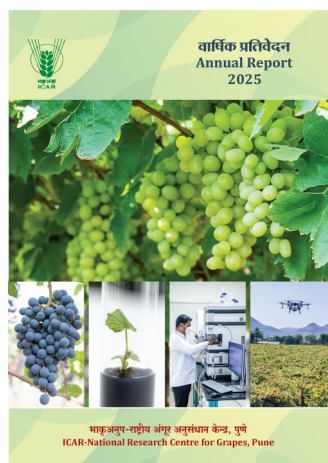




वार्षिक प्रतिवेदन Annual Report 2025



भाकृअनुप-राष्ट्रीय अंगूर अनुसंधान केन्द्र, पुणे
ICAR-National Research Centre for Grapes, Pune



आवरण चित्र / Cover Photographs

ऊपर: अवशेष-अनुपालक थॉम्पसन सीडलेस अंगूर की स्वस्थ बाग।

Top: Healthy vineyard of residue-compliant Thompson Seedless grapes.

निचली पंक्ति, बाएँ से दाएँ / Bottom row, left to right:

1. **मांजरी मधुरा:** टेबल उपयोग और किशमिश उत्पादन के लिए विकसित दोहरे उपयोग वाली नई काली अंगूर किस्म।

Manjari Madhura: A newly developed dual-purpose black grape variety for table use and raisin production.

2. **भ्रूण-उद्धारित संकर संतति:** अंगूर आनुवंशिक सुधार के लिए इन विट्रो संवर्धन के माध्यम से विकसित।

Embryo-rescued hybrid progeny: Developed through *in vitro* culture for grape genetic improvement.

3. **एपीडा-समर्थित राष्ट्रीय संदर्भ प्रयोगशाला, भाकृअनुप-राअंअनुके:** ईयू-एमआरएल गैर-अनुपालन अलर्ट में कमी लाने में योगदान, जो 2004 में 24% से घटकर 2025 में 0.89% हो गया।
APEDA-supported National Referral Laboratory at ICAR-NRCG: Contributed to a reduction in EU-MRL non-compliance alerts, from 24% in 2004 to 0.89% in 2025.

4. **ड्रोन छिड़काव प्रदर्शन:** भाकृअनुप-राअंअनुके ने एग्री-ड्रोन परियोजना के अंतर्गत लक्षित 500 हेक्टेयर ड्रोन छिड़काव प्रदर्शन पूर्ण किए, जिससे अंगूर बागों में आधुनिक अनुप्रयोग तकनीक को बढ़ावा मिला।
Drone spraying demonstrations: ICAR-NRCG completed the target of 500 hectares drