micro-propagation employed for virus elimination.
- Multiplication of nucleus stock carried out under protected conditions to maintain purity.
- Guaranteed true-to-type and free from diseases, insect pests, nematodes, and viruses.

Foundation Stock:

- Managed by ICAR-IARI (north Indian varieties & rootstocks), ICAR-NRCG (central Indian varieties & rootstocks), and ICAR-IIHR (south Indian varieties & rootstocks).
- True-to-type and visually inspected for freedom from diseases, insect pests, nematodes, and viruses.
- About 5% of plants tested for GLRaV freedom using ELISA/PCR, with a requirement of 100% freedom from GLRaV.
- Certified nurseries produce foundation stock for further propagation.

Certified Planting Material:

- Produced by participating nurseries across different regions.
- More nurseries needed in Maharashtra, Karnataka, Andhra Pradesh, Telangana, Tamil Nadu, and Mizoram to meet demand.
- True-to-type and visually inspected for freedom from diseases, insect pests, nematodes, and viruses.
- Complies with Seed Act (1966) regulations to ensure quality and authenticity.

A three-stage system, aligned with the Seed Act 1966 and NSC-TCP 2006, is proposed for quality grapevine planting material production. Extension programs are vital for educating growers about virus prevalence and its impact on productivity. Successful implementation will help Indian growers maintain healthy vineyards, ensuring high grape and wine

Chapter-3

Canopy management practices for production of quality grapes

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Introduction

Grapevine is a climber. It has indeterminate growth with weak stem. It needs support not only for the weight of its aerial parts and fruits but also for maintaining the canopy architecture. The trellis and the system of training shape the canopy architecture of vines. The fabricated structure used for training the vines is called the trellis while the process of shaping the canopy is called training. The way a grapevine is trained does not only influence the vine growth, productivity and quality but also brings about variation in microclimate. Canopy management starts with the use of cultivar, vineyard site, seasonal climate, inputs and the trellis system. Canopy management of grapevines deals with the development and maintenance of their structure in relation to size and shape for maximum productivity and quality. The basic concept in the canopy management of perennial vines is to make the best use of land and climatic factors for increased productivity. Tree vigour, sunlight, temperature, and relative humidity of that region play a great role in the production and quality of fruits. Canopy management practices followed to produce quality grapes are presented below.

1. Training

Grapevine is trained to achieve high quality production. There are number of training systems used worldwide, however, no single training system is appropriate for all situations. Based on the vine vigour, degree of vineyard mechanisation and availability of the skill workers the selection of training system is decided. The growth potential of grapevine and the condition under which the vine is grown are never uniform. The trellis used for training the vine is decided during the first year itself. Training system used in vineyard should fulfil the following requirements.

Fig 1. Grafting of scion

Fig 2. Training of rootstock

Fig 3. Training after grafting

1. The training system should be cheap and economical.
2. The training system should help to expose maximum leaf area to the sunlight for better photosynthesis.
3. The vine trained to any type of training system should promote maximum bud break.
4. The training system should offer a scope for mechanization with respect to efficient fungicide/ insecticide sprays, harvesting of maximum produce and pruning practices.
5. The training system should support the crop load to harvest good quality grapes.

The training of grapevine is performed to train different vine parts in the initial year. These are as below.

1.1 Training of rootstock

After the re-cut of rootstock in the field (before grafting), the selected shoots are trained to the bamboo sticks to encourage straight growth of trunk after grafting. This helps in storage of required food material in the developing trunk.

1.2 Training the trunk of grafted vine

The grafted vine is tied with bamboo stick to train the trunk straight.

The grafted vine is tied with bamboo stick to train the trunk straight.

Fig 4. Training of primary arm

Fig 5. Training of secondary arms

1.3 Training of primary arms on Y trellis

Immediately after re-cut of grafted vines, the shoot grows vigorously. This shoot should be pinched six inches below the first wire to train the primary shoot in a slanting position. This will avoid the direct sunlight exposure of the primary arm.

Fig 6. Well trained vineyard

1.4 Training of secondary arms (cordon)

The cordon development should be done based on the vigour of the vine. Due to the presence of prominent apical dominance in Thompson Seedless and its clones, the cordon development and training should be done following 'stop and go' method. This will help to obtain complete cordon with desirable length during the first year.

2. Pruning

The pruning can be defined as removal of plant parts to obtain appropriate number of fruiting units. The objective of pruning includes

Fig 7. Back pruning in grapes

1. Controlling the size and form of a vine.
2. Increasing the fruiting area on a vine.
3. Maintaining the balance between vegetative growth and fruiting.
4. Optimizing the production potential of a vine.
5. Obtaining the better-quality fruit from a vine.

The pruning is done based on the prevailing weather conditions in that region. Under central parts of India, the vine grows vigorously throughout the year. Hence, double pruning pattern is followed for grape cultivation. The vines are pruned during April by leaving basal single bud on the shoot proximal to the cordon. Since, the whole portion of cane is pruned; this pruning is called as back pruning. Fruit pruning is done during October for fruits, hence, it is also called as fruit pruning. During fruit pruning, the matured canes are pruned either after knot on the sub-cane or at 6-7 bud position in case of straight canes. However, the pruning position varies with cane vigour and varieties.

3. Canopy Management

Canopy management refers to the practices followed to obtain the ideal characteristics in various canopy components to realize the maximum yield of quality grapes.

3.1 Canopy architecture

Canopy refers to the size and shape of vine structure. The size and shape of the canopy is dependent on canopy components such as primary arms and cordons, canes, shoots and also on a given trellis/ training system.

Fig 8. Correct stage of sub cane

Fig 9. Vertical shoot position after back pruning for effective fruit bud differentiation

The ideal canopy should fulfil the following requirements:

1. It should give the grapevine a desirable shape and support the crop load.
2. It should offer scope for convenient field operations and mechanization.
3. It should have adequate number of fruitful canes.
4. It should allow sufficient light and ventilation into the canopy during the growth season.
5. It should give maximum proportion of quality grapes per unit area.
6. It should have sufficient foliar coverage to nourish and protect bunches during the fruiting season (November-March).

7. It should avoid overlapping of the foliage to facilitate efficient photosynthesis by every leaf.
8. It should offer scope for effective spray coverage with pesticides and growth regulators.
9. It should not build up micro-climate that is congenial for disease development.

The requirement of canopy during each pruning under tropical region is as below.

3.2 Canopy management after foundation pruning

1. The ideal stage for shoot thinning is at 4-5 leaf stage. This helps in reducing the loss of nutrients from the vine.
2. The number of shoots retained on vine should be 0.70-1.0 per ft^2 for quality produce.

Fig 10. Fruit Pruning of vine

Fig 11. Pre bloom stage of a bunch

3. The canopy should be open during April-September to facilitate optimum sunlight harvesting required for efficient photosynthesis.
4. The shoots on each cordon should be vertically positioned to harvest maximum sunlight required for fruit bud differentiation.
5. While removing the excess shoots from the cordon, remove both vigorous and weaker shoots so that all the shoots will be uniform in diameter. This will promote uniform bunch development after fruit pruning.
6. Vines with vigorous shoots should follow sub cane system while straight cane is followed in less vigorous vines.
7. While making the sub cane, pinch the shoot to 7- leaves at 9- leaf stage so as to develop proper sub-canes.
8. Top the side shoot again at 5th leaf when it is at 7- leaf stage.
9. Impose soil moisture stress at 7+5 leaf stage. This helps in increasing the fruit bud differentiation.

10. Top the shoots to 15- leaves (7+8) when the shoots start maturing. This helps to store enough food material and advance cane maturity.

Fig 12. Stage of excess shoots removal

3.3 Canopy management after fruit pruning

- Before fruit pruning, collect the canes (about 40 canes/acre) of different thickness (6-8 mm, 8-10 mm and >10 mm diameter) and examine their buds under microscope for position of fruitful bud. This helps to decide pruning position to obtain maximum number of bunches.
- The canes of 6 mm and less thickness are to be removed during fruit pruning.
- Swab hydrogen cyanamide only to apical 2-3 buds on each cane. This helps in early and uniform bud break.
- Based on the bud-break and the bunch emergence, shoot thinning is to be performed at 4-5 leaf stage.
- Bunches are to be retained based on vine spacing. Retain one bunch for every 1-1.5 ft^2 of canopy for quality grapes.
- Excess shoot removal to be done at 4-5 leaf stage.
- Bunch thinning should be followed at pre- bloom stage only.
- Retain only one or two bearing shoots on each cane. If the cane diameter is more than 8 mm, retain two bearing shoots and only one shoot if the diameter is less than 8 mm.
- Encourage the shoot growth by applying more nitrogen and water until one month after fruit set.

Fig 13. Stage of excess shoots removal after fruit pruning.

- Thin the berries and clip the clusters to reduce the number of berries in relation to the cane thickness. Retain 16 berries in a cluster per mm diameter of the cane.
- Position the shoots appropriately to provide shade to the bunch on the South-West side of the canopy.
- Retain only 100-120 berries in a bunch and remove all excess berries. This

operation should be done immediately after berry setting. This helps in Proper berry development and achieving the desirable berry size for quality produce.

Fig 14.Well-filled bunch after berry thinning

- Shoot topping is done at 10-12 leaf above bunch after fruit pruning to avoid competition for nutrients by the shoot and consolidate the food material in the developing bunches. This helps in increasing the berry size.
- To increase the berry size, girdling is one of the important operations beside use of growth regulators and cluster thinning. All these are complementary to each other. Therefore, care should be taken to use these practices judiciously. Girdling helps in increasing the berry size at least by one mm diameter.

Fig 15. Export quality bunch

- The time of girdling differs among varieties. In Thompson Seedless, the girdling is done at 4-6 mm berry size whereas in Sharad Seedless, it is done at 6-8 mm berry size.

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Chapter-4

Water and Nutrient Management in Vineyard

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Introduction

Water management:

In arid and semiarid areas, that remain essentially dry during major part of the year, water and not the land becomes the most limiting resource for production. Under such conditions, increasing productivity per unit water use as compared to the land use becomes an important strategy. Water scarcity and low availability of nutrient often limit crop growth and production potential in agro-ecosystems because most crops are sensitive to water and nutrient deficits during different critical stages. At the same time excess water use can increase the cost of production, and at the same time cause environment pollution. Grape is no exception. For quality grape production, management of canopy, nutrient, water, pest and disease and their timely operations are important. Amongst the inputs, water holds the key to achieving higher production and is known to contribute towards 60-70% in realising the genetic potential of the crop. Climate change is becoming a reality. Even though the total rainfall remains same for a given area, nevertheless, the number of rainy days is decreasing and high intensity rains over a shorter period is becoming more frequent. This calls for proper use of water for meeting the crop need.

What a grower needs to understand

The first question that always comes to the mind is what you mean by judicious use of irrigation water. This is especially true if irrigation water availability is limited and sometimes sufficient water is not available to meet the crop need. For this, the grower needs to ask the following questions to himself:

a) What is my irrigation water requirement during Foundation as well as Fruit pruning season? For this one needs to understand the importance of the growth stage and their water requirement.

b) What is root zone of grapevine? Majority of the roots are located in top two feet of the soil as the crop is drip irrigated. Soil type and its depth will have direct impact on root proliferation and water and nutrient use. The root zone should be loose for the vine roots to spread with least use of energy. It should be free of salts. Compaction in the rows due to movement of tractors restricts the root spread. This affects the water use efficiency. Making bunds increases the root zone volume and area available for the roots to mine the soil for nutrient and water.

c) Do I understand the quality of water available for irrigation? The farmer first needs to get his irrigation water tested for its quality. This will have direct bearing on the total water requirement. More the EC of the irrigation water more is the water required by the vines. Sodium in the irrigation water will lead to collapse of soil structure. Thus, nutrient and water movement through the root zone is affected. High pH of irrigation water can progressively reduce the availability of nutrients, particularly iron, manganese, boron, zinc and copper.

d) What is the status and efficiency of my irrigation system? The delivery system needs to be taken care of. Delivery system comprises of pump, pipelines, laterals, drippers etc. Uniformity of irrigation water application in the vineyards is very important. One needs to understand the vineyard variability (soil depth, slope, soil type – heavy, medium, light) to plan irrigation system for proper deliverance of nutrient and water.

e) If he is clear about above four (item a to d) and knows that the available water is not sufficient to meet his crop needs, then, what are the water-saving techniques that should be adopted during the irrigation season.

Growth stage of vine and their importance for water management

The need for water varies with different stages of vine growth. For some stages of the vine moisture stress is beneficial and for some stages it is harmful.

During the stage covering the period from foundation pruning to bud differentiation stage (normally mid-April to May) the water requirement is maximum. Vines should not be stressed in order to obtain canes of desired thickness (8-10 mm) and sufficient canopy. In the bud differentiation stage, irrigation should be reduced to facilitate better bud differentiation. Shoot maturity and fruit bud development stages coincides with rainy season but still there is a need to irrigate the vines as the rainfall is highly erratic and distribution is not uniform. There are hardly 40-50 rainy days in a year. Most of the soils are heavy textured with low infiltration rate and much of the rainwater is lost as run off. Irrigation should be withheld till the soil is at field capacity after the rain.

The effect of water stress from shoot growth to canopy maturity stage during foundation pruning could reduce the fruitfulness of vines. Studies carried out at ICAR-NRC Grapes in heavy soils in year 2013 has clearly shown that irrigating at 50 % of recommended schedule followed by no irrigation during fruit bud differentiation stage reduces the yield of Thompson Seedless vines by 10% over the recommended schedule. Subsequently, in the next year, it was observed that irrigating at 50 % of recommended schedule followed by no irrigation during fruit bud differentiation stage till 100 days of crop growth reduced the fruitfulness by 25%.

In the fruit pruning or forward pruning season (normally during the month of October) the vines should receive sufficient irrigation to promote strong shoot growth and adequate leaf area. Water stress during pre-bloom stage will lead to uneven and poor sprouting which will have adverse impact on number of bunches. Fruit-set is not a problem in Indian vineyards, mild stress during berry set to shatter stage helps in reducing berry set which are otherwise to be thinned. However, bunches can be completely desiccated by high levels of water stress during flowering, resulting in complete yield loss. Further at the time of fruit setting, high levels of water stress can reduce yield due to berry drop or poorberry development. Berry growth to veraison period is most critical stage as cell division and elongation are occurring in the fruit. Water stress at this stage reduces the berry size and yield. During the period from veraison to harvest the vines should not be over-irrigated in order to avoid berry cracking and delay in harvest. In highly vigorous vineyards the irrigation may be withheld for few days to discourage the new shoot growth. Depending upon the stored water in soil the irrigation may be stopped a week before to increase sugar content in the berries. Moisture stress at this stage however results in berry drop. Severe water stress during ripening results in leaf senescence thereby leading to poor sugar accumulation, which is crucial for quality-raisin production. At ICAR-NRC Grapes, it was observed that irrigating vines 50 % of the recommended irrigation schedule at berry development stage to harvest in heavy soils reduced the yield by 8.90% compared to recommended irrigation in year 2013. The yield losses could be higher in light textured soils as the water holding capacity is low compared to heavy soils.

During rest period i.e. after harvest the vines can survive on stored soil water in heavy soils. If the rest period is more than a month then the vineyard should be irrigated twice or thrice during this period.

Factors related to water quality in grape production

Good managers have used relatively poor water successfully and poor managers with subsequent severe salinity problems have misused relatively good water. Four types of grape production related problems have been recognized.

1. Salinity: Salts are added to the soil by irrigation water and accumulate in soil.
2. Soil permeability: Salt water or relatively high sodium water may reduce soil permeability.
3. Toxicity: Chlorides and boron accumulate in the leaves. Excessive accumulation because leaf burn and reduces yields. Sprinkler applied water containing as little as 100-ppm chloride, 70 ppm sodium or 1 ppm boron may also cause injury. Damage from leaf absorption is much less if the relative humidity remains above 30-40 per cent.
4. Problems associated with a water pH above 8.40 or below 6.5 are usually related to toxicity, nutritional imbalances or soil permeability. Nutrients such as nitrogen may cause excessive vigour and lowered yields. Water high in bicarbonate may result in an objectionable white deposit of lime on leaves or berries. Problems related to high bicarbonate in irrigation water can be reduced by addition of sulphuric acid at controlled rate to reduce water pH to 6.50.

Water salinity with EC_w less than 1 dS/m is considered excellent for grapes under average vineyard management. Water salinity in excess of EC_w 1.0 dS/m may still be satisfactory if appropriate soil management practices are adopted. General guidelines for evaluating water quality are given in Table 1. These guidelines are however, flexible and can be modified when warranted by local practices, experience, special conditions etc.

Table 1. Effect of various water parameters on the growth of grapevine

Water parameter and its effect	**No effect**	**Increasing effect**	**Severe effect**
Salinity: Affects water availability EC_w (dS/m)	< 1.00	1.0 – 2.7	> 2.7
Permeability: Affects rates of water movement into the soil and through soil EC_w (dS/m)	> 0.5	0.5 – 0.2	< 0.2
Adjusted SAR (An estimate of permeability hazard)	< 6.0	6.0 – 9.0	> 9.0
Toxicity: Specific ions cause toxicity and affect crop growth			
Sodium (meq / l)	< 20	—	—
Chloride (meq / l)	< 4	4 – 15	> 15
Boron (ppm)	<1	1 – 3	>3
Miscellaneous bicarbonate (meq / l)	< 1.5	1.5 – 7.5	> 7.5
Nitrate-N (ppm)	<5	5 – 30	> 30

Peacock and Christensen Interpretation of soil and water analysis

NOTE: Guidelines are flexible and should be modified when warranted by local practices, experience, special conditions. Interpretations are based on chemical analyses of the soil saturation extracts from soil samples representing a major portion of the root zone-usually the top 2 to 3 feet of soil

There is a saying ‘Hard water produce soft soils and soft water produce hard soils’. Extremely low salt water results in poor water penetration. Relatively high sodium reduce water infiltration and calcium improves it. Salinity effects on soil permeability are relatively less in clay than sandy loam. Low permeability soils should be irrigated more frequently or for longer duration.

Strategies for improving water use efficiency in grapes

1. **Provide need-based irrigation**

The adequacy of the irrigation water should also be ensured before selecting a site for grape cultivation. Water requirement of grapes varies with the atmospheric aridity and the stage of the growth of the vines. Scheduling of water is to be based on the pan evaporation reading, which is an index of water lost from the plant. Further, quantum of water applied should conform to the crop requirement at a given stage. This calls for irrigation scheduling.

The grapes grafted on rootstocks have better root systems for exploitation of soil moisture from deeper layers and hence less irrigation water is required compared to own rooted vines. On the basis of experimental data generated at this institute, the best irrigation scheduling for grape grafted on rootstock under saline irrigation is given in table 2. In case, the irrigation water quality is good, about 20% less irrigation water will be required. On the basis of pan evaporation reading, the water requirement of grapes can be worked out as per crop growth stage.

Table 2. Recommended irrigation schedule for grapevine based upon pan evaporation

Growth Stage	Expected duration (days after pruning)	Water requirement (litres/day/hectare per mm of evaporation)	Month of operation	Expected monthly Pan evaporation (mm) in different grape growing regions	Approximate water (litres /hectare/ day)
Foundation Pruning					
Shoot growth	1-40	4200	April-May	8-12	33,600-50,400
Fruit bud differentiation	41-60	1400	May-June	8-10	11,200-14,000
Cane maturity and Fruit bud development*	61-120	1400	June-August	0-6	0-8,400
121 days - fruit pruning*	121 -	1400	August-Fruit pruning	0-6	0-8,400
Fruit Pruning					
Shoot growth	1-40	4200	October-November	6-8	25,200-33,600

Bloom to Shatter	41-55	1400	November-December	4-6	5,600-8,400
Berry growth and development	56-70	4200	December - January	3-6	12,600-25,200
Berry growth and development	71-105	4200	December - January	3-6	12,600-25,200
Ripening to Harvest	106- harvest	4200	January - March	8-10	33,600-42,000
Rest period	Harvest to Foundation pruning (20 days)	-	March-April	8-10	-

* The above growth stages generally coincide with rainy season and no irrigation may be required in heavy soils.

* The schedule has been worked based on experiment carried out in heavy and calcareous soils using saline irrigation water (EC ranging from 1.7-1.8 dS/m) and therefore this may be taken as guideline for stage wise irrigation for other soil types other than the one specified here.

Note:

- Depending on water quality, the amount of water needed may change. Irrigation should not be applied after the soil has reached field capacity after rain.
- Irrigation requirement will be less by 20% compared to above given schedule if low salinity water (EC less than 1.0 dS/m) is used.

2. Water saving techniques

a. Use of antitranspirants and mulching

Mulching and antitranspirants reduce the soil evaporation as well as transpiration losses from the leaf. Many types of material, organic and inorganic, may be used as mulch (fig.1). Organic mulches may break down in one season or less or persist for more than one season. They are usually decomposed enough over a period of time and they can be spaded or ploughed under, increasing the organic matter content of the soil and thereby improving soil structure. Further, mulch improves the soil as worms and soil microbes move it into the soil. The height of organic mulch should be at least 2″ and should cover at least 1.5′ on both the sides of the vine. Organic mulch not only helps in reducing evaporation but also improves soil conditions through organic addition. Plastic mulching can also be used, however, they should be properly anchored to the ground to prevent being blown away. The thickness of the plastic should be at least 25 microns. Both plastic and organic mulch also reduces weed incidence in the vineyards.

Antistress is a biodegradable acrylic polymer which when sprayed on plants minimize the water loss through evapo-transpiration. Further, it doesn’t interfere in metabolic activities of plant or the photosynthesis process. Due to the tensile strength the antistress film can be sustained up to the pressure of 300 m^2 and it does not affect the growth of leaves or berries. The usage of Antistress or any antitranspirant, should be checked for any restrictions on its application based on Good Agricultural Practices etc.

Three sprays on Thompson seedless vines during foundation pruning i.e. 4-6 ml antistress / litre after 30, 60 and 90 days after pruningand two sprays @4 ml antistress / litre at 25 and 55 days after fruit pruning in combination with bagasse mulching could save 25% of irrigation water.

Fig 1. Mulching in vineyards

b. Subsurface method of irrigation

Problems of lower availability of irrigation water, presents the farmers with difficult question of sustaining higher yield with lesser availability of water. One of the solutions could be sub surface irrigation, wherein the irrigation water is conveyed directly to the root zone. The method involves the usage of one feet length PVC pipes (2.5 inch diameter) placed nine inches below the soil with holes on all sides of the pipe (Fig. 2).

Fig 2. Subsurface irrigation

1 feet PVC pipe 9” deep placed in root zone

The micro tubes attached to the existing drip lines are directly placed in the pipes. This reduces the evaporation losses from the surface. Further, the roots escape the effect of salinity as more roots are distributed near the water application source i.e. at subsurface. By this method, saving to the extent of 25 % of irrigation water can be achieved.

c. Partial rootzone drying

In this technique, one half of the root system will be always in a dry or drying state while the other half is irrigated. The wetted and dried sides of the root system are alternated on a 7- to 15-day cycle depending upon the soil type. The roots that are drying leads to the synthesis of Abscisic acid and this is then transported to the leaves. Stomata respond by reducing aperture, thereby restricting water loss. Thus, the transpiration is reduced due to partial stomatal closure. This reduces the quantum of water required for profitable yield.

Other cultural practices to be followed

a. **Use of Cocopeat:** Light textured soil has low water holding capacity and use of cocopeat improves water holding capacity. Cocopeathas the ability to retain 6-8 times its weight in water and also can store and release nutrients to plants for extended periods. It also improves soil aeration that is important for healthy root development. For conserving moisture, cocopeat should be kept atleast 3-4 inches depth in the soil just below the dripper. Depending upon use of FYM, 1.5 – 2 kg dry weight cocopeat is required per vine.

b. **Canopy regulation:** Canopy regulation is another way of reducing the irrigation water requirement of the vines. Grapevines with vigorous growth tends to suffer in the event of moisture stress. It is always better to reduce unfruitful canes and excess growth, thereby, limiting the transpiration losses from the system.

c. **Nutrient Use:** Many of the grape growing vineyards have poor soil conditions and hence, the ability to hold water and retain nutrients in the soil is limited. Application of FYM/ green manures/ compost/ vermicompost will improve soil physico-chemical and biological properties. Normally for nutrient uptake in the plants, soil moisture is crucial as the nutrients dissolves in water and then is taken up by the plant. Thus, moisture stress will affect the nutrient uptake in the vines, particularly, potassium, calcium, magnesium and micronutrients. Heavy doses of fertilizers directly in the soil are not recommended under limited irrigation water availability, as the presence of unutilised fertilizer under limited water will increase soil salinity. This will further reduce the moisture availability to vines. Hence, fertigation and frequent foliar applications is the recommended way of supplying the nutrients to the vines. Foliar application of fertilizer on mature leaves should not exceed 0.50% concentration. Lower and frequent applications on young leaves are more beneficial.

d. Continuous falling of water through drip at one location could lead to surface sealing thus leading to runoff across the bunds and evaporation. Providing a shallow furrow on top of the bund under the drip line will reduce run-off by ponding the water until it has soaked into the soil. Alternatively, provide a thin layer of mulch just below the dripper in the furrow to allow the percolation of water in the root zone. Maintaining good soil condition on the bund will minimise evaporative loss of water by favouring water infiltration. Adequate mixing of the organics like FYM/ compost in the bunds will improve the water infiltration through the root zone.

e. Excessively dry topsoils can lead to water run-off and thus significant evaporative loss of water. It is thus, necessary to maintain adequate moisture at the soil surface to facilitate water entry at the next irrigation. Several short irrigations followed by a medium to long irrigation often helps to maintain surface moisture, enabling easier infiltration of water.

f. Water saving can also be achieved with drip irrigation by 'pulsing'. This water-application technique alternates irrigation from one vineyard section to another, allowing more time for water infiltration and less opportunity for water to evaporate at the soil surface. An additional benefit of pulsing is a widening of the wetted zone, especially in light soils, where rapid entry to the soil favours movement of water beyond the effective rootzone.

g. If the irrigation water is saline, the only way to reduce salinity is to apply more water to leach the salts. When irrigation water availability is low, it is suggested to saturate or flood the root zone just before the pruning to leach the salts below the root zone, so that the sprouting and initial growth is not affected. With age of the leaves, the impact of the salinity developed at a later stage will be less. Further, immediately after saturating the bund, apply mulch to keep the soil moist.

h. If sodicity is the problem, then improve the soil condition in the wetted zone by applying gypsum in the root zone. In case of calcareous soils use sulphur. Remember, though, that movement of gypsum/ sulphur into the soil is a slow process, unless mechanically incorporated.

i. Timely harvest – Harvesting the grapes as and when they are ready, reduces the water requirement of the vine as the water use reduces when the crop is harvested.

In India, grape is mainly grown in the semi-arid tropics with more than 90 % of the area concentrated in Maharashtra and Karnataka. Majority of the vineyards are either raised on heavy soils or on marginal lands. Though grapes can be cultivated on varied soil conditions, deep and well-drained soils with pH range of 6.5-8.0 is ideal. The soil pH above or below this range is known to restrict availability of some nutrient elements and thus inhibit growth and development. The weather is mostly dry with less number of rainy days (30- 40 days) during the year. Once planted, it stays at the site for atleast 10-15 years. Favourable rooting environment and proper understanding of the phenology is key to efficient water and nutrient management. Being double pruned and single cropped, the nutrient requirement differs between both the pruning seasons. However, this region suffers from abiotic stress namely moisture and salinity stress.

Nutrient management:

Nutrients are required by the plants mostly for the synthesis of carbohydrates, proteins, fats, electrolytes. In addition to these, other functions are also to be carried out like maintaining the electrolytic balance, formation of certain enzymes and vitamins which are also required for carrying out metabolic processes. Protein is composed of C, H, O, N, P and S; carbohydrates are composed of C, H, and O and fats are also composed of C, H, and O. In addition to these, chlorine, K, Na, Ca, Mg and certain other elements are required to maintain the electrolytic balance in the plants. Fe, Mg, Mn, Cu, B, Zn and Mo are actually required as a part of enzyme system for carrying out enzymatic activities. Above mentioned elements are called as **essential plant nutrients**, which when taken up by plants are converted into food elements. These are absorbed by plants in the form of inorganic ions. There are 16 essential elements C, H, O, N, P, K, Ca, Mg, S, Fe, Mn, Cu, B, Zn, Mo and Cl required by plants.

Determining fertilizer requirements of the grapevines

Soil analysis can reveal what is potentially available to the vine, but does not give good indication of soil-plant interactions. Often, little or no relationship is observed between soil and vine’s nutritional status. Soil testing is, however, quite helpful in understanding fertilization approaches when a need is identified. Petiole tests are better approach for determining the vine needs. The amount of fertilizer dose required will differ for different soils types and varieties even if the petiole test value is same. Hers is no well-defined formula to translate the soil/petiole test values directly in to fertilizer recommendations.

What is fertigation?

Application of nutrients through irrigation water is generally referred to as fertigation. This allows flexible fertilizer programmes, which are not feasible in case of direct soil application. The main advantages are control of timing, concentration, location and proportion of the nutrients.

The fertigation is definitely superior to conventional fertilization. Fertigation has become the need of hour in Indian viticulture also to sustain the production of grapes and minimize soil and environment related hazards. Keeping in view the nutrient requirement of vines at different stages, three fertigation schedules were tested in heavy soils using urea, phosphoric acid and potassium sulphate as N, P, K sources. The recommended fertigation schedule and economics of fertigation is given below in table 1

Table 3: Fertigation schedule for table grapes (Thompson Seedless 2 to 5 years age) example (266 kg N, 177.50 kg P_2O_5 and 266 kg K_2O/ha/year) under saline irrigation.

Growth Stage	**Expected duration (days after pruning)**	**Month of operation**	**Nutrient application (kg/ha)**		
			N	**P_2O_5**	**K_2O**
Foundation Pruning					
Shoot growth	1-30	April-May	60	-	-
Shoot growth	31-40	April-May	20	35.5	-
Fruit bud differentiation	41-60	May-June	-	71	-
Cane maturity and Fruit bud development*	61-120	June-August	-	-	80
121 days - fruit pruning*	121 -	August- Fruit pruning	-	-	-
Fruit Pruning					
Shoot growth	1-40	October-November	80	-	-
Bloom to Shatter	41-55	November-December	-	26.5	-
Berry growth and development	56-70	December - January	-	26.5	-
Berry growth and development	71-105	December - January	80	-	80
Ripening to Harvest	106-harvest	January - March	-	-	80
Rest period	Harvest to Foundation pruning (20 days)	March-April	26	18	26

Note: The nutrient doses given for fertigation should be modified according to the petiole nutrient status of the vines, as over the year's nutrient build up in the soil increases. Nutrient present in the irrigation water and the contribution of organic manures should be taken into consideration. Also there is need to make adjustments as per locations and climates as and when needed for determining the actual doses. This experiment was conducted in a row to row and vine to vine spacing of 10ft. × 6ft. Irrigation schedule can be suitably applied up to a row to row and vine to vine spacing of 8ft × 5ft.

Secondary and Micronutrients

- Sulphur deficiency is rarely observed in vineyards since considerable quantities are indirectly added by use of S containing fertilisers like SOP and S as fungicide
- Calcium deficiency in calcareous soils is not common and do not require specific fertiliser application unless vineyard soil has high pH or sodium. Certain climatic conditions (cold or rainy) or nutrient imbalance in soils may cause Ca deficiency in fruits (berries) which can be corrected by two to three foliar applications or bunch dipping between fruit set and veraison stage @ 0.3 to 0.5% (calcium chloride or calcium nitrate)
- Apply magnesium sulphate @ 100 kg per hectare per pruning season in four splits for maintenance dose. However, the application must be done only if need is established based on petiole test value since in many vineyards ground water irrigation source may add substantial quantities of Mg in soil.
- Amongst the micronutrients, zinc and iron are the most commonly deficient nutrients.
- Due to large variation in the type and content of calcium carbonate in soil, no specific recommendations are available. However, under established deficient conditions, on an average 50 kg per hectare each of zinc sulphate, ferrous sulphate and manganese sulphate should be applied per season.
- Micronutrients are preferably applied as foliar application and based on petiole analysis. On an average, 3-4 sprays of 0.2–0.4 % of sulphate forms of Zn, Mn and Fe in a pruning season meet the crop needs.
- Boron is strictly applied on the basis of petiole analysis report.

Fertilizers and their grades used for fertigation

i) All the nutrients are available in optimal quantity in the soil in the pH range of 6.0 - 6.5. The pH and EC of the commonly used liquid fertilizers is given in Table 2. The fertilizer solution with pH less than 3.5 is highly corrosive to metals. Further, in high bicarbonate waters acidic fertilizers should be added to avoid or at least minimize precipitation of $CaCO_3$, which may clog the drippers. Acidic fertilizers are those which will increase residual acidity in acid soils or reduce the residual alkalinity in alkaline soils e.g. ammonium-N fertilizers (urea, ammonium nitrate, ammonium sulphate and ammonium phosphates etc.), phosphoric acid etc. while fertilizers which increase residual alkalinity in alkaline soils, or reduce the residual acidity in acid soils are called alkaline fertilizers e.g. $NaNO_3$.

Table 4. pH and EC of some fertilizers at a concentration of l g/l of distilled water

Fertilizer	pH	EC (dS/m)
Ammonium sulphate	5.4	1.06
Urea	8.0	0.001
Liquid ammonium nitrate	6.6	0.87
Potassium nitrate	8.5	1.00
Mono-ammonium phosphate	4.0	1.00
Mono-potassium phosphate	4.5 – 5.0	0.75

ii) Solubility of fertilizers used for fertigation: Fertilizers that are used in fertigation system must have a high rate of solubility. e.g. urea, ammonium nitrate, ammonium sulphate, mono-ammonium phosphate, phosphoric acid, potassium nitrate to name a few from many grades available in the market.

iii) Compatibility for mixing fertilizers: Mixing the solutions of two soluble fertilizers can sometimes result in the formation of a precipitate. Such cases indicate that these fertilizers are not mutually compatible, and special attention has to be paid to avoid mixing them in one tank. Their solutions should be prepared in two separate tanks. If two chemical compounds with a relatively high-water solubility rate are mixed and mixing new compounds with a lower solubility are created, this will always be the direction of reaction.

If KNO_3 is mixed with ammonium sulphate, potassium sulphate will be created and excess amount of K in the solution will precipitate. High Ca, Mg and bicarbonate content in irrigation water will induce precipitation if phosphatic fertilizers are added.

Table 3 makes it clear that neither phosphoric nor sulphate fertilizers should be mixed with calcium fertilizers in the same tank. This separation prevents precipitation of calcium phosphate or calcium sulphate compounds in the tank or in the pipeline.

Table 5. Inter-compatibility of soluble fertilizers

Fertilizer .... Abbr.	Ur	AN	AS	MAP	MKP	PN	PN+Mg	PN+P	SOP	CN	$CaCl_2$	Mg+N
Urea .... Ur												
Ammonium nitrate.......... AN	C											
Ammonium sulphate .... AS	C	C										
Mono-ammonium phosphate MAP	C	C	C									
Mono potassium phosphate MKP	C	C	C	C								
Multi-K (potassium nitrate) PN	C	C	L	C	C							
Multi-KMg .... PN+Mg	C	C	L	L	L	C						
Multi-NPK...................PN+P	C	C	C	C	C	C	X					
Potassium sulfate........... SOP	C	C	C	C	C	C	C	C				
Calcium nitrate ....CN	C	C	L	X	X	C	C	X	L			

Calcium chloride ....$CaCl_2$	C	C	L	X	X	C	C	X	L	C		
Magnesium nitrate ..... Mg+N	C	C	C	X	X	C	C	X	C	C	C	
Magnesium sulfate........ MgS	C	C	C	X	X	L	C	X	C	L	L	C

C – Compatible, L – Limited compatibility, X – Incompatible

Calcareous soil: Calcareous soils have high calcium carbonate content that upon dissolution results in a high bicarbonate (HCO_3^-) concentration in solution which buffers the soil in the pH range of 7.5 to 8.5. Further, particle size distribution, surface area and reactivity are important properties of soil carbonates which influence the chemistry of the soil. Finer the particle more is the impact. In general, the presence of $CaCO_3$ directly or indirectly affects the chemistry and availability of nitrogen, phosphorus, magnesium, potassium, manganese, zinc, copper and iron.

Improving calcareous soils requires not only reducing the soil pH but also neutralizing calcium carbonate in soil. For this the most cost-effective solution is elemental Sulphur. To neutralize all calcium carbonate in the soil will require very heavy investments in Sulphur application. This is not practical. Instead of acidifying and neutralising the entire top foot of soil, one approach is to treat a portion of the rooting environment so that plants can grow without pH-induced chlorosis. Localized acidification can be accomplished by applying Sulphur in the drip wetted area which effectively reduces the quantity of Sulphur applied to one-third. Application of 50-100 kg elemental Sulphur in each pruning season on a per acre basis will be desirable depending upon $CaCO_3$ content. If soil has high calcareous content, regular application for atleast 2-3 year will be required. Even reduction in soil pH will improve the availability of phosphorus and micronutrients in the soil.

The high pH of the soil affects the nitrogen mineralization in the soil, thereby reducing the nitrogen use efficiency. Another important factor affecting the nitrogen use is Ammonia volatilization, which is more when nitrogenous fertilizer is applied on the surface. The extent of ammonia losses depends on the anion accompanying the NH_4^+ cations in the fertilizer, which forms the Ca salt. If anions like sulphate or phosphates are there then, insoluble calcium sulphates/ phosphates are formed and more ammonia volatilisation losses are there. Even ammonia losses can be there from urea also. So, to maximise the nitrogen use under such situations, it is imperative that ammonium sulphate or urea are applied in splits through fertigation so, that along with water the nitrogen reaches to the root zone where they are utilised immediately and not left for ammonia volatilisation losses on the surface.

Maximum availability to plants of both native and applied P is in the pH range of 6.0 to 7.5. In calcareous soils, as fertilizer P is added, it is converted to less soluble compounds such as dicalcium phosphate dihydrate or octacalcium phosphate. A variety of management practices can be used to slow these natural fixation processes and increase the efficiency of applied fertilizer for crop growth. Soluble P fertilizers (phosphoric acid, triple superphosphate, ammonium phosphates etc.) are the preferred source in calcareous soils. Organic matter has been found to interfere in the fixation reactions of P with lime. Thus, application of more organics in the soil will improve the P availability to the vines.

High Ca levels in soils suppress Mg and K uptake by crops. The reason being the proportion of Ca to other exchangeable cations generally exceeds 80%. Further, antagonistic relation between Ca and Mg and Ca and K also affects the potassium and magnesium availability. It is often difficult to increase leaf Mg and K levels with fertilizer applied directly to calcareous soils, which contain very high quantities of Ca. In general, also, potassium is generally deficient, but the same is not always true in case of magnesium. Use of soluble potassium sources like sulphate of potash, potassium nitrate etc. in multiple splits through fertigation will improve the potassium availability to the grapevine. Apart from that, 3-4 foliar application of potassium during foundation as well as fruit pruning season is advised.

Application of soluble magnesium sources like Magnesium sulphate, magnesium nitrate etc. in multiple splits through fertigation will improve the magnesium availability to the grapevine. Apart from that, 3-4 foliar application of magnesium during foundation as well as fruit pruning season is advised.

Iron is considerably less soluble than Zn or Mn in soils with a pH value of 8. Infact, high pH, high lime content and active lime leads to lime induced iron deficiency. Thus, inorganic Fe contributes relatively little to the Fe nutrition of plants in calcareous soils. Application of iron to the soil renders it insoluble within a short time for use by the vines. Wherever, the problem of lime induced iron chlorosis is there, inorganic iron fertilizers like ferrous sulphates should be applied in more splits and in high quantity through fertigation to make it available to the plants. The other option is soil application of Fe-EDDHA, chelated form of iron. The iron availability is increased as the chelates do not allow the reaction of iron with the carbonates. Even the plants can directly take up the same from the soil and break it within the system, thus making iron available to the leaves. Foliar sprays (2-3 no.) of ferrous sulphate (@ 2-3g/L) will provide temporary relief. However, the pH of the spray solution should be acidic. This should be followed by application of ferrous sulphate @ 25-30 kg/ acre through fertigation in multiple splits or Fe-EDDHA.

Zinc is also less available in calcareous soil due to high pH of the soil. Zinc forms precipitates like Zinc hydroxides and Zinc Carbonate that are insoluble and unavailable to the vines. Chelated Zn remains soluble and available to plants considerably longer than the inorganic forms like Zinc sulphate. But the availability of zinc sulphate can be improved by split application through fertigation. Around 15-20 kg Zinc Sulphate on per acre basis will be sufficient per pruning season. This should be coupled with foliar sprays (1-2 g $ZnSO_4$/L) to improve the petiole zinc content.

Soil pH affects boron availability more by sorption reactions than by formation of less soluble compounds. Availability of boron is highest in the pH range of 5.5-7.5. High levels of Ca at high pH reduce the uptake of B. This may explain the fact that high boron levels in calcareous soils, considered as toxic in other conditions, may not produce boron toxicity in vines.

Sodic soil

Soils are considered sodic if more than six percent of the CEC is occupied by sodium, and highly sodic if the figure is greater than 15 percent. The sodium dominates the exchange complex in comparison to calcium and magnesium and thereby affects the soil structure. The sodium weakens the bonds between clay particles when wetted. This results in dispersion of clay particle and swelling of the soil. The clay particles then block the pore spaces thereby restricting the movement of water and air through the soil. This leads to water logging, less water storage in soil, soil crusting and more runoff from the soil. When soil is repeatedly wetted and dried and clay dispersion occurs, it then reforms and solidifies into almost cement-like soil with little or no structure. The clay soils are at a greater risk than course textured soils for excess sodium to bind to them and cause breakdown of soil structure.

The problems related to sodicity in different regions are becoming obvious in vineyards having ESP in the range of 6-8 percent depending on soil potassium levels and soil type. Irrigation water is the major source of sodium hence those having irrigation water high in sodium needs planning to reduce its build up right from planting stage. The impact of the sodicity is both direct and indirect. The indirect impact is due to poor soil structure. Soil with poor structure or compact soil will reduce the root growth, soil aeration and ultimately nutrient uptake thus making the vine weak. The weak vines will be vulnerable to disease and pest attack.

Leaf blackening and necrosis has been found in the vineyards due to sodium toxicity and potassium deficiency. The symptoms are sometimes observed first on upper leaves of the shoot and sometimes on the lower leaves (Fig 1.). The symptoms are observed on both grafted as well as ungrafted vines mainly under saline irrigation. Initially the leaves turn black and later on necrotic. This leads to poor fruitfulness, premature leaf fall and even death of perennial vine parts. The studies carried out at ICAR-NRC Grapes revealed that Dogridge rootstock couldn't restrict sodium uptake under saline irrigation (water rich in Na).

The most common method to improve sodic soil is by applying amendments like gypsum or sulphur (Table 1). Gypsum is calcium sulphate ($CaSO_4 \cdot 2H_2O$). The solubility of the gypsum is very low (2.0–2.5 g/l) hence, soil should be sufficiently moist to dissolve the gypsum. It acts by replacing the sodium on the soil exchange complex and the sodium thus, displaced from exchange complex is leached by applying more water. In case of calcareous soils, sulphur should be used as amendment. The sulphur reduces the pH of the soil thereby leading to dissolution of calcium carbonate. This calcium then replaces sodium in the exchange complex. For leaching water one should use low sodium containing water. As availability of good quality water is a problem in the vineyards, gypsum or sulphur application should be done during foundation pruning season to take the benefit of pre-monsoon and monsoon rains for leaching of sodium from root zone. If subsoils are sodic, deep ripping may be necessary to help distribute the gypsum in the deeper layers before planting the vines. Restoration of sodic soils is slow because soil structure, once destroyed, is slow to improve. Soil practices to break the crusts and green manuring/ FYM/ compost/ sulphuric acid/ molasses application will improve the soil structure and lead to better leaching of sodium along with irrigation water. Flooding the land with large quantities of water must be avoided unless desired. Evaporation should be reduced so that salts from lower layers do not come to surface. For this mulching will be very helpful.

Soil analysis should be used to determine the application rate, as the requirement will depend on the soil type and actual sodium content. In close -spacing vineyards 50 % area may need gypsum or Ca application. For better results gypsum should be mixed in the soil and applied along with organic matter and green manure etc.

The pH of the sodic soil will generally be more than 8.5, thereby affecting the nutrient availability. There will be likely deficiency of calcium, magnesium and potassium in the sodic soil. In Indian vineyard K and Mg are most commonly deficient in high sodium containing vineyards. To correct these deficiencies, regular foliar spays of these nutrients apart from soil application are needed. On an average, 4-6 sprays of potassium and magnesium along with soil application in a pruning season will help in overcoming the deficiencies. Remember that sprays will only provide temporary relief and cannot meet all the vine requirements hence soil conditions needs to be improved for better nutrient uptake.

Among the fertilisers that are source of soluble calcium are SSP (SSP contains 50-60% gypsum), calcium ammonium nitrate, Calcium nitrate.Since pH of the soil is high in sodic soils, ammonium sulphate will help in reducing the soil pH over a period of time compared to urea.

Table 6: Estimated efficiencies for various materials to reclaim sodic soils compared to gypsum

Material	Tons of materials equivalent to 1000 kg of gypsum
Gypsum	1000
Sulfuric acid	570
Sulfur	180
Lime-sulfur	750

Fig 3. Leaf blackening and necrosis caused by sodium toxicity and potassium deficiency

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Chapter-5

Use of Plant growth regulators in grape production

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Introduction

Grape is a commercially important fruit crop of India. The grapes are exported to Europe, UK and Middle East countries. The export suffers because of poor berry quality and noncompliance to quality standards imposed by the importing countries, particularly with respect to the size and sugar content of the berries. It is possible to achieve these standards through excellent management practices coupled with the use of plant growth regulators at the different stages of berry development. These bio regulators have the capacity to modify or to regulate the crop growth though they are in minute quantities. Plant growth regulators (PGR) are synthetic substances that closely resemble the natural hormones found in plants.

Plant Growth Regulators: In plants, many behavioural patterns and functions are controlled by hormones. These are "chemical messengers" influencing many patterns of plant development. Plant hormones – a natural substance (produced by plant) that acts to control plant activities.

- Are produced in one part of a plant and then transported to other parts, where they initiate a response.
- They are stored in regions where stimulus are and then released for transport through either phloem or mesophyll when the appropriate stimulus occurs.
- Plant growth regulators – include plant hormones (natural & synthetic), but also include non-nutrient chemicals not found naturally in plants that when applied to plants, influence their growth and development.

5 recognized groups of natural plant hormones and growth regulators.

- Auxins
- Gibberellins
- Cytokinins
- Ethylene
- Abscisic acid

Plant's growth and development are under the control of two sets of internal factors.

¬ Nutritional factors such as the supply of carbohydrates, proteins, fats and others constitute the raw materials required for growth.

¬ Proper utilization of these raw materials is under the control of certain "chemical messengers" which can be classified into hormones and vitamins.

Hormone: The site of synthesis is different from the site of action. Plant hormones are physiologically active. The term Hormone is derived from a Greek root 'hormao' which means 'to stimulate' (Beylis and Starling, 1902). Thimann (1948) suggested using the term 'Phytohormone' for Hormones of plant.

Phytohormones are organic substances produced naturally by the plants which in minute/low concentration increase, decrease modify the growth and development.

Classification:

Natural hormone: Produced by some tissues in the plant. Also called Endogenous hormones e.g. IAA.

Synthetic hormone: Produced artificially and similar to natural hormone in physiological activity. Also called Exogenous hormones. e.g. 2,4-D, NAA etc.

On the Basis of Nature of Function

• **Growth promoting hormones/Growth promoter:** Increase the growth of plant. • e.g. Auxins. Gibberellins, Cytokinins etc.

• **Growth inhibiting hormones/Growth retardant:** Inhibit the growth of plant. • e.g. ABA, Ethylene.

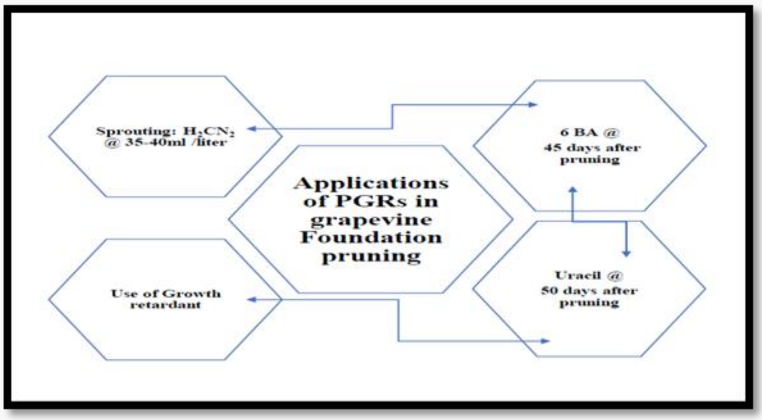
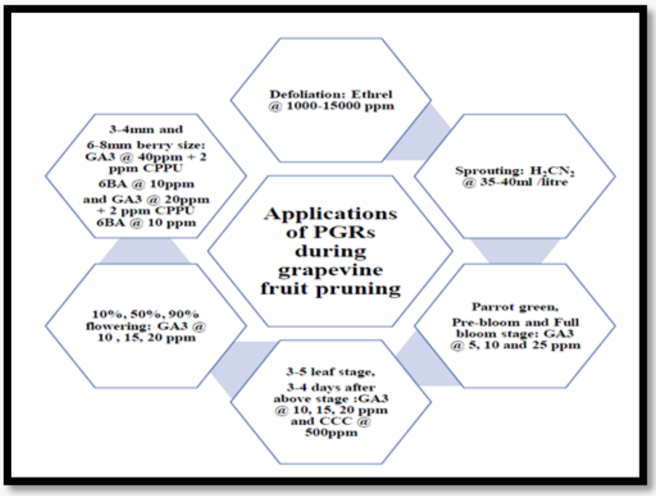


Fig 1 (a). Application of PGRs during foundation pruning



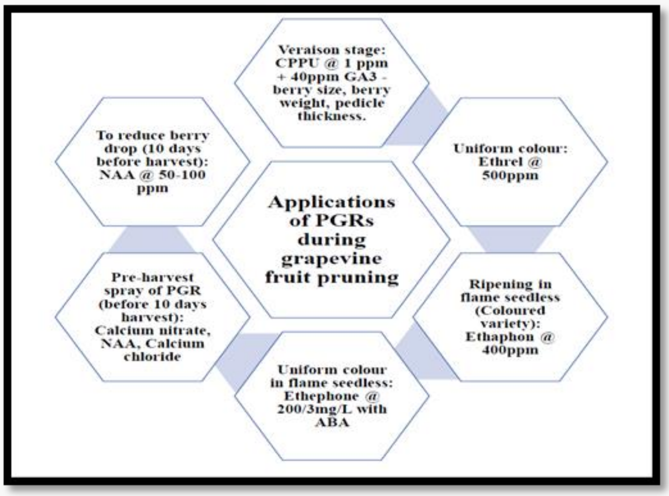


Fig 1 (b). Application of PGRs during fruit pruning

Auxins:

Auxins are a class of phytohormones that are produced at the tips of shoots and roots, moving from there to the zone of elongation.

Table 1 : Role of auxin

Growth Concentrations	Regulators	Time of Application	Effect
NAA	20ppm 15-20 ppm 20-25 ppm	Spraying at berry formation stage. Dipping bunches at sugar formation stage Spraying10-15 days before harvest.	Controls flower & berry drop. Improves berry luster and prevent berry drop
IBA	1000-1500ppm	Dipping of cuttings	Promotes root initiation

Gibberellic acid: Gibberellic acid (GA) is commonly used in grape cultivation to improve size of berries and length of clusters. GA3 can help grapes grow bigger in the early stages of their development, which can make them more appealing to customers. It can also help reduce berry thinning.

Table 2 : Application of GA_3 in flowering stage for Sonaka and Black varieties of grapes:

Sr. No	Stages of Application	Concentration of GA_3	Purpose
1.	10 % Flowering	GA_3@10 ppm	Berry elongation
2.	50 % Flowering	GA_3@15 ppm	Berry elongation
3.	90 % Flowering	GA_3@20 ppm	Berry elongation

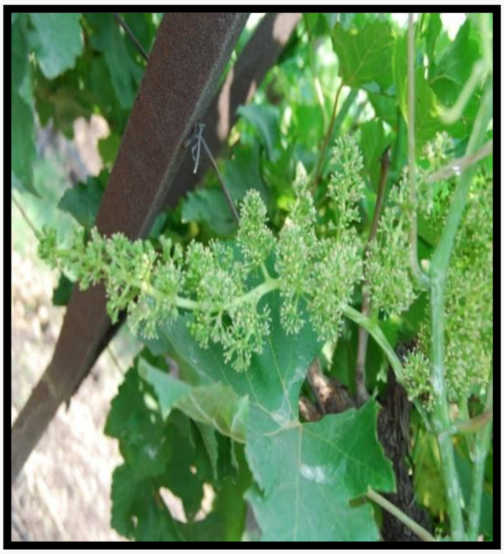


Fig 2 (a). 10 % Flowering Stage

Fig 2 (b). 50 % Flowering Stage

Fig 2 (c). 90 % Flowering Stage

Table 3: Application of GA_3 in Fruit set (Bunch Development)

Sr. No	Stages for Application (Berry size)	Concentration of GA_3	Purpose
1.	3-4 mm berry size	GA_3 @40 ppm as a bunch dipping	Increase in berry size
2.	7- 8 mm berry size	GA_3 @20ppm	Increase in berry size

Role of GA_3 for Cluster development in grapes:

To producing quality of a bunch, GA_3 play important role in cluster development. Flower cluster appears soon after the emergence of young shoots. The schedule of GA_3 followed from the pre-bloom stage. The following schedule is followed for cluster development.

Fig 3 (a). Stage: 3-4 mm berry size

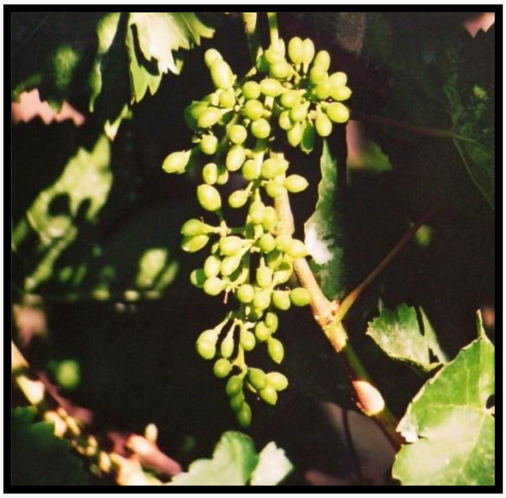


Fig 3 (b). Stage: 7-8 mm berry size

Fig 4 (a). 5-Leaf Stage

Fig 4 (b). 50 % Flowering Stage

Table 4: Role of GA_3 for Berry Elongation and berry Development in grapes

Sr. No	Stages of application	Concentration of GA_3	Purpose
1	5 leaf stage or bunch of parrot color (Pre-bloom)	GA_3@10 ppm	Rachis elongation
2.	3 to 4 days after the first phase	GA_3@15 ppm	Rachis elongation
3.	3 to 4 days after second stage as needed	GA_3@20 ppm	Rachis elongation
4.	50 % Flowering Stage	GA_3@ 40 ppm	Berry thinning.

Cytokinin:

Cytokinins are plant growth regulators which are involved in performing cell division in plant roots and shoot system.

Table 5: Effect and time of application of 6 BA and CPPU on grapes

Category	Concentrations	Time of Application	Effects
6 BA	10ppm	15-16leafstageafterAprilpruning	Increases fruit setting in the buds.
	10ppm	At3-4mmberry size along with 30-40 ppm GA after October pruning	Increases the berry size.
	10ppm	At6-7mm berry size along with 30-40 ppm GA after October pruning	Increases the berry size and shape.
CPPU	2 ppm	3-4mm berry size along with GA dipping	Increase the stalk thickness & berry size, promotes round berry shape and maintains the green colour of the berries.
	2 ppm	6-7mm berry size.	

Table 6: Effect of Cytokinins on berry development in grapes

Category and Concentrations	Time of Application	Effects
CPPU @2 ppm and GA3@ 40 ppm	3-4mm berry size	Increases bunch weight, berry weight , skin thickness and pedicel thickness
CPPU @1 ppm and GA3@ 40 ppm	6-7mmberrysize.	Increases bunch weight, berry weight , skin thickness and pedicel thickness

Ethylene:

Ethylene is a group of plant growth regulators which are used for ripening fruits, defoliation (shedding) of leaves and stimulate the opening of flowers.

Table no 7: Effects of Ethylene and its time of application:

Concentrations	Time of Application	Effects
100 ppm	5days after bud sprout following April pruning.	Reduces apical shoot growth.
200 ppm	At15-16leaf stage following April pruning.	Increases the cane thickness.
1000-1500ppm	3-4days before October pruning	Induces leaf drop.
250 ppm 4000ppm	At veraison stage or at sugar formation stage, 2 days after pruning	Increases the Brix%. Breaks dormancy.

Role of Ethephon on defoliation of leaves:

The ethephon is not only being used for berry colour development but it also helps in defoliation of leaves. During fruit pruning, the leaf is removed so that the bud gets exposed to sunlight and the food material is accumulated in the bud to be sprouted after fruit pruning. The ethephon is helpful in early leaf fall and uniform bud sprout. This also helps in appearance of a greater number of bunches per vine in addition to the early bud sprout.

Fig 5. Uniform colour formation due to application of ethrel

Role of Ethylene in Abscission:

Ethylene is an accelerator of abscission. It is capable of promoting changes associated with pre abscission and aging of leaves, petioles, flowers and fruits.

De-greening in fruits:

It occurs after ethylene treated fruit is exposed to air that accelerates maturity and induces uniform ripening in fruits.

Fig 6. Defoliation of leaves due to application of ethrel

Hydrogen cyanamide

Hydrogen cyanamide (HC) is a plant growth regulator that is used to break dormancy in grapevine floral buds. HC is generally applied to vines after pruning, about four to eight weeks before bud break. The bud break rates induced by HC were higher than those induced by pruning alone. HC stimulates grapevine bud break through transient activation of gene expression and accumulation of reactive oxygen and nitrogen species. HC induces grape bud endodormancy release through carbohydrate metabolism and plant hormone signalling.

However, the physiological efficacy and economic benefits of HC applications diminish with increased chilling exposure. After pruning within 48 hrs Sponging of hydrogen cynamide to the buds will enhance bud break.

Table no 8: Use of Hydrogen cyanamide based on the condition.

Temperature	Concentration(ml/lit)
35-40°C	30.0ml/lit
30-35°C	40.0ml/lit
25-30°C	50.0ml/lit
Cane diameter	**Concentration(ml/lit)**
Less than 6.0 mm	30.0ml/lit
6-8mm	35.0ml/lit
8-10mm	40.0ml/lit
10-12mm	40.0ml/lit (twice)

Fig 7. Pasting of Hydrogen cyanamide on cane

Table 9 : Application of bioregulators at different stages after fruit pruning

Sr. No.	Days after pruning	Growth Stage	Chemical	Concentration /dose
1	1-2	After fruit pruning	Hydrogen Cyanamide50 SL	30-40 ml/l
2	21-24	Parrot-green (Pre-bloom)	Gibberellic acid (GA3) technical	10 ppm
3	23-27	2nd pre-bloom dip	GA3 technical	15 ppm
			Urea phosphate	1000 ppm
4	48-50	After berry set 3-4 mm for white seedless	GA3 technical	40 ppm
			Forchlorfenuron (CPPU) 0.1% L	2 ppm
		for color seedless	Forchlorfenuron (CPPU) 0.1% L	0.5 ppm
5	60-62	After berry set 6-7 mm	GA3 technical	30 ppm

6	50-70	Once before or at veraison	Calcium nitrate	5000 – 10000 ppm

Table 10: GA_3 for Berry Elongation and berry Development in grapes

Sr. No	Stages of application	Concentration of GA_3	Purpose
1	5 leaf stage or bunch of parrot colour (Pre-bloom)	GA_3@10 ppm	Raches elongation
2.	3 to 4 days after the first phase	GA_3@15 ppm	Raches elongation
3.	3 to 4 days after second stage as needed	GA_3@20 ppm	Raches elongation
4.	50 % Flowering Stage	GA_3@ 40 ppm	Berry thinning

Table 11: GA_3 for Production of export quality Grapes

Sr. No	**Time of application**	**Concentration**	**Spray/dip**	**Purpose/use**
1.	3-4 mm berry size stage	40 ppm GA_3+ CPPU or BR or BA	Dipping of bunch	Berry elongation
2.	Red gram grain stage (6-7 mm stage)	25 ppm GA_3along with CPPU @ 2 ppm or BA @ 10 ppm or BR @ 1 ppm.	Dipping of bunch.	Berry elongation
3	3-4 mm berry size stage	30ppm GA_3 +10 ppm 6BA	Dipping of bunch	Berry elongation
4	Red gram grain stage (6-7 mm stage)	30 ppm GA_3	Dipping of bunch.	Berry elongation

Table 12 : PGR for enhancement of shelf life in grapes.

Growth regulators	**Concentration**	**Stage of application**	**Purpose**
NAA	50-100 ppm	10 days prior to harvest	To reduce wet drop
Calcium nitrate or Calcium chloride	0.5-1.0 %	75 or 90 or 105 days after pruning	To increase the cell wall turgidity

Do's and Don'ts for application of bio-regulators

- **Cluster and berry thinning**

Do's

1. Spray GA3 @ 10 ppm at parrot green stage of cluster and 15 ppm GA3 after 4-5 days of 1st spray.

2. GA3 spray solution should be acidic (pH 5.5 - 6.5). Use citric or phosphoric acid or urea phosphate as a adjuvant to lower down the pH of spray solution.
3. Dip the clusters with 40 ppm GA3 at 50% flowering if necessary. Treat individual cluster selectively.
4. Cut the tips of clusters immediately after set by retaining 8-10 apical branches depending on the number of leaves available for a bunch.
5. Thin the berries manually before 3-4 mm berry size stage.
6. If thinning is inadequate remove the alternate branch of the rachis to retain 5-6 branches and clip the tip of the bunch 8 days after set.
7. Use sufficient spray solution to have optimum coverage of foliage as well as clusters.

Don'ts

1. Do not use the solvent (acetone / methanol) more than 30ml per gm of GA3.
2. Do not spray GA3 at pre-bloom stage without fungicide if the weather is cloudy and humid, particularly if it is likely to rain, to avoid excessive flower drop.
3. Do not spray GA3 at full bloom or immediately after berry set to avoid berry shatter and formation of shot berries.
4. Do not girdle the vines before 3-4 mm berry size stage.
5. Avoid injury to the berries while thinning mechanically by scissors.
6. Do not use IAA along with GA3 for cluster elongation.

- **Berry size**

  Do's

1. 1-2 ppm CPPU to 30-40 ppm GA3 and dip the clusters in the mixed solution once at 3-4 mm stage and again at 6-7 mm berry size stage. Selection of concentration of growth regulators for dipping should depend on the number of leaves available per bunch.
2. Clip off the tip of the cluster by 1/3rd or 1/4th of its length, since the under developed berries are mostly formed in the lower half of the bunch.
3. Ensure that all berries in a cluster receive all GA3 treatments uniformly.
4. Ensure adequate leaf/fruit ratio for a developing bunch (6-8 berries / leaf).

Don'ts

1. Do not allow the clusters to develop on a shoot having less than 8 leaves.
2. Do not treat the clusters with CPPU when the bearing shoot has inadequate leaf area, and the shoots are less vigorous.
3. Do not delay berry thinning beyond 8-10 mm stage of berries.

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Chapter-6

Management of physiological disorders in grape

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Introduction

Yield reduction and deterioration of quality in any crops may occur primarily due to several biotic and abiotic factors. Various pre and post harvest disorders can reduce the marketable yield and quality of fruits. Abiotic aspects of deterioration consist of environment (eco-physiological), nutritional (deficient or excess) and on the appearance time (pre-harvest and post harvest). Thus, the factors beyond the optimum range leads to deterioration of physiological process during the pre and post harvest period leads to incidence of physiological disorders. Physiological disorders can be defined as abnormal growth pattern/ external/internal conditions of fruits caused by adverse environmental conditions during growth in fields or orchards or during harvest, storage, and marketing. Symptoms of physiological disorders may appear disease like; they can usually be prevented by altering environmental conditions. When the environmental factors and input become limiting or exceed their optimal conditions, grapevines suffer a setback in their physiological balance and express certain disorders. Direct injuries from unfavorable weather conditions are also connected with disorders.

Physiological disorders are often caused by

- The deficiency or excess of something that supports metabolism
- The presence of something that interferes with metabolism.
- Can affect plants in all stages of their development.
- Non-transmissible because they occur without or in absence of infectious agents.
- Dealing with physiological disorders often means dealing with the consequences from a past event.
- Generally damaged and undamaged tissue is clearly demarcated.
- Serve as the 'open door' (entry) for pathogens.

Types of physiological disorders are:

Various atmospheric and edaphic factors affect physiological functioning of fruit in different manners and resulted in specific type of symptoms.

On the basis of causal factors:

- **Temperature related disorders:** Injuries of fruits resulting from the reactions to temperatures outside the optimum range during the pre- and post-harvest period fall in this category.

- Various disorders of this nature are '*freezing injury*', '*chilling injury*', '*heat injury*', etc.
- Any physiological factors like temperature, nutrients, etc., if present beyond the required range can alter the internal metabolic process of plant/ plant part but the symptoms may develop after a period of time when environmental conditions favour the development of symptoms.
- Manifestation of fruit physiological disorder ensues in two phases called *induction phase* and *development phase*.

Nutrient related disorders: Imbalance supply of essential nutrients to the plant may also results in various types of physiological disorders

- Calcium and boron play very critical role in fruit development and harvest quality
- Deficiency of Calcium and boron lead to the physiological malfunctioning and deterioration of yield and quality in many fruits.

Atmosphere related disorders:

- Fruit disorders can also develop due to the macro and micro climatic conditions of the fruit.
- Very high or low concentration of CO_2 alters the normal metabolism of the plant and result in physiological injury.
- Many fruits are highly sensitive to ethylene and get deteriorated upon ethylene exposure.

On the basis of appearance time

i. **Pre-harvest physiological disorders:** These disorders develop in the field during fruit growth period
ii. **Predetermined physiological disorders:** The primary causes of these disorders are some pre-harvest factors. Visual symptoms develop only during post-harvest storage period under conditions that encourage the symptom development.

Post-harvest physiological disorders: Development of fruit disorders in response to imposed storage conditions

Some of the important physiological disorders in grape are:

A. Eco-physiological disorders:

1. Dead arm trunk splitting
2. Barreness of vines
3. Sun scald/sun scorch
4. Poor cane maturity

B. Physiological disorders

1. Water berries
2. Shot berries
3. Pink berries
4. Bud or flower drop
5. Post harvest berry drop

C. Nutritional disorders

1. Cluster tip wilting
2. Bunch stem necrosis

Dead arm and trunk splitting:

This is the common disorder observed in the vines which are affected by excessive moisture stress and also the direct sunlight falling on trunks and cordons during sever summer conditions. These symptoms of drying of leaves will be appeared about 3 to 4 weeks after back pruning and the conditions excess drought condition prevails, cordon splitting and trunk splitting can be observed later on. So, it is mainly associated with higher temperature, sunlight intensity, lower atmospheric humidity seems to be the causal agents for this disorder. In the vines affected with disorder no specific fungus has been identified.

Control measures:

- Early summer pruning
- White washing of trunk and cordons
- Maintaining adequate soil moisture through periodic irrigation during summer
- Removal of dried arms
- Adjusting the position of canes/canes to narrow angle (as wider angle exposes them to direct sunlight)

Barrenness in vines:

This is observed in quite older vines in the neglected vineyards where on the cordons lot of barren areas is observed without sprouting of buds. In the entire vine we could observe too much of barren wood, inadequate number of shoots/canes, production of un-fruitful canes and after fruit pruning, we could observe production of only unproductive shoots/vegetative shoots. It may be due to wrong viticultural operations like wrong pruning practices, imbalanced application of fertilizers, wrong canopy management practices etc. Barrenness in vines is mainly due to failure of buds to sprout and also due to poor fruit bud differentiation after back pruning due to wrong management practices which leads to vine barrenness with respect to fruitfulness after forward pruning.

Control measures:

Proper pruning and training practices, shoot positioning are helpful to prevent vine barrenness. Corrective measures during back pruning like removal of barren cordons and rectifying the faulty canopies by encouraging formation of new cordons can prevent vine barrenness during vegetative phase of the vine. Proper management practices during fruit bud differentiation stage (40 to 60 days after back pruning) like sub cane development, spraying 50 ppm uracil, phosphorus application and judicious water management practices can improve fruitful canes after forward pruning. Avoiding taking heavy yield in one year may also lead to vine barrenness in the coming years. Hence, crop regulation practices like bunch thinning, berry thinning and maintenance of proper source to sink ratio can overcome the problem of vine barrenness.

Sun Scald:

Sunscald manifests as a discoloration on grape clusters, which may appear as browning, cracking, or shriveling. Although sunscald is an abiotic disorder (not caused by pests), development of fruit rots also has been associated with sunscald damage. Sunscald can be a significant problem in regions with intense sunlight, or following extreme heat spikes in cooler regions – particularly after veraison when berries begin to soften. Direct sunlight on unprotected clusters, typically on clusters that began their development in shade, is common. Drought conditions may exacerbate the effects, as well as management practices like leaf removal, summer pruning, and shoot positioning. Row orientation to reduce fruit exposure to the hottest sunlight should be considered to decrease the potential for sunscald.

Control measures

- Row orientation – North south orientation can reduce the direct exposure of bunches to western scorching sunlight during noon hours.
- Shade Netting – prevents direct exposure of bunches to sun
- Shoot positioning – Position the shoots (vegetative, non-productive) to cover the bearing shoots
- Evaporative cooling – spraying through overhead sprinklers and micro sprinklers to reduce the damage (reduction in 5^0F)
- Spray of Particle Film Forming anti-transpirant chemicals
- Bagging of clusters which are directly exposed to western sunlight

Poor Cane Maturity in Grape:

In this type of disorder shoots fail to mature and their barks remain green until late in autumn. Such shoots turn pink-red due to low temperature in winter. It is more serious in vineyards, where the shoot growth is vigorous and dense; vines are planted closely and excess nitrogen and irrigation are provided.

Control measures:

Judicious shoot pinching to check excessive vegetative growth; shoot thinning 30 days after summer pruning to prevent mutual shading of the shoots and promote light interception are some of the suggested remedial measures. Avoiding excess irrigation and nitrogenous fertilizers during 40-70 days after back pruning helps to overcome cane immaturity.

Water berries:

This disorder can be observed during the ripening period and mostly starts after veraison. It is mostly observed in restricted varieties which tend to produce heavy crop. Berries are almost normal in size, but the flesh is not firm compared to normal berries with watery texture. The berries are dull in color and at the time of harvest they start wilting and drying. Excess shading and too much moisture and humidity during veraison and fruit ripening stage along with excess cropping results in formation of water berries. Excessive irrigation and nitrogenous fertilizers should be avoided during berry development to reduce the water-berry formation

Control measures:

- Application of potassium in right quantity at right time can reduce the incidence of water berries.
- Thinning of excess bunches at the time before fruit set can reduce the incidence
- Shoot thinning to reduce the build of excess shade in bunch zone can also reduce the incidence

Shot berries:

Usually in normal bunches, some of the berries are extremely small, soft and seedless compared to other berries, which are called as shot berries. Boron deficiency and incorrect application of GA_3 (both time and concentration) can lead to formation of shot berries at the later stages of berry development. Sometimes poor pollination and fertilization, defective flowers and improper carbohydrate nitrogen ratio can also leads to formation of shot berries. Shot berries are seedless and very small in seeded varieties while in the seedless varieties are they are extremely small, soft and white in color. This disorder is also called as hen and chicken disorder as the small shot berries are surrounded by big normal berries.

Control measures:

- Application of auxin can improve pollination in fertilization in varieties which tend to produce shot berries
- Application of GA_3 and girdling immediately after fruit set can reduce the incidence

- Application of micronutrient mixtures containing zinc and boron can reduce the incidence

Bud and flower drop:

It is the common disorder in most of the vineyards in all the grape growing regions of the country and world. In French this disorder is commonly referred as ‘coulure’ or ‘shelling’. In India this order is restricted to Northern region in specific varieties like Perlette, Beauty Seedless and is less common in South and Central India. After expansion of panicles the flower buds start dropping before anthesis, usually 8-10 days before full bloom. Slight shaking of panicles results in drop off of all the flower buds. Usually the unfertilized buds will fall off and at severe conditions entire flower buds will fall leaving rachis and rachillae. Low levels of carbohydrates, insufficient growth hormones like gibberellins, auxins and cytokinins along with environmental stress are the predisposing factors for this disorder.

Control measures:

Prolonged moisture before full bloom results in formation of abscission layer. Similarly, excessive moisture in the soil along with salts in the irrigation water can also leads to flower bud drop. Hence, judicious water management practices should be followed. Foliar application of micronutrients especially zinc should be given (as zinc is precursor for auxin synthesis) to prevent flower bud and berry drop.

Pink berries:

This disorder mostly occurs in Thompson Seedless and its clones in Maharashtra and Northern Karnataka regions. The berries become pink during the ripening and before harvest. One of the main reasons attributed to formation of pink berries is large diurnal variation in day and night temperature during berry softening stage (veraison). Assumption of pink berry formation occurs only in the bunches directly exposed to direct sunlight is not holds good such berries can be seen in the deeper canopies where too much shade prevails. Hence, it is very complex physiological process to understand the formation of pink berries. Initially pink tinge forms at the berry surface and gradually covers entire berry and bunch. Though the pink berries are very sweeter than normal berries, the shelf life is less. It affects the exportable grapes as the importing countries need amber/green colored berries, which fetch better market price.

Control measures:

As exact cause/reason for pink berry formation is not clear, it is recommended to cover the directly exposed bunches with paper bags. Tyvec bags and non-woven fabric bags were found to reduce the incidence of pink berry formation. Adjusting the pruning date to coincide with the time where veraison should not coincide with too much diurnal variation in the temperature occurs.

Post harvest berry drop:

This problem occurs to poor pedicel attachment to the berries. The ripened berries start dropping at the time of harvest and also even after harvest in the storage. Weak and thin pedicel, harvest during the high temperature, lack of pre-cooling facilities will increase the berry drop. Some varieties like Manjari Naveen, Thompson Seedless, Sharad Seedless are susceptible for this disorder. High levels of endogenous hormones like ABA and ethylene may aggravate this problem, if severe moisture stress occurs during the harvesting period.

Control measures:

Spray of Naphthalene Acetic Acid (NAA) @ 50-100 ppm during 8-10 days prior to harvest reduces post harvest berry drop. Spray of GA3 @ 40 ppm along with 1 ppm CPPU at 3-4 mm berry stage and 8-10 mm berry stage can reduce the post harvest berry drop. Similarly spray of Calcium Nitrate @0.5 to 1% at 90 to 105 days can increase the cell wall integrity and thus pedicel attachment.

Cluster tip wilting:

Light brown lesions on the apical end of the rachis affect the conductivity of the rachis. This results in shriveling and drying of the rachis at the tip of the bunch. In severe cases the tip of the bunch up to 30-40% dries up completely leaving hard small and light brown berries at the tip. Thompson Seedless is more susceptible to this disorder. Shriveling of berries located at the tip of the clusters is a common symptom which usually occurs after veraison. The shriveled berries dry up and remain in the clusters even at harvest time. Excess crop with relation to its maximum capacity is the prime reason for cluster tip wilting. Insufficient leaf area results in reduced source area which causes malnutrition to berries located at the tip of the clusters which results in drying of such berries. More compact bunches also leads to wilting of cluster tips. Poor micronutrient management and calcium deficiency are the reasons for cluster tip wilting.

Control measures:

Maintaining adequate leaf area per fruit bearing canes (source to sink ratio) can reduce this disorder. Judicious management of micronutrients can reduce the incidence. Proper thinning of compact bunches and pinching the tip of clusters at the time of berry thinning can drastically reduce this disorder. Spray of $CaNO_3$ (0.5 to 1 %) at veraison can reduce the incidence to some extent.

Bunch stems necrosis:

Bunch stem necrosis (BSN) in grapes affects fruit set and fruit ripening. It can occur around the bloom, in which case it is called early bunch stem necrosis, at veraison or later. The occurrence of it is associated with weather conditions and crop nutrition. Late bunch stem necrosis is a complex physiological disorder of grape vines; where the bunch stems (rachises) shrivel during ripening, followed closely by berry shrivel. This sudden change is frustrating for growers, when seemingly healthy vines produce unusable clusters. LBSN affects vineyards worldwide, but may be caused by a number of environmental stresses. No pathogens are believed to cause this condition. Instead, certain weather conditions and vine nutrition seem to be associated with its occurrence. Low temperatures and high humidity around bloom or excessive rainfall after veraison may be related to its development. Imbalances between calcium and potassium as well as low levels of nitrogen in vines are other possible causes. Unaffected portions of clusters develop normal fruit quality. Developing management practices is a complex, long term task that may vary from vineyard to vineyard. Some potential environmental causes of late bunch stem necrosis which has been proposed by previous studies in other parts of the world include, Mg, Ca and N imbalances in the soil, cooler than average rainy weather during ripening, wet and poorly dried soils, excessive pruning and unhealthy vines.

Control measures:

Too much nitrogen causes excessive vigor which again causes primary bud-axis necrosis, restricting table grape yields. Over-use of nitrogen has been implicated in the physiological disorder, bunch stem necrosis. Hence, judicious nitrogen management can reduce the incidene of bunch stem necrosis. Research suggests that low levels of sugars in storage organs and table grape fruit lead to nitrogen accumulation, particularly during cold weather at maturation. In this situation, 2 to 3 spray of magnesium sulfate starting before veraison can reduce the incidence of BSN. However, while foliar sprays can help, long-term magnesium shortages should be corrected using soil applied or fertigated magnesium fertilizer in a standard maintenance programme.

Berry cracking

Berry cracking is one of the most serious problems in grapes. Berry cracking, a physiological disorder where fruit surface crack leads to major commercial losses in the table and wine grape production by reducing both yield and quality. Cracking generally occurs due to the physical failure of cuticle or skin; results from stresses acting on skin and also due to heavy rainfall. The environmental and physiological causes of cracking or splitting of grape berry are not well understood. It probably involves interactions between environmental condition and the extensibility or integrity of the berry cell wall. This was reviewed to point out various factors contributing to cracking in grapes and to provide suggestion for prevention of cracking and to draw the directions for future research. Factors responsible for fruit cracking includes water on fruit stalk and surface, berry temperature, relative humidity, disease induced cracking, berry ripeness, berry cultivar and mechanical property of grape. Several strategies were described for the prevention of this disorder includes careful water management, monitoring soil moisture, spraying of growth hormones and the role of micronutrient. Some of the varieties like Sharad Seedless, Fantasy Seedless are susceptible for berry cracking.

Management

One of the important strategies to avoid cracking in fruits is careful water management. Proper water management must be in operation during all stages of fruit development. Daily assessment of the soil moisture within the root zone is needed to avoid berry cracking and to achieve high quality yields of fruits. Berry cracking can also be restricted or minimize by the spraying of some bio-regulators like GA3 and chemicals like calcium compounds. Application of both (GA3 and calcium compound) on young fruits are reported to minimize the fruit cracking. Some anti-transpirant and micronutrient like boron also have a vital role in restricting the berry cracking

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Chapter-7

Abiotic stress management for sustainable grape production

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Introduction

Total global area under grape cultivation has stabilized to 7.5 million ha with a production of 80.1 million tonnes. In India, grape area has grown from 47.5 in 2001-02 to 162 thousand ha in 2022-23 with production increasing from 1184 (2001-02) to 3477 (2022-23) thousand tonnes. Amongst the horticultural crops, it is an export-oriented crop with total export of 267.950 thousand tonnes valued at Rs. 2543.42 crores during the year 2022-23. More than 90% of the area is concentrated in Maharashtra and Karnataka. Unlike other countries where wine grapes dominate, in India majority of the grape produced is utilized for table purpose followed by raisins and very less for wine. The viticulture practices in India are quite different from other countries in Temperate and Mediterranean climate where grapes are grown under single pruning and single cropping system. However, in major grape growing regions of India, the practices involve double pruning (foundation and fruit pruning) and single cropping.

Climatic changes constraints to grape production

V. vinifera is a temperate climate species adapted to hot summers with mild winters. The suitability of a given grape cultivar to a local environment is based upon day length, heat summation, rainfall, length of the growing season, and minimum winter temperatures. On a broad scale the main grape production area is found between 30 and 50°N and 30 and 40°S latitudes, corresponding to the 10 and 20"^C yearly isotherms.' Grapes can be commercially grown in other areas where climate is moderated due to local geographical conditions (mountains, land masses, and ocean currents). Raisin production is limited to the latitudes of 30 and 39°N in the Northern Hemisphere and between 28 and 36°S in the Southern Hemisphere. This is due to the fact that the best suited raisin cultivars, Thompson Seedless' (syn. 'Sultinina') and 'Zante Currant', require warm temperatures for fruit bud differentiation and fruit maturation. In addition, the production of natural raisins (sun-dried grapes) requires high temperature sand lack of rainfall following harvest. Warm, dry weather also favors the production of table grapes as the incidence the fungal diseases is much reduced under these conditions.

With respect to grape production In India; last 5 to 6 years are adversely affected due to untimely rainfall during the grape season in states like Maharashtra, Karnataka, Tamil Nadu, Mizoram, and some eastern states. Grape growers face issues such as more infections of downy mildew and powdery mildew, flowering and fruiting issues, berry cracking, low quality of berry. Excessive rain or humidity during fruit ripening can lead to rot and spoilage problems. Additionally, during the time of grape bunch thinning and harvesting, if there is rainfall, it can lead to berry cracking, which in turn can lead to the entire crop getting damaged. Currently, the European Union is a major destination for grape exports. However, export is limited from February to April. Nevertheless, in recent years, grapes from countries like Chile, South Africa, and Peru have entered the market during this period.

Although hot extremes and heat waves are set to become more frequent over the course of this century (IPCC, 2007), the most imminent challenges facing the wine, table grape and raisin industries in arid and semiarid regions are probably not heat waves per se, but increasing drought and salinity because of higher evaporation coupled with declining water availability (Schultz, 2000; Stevens and Walker, 2002).

Majority of the grape cultivation in India is concentrated in the agro-ecological region-(K4Dd3) with the mean annual precipitation, ranging between 600 and 1000 mm, covers about 40 per cent of annual PET demand (1600 and 1800 mm). This results in gross annual deficit of 800 to 1000 mm of water. Grape growing regions comprising of districts of Ahmednagar, Beed, Solapur, Sangli (eastern parts), Satara (eastern parts), Osmanabad and Latur in Maharashtra state, and Bidar, Gulbarga and Bijapur in Karnataka State constitutes drought-prone areas. Severe drought spells repeat once in three years. The moisture availability mostly remains as sub marginal (Gajbhiye and Mandal, 2006).

Moisture and temperature stress not only affects the growth and yield of crop but also its quality. With the impact of climate change the occurrence of moisture and temperature stress events have become frequent, more severe and erratic. Seasonal changes in climatic conditions are impacting grape productivity either in terms of reduced fruitfulness due to high temperature, early/delay in monsoon arrival, unseasonal rainfalls or reduced rainfall. The soils also if not managed properly affects the productivity due its calcareous nature, sodicity issues, low organic carbon and compaction.

As a result, India needs to tap into markets such as China, Korea, Australia, and New Zealand for grape exports. Grape production and quality are sensitive to temperature, water availability, solar radiation and carbon dioxide. Yields are susceptible to weather events and conditions at key phenological stages during the growing season, such as at bud break and flowering. Among the many environmental factors that can affect flowering and fruit-set, cold or rainy weather around flowering can greatly reduce the number of grape clusters formed and thereby harvest yields. To achieve this, preparing for the peak season until December-January will involve managing grapevine fruit pruning schedule from July to September. In such circumstances, using plastic coverings for grape growers can be a viable alternative. Research conducted at the ICAR-National Grape Research Centre suggested to use plastic coverings can be a favourable option for getting ensured quality produce of grape in those areas of grape which are more prone to change in climatic conditions.

Moisture Stress

Ninety per cent (90%) of simulations predict increased droughts in the sub-tropics by the end of the 21st century (Bates et. al. 2008) while increased extremes in precipitation are projected in the major agricultural production areas of southern and eastern Asia, eastern Australia and northern Europe.

The water requirement of the grapevine differs based on the phenological stages, with stress being desirable at certain growth stages e.g. Bud differentiation stage, flowering stage. A general impact of moisture stress on grapevine includes reversible as well as irreversible effects. Reversible effects include decreased cell turgor pressure, reduced stomatal conductance, reduced photosynthesis (sugar production), decreased shoot growth and reduced berry size. As water stress intensifies, irreversible effects become more apparent depending upon the water stress severity which includes reduction in berry size, decreased fruit set, late sugar accumulation in fruits, reduction in fruit colour, leaf chlorosis and necrosis, berry shrivelling, defoliation and vine death. A number of studies have been conducted in different grape growing regions of the world on impact of moisture stress on phenology of grapevine. Vegetative growth of grapevines increases with water application rate (Van Zyl, 1984; Myburgh, 1996). This also applies to Sultanina (Araujo et al., 1995). Increased growth vigour (Buttrose, 1974; Myburgh et al., 1996) or leaf area per grapevine (Eastham & Gray, 1998; Myburgh, 1998) increases grapevine water consumption.

However, the increased vegetative growth which results when the availability of water is increased does not necessarily result in higher yields being obtained (Conradie et al.,1996; Conradie & Myburgh, 2000). Untimely irrigation, in particular during ripening, will also increase the risk of disease infection, such as *Botrytis cinerea* (Van Zyl,1984). More dense canopies will increase the risk of disease infection due to lower evaporative potential in the fruit zone (English et al.,1990). Hence, when irrigation induces excessive growth without increased yield, or even reduces yield (Carbonneau & Casteran, 1979), grapevine water-use efficiency in terms of irrigation applied per unit fruit produced will be reduced.

Severe water stress after flowering can induce cluster abscission (Hardie & Considine, 1976), whereas mild water stress will reduce vegetative vigour, possibly improving canopy light penetration and increasing yield (Williams et al., 1994 and references therein). Water deficits induced during fruit set will restrict cell division and reduce berry size (Hardie & Considine, 1976; Van Zyl, 1984; Matthews & Anderson, 1989; McCarthy, 1997). Sugar accumulation, which is crucial for quality-raisin production (Saayman & Albertse, 1984), can be reduced if severe water stress during ripening results in leaf senescence, but may be increased when mild water stress reduces vegetative growth (Smart & Coombe, 1983). Practical experience showed that a luxurious water supply before or during harvest may reduce sugar content and, consequently, induce poor raisin quality due to lower drying ratios

Fig 1. Grapevines Damaged due to heavy rain and hail storm

(Goosen, 1956). Scientific knowledge concerning the effect of water deficits on raisin quality is, however, limited. Water deficits induced by terminating irrigation ten weeks prior to harvest reduced sun- dried Sultanina raisin quality significantly compared to a cut-off five weeks before harvest (Christensen, 1975). However, this effect was not consistent over seasons. Fresh berry mass and raisin size tended to be larger when irrigation was terminated.

In India, due to lack of scientifically standardized irrigation schedule for grafted vines in India, the growers were irrigating the vineyards arbitrarily. Irrigation scheduling for vines grafted on Dogridge rootstock based on growth stage and pan evaporation resulted in an average 52% savings in irrigation water. Irrigating the vines at 50% or less rate compared to recommend irrigation schedule during shoot growth, berry growth and development stages although resulted in higher water use efficiency, it reduced the yield, bunch number and biomass significantly (Sharma et. al. 2008). Recent studies at NRC Grapes (2012-2016) have clearly brought out the impact of moisture stress at different crop growth stages on yield and quality. The yield loss in different moisture stress scenarios ranged from 6.4% to as high as 26.2 % during the period of experimentation. Mild water stress (50% of recommended irrigation schedule) during shoot growth stage coupled with dry period during foundation pruning season caused 26.2% yield loss worth of Rs 1,42,750/-. The sugar accumulation rates are lower in the moisture stressed vines as compared to vines irrigated with recommended irrigation schedule.

Water use efficiency is affected by the rootstocks used. Rootstocks (Dogridge and 110R) produced significantly higher yield, brix yield and pruned biomass than own rooted vines at the lowest as well as highest level of irrigation (50% of recommended irrigation level and recommended irrigation level) in all the three years of study. The water use efficiency in terms of kg brix yield/ mm/ha irrigation applied was in the order of B2/56 (9.66) > Dog Ridge (7.89) > own rooted vines (3.85). At the recommended irrigation level, cost-benefit ratio was highest in the vines grafted on B-2/56 (1.97) followed by Dogridge (1.84). Own rooted vines gave the lowest cost – benefit ratio (Upadhyay et. al. 2006b). Further, techniques aimed at reducing evapotranspiration like mulching + antitranspirant (Upadhyay et. al. 2006a), subsurface (Sharma et. al. 2007) improved the water use efficiency of grafted vines. The problem of sodicity is likely to be compounded by moisture stress as availability of irrigation water for leaching salts will be an issue. Dogridge, the most common rootstock cannot exclude sodium and under such conditions will lead to reduction in productive life span of the grapevines. Use of rootstocks like 110R, 1103P that could exclude sodium under saline irrigation, could be effective under such conditions (Upadhyay et. al., 2013).

Temperature stress

Grape growing regions are often classified into so-called ‘Winkler regions’ according to heat summation measured in cumulative growing degree days (GDD), a scheme originally proposed by Amerine and Winkler (1944). This method sums up the mean daily temperatures above a threshold typically set at 10°C over a 7-month ‘standard’ growing season (April–October in the northern hemisphere and October–April in the southern hemisphere). Each 1°C increment in mean temperature adds 214 GDD to the standard growing season. Therefore, if one assumes an average increase from the present of 1.5°C by 2020, cumulative heat units would increase by 321 GDD. A 2.5°C increase by 2050 would add 535 GDD to the current heat units. This simple estimate shows that the projected rise in temperature associated with global climate change (IPCC 2007) will likely shift several of the world’s growing regions into the next higher Winkler region by 2020, and that this shift will affect most regions by 2050.

These climatic changes can cause shifts in grapevine growth stages that are observable in terms of phenological events, such as budburst, flowering, veraison, harvest and then in yield as well. In fact, the seasonal changes to a greater extent can influence the formation and ratio (at favourable levels) of sugar and pro-phenols in grapes, thereby affecting the quality of produce. In a study covering 18 years of data collection, the percentage of fruitful buds in Thompson Seedless (TS) correlated highly with air temperature and hours of sunshine during a 20-day period at the beginning of a season (Baldwin, 1964). This critical period corresponds to growth stages 13 to 18 of the modified Eichhorn and Lorenz system (Coombe, 1995). When air temperature alone was varied in a growth chamber study (Buttrose, 1969b), bud fruitfulness of Muscat of Alexandria rose from zero at 20°C to a maximum close to 35°C, and was followed by a steep decline beyond 35°C.

The annual succession of phenological stages of grapevines is commonly observed to be accelerated with a rise in temperature (Alleweldt et al. 1984; Jones and Davis, 2000; Chuine et al. 2004; Duchêne and Schneider 2005; Wolfe et al. 2005; Webb et al. 2007). Such observations show a consistent trend towards earlier flowering, veraison and harvest. The timing of veraison may be of particular importance, because earlier veraison implies that the critical ripening period shifts towards the hotter part of the season. This has already been described for Alsace, France, where the period between budburst and harvest has become shorter, and ripening is occurring under increasingly warm conditions (Duchêne and Schneider, 2005). Because ripening grape berries are designed to minimize transpirational water loss (Radler, 1965; Possingham et al. 1967; Blanke et al. 1999; Rogiers et al. 2004), they cannot take advantage of the evaporative cooling mechanism that protects leaves from overheating. Thus, while high temperatures tend to accelerate grape ripening, too much heat can inhibit or even denature berry proteins, and may lead to symptoms of sunburn. Model calculations performed for Australian wine regions also project a forward shift in harvest date, which was arbitrarily defined as grapes reaching soluble solids content of 20°Brix (Webb et al. 2007).

Recent studies at ICAR-NRC Grapes (2012-16) have shown that in the two consecutive years (2013-15), the Thompson Seedless vines pruned on 1st May, sprouted earlier (12 days) as compared to the vines pruned on 1st April (17 days). This difference in days taken to sprout in the vines pruned on 1st April could be attributed to low day time RH (< 20%) along with high temperatures between 9 am to 6 pm. Further, vines pruned on 1st May 2013 had a smaller number of fruitful canes which could be attributed to early onset of monsoon leading to cloudy weather conditions. The vines pruned in April (Foundation pruning) and October (Fruit pruning) had significantly higher yield as compared to vines pruned in May (Foundation pruning) and fruit pruned in November. The decrease in yield in the second case was due to early onset of monsoon leading to cloudy weather conditions during the fruit bud differentiation stage in Foundation pruning season. The accumulated Growing degree days (°C) ranged from 1450.60 to 1464.60 in different pruning dates during Fruit pruning season. However, the number of days taken to accumulate the growing degree days ranged from 117 to 128 under different pruning treatments.

In another experiment at ICAR-NRC Grapes on Thompson Seedless vines subjected to moisture stress, use of shade nets after foundation pruning under high temperature 35.2°C to 41.2°C (average maximum temperature being 37.91°C) resulted in early and more number of sprouted buds per vine whereas without shade net the sprouting of buds was erratic and delayed. However, one needs to understand that a 1mm increase in pan evaporation due to increased temperature will lead to increase in irrigation water requirement by 4200L/ ha/ day. Use of shade in table grapes is common for protecting the bunches from temperature stress and hence, can be used under high temperature stress. High diurnal variations and low temperature have been found to increase the incidence of ‘pink berry’ disorder in white grapes varieties like Thompson Seedless and its mutants. Use of shade nets and covering the grape bunches with paper bags has proved an effective tool in minimizing the berry discoloration problem.

Soil salinity stress

Salinity is a significant concern in grape cultivation, particularly in regions where irrigation with saline water or soil salinization due to natural factors is prevalent. High levels of salts, such as sodium, chloride, and sulphate, can adversely affect grapevine growth, yield, and fruit quality. Here are some key aspects of salinity issues in grape

Effects of Salinity on Grapevines:

- Reduced Water Uptake: High salt levels in the soil can create an osmotic imbalance, making it difficult for grapevines to absorb water from the soil.
- Ion Toxicity: Excessive salts can lead to the accumulation of toxic ions in grapevine tissues, causing cellular damage and impairing physiological processes.
- Nutrient Imbalance: Salinity can disrupt the balance of essential nutrients in grapevines, leading to deficiencies or toxicities that affect plant growth and development.

- Reduced Yield and Quality: Salinity stress can result in decreased grape yield, smaller berry size, uneven ripening, and altered fruit composition, impacting overall quality.

Management of abiotic stress

Abiotic stresses in grape cultivation refer to non-living environmental factors that can adversely affect plant growth and productivity. These stresses include extreme temperatures, drought, salinity, water logging, and nutrient deficiencies. Here are some strategies for managing abiotic stress in grape cultivation

Site Selection and Soil Management

Choose suitable sites for grape cultivation with well-draining soils and good air circulation. Conduct soil tests to ensure proper nutrient levels and pH balance. Implement soil management practices such as mulching and cover cropping to improve soil structure and water retention.

Irrigation Management

Implement efficient irrigation practices to ensure adequate water supply while avoiding water logging. Drip irrigation systems can be particularly beneficial for delivering water directly to the root zone and reducing water wastage.

Canopy Management

Proper canopy management techniques such as pruning, trellising, and leaf removal can help regulate sunlight exposure, improve air circulation, and reduce the risk of fungal diseases and heat stress.

Soil Amendments

Incorporate soil amendments such as gypsum or organic matter to improve soil structure, enhance water retention, and mitigate salinity or alkalinity issues. Salinity Management Strategies:

- Soil Amendments: Gypsum (calcium sulphate) application can help improve soil structure and facilitate the displacement of sodium ions, reducing soil salinity levels.
- Irrigation Management: Implementing drip irrigation or other efficient irrigation systems can minimize the use of saline water and reduce salt accumulation in the root zone. Additionally, scheduling irrigations to leach excess salts below the root zone can help mitigate salinity.
- Salt-Tolerant Rootstocks: Using grapevine rootstocks that exhibit tolerance to saline conditions can enhance the resilience of grapevines to salinity stress.
- Soil Leaching: Leaching the soil with low-saline or freshwater can help flush out accumulated salts and lower soil salinity levels.

- Soil and Water Testing: Regular monitoring of soil and water salinity levels is essential for assessing the extent of the problem and guiding management decisions.
- Mulching: Applying organic mulches to the soil surface can help reduce evaporation, maintain soil moisture, and minimize salt accumulation.
- Crop Rotation and Cover Crops: Introducing salt-tolerant crops in rotation with grapes or using cover crops can help improve soil structure and reduce soil salinity over time.

Mulching and Cover Cropping

Mulching with organic materials such as straw or wood chips helps conserve soil moisture, regulate soil temperature, and suppress weed growth. Cover cropping with nitrogen-fixing plants can improve soil fertility and structure.

Nutrient Management

Maintain optimal nutrient levels in the soil through regular soil testing and appropriate fertilization practices. Balanced fertilization with macro and micronutrients is essential for healthy grapevine growth and tolerance to abiotic stress.

Genotypes adaptation and genetic improvement

Climatic change endangers vineyard sustainability in different ways. Water availability is a major limiting factor in wine production, as most of the current vineyards are located in semiarid areas. Together with agronomic approaches to face climatic change, the impressive genetic variability of the grapevine is a major source for adaptation. Among these genetic resources, the wild grapevine population scan offer interesting adaptations. There is also an impressive variability among the large list of existing cultivars and clones. The emergence of genomics and omics era offer new tools to identify adaptive characters. As the present review shows, the search for genotypes better adapted to climatic change conditions seems a promising field to face the climatic change challenges in a sustainable and cost-effective way.

Rootstock Selection

Choose grapevine rootstocks that are well-adapted to local soil and climatic conditions, including resistance to specific abiotic stresses such as drought, salinity, or alkalinity. Rootstocks ability to help scion to cope with biotic stresses, rootstocks can confer also tolerance to a large range of abiotic stresses. Among these, drought and high salinity have an enormous impact on crop production; indeed, they are one of the major factors limiting plant productivity and cause a severe yield reduction (Cramer et al., 2007; Tsago, Andargie, & Takele, 2014). Therefore, breeding of crop varieties that use water more efficiently is a key strategy for the improvement of agro systems (Marguerit et al., 2012). Based on the global climate models which predict an increase in the aridity in the next future (Dai, 2013), water deficit may become the major limiting factor. In this context, rootstocks may play an important role in limiting crop loss by improving water use efficiency, potential for survival, growth capacity and scion adaptability to stress conditions (Marguerit et al., 2012; Meggio et al., 2014; Serra, Strever, Myburgh, & Deloire, 2014). Case study at ICAR-NRCG at primary levels, the results of bio-chemical, root morphological and anatomical parameters revealed that 140Ru, 110R, SO4 and Dogridge rootstocks performed better under drought condition, whereas 1103P, 110R and 140Ru rootstocks under water-logging condition performed better as compared with other grape rootstocks.

Canopy Protection:

Implement measures to protect grapevines from extreme temperatures, such as installing shade cloth or using overhead sprinklers for cooling during heatwaves.

Use of Plastic cover for grape cultivation: Quality and cost of structure

Plastic covering in grape cultivation refers to the use of plastic materials, often in the form of plastic film or plastic sheet, to enhance the growing conditions and management of grapevines. This practice is employed to improve various aspects of grape cultivation and vineyard management. In countries like Spain, Italy plastic cover is used for quality grape production. This is a unique and specialized form of agriculture. The overall objective of use of protected structure is to modify the natural environment to achieve optimal productivity of grape by enhancing yields, improving quality, extending the effective harvest period and expanding production areas. This practice of use of plastic cover for quality grape production is used in some part of Nashik, Pune, Satara and Sangli districts in Maharashtra.

The type of plastic cover suitable for tropical conditions should be woven laminated film, UV stabilised to 580 kLy (Indian conditions) with anti-thermic properties (25% thermicity) that is helpful during winter season, in preventing infrared radiation from escaping from inside and could be helpful in berry development. The plastic cover should have 85 to 90% light transmission with 65 ±5% light diffusion with cloth weight of 140±5% gsm. As a number of sulphur sprays for control of powdery mildew and mites are used in the vineyard, the plastic film should have anti sulphur property to withstand up to 2000 ppm of sulphur sprays. There is tendency of the water vapour to condense below plastic; hence, the plastic cover should have anti drip property that allows the water directly to slide away from the surface of the plastic without dropping on the leaves. It should have anti-dust property for ease of cleaning.

The cost of establishing plastic cover in the vineyard depends upon the cost of the plastic cover and the structure.

In the existing vineyard, plastic cover can be installed in two ways viz.

i) Providing additional support on the existing Y trellis: Rs 2.5-3.0 lakhs/acre and

ii) Erecting independent support structure: Rs 3.5-4.0 lakhs/acre. For automation to open and close the plastic cover, another Rs 4-5 lakhs will be required. The layout of the plastic should be such that the centre of the plastic is at least 5' above the center of the vine cordon. To cover one-acre vineyard, a total of 5500m^2 with 3m width plastic is required. The cost of imported plastic per acre ranges between Rs 5.0-6.0 lakhs. Whereas for indigenously procured one it is approx. Rs 2.75 lakhs (plus accessories). The life of the plastic cover could range from 3 to 5 years depending upon quality of plastic.

The plastic cover on the vineyards has the following advantages:

- The problem of inflorescence necrosis/flowerdrop/bunch rot in addition to the heavy incidence of Downy mildew is addressed through plastic cover.
- It protects the vines from damage to the vine parts (cordons, trunk, canes) and bunches from hails.
- It also reduces the berry cracking incidence due to unseasonal rains (accompanied with hails).
- Plastic cover on vineyards reduces the impact of temperature on vine growth and productivity.
- Due to low transpiration loss from the leaves, the irrigation water requirement is also

Fig 2. Quality grapes under plastic cover

reduced under plastic cover especially during fruit pruning season.

ICAR-NRCG message to grape growers:

Plastic cover is one such technology that can be utilized for profitable grape cultivation under changing climate conditions, sometimes, losses can be as high as 100 percent. Plastic covering can help mitigate the damages. It can also be used in north India for quality grape production of varieties whose maturity period is about 130 days instead of depending on the few early maturing varieties.

Precision viticulture tools

Precision viticulture is a strategy that integrates the advanced information technologies and field research methodology data, aiming to maximize production efficiency, quality potential, and profitability, while minimizing environmental impacts (Hall et al. 2002; Rey-Caramés et al. 2015). Modern and sustainable viticulture requires objective and regular monitoring of key parameters for rational and differentiated agronomic management of vineyards regarding spatio-temporal variability of growth, yield, and grape composition at a local scale (Ferreiro-Armán et al. 2006). Through the acquisition of spectral data from several platforms (satellites, aircrafts, and remotely aerial systems), remote sensing is one of the tools used in precision viticulture to assess fine-scale temporal and spatial changes in soil moisture, canopy growth, water status, chlorophyll, and carotenoids levels, as well as grape composition and quality potential (Ferreiro-Armán et al. 2006; Lamb et al. 2008; Meggio et al. 2010; Zarco-Tejada et al. 2013). For instance, a recent study of Silva et al. (2018) introduced a model combining hyperspectral imaging and support vector regression to predict anthocyanin concentration, pH index and sugar content in "Touriga Franca" variety, which can be potentially used for a wider variety of grapevines in an environmentally friendly approach. Also, Acevedo-Opazo et al. (2008) proposed a possible site-specific approach to characterize grapevine water status variability. Several studies showed that remote sensed hyperspectral data could be also used for grapevine varietal mapping, representing a practical tool for winegrowers to manage grapevine variability, and for inventory purposes (Hall et al. 2002; Ferreiro-Armán et al. 2006). Hence, the association of high-resolution information and the development of site-specific agricultural management can produce a potential computer-based model, allowing the characterization of spatial-temporal variability at a vineyard level, with minimum impacts for the vine (Hall et al. 2002). Moreover, along with all the field research methodologies applied in grapevines, this technology represents a novel reliable approach to support the decision-making process.

Decision Support System

The major challenge in crop modeling is to develop user friendly economically viable decision support system that is readily adoptable by the decision makers as well as farmers

(Krishnan *et al.,* 2011, Rossi *et al*., 2010, Thomopoulos*et al.,* 2009). For the Decision Support System to be successfully developed and adopted as a tool, agricultural resource management, and the user's distrust of computer-generated information must be overcome. For practical purposes, the farmers require less complicated decision support systems (Rossi et al., 2010). Any model-based reasoning system which simplifies the information input and provides a user-friendly output format for crop management decisions such as when to irrigate and how much fertilizer to apply, the extent of crop management under extreme events etc will be very useful to the farmers.

Development of Decision support system will improve the farmer's ability to take crucial management decisions keeping the economics and long-term prospects of the standing crop. It will provide recommendations to a grower based on his/her crop data, farm data, and prevailing weather conditions that will support or assist grower's decision-making capacity. The occurrence of moisture and temperature stresses may differ in different years at different crop growth stages.

The farmer needs to be made aware about the measures taken to mitigate the problems of moisture and temperature stress at different crop growth stages. The extent of losses a farmer suffers will define his response to the situation. For e.g. Moisture stress during veraison stage will lead to reduced bunch weight and quality of grapes. Depending upon expected yield and quality loss percentage, a farmer can decide in advance to buy/ transport water from elsewhere to take care of this problem as the cost involved will be compensated by the yield increase.

This will help in timely decisions involving changes in management practices like pruning time to escape from stress, techniques to increase the water availability to vines and soil moisture conservation techniques, to be taken by the growers to save their crops from moisture and temperature stress conditions.

ICAR-NRC Grapes has developed and launched Web and mobile based DSS applications. DSS application handles queries relating to water requirement as per growth stage, nutrition requirement and problems caused due to heat and moisture stress like leaf curling, leaf drying, leaf blackening, leaf yellowing and leaf drop, stunted shoot growth, berry discoloration, berry cracking, berry drop etc.

Software has been further enhanced with new features like irrigation time requirement calculator; nutrient application based upon soil and petiole test, plot registration on mobile after profile creation on web and optimized advice based on feedback received from farmers. Web application is deployed and made available on http://grapesdss.icar.gov.in. Mobile application is being made available over Google Play store. Grower can download it at any time and start using it. All basic functionalities are made available on mobile starting from grower profile creation, plot and crop registration and asking queries.

Majority of the grape growing area in India lie in the semi-arid tropics of Maharashtra and Northern Karnataka. Moisture and temperature stress are the most important abiotic stress affecting the grapevine productivity. Fluctuation of temperature during the ripening period will affect the quality of grapes. Increasing temperature during the foundation pruning season will lead to delayed/ uneven sprouting. The rise in temperature will accelerate the succession of phenological events that could have a direct bearing on the quality of grape. Early onset of monsoon will impact the fruitfulness of the vines, leading to decline in productivity. Moisture stress affects during crop growth stages on grapevine productivity has been quantified. Breeding of varieties for abiotic stress is a time taking process, various crop production techniques have been developed that could help in alleviating temperature and moisture stresses. Utilisation of Decision support system that handles queries on irrigation, nutrition and problems caused due to moisture and temperature stress will go a long way in addressing the concerns of moisture and temperature stress.

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Chapter-8

Breeding approaches for grapevine improvement

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Introduction

The breeding of seedless, colorful, disease-resistant new grape varieties with large berries is one of the important topics studied in viticulture. In addition to traditional methods such as clonal selection and conventional crossbreeding, biotechnological methods such as embryo rescue techniques and polyploidy have gained importance in seedless grape breeding.

The brief account of various breeding methods relevant to the grape improvement program is given below;

1. Plant Introduction

Plant introduction is applicable to all three groups of crop plants, *viz.*, self-pollinated, cross pollinated and asexually propagated species. It is an oldest and rapid method of crop improvement. The introduced material may be used in three ways *viz.*,

(1) Directly as a variety

(2) As a variety after selection

(3) As a parent in the hybridization for development of variety or hybrid

The introduction of the exotic grape varieties viz., Abi or Bhokari, Fakiri, Habshi, Sahebi, Anab-e-Shahi in the Deccan region of the country by Muslim rulers was an important event in Indian viticulture. In India, a large number of grape varieties were introduced firstly under the leadership of S.B.S. Lal Singh, then Professor of Horticulture at Punjab Agricultural College, Lyallpur (116 grape varieties) in 1928 and late 1950s by Dr S. G. Randhawa (about 1002 grape varieties) of Indian Institute of Agricultural Research, New Delhi especially from USSR, Yugoslavia, Australia, France, Germany, Italy, Bulgaria, and many other countries. The grape gene pool thus created through introduction contained the various commercial grape varieties from all over the world viz., Thompson Seedless, Perlette**,** Beauty Seedless, Kishmish Chernyi, Red Globe, Flame Seedless, Fantasy Seedless, Crimson Seedless, and Centennial Seedless. From this base material Indian grape growers identified various clones for berry and bunch characters like Tas-a-Ganesh, Manik Chaman, Sonaka Sharad Seedless, Rao Sahebi, Dilkush etc. during 70s and 90s.

2. Selection

Selection is basic to any crop improvement. Isolation of desirable plant types from the population is known as selection. It is one of the two fundamental steps of any breeding programme viz.,

1. Creation of variation
2. Selection.

There are two agencies involved in carrying out selection: one is Nature itself (Natural selection) and the other is man artificial selection. Though both may complement each other in some cases, they are mostly opposite in direction since their aims are different under the two conditions (nature and domestication). The effectiveness of selection primarily depends upon the degree to which phenotype reflects the genotype. Before domestication, crop species were subjected to natural selection. The basic for natural selection was adaptation to the prevailing environment. After domestication man has knowingly or unknowingly practiced some selection. Thus, crop species under domestication were exposed to both natural and artificial selection i.e. selection by man. For a long period, natural selection played an important role than selection by man. But in modern plant breeding methods natural selection is of little importance and artificial selection plays an important role.

Clonal selection is used in asexually propagated species. In this method progeny of a single best clone is released as a variety. Such variety has heterozygous but homogeneous population.

Clonal selection by Indian grape growers has played a crucial role in varietal development especially in table grapes. Indian grape growers with their experience, knowledge and efforts developed several promising natural mutants mostly from Thompson Seedless and Kishmish Chernyi. These clones are widely accepted for commercial cultivation and still under cultivation on large area. The two basic requirements for select on to operate are;

1. Variation must be present in the population.
2. The variation should be heritable.

3. Hybridization

The mating or crossing of two plants or lines of dissimilar genotype is known as hybridization. In plants, crossing is done by placing pollen grains from one genotype, the male parent, on to the stigma of flowers of the other genotype, the female parent. It is essential to prevent self-pollination as well as chance cross-pollination in the flowers of the female parent. At the same time, it must be ensured that the pollen from desired male parent reaches the stigma of female flowers for successful fertilization. The seeds as well as the progeny resulting from the hybridization are known as hybrid or F1. The progeny of F1, obtained by selfing or intermating of F1 plants, and the subsequent generations are termed as segregating generations. The term cross is often used to denote the products of hybridization, i.e. the F1 as well as the segregating generations.

The chief objective of hybridization is to create genetic variation. When two genotypically different plants are crossed, the genes from both the parents are brought together in F1. segregation and recombination produce many new gene combinations in F2and the later generations, i.e. the segregating generations. The degree of variation produced in the segregating generations would, therefore, depend on the number of heterozygous genes in the F1. This sill, in turn, depends upon the number of the genes for which the two parents differ. If the two parents are closely related, they are likely to differ for a few genes only. But if they are not related, or are distantly related, they may differ for several, even a few hundred, genes. However, it is not likely that the two parents will ever differ for all their genes. Therefore, when it is said that the F1 is 100 per cent heterozygous, it has reference only to those genes for which the two parents differ. The plants or lines involved in hybridization may belong to the same variety, different varieties of the same species, different species of the same genus or species from different genera. Based on the taxonomic relationship of the two parents, hybridization may be classified into two broad groups:

1. Inter-varietal and
2. Distant hybridization

Crossing between two different species of the same genus or two different genera of the same family is called distant hybridization. Such crosses are called as wide crosses or distant crosses. Wide hybridization is an effective mechanism in transferring desirable genes into cultivated plants from related species and genera. It mainly depends on chromosome number, cross-ability, fertility and homology between the two species. Hybridization is of two types

(a) Interspecific hybridization and

(b) Intergeneric hybridization.

A. Interspecific hybridization: Crossing two different species of the same genus is called as interspecific hybridization e.g. *V. vnifera x V. Labrusca*

B. Intergeneric hybridization: It refers to cross a between plants from two different genera of the same family e.g. *V. vnifera x Muscadinia*

4. Back cross

A cross between a hybrid (F1 or a segregating generation) and one of its parents is known as backcross. Back cross procedure conserves all good characteristics of a popular adapted variety and incorporates a desirable character from another variety. In Back cross method, the hybrid and the progenies in the subsequent generations are repeatedly back crossed to one of their parents. The objective of back cross is to improve or correct one or two specific defects of a high yielding variety, which is well adapted to the area and has other desirable characteristics. It is widely used to transfer a desirable trait from one genotype to other. The type of parents involved in back cross methods are;

- **Recipient parent**: Well, adapted, high yielding variety, lacking one or two characters and hence receives these genes from other variety.
- **Donor parent**: The variety which donates one or two useful genes.
- **Recurrent pare**nt: Since the recipient parent is repeatedly used in the back-cross programme, it is also known as the recurrent parent.
- **Non-recurrent parent**: The donor parent, on the other hand, is known as the non-recurrent parent because it is used only once in the breeding programme (for producing the F1 hybrid).

5. Mutation Breeding

Mutation breeding is common in self-pollinated and asexually propagated species and rare in cross pollinated species. A mutant variety differs from parent variety in one or few characters. A mutant differs from a segregant in two main ways. Firstly, the frequency of segregants is very high and that of mutant is extremely low (0.1%). Secondly, mutant differs from parent variety in one or few characters, where as a segregant differs from parent material in several characters.

Applications of Mutation Breeding: Mutation breeding has been used for improving both oligogenic as well as polygenic characters. Mutagenesis has been used to improve morphological and physiological characters including yielding ability. Various applications of mutation breeding are;

1. Induction of desirable mutant alleles which may not be available in the germplasm
2. It is useful in improving specific characteristics of a well-adapted high yielding variety.
3. Used to improve various quantitative characters including yield.

Mutation is a sudden heritable change in characteristics of an organism other than due to recombination or segregation. Mutations produced by changes in the base sequence of a gene are known as *gene or point mutation*. The mutations produced by changes in chromosome structure and number are termed as *chromosomal mutations*. The changes in cytoplasm is known as cytoplasmic or plasma gene mutation. Generally, mutation refers to gene mutation. Based on the occurrence mutations are of two types mainly;

Induced mutation: Mutation produced by treatment with either a chemical or physical agent is called induced mutation. The agents which induce mutation is called as a *mutagen*. The individual which undergoes mutation is termed as *mutant*. The utilization of induced mutations for crop improvement is known as *mutation breeding.*

Spontaneous mutation: Mutations that occur in natural population at a low rate without any treatment by humans is known as spontaneous mutation. The frequency of spontaneous mutation is 1 in 10 lakhs i.e. 10^{-6}. Spontaneous mutation occurs due to error in DNA replication and mutagenic effects of the environment. Using spontaneous mutation several grape varieties has been developed by Indian grape growers like Sharad Seedless, Sonaka, Tas-Ganesh, Manik Chaman etc.

6. Polyploidy Breeding

Polyploidy breeding is common in asexually propagated species and rare in self- and cross-pollinated species. A polyploidy variety differs from parent variety in chromosome numbers and exhibit gigant morphological characters. In euploids, the chromosome number is an exact multiple of the basic or genomic number. Euploidy is more commonly known as polyploidy. When all the genomes present in a polyploidy species are identical, it is known as autopolyploid and the situation is termed as autopolyploidy. In the case of allopolyploids, two or more distinct genomes are present.

Origin and production of doubled chromosome numbers:

- **Spontaneous**: chromosome doubling occurs occasionally in somatic tissues and unreduced gametes are produced in low frequencies.
- **Treatment with physical agents**: Heat or cold treatment centrifugation, x-ray or gamma ray irradiation may produce polyploids.
- **Regeneration in vitro**: polyploidy is a common feature of the cells cultured in-vitro.
- **Colchicine treatment**: Colchicine treatment is the most effective and the most widely used treatment for chromosome doubling.

7. Transgenic Breeding

Transgenic breeding is applicable to all three types of crop species. This method is used to solve specific problems which cannot be solved by conventional breeding techniques. This method serves as a tool and cannot be used as a substitute for conventional breeding methods.

To support the aforementioned breeding methods *Marker Assisted Selection* and *Embryo Rescue techniques* are used in genetic improvement of grape as per requirement.

- **Marker-Assisted Selection**

Genome of each organism is the blue print that determines the ultimate life. Genes in each genome are identified based on the phenotypes produced by them. However, many of the genes are not identified because of complex phenotypic outputs.

Since breeding by the conventional crossbreeding method requires a long time and high costs, studies on the development of selection with the help of DNA-based markers have gained importance in recent years. In this context, the segregation of seedless genotypes in the progeny obtained by the crossbreeding of seeded and seedless parents is performed with the help of molecular markers. Markers at DNA level include short DNA sequences, whole genes or even longer sequences of DNA. DNA marker analysis help in fast screening of desirable plant traits at early growth stages with greater speed.

- **Embryo Rescue Technique**

In the traditional breeding technique of grapes is a difficult to obtain hybrid progeny. It is known that seedless grape fruits develop either through parthenocarpy or stenospermocarpy. Parthenocarpy grapes develop fruits without pollination, but in stenospermocarpy grapes fertilization occurs subsequent embryo development soon stops and aborted. It is one of the main and unresolved barer for the conventional breeding programs and secondly all seedless stenospermocarpy grapes are sterile and recessive.

In conventional crossbreeding studies on breeding seedless grape varieties, a seedless parent is used as the father (pollinator) and a seeded parent is used as the mother. However, in seeded x seedless crosses, the seedlessness rate obtained in the progeny is , varying between 0% and 49%, depending on the parental combination. The successful culture of the abortive embryos of stenospermocarpy grapevine varieties has enabled seedless x seedless crosses in conventional crossbreeding studies. Embryo rescue technique increases the rate of seedlessness observed in F1 plants in seedless x seedless crosses depending on the parental combination.

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Chapter-9

Role of light in quality grape production

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Introduction

The grape industry in India has witnessed remarkable growth, particularly in regions like Maharashtra, Karnataka, and Tamil Nadu, where grapes have adapted to tropical conditions. This transformation has been facilitated by innovative viticulture practices, including double pruning and single cropping, which have significantly boosted grapevine yield in these warm climates. The prevalence of hot and dry weather in these regions has proven to be conducive to grape plant development and fruiting, leading to the predominance of varieties like Thomson Seedless. India's grape cultivation landscape has expanded substantially, covering vast hectares and representing a significant portion of the country's fruit production. Furthermore, India has emerged as a key player in the global grape market, showcasing its prowess by exporting substantial volumes of grapes annually.

However, amidst this success, the role of light in grape production remains a critical and often overlooked aspect. Photosynthesis, the fundamental process driving plant growth and fruit development, is heavily dependent on light availability and quality. Optimal light exposure is essential for maximizing photosynthetic efficiency, ensuring healthy leaf development, and ultimately enhancing grapevine productivity and fruit quality. This article delves into the importance of light in photosynthesis, exploring its impact on grapevine growth, development, and overall vineyard management strategies. By understanding and optimizing light conditions in vineyards, grape growers can further improve the quality and yield of grapes, solidifying India's position as a prominent player in the global wine industry.

Importance of light in photosynthesis

The rate of photosynthesis depends on the amount of green fluid in the leaves. That is why it is necessary to have healthy and disease-free leaves to produce the necessary food material for the development of grape vines. So, the quality production of grapes depends on the amount and quality of light available for the activity of

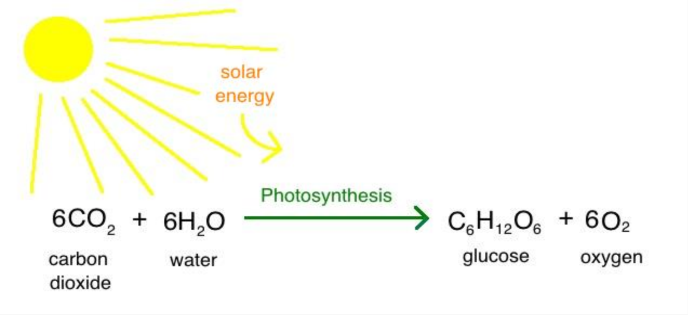

Fig 1. The process of photosynthesis in

photosynthesis. The rate of photosynthesis in grapevines decreases in the shade, which increases the incidence of insects and diseases, reduces colour development, and slows down the rate of biochemical processes.

The synthesis of other metabolites, such as sugars and organic acids, is lowered by the diurnal change in light intensity, which also lowers photosynthetic activity and carbon dioxide fixation. Apart from this, excessive use of stickers while spraying fungicide leads to the formation of a coating on the surface of the leaves, which greatly slows down the photosynthesis process, thus hampering the production of quality grapes. Therefore, given the impact of seasonal climate change on light availability, the importance of photosynthesis in the vine needs to be highlighted. Thus, it will help to improve the quality of vineyards by maximizing photosynthesis even in stressful conditions.

Light intensity

Photosynthesis is a vital process that utilizes light absorption from leaves, ranging from 300 to 3000nm (nanometer). The visible spectrum, which includes near ultraviolet (UV), blue light, green light, red light, and far red light, is 380 to 750 nm long. Photosynthesis uses specific wavelengths, with leaves absorbing 90% of solar radiation, reflecting 6%, and transmitting only 4% to the second canopy layer. The rate of photosynthesis varies with wavelength categories and light availability across different leaf layers. The optimal light intensity for photosynthesis is 500 to 1000 PPFD (Photosynthetic photon flux density), with a light compensation point at 25 PPFD. Optimal light exposure is crucial for grapevine growth and development. Understanding and adhering to these specific light requirements can significantly contribute to the overall health and productivity of grapevines, making it a crucial aspect of vineyard management strategies.

The intricate relationship between light, atmosphere, and temperature plays a crucial role in the photosynthetic processes of grapevines, influencing their growth, development, and ultimately, the quality of the PPFD fruit produced. Optimal conditions, such as a temperature range between 25 and 35 °C, are considered ideal for photosynthetic activity. However, extreme temperatures, either too high or too low, can hinder the efficiency of photosynthesis. High temperatures, exceeding 40 °C, significantly reduce the rate of photosynthesis in grapevines. This reduction is attributed to disrupted biochemical processes and the closure of stomata, crucial for maintaining water levels in leaves.

Furthermore, the presence of carbon dioxide in the atmosphere, currently around 410 ppm, plays a pivotal role. Increased CO_2 levels generally enhance the rate of photosynthesis, but the benefits might be compromised in extreme temperatures particularly in C_3 species like grapevine. Grape varieties exhibit distinct responses to light and temperature variations, as the genetic material is activated or deactivated in response to changes in light wavelength and temperature. Humidity also emerges as a key factor, with vine leaves requiring 75 to 80 percent moisture for optimal photosynthetic absorption. This moisture content not only facilitates the absorption of light but also enhances chemical processes within the leaves. Additionally, managing atmospheric humidity in the vineyard, along with proper canopy management practices like removing lower leaves, becomes essential for maintaining an environment conducive to photosynthesis.

Temperature significantly influences the composition of grape berries, affecting components like water, sugars, organic acids, nitrogen compounds, minerals, pectin, phenolic compounds, and aromatic compounds. The metabolic processes within the berries are highly dependent on ambient temperature, affecting their overall quality. Temperature fluctuations alter acidity levels, affecting the taste and flavor profile of the grapes. The metabolism of malic acid is accelerated at higher temperatures, leading to reduced malate storage. The optimal temperature range for malate storage is 20-25°C. Maintaining a desirable pH level is crucial for quality grape production, with lower night time temperatures preserving a low pH and contributing to desired acidity levels. Temperature changes also affect anthocyanin production, which is responsible for the coloration of grape berries. An increase in temperature, especially beyond 30°C, can decrease anthocyanin production, affecting the color intensity and visual appeal of the grape.

Management practices to improve photosynthetic efficiency in grapevine

- Minimize the use of stickers when spraying fungicides and insecticides, so that no coating is formed on the leaf surface. The sunlight will be properly distributed on the leaves and photosynthesis will be carried out smoothly.
- Leaves that receive sufficient light exposure tend to experience lower incidences of pests and diseases. The presence of insects and diseases can lead to a decrease in leaf area and act as inhibitors to the process of photosynthesis.
- Adequate distance between two branches should be maintained for proper photosynthesis. Excess leaves should be pruned. Only 17 to 18 leaves should be kept on each branch. Therefore, the spray coverage will cover the entire canopy and every area will receive sunlight of the same wavelength.

- Buds oriented towards sunlight typically yield fruits more effectively. Adequate sunlight penetration of at least 30 percent through the canopy is essential for optimal bunch formation. In shaded areas, bunch formation tends to be inadequate.
- Excessive application of agrochemicals can lead to the hardening and tearing of leaves, thereby hindering their ability to produce food at their maximum potential.

Fig 2. Coating formed by continuous

Fig 3. Healthy leaf

- Bower and Y trellis systems are mainly followed in the grape production area. In the Y trellis method, the branches are twisted vertically, making it the most effective approach for maximizing the utilization of solar energy. In this method, the bunches and leaves are properly exposed to sunlight and the grape seed increases protein by proper cell division thereby helping to meet nutrient requirements through synthesis. However, in the bower system, the branches are less effective in receiving solar energy because they grow horizontally. Also due to the dense canopy sunlight does not reach the second and third layers of leaves properly. Therefore, the lower layer leaves become dependent on other leaves for nutrients and become parasitic. In such climates Y trellis rotation method should be adopted for proper sunlight utilization and quality grape production.

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Chapter-10

Integrated pest management in grapes

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Introduction

In peninsular India, thrips, leafhopper, mealybug, stem borers, flea beetle, caterpillars, and red spider mite are major grapevine pests, causing significant damage almost annually. Additionally, the stem girdler beetle occasionally affects new vineyards. During the rainy season, snails may also cause damage. Understanding the biology of these pests, including their life cycle, identification, symptoms, and damage nature, is crucial for effective pest management.

1.Thrips

Thrips are the sucking pests which prefer to feed on all the above ground succulent and tender grapevine parts, like young leaves, leaf tips, leaf veins, stem, shoots, pre-flowering bunch, bunch peduncle, flowers, rachis and young berries. This insect enjoys the warm, bright sunlight combined with slightly higher temperature and low relative humidity. The thrips disperse very easily in the vineyard as they are very active insects. Mainly two thrips species, viz., *Scirtothrips dorsalis* and *Rhipiphorothrips cruentatus* cause damage to table grapes in peninsular India. A third thrips species, *Retithrips syriacus* is also reported in grapevine, however, it remains only on old leaves and does not cause any economic damage either to berries, flowers or leaves. Nymphal stage of *Retithrips* is reddish in colour and farmers often confuse it with red spider mites, therefore, correct identification is important.

Both nymphs and adults suck the vine sap, which result in the curling and cupping of young leaves. The damage after the foundation pruning is mainly confined to vegetative parts of the vine but after the fruit pruning, in addition to the damage on vegetative parts, they also damage the pre-flowering bunches, flowers and young berries. On pre-flowering stage bunch, the thrips damage can lead to necrotic spots on berries and the whole bunch may die if not controlled timely. Thrips suck the sap from the ovaries of flowers in the berry setting stage, which leads to flower shedding and loss in yield. This is the loss in terms of quantity; however, the loss in terms of quality is also very serious as rasping and sucking of young berries by thrips results in the brownish net-like appearance on the berry surface called as berry scarring. Therefore, the new flush emergence stage, pre-flowering, flowering, berry setting and early berry development, stages are the critical stages for damage by thrips.

There are certain points which should be considered for management of thrips. Regular monitoring and timely management interventions are very important for the effective management of thrips. To monitor thrips population, tap grapevine shoot on white paper and count the number of thrips fallen on the paper. It was observed that during fruit pruning season, higher thrips population is found on canopy during afternoon hours in comparison with morning or evening hours. Therefore, the monitoring for thrips should be done during afternoon. The time of spraying of insecticides does not have any effect on efficacy of the insecticides against thrips.

Sometimes there may be a situation when thrips population reaches remarkably high levels, like, when shoot is tapped on white paper, more than 40 thrips per shoot may be noticed. In conditions like this, the single spray of effective insecticide may not be sufficient to bring the thrips population under control. Therefore, two insecticidal applications, at gap of one day in between, may be given. Repetitive applications of insecticides with same mode of action should not be done and insecticides with different modes of action should be used to avoid development of resistance in thrips against insecticides. Most of the insecticides recommended for use against thrips generally take time of 2-3 days for providing desirable efficacy, therefore, it is advisable to wait for 2-3 days to see the effect of sprayed insecticide. However, some reduction in thrips population is seen one day after the spray. If there is no reduction in thrips population next day of spray or the thrips population increases, it may mean that the insecticidal spray was ineffective. In such scenario, decision of spraying effective insecticide may be considered.

2.Leafhopper

Leafhopper, *Amrasca biguttula biguttula* mainly infests vineyards in Maharashtra and Karnataka during mid-September to mid-December months of the calendar year with the peak during mid-October to mid-November months. The reasons for this high population build up may be the favourable weather conditions, presence of most of the vineyards in the highly susceptible stage and shift of leafhoppers from other host plants to grapes due to reduction of food resources post monsoon period as weeds start drying in empty fields. The leafhopper population is higher in vineyards where heavy weed growth is there in the vineyard or in the empty fields adjacent to the vineyards. Therefore, the vineyards and adjacent areas should be kept weed free. The grapevines upto about 40-50 days after fruit pruning are highly susceptible for leafhopper damage. They suck the sap from young leaves which results in leaf curling. Removing excess shoot growth after berry setting after forward pruning may help in reducing leafhopper incidence.

To monitor leafhopper population, gently hold the shoot and count number of leafhoppers per shoot. It was observed that during fruit pruning season, higher leafhopper population is found on canopy during evening hours and night in comparison with morning or daytime. Therefore, the monitoring for thrips should be done during late evening. The spraying of insecticides for leafhopper management should be carried out during late evening during dark. At the time of spraying, a high wattage white light bulb may be installed at the back side of the tractor. The leafhoppers are attracted towards light and installing light behind tractor will make leafhoppers active and they will come into direct contact with the insecticide providing better efficacy.

The most effective way to manage leafhoppers is to install near ultra-violet light (black light) traps near vineyards and run them between 7 to 11 pm every night during September to December months. The care should be taken that a light trap should not be installed inside the vineyards, otherwise the plants in vicinity of the trap may have higher pest damage. It is because all the attracted insects will not be trapped and killed. The light trap can also be made at home by using any high wattage white light bulb and a plastic tub. The care should be taken that the bulb should not become too hot, otherwise insects will not come near it. Place the tub under the light and fill it upto half with water and pour kerosene or any contact insecticide over water surface to kill attracted insects. Number of the traps to be installed depends on the luminance capacity of the light bulb.

3.Mealybug

Pink mealybug, *Maconellicoccus hirsutus* is the major mealybug species infesting grapes in peninsular India. Both the adults and nymphs suck the plant sap from the tender vine parts. At the time of forward pruning, majority of the mealybugs remain hidden under the bark of main trunk and cordons. During the new flush emergence stage especially after fruit pruning, mealybug feeding leads to the curling and malformation of growing shoot and thereby arresting it’s further growth. During veraison stage, mealybugs migrate from the main trunk, cordons and shoots to developing berries and produce profuse quantity of honeydew leading to sooty and sticky bunches which considerably reduces the quality and marketability of the fruits. Ants association with these pests will further aggravate the problem as they help the pest to migrate easily from one vine to another besides protecting from the natural enemies.

The mealybugs increase in numbers due to imbalance in the ecosystem. In a balanced agro-ecosystem, mealybug populations are usually kept under check by their natural enemies. Two prunings in grapes and use of broad-spectrum insecticides reduce natural enemy activity and upset the balance. Two prunings seem to be a necessity to ensure fruitfulness in semiarid tropics like Maharashtra, Karnataka, Telangana and Andhra Pradesh grape growing regions but by avoiding use of broad spectrum insecticides, natural enemies can be conserved and pest populations can be kept under check naturally, which can ultimately lead to lesser insecticidal applications and less number of residue detections.

Broad-spectrum insecticides such as fipronil, lambda cyhalothrin, methomyl and imidacloprid should be used only sparingly and should be completely avoided when natural enemy activities are higher. For example, during rainy season due to high humidity conditions mealybug natural enemies such as *Anagyrus* spp. and *Scymnus* spp. increase in numbers and control mealybugs naturally. Therefore, use of such chemicals should be avoided during this period. Alternatively, entomogenous fungus such as *Metarhizium*, *Lecanicillium*, and *Beauveria* can be used. The establishment of these fungi is favoured by prevailing high relative humidity conditions. If use of broad-spectrum insecticides such as methomyl, chlorpyrifos, cartap hydrochloride, profenofos, etc. is avoided during rainy season, the mealybug infestation during coming fruiting season is expected to be lesser due to natural enemy activity. During fruit pruning season, frequent preventive applications of *Beauveria*, *Metarhizium* and *Lecanicillium* at about every 15 days intervals will help in reducing mealybug population build up. If insecticidal application becomes necessary to control mealybugs, buprofezin 25 SC @ 1.25 ml/L water should be the preferred option as it is safer to natural enemies. Use of methomyl should be avoided and should never be used after flowering as it is broad spectrum and persistent in nature. Soil drenching of systemic chemicals is beneficial as compared to spraying as it helps to conserve natural enemies thus should be preferred option.

4.Flea beetle

Scelodonta strigicollis is the major species of flea beetle infesting grapes in India. These are metallic brown beetles with black spots on the dorsal side. They are active especially during the bud breaking stage of the vine after the pruning. Adults are damaging stage of the pest. Adults eat away the young buds and leaves. As a result, the shoot growth is arrested. Linear and rectangular shaped holes on the leaves are the characteristic damage symptoms by this pest. Flea beetles can also feed on young stems, bunch peduncle and mature leaves. They remain hidden away from sunlight during the day and actively feed during night. Therefore, flea beetle management is better when sprayings are carried out during night. Flea beetle grubs are seen in the soil but have not been reported causing any economic damage. High flea beetle incidence is noticed in Nashik and Sangali regions.

5.Caterpillar

Spodoptera litura is the major caterpillar species causing damage in two pruning single yield viticultural system of India. Sometimes, hornworms may also be found infesting grapes. Caterpillars are biting and chewing type of insects and feed on mainly grapevine sprouting buds and leaves. Whenever relative humidity increases due to rainfall, they may become serious pest. The highest damage in grapes is caused by *S. litura* during bud sprouting stage. Just after fruit pruning, there is no canopy on the grapevine. Therefore, *S. litura* larva remain hidden under loose bark of stem, in soil under leaf-litter or inside cracks in ground during daytime. They come out during night and feed, therefore, their presence in the vineyard goes undetected and they can cause huge damage during sprouting stage. They can eat away the sprouting bud and fruitful canes fail to emerge, thereby affecting yield. They can be easily monitored by regular inspection of vineyards at night during bud sprouting stage. At this stage, application of insecticides is generally not effective and frequent applications of insecticides may be required to manage them. This will also increase the cost of cultivation. The economic way of managing this pest is to wrap the main trunk and supporting bamboo with polypropylene adhesive tape (about 2 inches width) at about 2-3 feet height from the ground. Care should be taken that the sticky side of the tape is towards the stem and the shiny slippery side is outwards. The *S. litura* larva who try to climb the trunk during the night will not be able to climb due to the slippery surface and the damage can be managed very effectively. If the vineyard is old and has loose bark, then the loose bark should be removed before applying the adhesive tape otherwise the larva will remain hidden under the bark above the tape. Installation of light traps during rainy season is also very effective in controlling the moths of *S. litura*.

6.Red spider mite

Red spider mite, *Tetranychus spp.* is a major pest causing damage to grapes in peninsular India. They are also sucking pests and prefer high temperature and low relative humidity. Their population starts increasing from second week of December and reaches to a peak during February-April. They prefer to feed on older leaves but increase in population leads to their migration to even bunches. Both nymphs and adults cause damage. Their feeding causes yellowing and discolouration of leaves. Serious infestation may lead to extensive defoliation especially during January to April which may reduce the TSS in the berries and resulting into poor quality fruits. The defoliation also results in direct exposure of berries to sunlight causing sun-burn. Red spider mite infestation becomes higher in vineyards nearing harvest thus has potential to contribute to increased residue detections.

Best strategy for mite management is timely application of acaricide to reduce population build-up. Once majority of leaves show chlorosis and webbing due to mite incidence, the mite management will become difficult. Any vineyard with more than 50 days old canopy can easily become susceptible to mite incidence. Therefore, critical monitoring for mite population build-up is necessary. With the increase in temperature during February, the mite incidence also increases and reaches peak levels during March-April months. If temperature is high, weekly water sprays @ 1000 litres water per acre can help in washing dust from the leaf and decrease leaf temperature which can help in reducing mite population. Additionally, water sprays can also help in breaking webbings, thus increasing efficiency of insecticidal applications. Many alternate hosts plants such as *Parthenium* weed, etc. act as breeding grounds for mites, thus, they should be removed from the vicinity of the vineyards. Use of broad-spectrum insecticides such as imidacloprid, methomyl, fipronil, etc. should be avoided after 50 days of fruit pruning as they can kill mite natural enemies and increase the mite populations.

7.Stem Borers

Celosterna scabrator, Stromatium barbatum and *Dervishiya cadambae* are the major stem borer species infesting grapevine in peninsular India. All three stem borer species cause extensive damage to the sapwood and heartwood of grapevine stem and reduce both vitality and productivity of the vines.

7.1 *Celosterna scabrator*

C. scabrator larva can feed only on live plants and make gallery inside. The characteristics symptoms of its damage are that it removes the frass out from hole which can be noticed around the plant and the leaves of infested plant shows interveinal chlorosis at later stages. The time of adult emergence and oviposition for *C. scabrator* is exceedingly long which starts with the initiation of monsoon and lasts for about 120-150 days. The eggs are laid inside the stem by making a cut and covering with a substance which hardens after some time. Therefore, targeting adults and eggs for management is not feasible. The larva start feeding inside and make galleries. The best way to manage *C. scabrator* is to tag infested plants, tear apart the gallery and remove the larva. Most active period of *C. scabrator* adult is from June to September (highest number in August). They are easily visible during day time feeding on the bark of the young stem of grapes. They can be easily captured by hand and killed whenever noticed in the vineyards during this period. Spraying any insecticide is not economically effective to manage the adults. When the larva comes out of the egg and eats the stem, the grapevine secretes a watery secretion. These symptoms appear only in the morning. Grapes with these characteristics can be easily identified from October to December. On closer inspection, small amount of frass can easily be seen. The grub can be located feeding just under this frass using a iron wire and can easily be removed and killed. If the larvae are not controlled at this time, the larvae go deeper into the stem and cause damage and the yield of the plant is reduced by 4-6 kg per plant. The initial symptoms of frass fallen on the ground can be seen on infested plants. Monitor the vineyards every 10 days from December to April. Use ribbon to tag all the grape plants showing fallen frass on the ground. Remove the fallen frass on the ground and inspect it after two days for fresh frass and mark the hole just above as the active hole. Additionally, holes with wet frass near holes in the early morning hours can also be marked as active holes. Widen the active hole and tear off the stem towards the direction of the gallery using scissors or a screwdriver and hammer until the appearance of the *Celosterna* grub. Remove the grubs and kill them. Tie the treated stem with the help of jute twine rope for healing.

7.2 *Stromatium barbatum*

S. barbatum species of stem borer is pest of 6-7 years or older vineyards. The grubs of this species feeds inside the stem and convert the stem wood into powder like termites. Primarily this is pest of dead wood, therefore, it prefers older vineyards in which deadwood formation is there. Adults of stem borer Stromatium barbatum may start emerging during the first week of June and by mid-June majority of adult emergence takes place. However, small numbers of stem borer adults may keep on emerging till September.

Installation of light traps outside the vineyards will be helpful in monitoring the initiation of emergence of stem borer adults so that timely management can be carried out. Adults of stem borer will remain hidden under the loose bark of grapevine stem and cordons and majority of the eggs are also laid under this loose bark. Therefore, if this loose bark is removed just before the onset of monsoon, the adults will not find places to hide and lay in the vineyard and stem borer infestation will reduce. Further, removal of loose bark will help in exposing adults and eggs, if present any, on main trunk and cordons for their management by insecticides. Neem oil or neem seed or leaf extract or simply hanging neem leaves in the vineyard acts as a repellent for adult *S. barbatum*.

The larval period is of about 9 months. There is no external symptom on the plant visible in the vineyards infected by this species. During December to March months, when larva is feeding on the dead dry wood, the feeding sound can be heard in the old vineyards. More than 100 grubs of stem borer can be found in a single plant in case of high infestation. Two to three years of infestation can reduce the productivity of vineyards by 50%. This stem borer normally goes into pupation during second fortnight of March to mid-May. The pupal period is of about four weeks and the adult will remain inside the stem and wait for monsoonal rains to start.

7.3 *Dervishiya cadambae*

D. cadambae young larvae feed under the bark and later instars bore inside stem and make galleries. For *D. cadambae*, regular monitoring, removal of loose bark and two stem and cordon washes with entomogenous fungus *Metarhizium brunneum* when the young larvae are feeding under loose bark is effective.

Note: Kindly refer Annexure V of Residue Monitoring Programme for recommended list of insecticides.

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Chapter-11

Bio-intensification for disease management in grape

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Introduction

In India, grape (*Vitis vinifera*) is infected by many fungal and bacterial pathogens and causes huge crop loss. Till date, maximum share of disease management is governed by chemicals followed using biological control agents (BCAs). For efficient control of fungal and bacterial diseases in grapes, need to have potential strains of BCAs originating from plant/plant parts which are known as endophytes. Biological control of diseases using endophytes is an important approach for quality and quantity production of grapes. Endophytes were first described by the German botanist Johann Heinrich Friedrich Link in 1809 and first time introduced by Anton de Bary in 1866 for their use in agriculture. In addition to biological control, endophytes have immense potential to enhance host growth, plant nutrient acquisition, improve the plant's ability to tolerate against abiotic stresses, such as drought, salinity. Endophytes play an important role in improving quality and yield attributes of the plants, therefore identification, evaluation, and impact assessment of potential endophytic strains of bacteria and fungi in grapevines need to be carried out. In India, least information is available on the exploitation of the fungal and bacterial endophytes originating from grapevines for management of fungal and bacterial diseases. Biological control using endophytes is eco-friendly approach because it has a great potential in minimizing use of chemicals and thereby residue. Moreover, from elsewhere, grapevine endophytes have been identified as plant growth promotion activities, inducing systemic resistance to pests and diseases, nutrient solubilizing ability, and improvement in yield and yield contributing parameters.

An endophyte is an endosymbiont, often a bacterium or fungus that lives within the plant for atleast part of its life cycle without causing any apparent disease. Based on genetics, biology and mechanism of transmission, the endophytes are classified as systemic and non-systemic. Similarly, based on taxonomy, host range, host tissues colonized, colonization, biodiversity, mode of transmission and fitness benefits endophytes are classified further as clavicipitaceous and non-clavicipitaceous. Clavicipitaceous are sub-divided as class 1: cool and warm season grasses, class 2: grow in plant tissues both above and below ground, class 3: restricted to growth in below ground plant tissues and form in localized areas of plant tissue, and class 4: restricted to plant tissues below ground but can colonize much more of the plant tissue. Fungal endophytes are present in intercellular spaces of the plant tissues, meristems, leaves and reproductive structures. Fungal endophytes are belonging to basidiomycota and ascomycota and may be certain hypocreales, xylariales, sordariomycetes (Pyrenomycetes) and arbuscular mycorrhizal fungi. Endophytes are having different roles and widely used in agriculture especially for developing resistance to biotic and abiotic stresses, plant growth promotion, nitrogen fixation, increase crop yields, biological control of pests and diseases, phytoremediation, and uptake of valuable nutrients.

Grapevine Diseases

Downy Mildew caused by *Plasmopara viticola*, is one of the most destructive disease of grapes in India and causes huge losses under favourable conditions. White cottony growth is visualized on lower surface of leaves, cluster, flowers, rachis, pedicle, young berries or young shoots. On the upper leaf surface yellow circular spots with an oily appearance in white grape varieties and red spots in coloured grape varieties. Powdery Mildew caused by *Erysiphe necator*, is a serious disease occurs during the vegetative growth stage when cloudy and humid conditions are prevailing. Initially, white coloured lesions are found on the under surface of leaves. As the disease progresses, lesions become apparent on the upper surface of leaves. Subsequently, grey to whitish powder is usually seen on rachis during severe infections which result in dropping of berries. Anthracnose caused by *Colletotrichum gloeosporioides*. Anthracnose occurs during warm, wet and cloudy weather conditions and kills the new leaves and shoot and thereby reduce the plant vigour. In severe conditions fruits drop and affects yield and quality of grapes. The disease occurs mainly during monsoon i.e. vegetative growth season

Bacterial Blight is caused by *Xanthomonas citri* pv. *viticola* occurs on almost all the aerial parts of the vine during wet and warm weather. Minute water-soaked lesions are seen on the lower surface, which enlarge and become angular and brown. Stunting, cracking and irregular growth of shoots is seen in advanced stage of infection. In severe infection, leaves becomes brown and dried completely. Rust caused by *Phakospora euvitis* can cause severe defoliation during rainy season July-August and during veraison stage i.e. during January-February, which affects the berry ripening and development.

Management approaches of IDM

Managing of grape diseases is difficult due to fast spreading nature of pathogens and transmission through infected to healthy plants. Disease severity varies from different varieties cultivated in different agro–climatic conditions and with varied weather conditions.

Nevertheless, integrated management strategies including cultural, chemical, and biological control need to be followed.

- **Cultural Practices:** Clean crop cultivation is very important in the management of downy mildew of grapevines.
- **Mechanical:** The pruned and fallen leaves should be collected and buried in compost pit. Vines should be trained in such a manner that leaves are not touching or near the soil.
- **Chemicals:** Fungicides should be applied judiciously and applied as when required during the disease risk period and as per the recommended doses mentioned in annexure – 5. Heavy and repeated application of same fungicides may lead to development of resistance in pathogens.

Biocontrol

Biological control is an important component of IDM where deliberate use of bioagents/biopesticides are made in the crops to maintain the pest pathogen population level below that causing economic loss by introducing them into the environment of pest or pathogen or by increase in the effectiveness of those already present in the field. *Trichoderma asperelloides*, *Bacillus subtilis*, *Ampelomyces quisqualis*, *Paecilomyces*, *Pseudomonas fluorescence* are the effective biocontrol agents used for disease management in grapes. Major Advantages of use of biocontrol agents that they are inherently less harmful than the conventional pesticides and they generally affect the target pest/pathogen and closely related organisms in contrast to broad spectrum conventional pesticides that may affect organisms.

The **s**oil application of *Trichoderma* during monsoon or rainy season during September/October helpful for reducing inoculum of pathogen. *Ampelomyces quisqualis* – a control agent for powdery mildew and is a naturally occurring hyperparasite of powdery mildew It infects and forms pycnidia within the powdery mildew hyphae, conidiophores and cleistothecia, this parasitism reduces growth and eventually kill the mildew colony. Application of *Trichoderma harzianum* helpful in grapes for the control of post-harvest pathogens. In grapes meant for export: 2-3 sprays of *T. harzianum* @ 20th and 3 to 5 days before harvest can be provide good quality control of post-harvest diseases. In case of rotting of grapes due to raisins occurring few days before harvest, spray of *Trichoderma* has effectively prevented the spoilage of fruits. *Trichoderma* @ 2-3 g/lit to control leaf spot diseases. 1-2 sprays @ an interval of 10 days may be given when high humidity prevails during September/October.

Application of fungal endophytes for disease management

In Germany, endophytic fungi from rootstocks of grafted grapevines were isolated and identified as belonging to Deuteromycetes, especially Moniliales and Coelomycetes. In Italy, the endophytic *Alternaria alternata* inhibited the sporulation and ultrastructural alterations of grapevine downy mildew pathogen *Plasmopara viticola* (Musetti et al., 2006). Similarly, *Aureobasidium pullulans* and *Epicoccum nigrum* have been isolated as endophytes from grapes mainly from near midribs, berries and dormant buds and inhibits the growth of *P. viticola* and *Botrytis cinerea.* (Identified as PGP and BCAs). Endophytic fungus *Flavodon flavus* and *Colletotrichum gleosporioides* isolated from *Vitis labrusca* strongly inhibited growth of *Fusarium oxysporum* f.sp. *Herbemontis* (Brum et al., 2012). Enophytic *Beauveria basiana* activates the expression of defense genes in grapevine and prevents infection of grapevine downy mildew, *P.viticola* (Rondot and Reineke, 2019). Niem et al. (2020) studied the diversity profiling of grapevine microbial endosphere and antagonistic potential of endophytic *Pseudomonas* against grapevine trunk diseases (GTD) in Australia. In China, Pan et al. (2020) evaluated the symbioses of endophytic fungi *Nigrospora oryzae* induced production of novel metabolites in Rose honey leaves. Endophytic bacteria (EBs) produce beneficial effects on their hosts through enhancing the nutrient assimilation through solubilization of mineral phosphates, production of siderophores, or ammonia release. EBs additionally possess plant-growth-promotion traits related to growth regulatory mechanism like ethylene-1-aminocyclopropane-1-carboxylic acid (ACC) deaminase activity, synthesis of indole-3-acetic acid and other auxins. EBs and their secondary metabolites directly or indirectly reduces the growth of pathogens by antibiosis, and regulating other plant defense mechanisms. Bacterial Endophytes isolated from grapes including *Bacillus* spp., *Paenibacillus* spp. *Lysinibacillus* spp. *Brevibacillus* spp. having PGP and antagonistic activities against different pathogens.

Mechanism of fungal endophytes

Mechanisms of fungal endophytes in biological control of plant pathogens include direct inhibition of the pathogen by the endophyte through competition, antibiosis or mycoparasitism, or indirect inhibition through induction of resistance. Induced resistance is governed by production of different compounds (effectors, metabolites, enzymes) secreted by the endophyte during the colonisation process and released from the cell wall (e.g. chitin, β-glucans) that can act as inducing agents and trigger production of a signal in the plant. Systemic translocation of a signal/s results in elevated activation of defence responses at the site of pathogen attack. Defence responses include the strengthening of structural barriers that affect the pathogen penetration, generation of reactive oxygen species (ROS), production of anti-microbial metabolites and proteins that inhibit pathogen growth. Mycoparasitism of pathogens by the endophyte can be direct (coiling, penetration of prey) or indirect (no physical contact). In both the conditions the endophyte use nutrients from the pathogen by production of lytic enzymes and toxins. These compounds can also induce resistance after recognition by the plant. The pathogen is inhibited by anti-microbial proteins and metabolites produced by the endophyte known as antibiosis. Movement of these compounds can provide a systemic protection of the plant. They can also induce resistance if detected by the plant. During the colonisation process, the endophyte grows inside the apoplast, taking up nutrients or other plant resources, and thereby competing for this niche with arriving pathogens this phenomenon is known as competition. The use of endophytic biological control agents (BCAs) in the management of plant disease has gained importance and an alternative to chemical application, human and environmental safety.

Endophyte research in Indian grapes

Till date least information is available on endophytes from grapevines and their efficacy against grape diseases. In view of enhancing the bio-intensive disease management strategies in grapes, ICAR-NRC for grapes has tried to explore untapped biocontrol potential of different endosymbionts. From grapevines, various varieties and plant parts have been used to isolate >200 microbes, and identified based on colony and spore morphology, sequence information and studied *in-vitro* their direct and indirect antagonistic potential against *Colletotrichum gloeosporioides*, *Xanthomonascampestris* pv. *campestris* known to cause anthracnose and bacterial blight in grapes, respectively. Based on the *in-vitro* results formulations have been developed. Moreover, studies on their efficacy against different diseases under field conditions are in progress.

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Chapter-12

Adaptive spraying technologies and effective chemical solutions for disease management in grape

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Introduction

Adaptive spraying technologies

The application of pesticides has been a concern for many years, particularly methods of reducing drift, improving deposition and coverage along with the maintenance of spray equipment. Most growers know that there are three factors which affect application rate i.e. forward speed, nozzle size and system pressure but often overlook the factors which help get the spray onto the target i.e., Timing, Coverage, Dosage, and canopy structure. Progress lies in a better understanding of the factors involved in getting the spray from the tank to the vines. Some of the salient points regarding effective application of pesticides are briefly discussed as follows:

- ***Timing:*** It is important to know the most vulnerable stage of development of the disease in grape vines. The weather parameters and epidemiological factors needs to be consulted for this understanding. The decision also needs to be taken whether a particular chemical is to be applied during the early incidence of disease or as a prophylactic measure. In many instances a slight delay in the application might lead to a heavy loss of the crop. In majority of the cases growers wait for the disease symptoms to appear and then resort to curative spray but this should be monitored carefully so that the application is done in the optimum time frame.
- ***Coverage*****:** The coverage depends on the number of droplets per given area and more the number of droplets impinging per unit area, better is the efficacy. Normal volume sprayer has droplet size about 300 microns while that in low volume sprayer is 50 microns. If one droplet of 300 micron drops on leaf surface it is likely to be rolled off. Moreover, if it remains on leaf surface it will occupy at least 6 times less area than that occupied by droplets of 50 microns. Hence smaller droplets give better coverage of the plant surface.
- ***Dosage*****:** In India doses are mentioned as g of pesticide / litre of water. Normally 1000 L of water per hectare is required when spraying is done with normal volume sprayer. For low volume sprayer water required may be proportionately low as in case of 2x,

or 4x low volume sprayer water required will be 500 or 250 L of water respectively. The dose of pesticide per hectare remains same even though spray volume is reduced in low volume sprayers.

- ***Canopy structure*:** The total spray volume required depends upon the canopy structure and size. If 1000 L of spray volume is required per hectare when the canopy is 100% (Dense canopy where light penetration in inside canopy is much less. At noon no light is seen on soil beneath the canopy), 700 L will be required in 70 % canopy (Canopy immediately after pruning)

Sprayer Calibration

Calibration is a compulsory exercise, to guarantee the legal amount of product and water that will be required to treat the target area. Calibration should be done when spraying is done for the first time with a new equipment or at the beginning of each season or after changing nozzle, speed, or spraying pressure. It is advised to do calibration at least two times in a spray season. The advantages of proper calibration are manifold. This allows us to spray the correct amount and the wastage of chemical is avoided. Effective control of pests and diseases is possible and the environment is protected from pollution. The application of pesticides has been a concern for many years, particularly methods of reducing drift, improving deposition and coverage along with the maintenance of spray equipment. There are many inter-related factors which affect spray application, depending upon the target, the efficacy of the spray, the attitude of the operator, the standard of management, the weather etc.

Calibration in Low volume and high-volume sprayers

Efficiency of the sprayers depends up on droplet size. Smaller the droplet size better will be the coverage of plant surface. The size of the droplet emitted by the sprayer depends on type of nozzle. There are two common types of nozzles:

1. **Pressure nozzles:** The liquid under high pressure is released through small diameter jet to automize it in to small droplets. Increase in pressure on liquid leads to reduction in droplet. However, in case of such nozzles normally about 85% droplets are in the range of 250 – 300 microns and by increasing pressure the droplet size is not reduced further.
1. **Air-shear nozzles:** In case of air shear nozzles, air with high velocity is passed through venturi tube and liquid to be atomised is introduced without pressure at the throat of the venturi tube. The liquid is sheared by air into fine and uniform droplets. Studies have shown that about 90% of the droplets in such nozzle are 50 – 100 microns in size. As the droplet size becomes small instead of water being the carrier of the chemical to be sprayed, air becomes the carrier and volume of liquid required for spraying is reduced.

- The sprayer with the pressure nozzle, which is commonly used, is called as normal volume sprayer while sprayer with air shear nozzle called as low volume sprayer as it requires relatively low volume of water for spraying. Depending up on the extent of reduction in volume the sprayers are called 2x, 3x or 4x sprayer. These sprayers require 2, 3, 4, times less water for spraying as compared to normal volume sprayer respectively.
- Once it is known how much spray volume is to be used, to ensure correct application rate one should know how much volume the sprayer is releasing per minute. The sprayer manufacturer should make this information available. However, it is not provided by the most Indian manufacturers. Rough estimation can be done at field level. For such estimation following values should be known:

I. **Total output of water from nozzles**: It can be estimated by fixing hose pipe on one or two nozzles when sprayer is in action. Water released by the nozzles at known speed of the tractor is collected in any container with the help of hose fixed on it and its volume is measured. Based on total number of nozzles fixed on each sprayer total output from the nozzles can be estimated

II. **Tractor speed in km / h**: It can be read from the speedometer

III. **Width of the row where spray droplets are covered**

Once the water output of the sprayer and factors determining it are known, one can easily optimize the sprayer output by changing number of nozzles and tractor speed.

Selection of nozzles

Usually in Indian vineyards, two types of nozzles are used i.e. Pressure nozzles, and Air-shear nozzles. In pressure nozzle the liquid under high pressure is released through small diameter jet to automize it in to small droplets. In case of air shear nozzles, air with high velocity is passed through venturi tube and liquid to be atomised is introduced without pressure at the throat of the venturi tube. The liquid is broken by air into fine and uniform droplets. Based on their use there are different types of nozzles which are in use viz., Cone nozzles (Hollow cone, Full cone, and Variable cone), Fan nozzles (Standard fan, spray fan and Low-Pressure fan) and deflector nozzles. Nozzles made of plastic and stainless steel should be used as they are less damaged with constant use.

Drift management

It is the part of the spray not reaching the target mainly due to improper wind velocity. There are two types of drift i.e. vapour drift (associated with volatilization, gases, fumes) and particle drift (movement of spray particles) Drift results in loss of chemical, damage of neighbour crops or environment and contamination of farm workers which in turn leads to higher costs and inefficient application. Spraying should be avoided at any wind speed if itis blowing towards sensitive areas as all nozzles can drift. Spraying operations should be carried out when breeze is gentle, steady, and blowing away from sensitive areas. To reduce drift anti-drift nozzles should be used. Moreover, buffer zones need to be maintained as it helps in protection of the drinking water and protection of neighbor's property and neighboring crops.

Use of electrostatic sprayer for better coverage and drift reduction

In these sprayers air and spray fluid enters the rear of the nozzle separately. As the spray mix is atomized, the droplets pass an electrode that induces a negative charge on each one of them. Force of air propels the charged droplets into the plant canopy and the positive electrical charges on plant surface causes natural attraction of droplets. Some droplets wrap around (wrap around effect) the plant leaves and stems to coat their undersides as well. Once the droplets contact the leaves, they lose their electric charge. The major advantages are the following:

- They produce spray droplets which are 900 times smaller than those of conventional sprayers
- The spray fluid is carried deep inside canopy in a high-speed air-stream.
- Twice the deposition of spray material occurs than both hydraulic and non-electrostatic air-assisted sprayers.
- It requires 10-25 times less water carrier

Agitation of spray mixture

Wettable powder (WP) and emulsifiable concentrates (EC) formulations most commonly in use and they are not water soluble. Hence, formulations are made to ensure uniform suspension of the active ingredient (a.i.) in spray liquids. Stability of these suspension is usually very low and while spraying if the spray liquid is not agitated, the active ingredient settled at lower surface is pumped out early by the sprayer pump and concentration of the active ingredient in left over solution is proportionately reduced. It may go below lethal concentration and in area where this liquid is sprayed may develop resistance in pest against pesticide due to presence of sub-lethal doses. To avoid such serious consequences, it is essential to have good agitator in the sprayer tank.

Diseases of grapevine and their chemical management

Downy mildew (*Plasmopara viticola* (Berk. & Curt.) Berl. & de Toni), Powdery mildew (*Uncinula necator* (Schw.) Burr.) and Anthracnose (*Elsinoe ampelina* (de Bary) Shear, anamorph *Sphaceloma ampelinum* de Bary (Syns. *Gloeosporium ampelophagum* (Pass.) Sacc.), the three most important diseases of grape, have rapid repeating cycles in the same season and have potential to develop into epidemics if proper control measures are not taken in time and cause severe losses.

In major grapes growing areas in Maharashtra, Andhra Pradesh and Karnataka regions adjoining Maharashtra, ‘two pruning - one yield’ system of grape cultivation is followed wherein foundation pruning is done during April and forward or fruit pruning is done during October. The growth after foundation pruning is not exposed to high disease risk, as by the time rain start the leaves are already matured. Matured growth is easily managed. Only young growth when gets wet or humid conditions are in risk of diseases and infections on young growth leads to economic losses. In most grape growing areas mentioned above, normal time of forward pruning is around 15th of October, but it can range from first week of July to last week of November. From disease management point of view forward pruning taken before 15th of October, has greater risk of downy mildew, as there are more chances of rains and temperature is warmer. After forward pruning about 8-10 days are needed for sprouting of buds. Thereafter on an average every three days interval new leaf is developed. At fifth leaf there will be a bunch, which takes about 35 to 45 days from forward pruning to develop to flowering stage and by 50 to 55 days fruits set in. First 50 to 55 days after pruning, risk of damages due to downy mildew infection on bunches is very high. Rains and heavy dew during this period help development of downy mildew on bunches. Leaf wetness for continuous period of three hours after sunrise is favorable for new infection. If such conditions prevail during first 55 days of pruning sprays of fungicides are needed at shorter intervals for effective control of downy mildew. Berries develop to 10 to 12 mm size within first 70-75 days of forward pruning and thereafter the risk of downy mildew gradually reduces. Rains during November and December are rare, but in years when it rains during November or thereafter, heavy losses due to downy mildew are observed. Normally, 5 to 6 sprays of fungicides are required during first 55 days of pruning for effective management of downy mildew. This number of sprays may be increased to 9 in the event of rains during November December, while it can be reduced to 3-4 when wet weather is absent after forward pruning. Because all these three diseases can cause near total losses under favourable environmental conditions, growers as a precaution rigidly follow predetermined spray schedules throughout the susceptible period. While such a system may be advantageous when environmental conditions are continuously favorable for disease development, it often leads to increase in cost of cultivation due to extra use of fungicides and labour when environmental conditions are not favourable for diseases. Under unfavourable weather conditions, risk of losses due to diseases are much less and plant protection cost can be reduced by increasing gap between two preventive sprays or by using less costly non-systemic fungicides instead of costly systemic fungicides, during low disease risk periods. The occurrence and severity of these diseases is dependent on weather conditions and hence, it is possible to forecast likely risk of development of these diseases in prevailing meteorological conditions based on thorough knowledge of their epidemiology. For such predictions 'Disease Forecasting Models' have been developed. These models are used for taking day to day decisions on spraying of fungicides in vineyards for disease management. The data on critical weather parameters for disease development are primary inputs for such models. Even though diseases are the interaction of host plant, the pathogen and environment, the disease forecasting models estimate disease risk in prevailing weather conditions, assuming the active pathogen is always present. Thus, decision on sprayings can be taken after considering condition or growth stage of the host plant. Some of the relevant information for forecasting of above three diseases has been summarized below:

Downy mildew

Primary inoculum

In southern India from April to June the pathogen survives in soil as oospores or resting sporangia or on twigs as dormant mycelium. Primary inoculum becomes active if soil and / or foliage remains wet at least for 22 to 24 hours due to rain / irrigation / dew and when temp. is above 9–10^{o}C (Mathew and Heyns, 1969; Magarey and Wicks, 1985). Primary inoculum produces sporangia, which germinate to develop water-borne zoospores. These zoospores infect foliar plant parts through stomata or lenticles. The 'oil spots and downy growth consisting of wind-borne sporangia are developed after about 3-7 days of incubation, depending on temperature and plant growth stage.

Secondary inoculum

Sporangia developing out of infections caused by primary inoculum are secondary inoculum and are responsible for spread and development of the disease in vineyard under favorable conditions of weather, plant growth stage etc.

Weather parameters

(i) Sporulation:

- At least 4 hours of darkness, more than 98 % RH, and temperature more than 13^{o}C is required for sporulation on lesions (Bleaser and Weltrian,1978; Brook, 1979).

(ii) Infection:

- Availability of viable sporangia and > 2 hrs. leaf wetness during early morning, is required for infection.
- The disease is developed early and is more severe in vineyards irrigated at shorter intervals than in those irrigated at longer intervals.
- Based on regression analysis scientists have indicated that following conditions favour primary infection
  a) Rainy weather for 3-4 days sufficient to keep the leaves wet
  b) Temperature: 17 – 32.5°C
  c) Afternoon RH more than 48 %
- For secondary spread mean maximum temperature from 27-30°C, mean minimum temperature from 11-22.5°C and RH from 88-90°C were favourable.
- Similarly, it has been shown that the disease can occur when temperature is in the range of 10.2 to 31.5°C, and RH is in the range of 47–97% for three days. However, the rate of disease multiplication becomes zero if during these three days the temperature remains more than 28°C for 17 hours, and more than 90% RH is maintained for only 9 or less hours.

Growth stage and disease:

Earliest downy mildew infection can occur at 3-leaf stage after budbreak. A new leaf becomes susceptible after every 3 days. Relatively older leaves (34-48 days old) develop disease faster than younger (14-18 days old) leaves. Flower buds show maximum downy growth. In case of mustard and pea size berries downy growth is restricted to pedicle end, while no growth is seen on berries whose diameter is more than 12.5 mm or 1 month after their set.

Powdery mildew

Primary and secondary inoculum:

Dormant mycelium in buds is the primary source of inoculum, which becomes active as the new shoot develops from the bud. Conidia, which are air borne, and develop on foliar parts are responsible for secondary spread. It is believed that the powdery mildew is active throughout the year in at least one grape growing area in southern India.

Weather parameters:

- Low humidity, cloudy weather are favorable for disease development, while heavy rains, and hot and dry weather are unfavorable for the disease.

- The pathogen does not grow if temperature is below 10^{o}C or above 37.7^{o}C (Butler and Jones, 1949).
- Minimum temperature in the range of 20.1 – 21.9^{o}C and RH in the range of 57.6-68.2% were favorable for powdery mildew.
- More than 40% RH during afternoon, with temperature ranging between 17 – 34^{o}C helps in the establishment of epiphytotic of powdery mildew.
- Temperature in the range of 11–32^{o}C and more than 57% RH favored the disease development. While temperature below 8.6^{o}C or above 34^{o}C and RH below 47% show zero rate of disease development.

Growth stage and disease

The fungus can attack all growth stages of vines. Berries are susceptible from 2 weeks after bloom till veraison. After veraison normally the disease is not developed on berries, but green rachis can develop powdery mildew infection affecting shelf life of the table grapes.

Anthracnose

Primary and secondary inoculum

Cankerous lesions on the canes, bud spurs, stems and branches are the main primary inoculum. Rain / dew are required for the sporulation of the pathogen. Young developing tissue in the foliage are susceptible. The fungus can invade directly. The conidia developing from lesions caused by primary inoculum are secondary inoculum. The secondary inoculum produces conidia which again causes infection. This cycle repeats itself many times in the season depending on weather conditions.

Weather parameters

- Presence of high temperature along with high RH during new shoot development favors the disease. Relative humidity and precipitation were more important for disease development than temperature. Rain or dew favored the spread of the spores and their germination. Already formed lesions continue to increase in size even in the absence of rain.
- The fungus grows in temperature between 9–35^{o}C, while maximum growth and sporulation was observed at 29°C and no growth at 40°C.
- The disease appeared when mean max. temperature was in the range of 29–29.8°C, mean min. temperature was in the range of 21–22°C, and when the RH was in the range of 82– 95%.
- Rainfall of 49.99 mm distributed over 3-16 days per week and prevalence of cloudy weather helped to cause severe infection on susceptible young tissues.

- Darkness was most congenial followed by diffused light for the growth and sporulation of the fungus.

Growth stages:

The disease occurs on all young green plant of the vines. A 20-day-old leaf becomes resistant to anthracnose.

Methods of disease forecasting

Above mentioned epidemiological information is used for developing forecasting models, where regression equations are established indicating relations of key factors such as weather parameters (Rain, Temperature, R.H., Leaf wetness period etc.), Susceptible growth stage/ variety, Time lapsed after last spray (systemic/ non-systemic) of fungicide, with rate of disease development. With the help of such equations one can estimate the rate of disease development under prevalent conditions in specific area or vineyard. With the help of such estimated rate of disease development predictions are made on the possibility of disease outbreak with reasonable accuracy and well in advance of actual outbreak of the disease. Growers thus can undertake suitable control measure well in time and only when it is required. Forecasting of diseases thus will be beneficial in two ways

1. For effective control of disease by application of suitable fungicides when inoculum load is minimum and before the severe outbreak of the disease
2. For avoiding unnecessary sprays when there is no possibility of disease outbreak

Basic requirements for forecasting diseases:

1. Weather data recording device, which can record data continuously at predetermined intervals
2. Forecasting model that can predict the possibility of disease outbreak using recorded weather data and another vineyard information
3. Specific recommendations on control measures to be adopted under predicted severity of disease outbreak

Currently compact computerized devices consisting of all three above requirements are available commercially for the forecasting of specific diseases of specific crops. Computer softwares for forecasting grape diseases and pests are also available outside the country, which can be used on any PC if weather data is available.

Forecasting based disease management

Downy mildew

What is done on computer can also be done manually? One such forecasting model for forecasting of downy mildew in grapes was proposed and it is mentioned below as an illustrative example.

Tentative forecasting can be done with the help of manually recorded observations. However, it is practically very difficult to record the needed observations as many of them are to be observed during night. Automatic weather data recorder therefore is indespensible to record authentic data on which the accuracy of the forecasting is dependent. In India several organizations offer Automatic Weather Stations (AWS) along with software for disease forecasting which can be easily installed in vineyards, which shows weather data and disease risk on small LCD screen with press of button. ICAR-NRC for Grapes, recently has developed model for management of downy mildew and powdery mildew which can take data from any AWS. The model is licensed to several users.

Secondary infection checklist **Date: ---------------------**

Secondary Infection Checklist	
Question	**Answer**
Are downy mildew oil spot present?	Yes / No
Was the RH more than 98% for a minimum of 4 hours?	Yes / No
Was the temperature equal to or more than 13°C during the above?	Yes / No
Did the above occur at night (darkness)?	Yes / No
Were leaves wet from irrigation, rain or dew for at least 2 hours from dawn?	Yes / No
Has significant vine growth occurred since the last cover spray?	Yes / No
If No to any one of the above questions, the disease cannot spread	

Primary infection assessment checklist						Date: --------------------	
0	4	8	12	16	20	24	Hours
							Irrigation hours
							Irrigation units
							Period of rain
							Soil wetness
------------							Water splash
------------							Leaf wetness

Question	**Answer**
Was the temperature greater than 10°C for the duration of the wet period?	Yes/No

Was the wet period caused by greater than 10 mm of rain or irrigation?	Yes/No
Did the soil remained wet for continuously wet for than 20 hours?	Yes/No
Did the significant water splash occur from the rain or irrigation in the 18 to 24 hrs period of soil wetness?	Yes/No
Did the leaves remain wet for at least 2 hours in the 18 to 24 hours period of soil wetness?	Yes/No
Has significant vine growth occurred since the last cover spray?	Yes/No
The assessed risk of primary infection occurring is as follows if answers for questions are All Yes One No Two or More No High Low Nil	

Powdery mildew forecasting model

For germination of the spore's minimum temperature should not be less than 6°C. For infection and spread 17°C temperature is required. Germination of spores, infection and spread of the disease is maximum between 21-30°C. If the leaf temperature is between 31.5-33.5°C, then spores will not germinate.

Research conducted at Agriculture Meteorology Centre for Higher Studies, Agriculture College, Pune has shown that maximum incidence of powdery mildew will be at 10.5-30.7°C temperature and 53.4-97% RH. Powdery mildew does not grow at temperature below 7.7 or above 33.3°C or at RH below 47.4%. Based on temperature and relative humidity the 'climatic disease severity values' were fixed in a scale of 0-2 as shown below:

Micro-climate at canopy	Climatic disease severity value		
	0	**1**	**2**
Minimum temperature (°C)	<7.7	7.7-10.5	>10.5
Maximum temperature (°C)	>33.3	31.1-33.3	<31.0
Maximum RH (%)	>99	<86	86.99
Minimum RH (%)	<47	47-57	>57

Using daily observations on all four parameters, disease severity values for the day are estimated. The cumulative values are estimated for 4 to 8 successive days. When the cumulative total of these values exceeds 34 the risk of powdery mildew starts. Severity of the disease risk is determined on number of days required to accumulate cumulative value 34. The spray for management of powdery mildew should be taken up during the risk period.

While choice of fungicides and time of spray is based on severity of risk and actual growth stage in vineyard in question.

Growers can record the data on temperature and RH in their vineyards using minimum-maximum thermometer and wet and dry bulb thermometer and use this chart to forecast powdery mildew in their vineyards. ICAR-NRC for grapes, Pune has made the disease forecasting and decision support system available to grape growers and the program is installed in computer, and input on weather parameters and growth stage in entered manually to get the estimated risk of powdery mildew and advice on actions to be taken for management of the diseases.

Weather forecasting and disease management

All disease forecasting methodologies mentioned above are based on actual weather data recorded on weather stations. However, now technology is available to forecast weather very accurately for next 7 days. Forecast on possibility of rain, extent of cloud cover, temperature, humidity, etc is obtained using satellite information. Many websites give such forecast free of cost. NRC for Grapes, Pune gives summery of weather forecast of 7 days, for major grape growing areas on their web site. http://nrcgrapes.nic.in/

All above sites give information based on relatively low-resolution data of satellites, where level of accuracy is relatively low. Information given is village or city specific. Now a days, very small location specific weather forecast can be generated, using high resolution satellite data. Using GPS (Geographical Positioning System) one can easily find out longitude and latitude of location of interest, and locate that location on globe in digital map. Using the geographical position of any location, and high-resolution satellite data, one can generate weather forecast for that location. If the weather forecast is accurate, one can estimate level of risk of the important diseases in a similar manner as it is estimated from recorded weather data. In case of grapes, risk of disease is normally associated with growth stage also. If both, weather related risk and growth-related risk is known one can take decision whether control measure is needed or not.

How weather forecast helps in scheduling sprays for management of downy mildew and powdery mildew?

Location specific weather forecast for next 5to 7 days is now a days available on internet. Information on forecast of rain is often useful in scheduling sprays for management of downy mildew, especially during critical stages of growth. In most cases rainy condition does not last for period more than 2 to 3 days. Preventive spray given before rains often protects vineyard from downy mildew for 2 to 3 days of rainy condition. Even if new downy mildew infection takes place, its establishment and appearance of first symptom such as oily spots and subsequent sporulation needs at least 3 days after infection in most favourable conditions. This means if the preventive spray is given just before rains, the grower can safely wait for 3 to 4 days of rainy weather and give subsequent spray only after rains have stopped. However, this can be effectively done when location specific weather forecast is available. If probable time of expected rains is known sprays can be given 1 to 2 days before rains and then if required next spray can be given after receiving few showers and on the day when rains are not likely. Second spray can also be decided based on actual presence of active disease in vineyards, and forecast on possibility of rains during next few days. With such a strategy many sprays can be avoided and sprays can be given when needed.

Overcast cloudy conditions often present continuously for long period without actual rain in the area. Such conditions often increase the risk of powdery mildew. Powdery mildew sprays are often given at long intervals based on growth stages. These intervals can be reduced or extended based on information on cloud cover.

Strategies for Choice of fungicides in disease management

List of recommended fungicides for use in grapes for management of different diseases is updated every year by ICAR-NRC for Grapes, Pune. All the fungicides listed the list not only have been tested effective by ICAR-NRC for Grapes, Pune or the Centre's of All India Co-ordinated Research Project, but necessarily have label claim registered with Central Insecticide Board (CIB), where in target disease, dose, PHI (Pre-harvest interval), and MRL (Maximum Residue Limit) is mentioned. Therefore, any of the fungicide listed in the list can be used for management recommended target pathogen.

The fungicides have been classified in to two categories viz. systemic fungicides and non- systemic fungicides. Downy mildew risk after forward pruning starts after 3 leaf stage (10 to 12 days after forward pruning) and lasts normally up to fruit set (About 50 days after forward pruning.). During this period shoot is continuously growing giving out one leaf at 3 days interval. This means at every 3 days one leaf on each can will be emerged which is not protected by fungicide sprays. To protect such leaves systemic fungicides are needed. Fungicides are efficiently systemic in young growing leaves; hence they are best used on young leaves.

Systemic fungicides are very specific in their mode of action and thus pathogen can develop resistance against systemic fungicides relatively with ease. Non-systemic fungicides have multipoint mode of action and so, resistance development against non-systemic fungicides is very rare. Resistant fungus to systemic fungicide can be killed by non-systemic fungicide. Hence, use of systemic fungicide along-with non-systemic fungicide, or spray of non-systemic fungicide within short interval after the spray of systemic fungicide, will often help in reducing the chances of field establishment of resistant pathogen against systemic fungicide in vineyard.

Suggested spray interval for most systemic fungicide formulations is 5 days during risk period for downy mildew. If presence of favourable conditions for target disease within 5 days after spray of systemic fungicide are observed, additional spray of non-systemic fungicide effective against same target disease is suggested for better disease management.

The pathogens develop resistance against some systemic fungicides, much faster than other fungicides. Such fungicides are classified as high-risk fungicide. FRAC (Fungicide Resistance Action Committee) a official technical group of “Crop Life International” collects all relevant information and classify every fungicide under high risk, medium risk, low risk and no risk groups. The detail updated information is available on their website http://www.frac.info/frac/publication/q_ publication.htm The FRAC also prepare resistant management strategy for every group of fungicides.

Like fungicides some pathogens develop resistance to most systemic fungicides much faster than other pathogens. Such pathogens are also high-risk pathogen. For example, downy mildew develops resistance much faster than powdery mildews. Thus, use of high-risk fungicides for downy mildew has double risk. Theoretically, chances of development of resistance are more when high risk fungicide is used as curative instead of preventive. Hence, high risk fungicides should not be used as curative, or after the outbreak of the disease. However, in case of downy mildew very few fungicides have been classified as medium risk or low risk fungicides. Fungicides like amisulbrom, cymoxanil, dimethomorph, and iprovalicarb are medium risk fungicides among recommended fungicides for management of downy mildew. Hence, it is suggested to use them during early growth stages or as curative when unavoidably needed.

For management of powdery mildew, fungicides belonging to triazole group (SBI fungicides) are more preferred, over strobilurin (QOI fungicides) fungicides as later are high risk fungicides. In the recent times, use of biological control agents is highly recommended along with fungicides

Integrated disease management for residue free grapes

Commercial grape varieties belonging to *Vitis vinifera* are highly susceptible to three important disease viz. downy mildew, powdery mildew, and anthracnose. However, during recent times rust infection is becoming serious in certain areas, especially in the nurseries.

Similarly, in hotter areas, where warm and humid conditions prevail bacterial infection is also seen. Both rust and bacterial spot diseases cause premature leaf drop. Grapevine leaf roll associate virus-3 too has been observed in some vines. The incidence and severity of most of the grape diseases depend on young growing tissues and weather conditions. Generally, from April to first week of June the climate is hot, and hence there is less chance of disease development, but during south-west monsoon season chances of infection of powdery mildew, downy mildew and anthracnose are increased. Thus, the strategy of disease management after foundation pruning, aims at providing protection during wet weather to reduce the disease.

Downy mildew

Downy Mildew (c.o. *Plasmopara viticola*) is the most destructive disease of grape and causes colossal losses under favorable conditions. White downy growth is seen on the leaves, cluster, flowers, rachis, pedicle, young berries, or young shoots. On the upper leaf surface yellow circular spots with an oily appearance in white grape varieties and red spots in colored grape varieties are observed while the white downy growth later can be seen on the lower leaf surface on the underside of these spots (Fig 1). Young clusters turn necrotic and young infected berries appear greyish (Fig.1).

A temperature of 17 to 28ºC with a rainfall/irrigation of 10 mm and relative humidity more than 40% favors infection. Wetness of leaf or soil further predisposes the plants to the disease. If running water flows in the vines for 2-3 days, then there is a high probability of disease incidence. A moist, dark condition following a period of light favors maximum sporulation.

Downy mildew infections are first observed after the start of the monsoon rain and when the maximum temperature is below 30ºC. Several cultural practices like removal and burning of infected leaves as well as removal of excess new shoot growth during monsoon may help in reducing primary infection. Proper tying of shoots to the trellis and avoidance of excess doses of nitrogen also reduces the primary inoculum.

Systemic fungicides for the control of downy mildew are not encouraged after foundation pruning. Low risk systemic fungicides are used during 25 days after fruit pruning and after high-risk fungicides are used. In one fruiting season maximum 5 sprays of low-risk systemic fungicides and 2 to 3 sprays of high-risk fungicides are recommended. Prophylactic use of Mancozeb 75WP is recommended as it inhibits the formation of secondary haustoria and growth of mycelium. A tank mix of potassium salt of phosphorus acid @4g/L and

Mancozeb75WP @ 2g/L gives a good control of the disease. The current list of fungicides, their nature, recommended doses, pre harvest interval (PHI) and the European Union Maximum Residues Limit (MRL) are given in annexure 5 available at the ICAR-NRCG, Pune website. The regularly updated list can be accessed at https://nrcgrapes.icar.gov.in/Warning system through weather-based advisory enable effective control of downy mildew with reduced numbers of sprays.

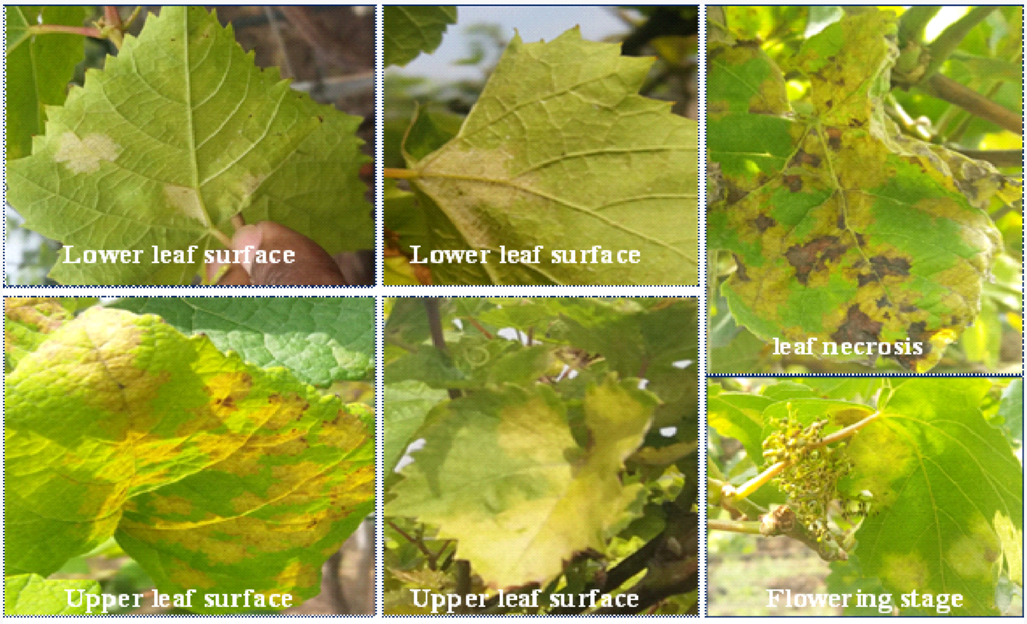

Fig 1. Symptoms of downy mildew on grapes

Table 1: List of recommended fungicides for the control of downy mildew by ICAR-NRCG.

Chemicals		Nature	Dose	EU-MRL (mg/kg)	PHI (days)
Low risk fungicides: Non-systemic					
1	Mancozeb 75 WP	NS	1.5-2 g/L	5.0	66
2	Propineb 70 WP	NS	3 g/L	1.0	75
3	Copper Oxychloride 50 WP	NS	2.5 g/L	50.0	42
4	Copper hydroxide 53.8 DF	NS	1.5 g/L	50.0	12
5	CopperSulphate 47.15% + Mancozeb 30% WDG	NS	5000 g/ha	50.0 + 5.0	66
6	Dimethomorph 50 WP	S	0.50-0.75 g/L	3.0	34
7	Amisulbrom 17.7% SC w/w (20% SC w/v)	NS	0.375 ml/L	0.5	59
Low risk fungicides					
8	Cymoxanil + Mancozeb 8 + 64 WP	S+NS	2.0 g/L	0.2 + 5.0	66
9	Dimethomorph 50WP + Mancozeb 75 WP	S+NS	0.5-0.75 g/L + 2.0 g/L	3.0+5.0	66

10	Iprovalicarb + Propineb 5.5+61.25 WP	S+NS	2.25g/L	2.0+1.0	75
11	Mandipropamid 23.4%	NS	0.8ml/L	2.0	5
12	Fosetyl Al 80 WP	S	1.4-2g/l	100.0	30
13	Potassium Salt of Phosphorus Acid	S	4g/L	-	-
14	Ametoctradin 27 + Dimethomorph 20.27 SC	NS + S	0.8-1.0 mL/L	6.0 + 3.0	34
15	Fluopicolide 4.44**%** + Fosetyl-Al 66.67% WG	S	2.25-2.5 g/l	2.0+100	40
High risk fungicides					
16	Metalaxyl + Mancozeb 8 + 64 WP	S+NS	2.5g/L	2.0+5.0	66
17	Metalaxyl M + Mancozeb 4 + 64WP	S+NS	2.5g/L	2.0+5.0	66
18	Benalaxyl-M 4% + Mancozeb 65% WP	S+NS	2750 g/ha	0.3 + 5.0	66
19	Fenamidone 4.44% + fosetyl-Al 66.66% WDG	S	2000-2500 g/ha	0.6 + 100	90
20	Metiram 44% + Dimethomorph 9% WG	S+NS	2500 g/ha	5.0 + 3.0	66
21	Kresoxim methyl 18% + Mancozeb 54% WP (72 % WP)	S+NS	1500 g /ha	1.0 + 5.0	66
22	Fenamidone+Mancozeb10 + 50 WG	S+NS	2.5 to 3g/L	0.5+0.5	66
23	Azoxystrobin 23 SC**	S	494ml/ha	2.0	7
24	Azoxystrobin 8.3% + Mancozeb 66.7% WG *	S + NS	1500 g/ha	3.0 + 5.0	66
25	Famoxadone16.6% + Cymoxanil 22.1%SC	S+NS	500ml/ha	2.0+2.0	27
26	Kresoxim methyl 44.3SC	S	600-700ml/ha	1.0	30
27	Pyraclostrobin 5% + Metriram 55% 60 WG	S+NS	1.5 - .75kg/ha	1+5	15
28	Dimethomorph 12% + Pyraclostrobin 6.7% WG*	S + S	1500mL/ha	3.0 + 1.0	55
29	Azoxystrobin 11% + Tebuconazole 18.3% w/w**	S + S	750 mL/ha	3.0 + 0.5	60
30	Cyazofamid 34.5% SC	NS	200 mL/ha	2.0	50

S=Systemic; NS= non-systemic

Powdery Mildew

Powdery Mildew (c.o. *Erysiphe necator*) is a serious problem during the vegetative growth phase especially when cloudy and humid conditions prevail. Thick canopy creates favorable conditions for disease development. Optimum temperature for growth is 20-27˚C but no fungal growth occurs below 6˚C or above 32˚C. Relative humidity more than 60% favor and less than 30% does not favor the disease respectively. The first powdery mildew lesions are frequently found on the undersides of leaves. As the disease progresses, lesions become apparent on the upper sides of leaves as well. Grey to whitish powder is usually seen on rachis and severe infections of the rachis can result in clusters being dropped (Fig. 2). Berries turn into an ash grey color and quickly become covered in spores giving them a floury appearance. Affected berries dry out and may drop off Cleistothecia of the fungi is not found in India due to the absence of mating types. Excessive use of nitrogen fertilizer should be avoided and by removing non- photo synthetically active and non-bearing shoots will help to open up the canopy and improve the efficacy of spray application. *Bacillus subtilis* @2g/L and *Ampelomyces quisqualis*@ 4-5 g/L gives a good control of the disease and should be applied during the rainy season when humidity is high for their profuse multiplication. Though several fungicides have been evaluated against powdery mildew, at present only the following are registered for use in grapes in India. The regularly updated list can be accessed at https://nrcgrapes.icar.gov.in/.

Fig 2. Symptoms of powdery mildew on old leaves of grapes

Table 2: List of recommended fungicides to control of powdery mildew by ICAR NRCG

Sl. No	Chemicals	Nature	Dose	EU-MRL (mg/kg)	PHI (days)
Low risk fungicides					
1	Sulfur 40SC,55.16SC, 80WP, 80 WDG, 85 WP	NS	3.0 ml,3.0 ml,2.50 g,1.87-2.50 g, 1.50-2.0 g/L	50	15
2	Meptyldinocap 48EC	NS	308.6-342.8 mL/ha	0.05	50*
Medium risk fungicides					
3	Hexaconazole 5SC	S	1.0ml/L	0.1	38
4	Difenoconazole 25EC	S	0.50ml/L	0.5	45
5	Tetraconazole 3.8EW	S	0.75-1ml/L	0.5	30
6	Myclobutanil 10WP	S	0.40g/L	1.0	30
7	Metrafenone 50% SC	S	0.25mL/L	7.0	22
8	Polyoxin D zinc salt 5% SC	S	0.6 ml/L	0.01	35
High risk fungicides					

8	Azoxystrobin 23 SC	S	494ml/ha	2.0	7
9	Kresoxim methyl 44.3 SC	S	600-700ml/ha	1.0	30
10	Pyraclostrobin 5% + Metiram 55% 60 WG	S+NS	1.5-1.75g/l	1+5.0	15
11	Fluopyram 200+Tebuconazole 200SC	S+S	0.563mL/L	1.5+0.5	60
12	Meptyldinocap 35.7% EC	NS	308.6-342.8 mL/ha	1.0	50
13	Fluxapyroxad 75 g/L + Difenoconazole 50g/L SC	S+S	800 mL/ha	3.0 + 3.0	45
14	Tebuconazole 50% + Trifloxystrobin 25% WG	S+S	0.175g/L	0.5+3.0	34
15	Fluxapyroxad 25% + Pyraclostrobin 25% SC	S+S	0.2mL/L	3.0+1.0	60
16	Boscalid 25.2% + Pyraclostrobin12.8% w/w WG	S+S	0.5-0.6mL/L	5.0+1.0	55

S=systemic; NS= non-systemic;

Anthracnose

Anthracnose (c.o. *Colletotrichum gloeosporioides*) occurs during warm, wet and cloudy weather and can cause complete kill of new growth, reduce the vigor, fruit falling, yield and quality. The disease occurs mainly during monsoon corresponding to vegetative growth season. Small, yellowish spots on the leaves are seen, which turn into circular, grey lesions (Fig. 3). Numerous lesions are formed on the leaf and the dead tissue drop out the spots causing hole in the centre, which is a typical symptom of anthracnose called as **"Shot Hole**". The lesions may show cracking at the late infection stage and if the infection is at the base of the stem, the stem may crack and break.

Fig 3. Symptoms of anthracnose on various crop growth stages of the vine

To control the disease all shoots canes with anthracnose lesions should be removed at the time of pruning. Through a few fungicides have been evaluated against anthracnose, at present only the following are registered for use in grapes in India. The regularly updated list can be accessed at https://nrcgrapes.icar.gov.in/.

Table 3. Fungicides presently registered for management of anthracnose by ICAR-NRCG

Sl No.	Chemicals	Nature	Dose	EU MRL (mg/kg)	PHI (days)
1	Propineb70WP	NS	3.0 g/L	1.0	40
2	COC 50WP	NS	2.5 g/L	50.0	42
3	Carbendazim 50WP	S	1.0 g/L	0.30	50
4	Thiophenate methyl 70 WP	S	1.0 g/L	0.1	50
5	Fluopyram 200+Tebuconazole 200SC	S+S	0.563 mL/L	1.5 + 0.5	60
6	Kresoxim methyl 18% + Mancozeb 54% WP (72% WP)	S + NS	1500 g /ha	1.0 + 5.0	66
7	Azoxystrobin 8.3% + Mancozeb 66.7% WG	S+NS	1.5 g/L	3.0 + 5.0	66
8	Copper Sulphate 47.15% + Mancozeb 30% WDG	NS+NS	5.0 g/L	50.0 + 5.0	66
9	Carbendazim 12% + Mancozeb 63% WP	S+NS	3.0 g/L	3.0 + 5.0	66
10	Kasugamycin 5% + Copper Oxychloride 45%WP	S + NS	750 g/ha	0.01 + 50.0	70

S=systemic; NS= non-systemic; Note: Water volume used in the spray is 1000 L/Ha

Rust

Rust (c.o. *Phakospora euvitis*) can cause severe defoliation during July-August and January-February, which usually coincides with veraison and thus hampers the berry ripening and development. After the introduction and adoption of Dogridge as a rootstock for table grapes, rust was observed on Dogridge rootstock plants and from the infected Dogridge plants it was seen getting transmitted to the scion plants. Thus, in recent years rust is also being observed during September-October *i.e.* at the end of monsoon period on Thompson Seedless and its clones in Maharashtra.

Fig 4. Symptoms of rust in grapes

Characteristic sign of the disease is numerous yellow-orange-colored pustules present on the lower surface of the mature leaves. Sometimes these pustules are also present on the petioles, young shoots, and rachis as well. Occasionally the upper surface of the leaf corresponding to the uredial pustules shows brown necrotic spots. In severe infections the entire leaf area may be covered by these fruiting bodies and the leaves fall off.

Copper based fungicides e.g. Bordeaux mixture, copper hydroxide or copper oxy-chloride or chlorothalonil provide effective control of the disease. Curative applications with triazole fungicides also showed good control of the disease.

Bacterial blight/ leaf spot

Bacterial blight (c.o. *Xanthomonas citri* pv. *viticola*) occurs on all the aerial parts of the vine during wet and warm weather. Minute water-soaked lesions are seen on the lower surface, which enlarge and become angular and cankerous. Stunting, cracking, and irregular growth of shoots is seen in advanced stage of infection. Recent studies depict that spray of mancozeb 75WP @2-2.5g/L gives a good control of the disease. Kasugamycin 5% + Copper Oxychloride 45%WP @750g/ha is also registered against the pathogen.

Fig 5. Symptoms of bacterial blight in grapes

Conclusion

Attention should be given regarding application of pesticides and maintenance of sprayers to get a satisfactory control of diseases and pests. Use adjustable louvres allow air adjustment of the sprayers on the move and matches air flow to the changing crop canopy. Sensors can also be used to adjust liquid flow particularly in early season when minimum foliage exists to intercept the spray. Spraying requires thorough preparation, attention to detail, and constant vigilance if mistakes are to be avoided and an efficient application is to be made to obtain a durable protection to the crops. Weather-based advisories generated by ICAR-NRCG should be followed for effective control.

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Chapter-13

Post-harvest excellence to promote startups in the viticulture

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Introduction

Grape is known to originate from temperate region. But due to wider adaptability of grapevines to growing conditions, the grapes are being grown in temperate to tropical conditions of different countries. Grape growing has presence in all continents except Antarctica. China, Italy France, USA and Spain are major grape growing countries. India ranks 7th in total grape production while in table grape production India is at rank 2 just after China. About 50% of global grape production is processed to wines, 42% is consumed as table purpose while only 2% is dried for raisin making. The productivity of grape production can vary widely depending on factors such as climate, soil quality, agricultural practices, and technological advancements. Presently India is producing about 3.7 million tons of grapes with the productivity of 21.8 t/ha. In India, grape is mainly grown in tropical areas and Maharashtra and Karnataka produce more than 90% of total production of the country.

What is Startup?

A Startup is a newly established business enterprise, usually in its early stages of development. These companies are often founded by entrepreneurs aiming to develop a unique product or service and bring it to market. Startups are characterized by their innovative ideas, flexibility, and potential for rapid growth. Main features of startup are as follows:

1. **Innovation:** Startups typically focus on introducing innovative products, services, or business models. They often aim to disrupt existing markets or create entirely new ones through their unique offerings.
2. **Risk:** Startups operate in an environment of uncertainty and high risk. Many startups fail within the first few years of operation due to various factors such as market dynamics, competition, funding challenges, and internal issues.
3. **Growth Potential:** Despite the inherent risks, successful startups have the potential for rapid growth and scalability. With the right product-market fit and execution strategy, startups can attract customers, generate revenue, and expand their operations quickly.
4. **Entrepreneurship:** Startups are typically founded by entrepreneurs who are willing to take risks, think creatively, and persevere through challenges. These individuals

often possess a strong vision for their company and are driven by the desire to create something impactful.

Stages of Startup Development:

I. **Idea Stage:** This is the initial phase where entrepreneurs develop their business idea, conduct market research, and validate the concept's feasibility.

II. **Seed Stage:** In this stage, startups typically secure funding from sources such as angel investors, venture capitalists, or bootstrapping. The focus is on building a minimum viable product (MVP) and testing it with early adopters.

III. **Early Growth Stage:** With positive feedback from customers and initial traction, startups enter the early growth stage. The emphasis is on scaling the business, acquiring more customers, and refining the product or service based on user feedback.

IV. **Expansion Stage:** At this stage, startups have achieved significant growth and are looking to expand their market reach, scale operations, and possibly enter new geographic regions or market segments.

V. **Maturity Stage:** Successful startups eventually reach a stage of maturity where they have established a strong market presence, sustainable revenue streams, and a solid customer base. Some may choose to go public through an initial public offering (IPO), while others may be acquired by larger companies.

Grape-Tech Startups:

- **Precision Agriculture Solutions:** Startups are leveraging technology such as drones, satellite imaging, and IoT sensors to optimize grape cultivation. These technologies enable farmers to monitor vine health, soil moisture levels, and weather conditions more accurately, leading to improved crop yield and quality. Companies like VineView and Tule Technologies offer innovative solutions in this space.
- **Robotic Grape Harvesting**: Startups are developing autonomous robots designed specifically for grape harvesting. These robots use computer vision and robotic arms to identify and pick ripe grapes, reducing the labor-intensive nature of traditional harvesting methods. Examples include Octinion's Rubion and Dogtooth Technologies' VineScout.
- **Wine-Tech Startups**: In addition to grape cultivation, startups are innovating in the wine production and distribution sectors. From fermentation monitoring systems to blockchain-based supply chain management platforms, these startups are revolutionizing various aspects of the wine industry. Companies like Vintrace and eProvenance are pioneers in this field.

- **Grape Genome Editing**: With advancements in biotechnology, startups are exploring genome editing techniques such as CRISPR to develop grape varieties with enhanced traits such as disease resistance, drought tolerance, and flavor profiles. These genetically modified grapes have the potential to revolutionize the grape farming industry by increasing yields and reducing reliance on pesticides.
- **Wine eCommerce Platforms**: Startups are disrupting the traditional wine distribution model by creating online platforms that connect consumers directly with vineyards and wineries. These platforms offer a wide selection of wines, personalized recommendations, and convenient delivery options, bypassing the need for traditional brick-and-mortar retailers. Examples include Vivino, Wine.com, and Naked Wines.

Startup ideas in table grape sector:

a. **AI-Based Harvesting:** Implementing artificial intelligence (AI) algorithms to automate the harvesting process by analyzing factors such as grape ripeness, color, and size, ensuring optimal timing for harvest.

b. **Sensor-Based Quality Check Prior to Harvest:** Installing sensors in vineyards to monitor key parameters like sugar content, acidity levels, and moisture, allowing growers to make informed decisions about when to harvest for optimal grape quality.

c. **Rejection of Defected Bunches:** Utilizing computer vision and machine learning algorithms to inspect grape bunches before harvesting, identifying and rejecting bunches with defected or damaged berries, thereby ensuring higher quality yields.

d. **Machine Learning for Grading:** Implementing machine learning techniques to automate the grading process based on parameters such as size, color, and sugar content, enabling more accurate and efficient sorting of grapes for different market segments.

e. **Smart Packaging:** Introducing intelligent packaging solutions equipped with sensors and IoT technology to monitor and control factors like temperature, humidity, and gas composition, extending the shelf life of grapes and maintaining their freshness during transportation and storage.

f. **Supply Chain Management:** Utilizing blockchain technology and other AI based approaches to create transparent and traceable supply chains, allowing stakeholders to track the journey of grapes from the vineyard to the consumer, ensuring quality control and reducing waste.

g. **Market Identification:** Leveraging data analytics and machine learning algorithms to analyse market trends, consumer preferences, and real-time availability of grapes, enabling growers to identify suitable markets and optimize their distribution strategies for maximum profitability.

Grape Processing:

- **Wine:** Fermented grape juice, typically produced from wine grapes through crushing, fermentation, aging, and bottling. It comes in various styles such as red, white, rosé, and sparkling, with diverse flavor profiles influenced by grape variety, region, and winemaking techniques.
- **Dried Grapes (Raisins):** Grapes dried naturally in the sun or through artificial dehydration methods, resulting in concentrated sweetness and chewy texture. Raisins are commonly used as snacks, baking ingredients, or toppings in cereals and desserts.
- **Grape Juice:** Extracted from fresh grapes through pressing or crushing, grape juice is a non-alcoholic beverage enjoyed for its refreshing taste and nutritional benefits. It can be consumed on its own or used as a base for cocktails, smoothies, and mocktails.
- **Grape Seed Oil:** Cold-pressed oil extracted from grape seeds, known for its light texture, neutral flavor, and high smoke point. Grape seed oil is used in cooking, salad dressings, and skincare products due to its antioxidant properties and potential health benefits.
- **Grape Vinegar:** Fermented grape juice that undergoes acetic acid fermentation, resulting in vinegar with a tangy flavor profile. Grape vinegar is used in salad dressings, marinades, and sauces, adding acidity and depth of flavor to dishes.
- **Grape Jam and Jelly:** Preserves made from cooked grape juice and sugar, often flavored with spices or citrus zest. Grape jam and jelly are spreadable condiments enjoyed on toast, sandwiches, or paired with cheese.
- **Grape Concentrate:** Concentrated grape juice obtained through the removal of water, used as a sweetening agent, flavor enhancer, or base for fruit juices, smoothies, and desserts.

Indian wine industry:

- Registered Wineries in Maharashtra and Karnataka: Maharashtra, particularly regions like Nashik, Pune, and Sangli, along with Karnataka, including Vijayapura, Bagalkot, and Bangalore, have a combined total of 93 registered wineries. These regions are significant players in India's wine industry, known for their favorable climate and soil conditions conducive to grape cultivation. Presently few wineries are crushing and producing quality wines. A growth rate of 10-15% is being overserved in this sector.

- Geographical Indication (GI) for Nashik Valley Wine: Nashik Valley, located in Maharashtra, has been granted Geographical Indication (GI) status for its wines. This recognition signifies the unique terroir and characteristics of wines produced in this region, boosting their reputation and value in the market.
- Red Wines: The red wines produced in Maharashtra and Karnataka encompass a variety of grape varietals, including Cabernet Sauvignon, Shiraz, Merlot, Malbec, and Zinfandel. These wines are known for their rich flavors, complexity, and ability to age well. Each varietal offers distinct characteristics, ranging from bold and tannic to fruity and spicy, catering to diverse consumer preferences.
- White Wines: Similarly, the white wines crafted in these regions feature grape varietals such as Sauvignon Blanc, Chenin Blanc, Chardonnay, and Riesling. These white wines are prized for their crisp acidity, vibrant fruit flavors, and refreshing qualities. Each varietal brings its unique aroma and taste profile, from citrusy and tropical to floral and mineral, appealing to a wide range of wine enthusiasts.

Wine industry waste (Pomace, Wine lees and Stems) Possible uses:

a. Alcohol
b. Bio fuel
c. Food industry
d. Natural colours and dyes
e. Cosmetic industry
f. Nutraceuticals
g. Cattle feed

Wine lees for enrichment of Dairy products:

Addition of processed fine wine lees of Cabernet Sauvignon wines was added to improve nutraceutical, sensorial and rheological properties of dairy products like ice cream, low sugar ice cream and yoghurt. It delayed ice cream melting, added natural colour and improved overall appearance of dairy products.

Grape Drying (Raisin Making):

Raisins are dried grapes and can be prepared by adopting different drying methodologies like, sun drying, shade drying, mechanical drying, Drying on Vine (DoV) etc. Adopting of grape drying method depends on environmental conditions, available resources, consumers preferences, etc. In India, Australian method of grape drying is adopted with suitable modifications. The grape bunches are pretreated with solution of ethyl oleate (1.5%) and potassium carbonate (2.5%) for 2-4 minutes prior placing of grape bunches on rack with the density of 1.25 to 1.50 kg grapes/square feet. Grape drying sheds are established in the areas where congenial environment conditions like high temperature (about 40C), lower RH ()10-15%), no water bodies in vicinity, wind velocity, etc. Under these conditions, grapes become raisins within 12-15 days. The dried grapes (raisins) are removed at 14-16% moisture level, cleaned, washed and graded raisins are stored at low temperature. Processors give sulphur fumigations to give uniform colour to raisins. This treatment helps maintain the raisins' bright color and inhibits microbial growth, extending their shelf life.

Juice preparation:

Grapes are harvested when they reach optimal maturity, typically indicated by a sugar content of around 20°Brix. After harvesting, the grapes are destemmed, and the berries are separated from the bunches. The separated grape berries are pressed to extract the juice. Juice is pasteurized (HTST) for microbial stability or approved preservatives are also added.

Manjari Medika: A game changer juice variety suitable for Wealth from Waste

Game Changer Variety: Manjari Medika is a pioneering juice variety that embodies the concept of "Wealth from Waste," utilizing grape pomace to create a valuable product. It combines the genetic traits of Pusa Navrang and Flame Seedless grapes, resulting in a unique and desirable grape variety. It has juice recovery of more than 70%. Due to teinturier in nature, these grapes produce very dark red colour juice which reflects more anthocyanin contents. Manjari Medika grapes contained 5-6 g anthocyanins/ kg of grapes.

Zero waste processing: Manjari Medika

The Manjari Medika grape variety offers various opportunities for value addition through its juice, pomace, and other components. Here's a breakdown of potential products derived from Manjari Medika grapes:

I. **Juicing:**

- Pure Juice: The pure juice can be bottled and marketed as a premium beverage, highlighting its superior quality and health benefits.
- Blended Juice: Manjari Medika juice can also be blended with other fruit juices to create unique flavor combinations and appeal to diverse consumer preferences.

II. **Skin Powder:**

- Enriched Bakery Products: Grape skin powder can be incorporated into bakery products such as bread and cookies to enhance their nutritional value and add natural colour, fibres and flavor.
- Food Additives: Grape skin powder can also be used as a natural food additive in various food products, to boost their antioxidant content and impart health benefits.

III. **Grape Seed:**

- Seed Oil: Grape seeds can be subjected to solvent extraction to obtain grape seed oil, which is rich in antioxidants and essential fatty acids. Grape seed oil can be used in skincare products, and dietary supplements.
- Seed Extracts: Extracts from grape seeds can be utilized in various applications, including cosmetics, nutraceuticals, and functional foods, due to their antioxidant properties and potential health benefits.

IV. **Solvent Extraction:**

- Pure Anthocyanins: Anthocyanins, the pigments responsible for the dark red color of Manjari Medika grapes, can be extracted using solvents.
- Spray Dried Formulation: The extracted anthocyanins can be formulated into a spray-dried powder form for ease of handling and incorporation into various products.
- Value-Added Products: Anthocyanins can be used as natural colorants and functional ingredients in beverages, confectionery, and supplements, offering both visual appeal and health benefits.

Startup opportunities in grape processing:

There are startup opportunities in grape processing, leveraging innovative technologies and approaches to add value to the industry. Here are some potential startup ideas:

1. **AI-Based Grape Harvesting Prediction:**
   Develop AI-based algorithms that analyse various factors such as weather conditions, soil moisture levels, grape ripeness, and historical data to predict the optimal timing for grape harvesting. Provide growers with actionable insights and recommendations to optimize harvesting schedules, improve yield, and enhance grape quality.
2. **Waste-to-Wealth Nutraceutical Products:**
   Explore waste-to-wealth solutions by repurposing grape byproducts such as pomace and seeds to develop nutraceutical products with high-value health benefits. Innovate novel extraction techniques and formulations to extract bioactive compounds from grape waste and transform them into dietary supplements, functional foods, or cosmeceuticals.
3. **New Product Development for Special Consumers:**
   Identify niche markets and consumer segments with specific dietary preferences, health concerns, or lifestyle needs. Develop specialized grape-based products tailored to meet the requirements of special consumers, such as organic, gluten-free, low-

sugar, or functional food products targeting athletes, seniors, or individuals with dietary restrictions.

4. **IoT-Based Supply Chain Management:**

   Design IoT-based systems and sensors to monitor grape quality, temperature, humidity, and handling conditions throughout the supply chain. Provide real-time tracking and traceability solutions to ensure the integrity and freshness of grape products during transportation and storage, ultimately delivering high-quality products to consumers.

5. **Packaging Material Design and Development:**

   Innovate sustainable packaging materials and solutions that enhance shelf life, preserve freshness, and reduce environmental impact. Explore biodegradable, compostable, or recyclable packaging alternatives to traditional plastics, catering to the growing demand for eco-friendly packaging options.

6. **Smart Packaging Solutions:**

   Integrate smart packaging technologies such as QR codes, NFC tags, or RFID sensors to provide consumers with access to product information, authentication, and interactive experiences. Develop intelligent packaging systems that monitor product freshness, detect tampering or spoilage, and deliver personalized content or promotions to consumers.

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Chapter-14

ABI Draksha: Empowering Grape Industry Startups for Sustainable Growth

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Introduction

Entrepreneur and entrepreneurship ?

An entrepreneur is an individual who creates a new business, bearing most of the risks and enjoying most of the rewards. The process of setting up a business is known as entrepreneurship.

Entrepreneurs play a key role in any economy, using the skills and initiative necessary to anticipate needs and bring new ideas to market. Entrepreneurship that proves to be successful in taking on the risks of creating a startup is rewarded with profits and growth opportunities.

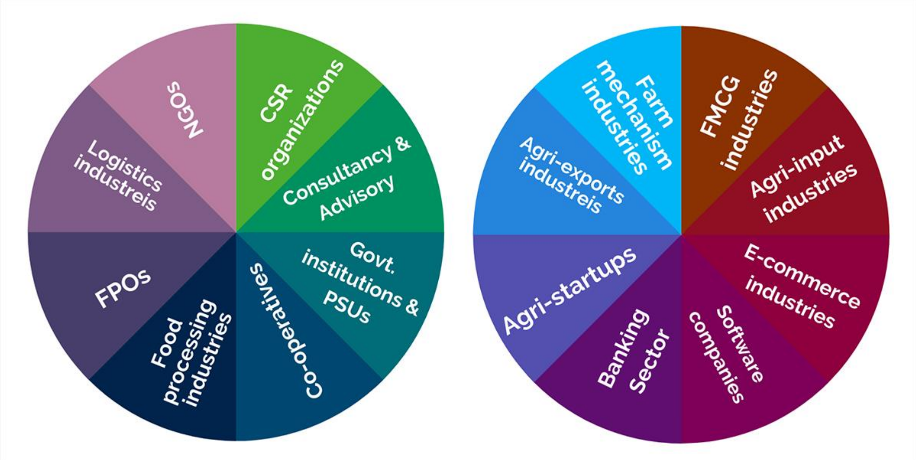
Key takeaways;

- A person who undertakes the risk of starting a new business venture is called an entrepreneur.
- An entrepreneur creates a firm to realize their idea, known as entrepreneurship, which aggregates capital and labour in order to produce goods or services for profit.
- Entrepreneurship is highly risky but also can be highly rewarding, as it serves to generate economic wealth, growth, and innovation.
- Ensuring funding is key for entrepreneurs: Financing resources include Small Business Administration loans and crowd funding.
- The way entrepreneurs file and pay taxes will depend on how the business is set up in terms of structure.

What is Agripreneurship? **(**Agriculture + Entrepreneurship)

Agripreneurship is the entrepreneurial process taken up in agriculture or the allied sectors. It is the process of adopting new methods, processes, techniques in agriculture or the allied sectors of agriculture for better output and economic earnings.It includes agriculture, animal husbandry, agro-based industries, agribusiness, agro-based enterprises, rural &allied sectors as well as agriculture exports.

Agripreneurship plays an important role in the growth and development of national economy through entrepreneurship development which increases the income level and employment opportunities in rural as well as urban areas.



Source: https://iisg.ac.in/www.iisg.ac.in

Fig 1. Diversity in Agripreneurship

What is Start-up

- Start-ups are young companies founded to develop a unique product or service, bring it to market and make it irresistible and irreplaceable for customers.
- Rooted in innovation, a start-up aims to remedy deficiencies of existing products or create entirely new categories of goods and services, disrupting entrenched ways of thinking and doing business for entire industries.

On a high level, a start-up works like any other company. A group of employees work together to create a product that customers will buy. What distinguishes a start-up from other businesses, though, is the way a start-up goes about doing that. Regular companies duplicate what's been done before. A prospective restaurant owner may franchise an existing restaurant. That is, they work from an existing template of how a business should work. A start-up aims to create an entirely new template. In the food industry, that may mean offering meal kits, like Blue Apron or Dinnerly, to provide the same thing as restaurants—a meal prepared by a chef—but with convenience and choice that sit-down places can't match. In turn, this delivers a scale individual restaurant can't touch: tens of millions of potential customers, instead of thousands.

There's another key factor that distinguishes startups from other companies: speed and growth. Startups aim to build on ideas very quickly. They often do this through a process called iteration in which they continuously improve products through feedback and usage data. Oftentimes, a startup will begin with a basic skeleton of a product called a minimal viable product (MVP) that it will test and revise until it's ready to go to market.

How Are Startups Funded?

Startups generally raise money via several rounds of funding:

- There's a preliminary round known as bootstrapping, when the founders, their friends and family invest in the business.
- After that comes seed funding from so-called "angel investors," high-net-worth individuals who invest in early stage companies.
- Next, there are Series A, B, C and D funding rounds, primarily led by venture capital firms, which invest tens to hundreds of millions of dollars into companies.
- Finally, a startup may decide to become a public company and open itself up to outside money via an IPO, an acquisition by a special purpose acquisition company (SPAC) or a direct listing on a stock exchange. Anyone can invest in a public company, and the startup founders and early backers can sell their stakes to realize a big return on investment.

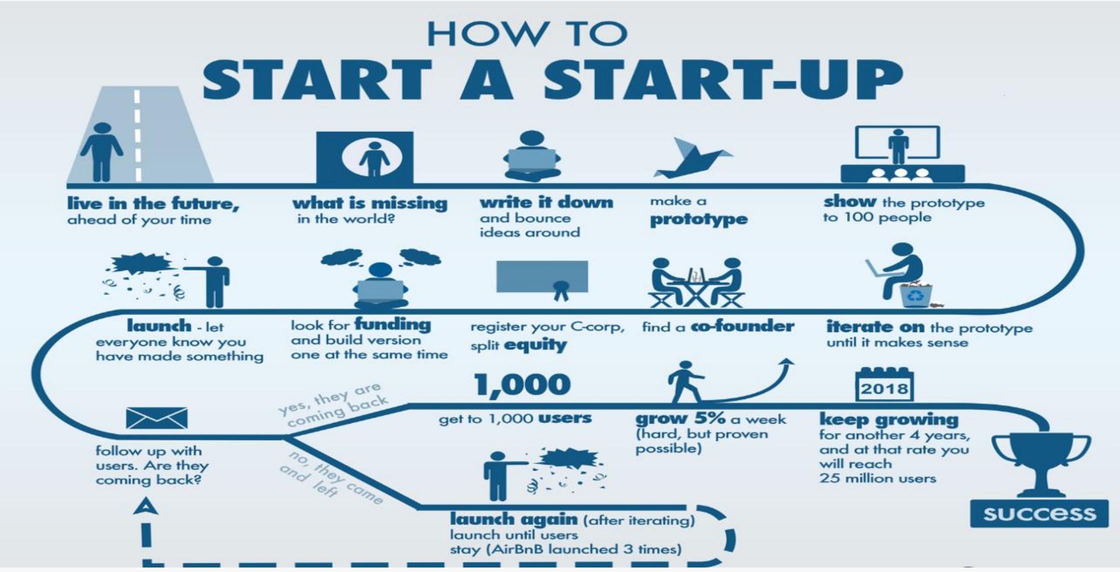


Fig 2. Schematic representation of a successful start-up process

Government schemes to support Indian startups

- **Atal Innovation Mission (AIM)**
  The scheme was launched by the government in 2016, and the scheme aims to foster innovation as the government creates new programs and policies to assist start-up development in several economic areas. The Atal Innovation Mission (AIM) grants approximately Rs 10 crores to finance firms over five years. This scheme can be utilised by all the emerging organisations in health, agriculture, education, transportation, etc.

- **Multiplier Grant Scheme (MGS)**

  The Department of Electronics and Information Technology initiated the Multiplier Grant Scheme (MGS) to empower collaborative research and development among industries for the growth of goods and services. The government gives a maximum amount of Rs 2 crore per project for a duration of less than two years.

- **Dairy Entrepreneurship Development Scheme (DEDS)**

  The Department of Animal Husbandry, Fisheries, and Dairying has launched the DEDS scheme, which aims to create self-employment in the dairy sector. The activities include milk production, procurement, preservation, marketing, etc. The DEDS scheme offers back-end capital for bankable projects for 25 per cent of total project cost for general category candidates and 33.33 per cent for farms that belong to the SC/ST category.

- **Startup India Initiative**

  This is one of the most popular government schemes for startups in India. The Startup India Initiative aims to provide tax benefits to entrepreneurs for over five years. As of now, the government has recognised 114,458 startups by the Department for Promotion of Industry and Internal Trade (DPIIT). To recognise startups under this government scheme, the maximum age for eligible startups is 7 years; for biotechnology companies, the age is 10 years after the date of establishment.

- **Startup India Seed Fund Scheme**

  The government of India introduced this scheme in January 2021 to assist early-stage startups. The selected entrepreneurs under this scheme will get the funding of Rs 5 crore. Startups will receive up to Rs 20 lakhs for developing concepts or demonstrations and up to Rs 50 lakhs for growing their goods or services. Over 1000 startups have received more than Rs 177 crore under the Startup India seed fund scheme.

Agri-Business Incubation Centre at ICAR-NRCG, Pune- ABI Draksha

ABI DRAKSHA

We nurture your ideas!

ICAR – National Research Centre for Grapes (NRC for Grapes) was established on 18th January, 1997 at Manjari, Pune. It is a well accomplished institute which targets basic, strategic and applied research on genetic resource management, crop improvement, production and post- harvest technologies for profitable and sustainable production of grapes. ICAR – NRC for Grapes developed different technologies which are widely popular among the stakeholders. ABI Draksha (ABI Centre) at ICAR - National Research Centre for Grapes (NRC for Grapes) was sanctioned in the year 2019 by ICAR Incubation Fund (Component II) under XII Plan scheme of IP&TM unit, ICAR i.e. National Agricultural Innovation Fund (NAIF).

Through this ABI Centre, ICAR – NRC for Grapes would extend support to prospective entrepreneurs by providing technical assistance, consultancy, infrastructure facility, guidance and training for sustainable business establishment.

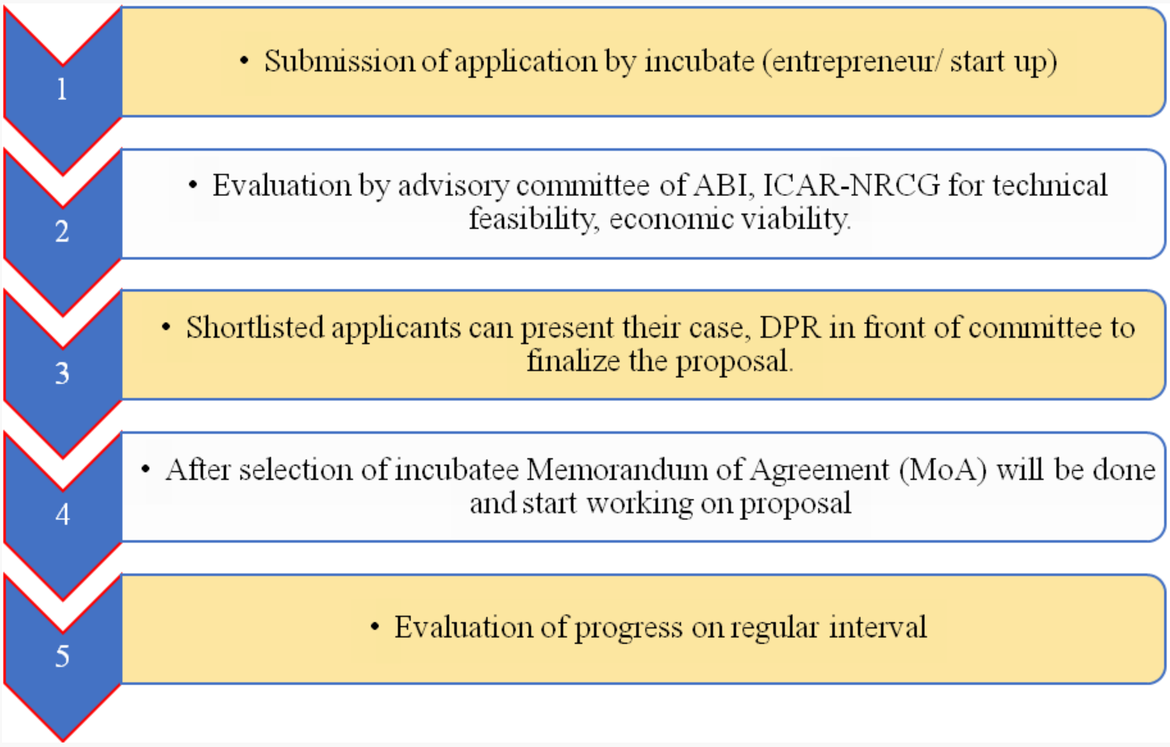
ABI Draksha-Objectives:

- To provide incubation facility and technical assistance for Agri-business development
- To scale up the technologies in collaboration with stakeholders
- To impart training and capacity building to prospective entrepreneurs in agribusiness ecosystem
- To promote innovation, entrepreneurship and business creation in agriculture and allied sector by skill development, capacity building and technology scale up;
- To promote an integrated approach for technology acquisition, R&D, commercial technology transfers and knowledge dissemination
- To facilitate evolution of an Agri-Start-Up ecosystem by support for cost effective, value added services including technical, legal, financial, intellectual property and regulatory compliance related services to agripreneurs.

Following services will be offered by ICAR – NRC for Grapes to the on-site incubate clients upon registration:

1. Office space & Lab space
2. Capacity building and training
3. Scientific Services and Technical support
4. Business facilitation
5. Industrial connects for business development support

The flow chart indicating the selection process for incubates:



For details of ABI-Draksha; Please visit https://nrcgrapes.icar.gov.in/ABI.htm

ICAR-NRCG Technologies: Available for commercialization at ICAR-NRCG

Technology title	**Potential Stakeholders**
Manjari Medika Grape-Juice Variety (PPV&FR Registered)	Juice industry, Nutraceutical, health care industries having contract farming with grape growers
Manjari Kishmish Table and Raisin Variety (PPV&FR Registration in process)	Raisin/Food industry, Grape Grower Associations, FPO's
Manjari Shyama Coloured Table Grape Variety (PPV&FR Registration in process)	Grape Grower Associations, FPO's, Grape exporters
Enriched cookies: Technology for the preparation of cookies using pomace of Manjari Medika grapes	Bakery/Food industry
High value breads: Ingredients: Maida, yeast, salt, sugar, butter, and pomace powder of Manjari Medika grapes. Attractive colour breads with antioxidant properties and fibres.	Bakery/Food industry

High value ice cream: Ingredients: Milk, cream, SMP, sugar, processed fine wine lees from Cabernet Sauvignon wine. Ice cream having antioxidant properties, natural attractive colour with slow melting	Dairy/Food industry
High value low sugar ice cream: Ingredients: Milk, cream, SMP, Saccharin, processed fine wine lees from Cabernet Sauvignon wine. Ice cream suitable for diabetic people with pleasant natural colour and higher nutraceutical properties.	Dairy/Food industry
Decision Support System for Grapes for farm-specific advisory to the farmers	Agro-tech service providers, Weather data service providers, Agri input service providers. Presently commercialized to Rallis India Limited, Mumbai, Amicus Agro Tech, Kolhapur, Sensartics Private Limited, and Nasik.
Microencapsulated anthocyanin capsule (Patented)	Nutraceutical, health care industries
Yoghurt with antioxidants (Patented)	Dairy industry/Food industry
Process for Super Critical Fluid Extraction (SFE) of grape seed oil (Patent applied)	Nutraceutical, health care and Cometic industries
Pheromone based attractant formulation for pink mealybug (Patented)	Plant protection industry
Bio-remediation of pesticides using Bacillus subtilis strain DR-39 bio formulation	Bio-pesticide industry, pesticide industry
Mass multiplication of *Trichoderma asperelloides* strain 5R on liquid and solid medium	Pesticide companies

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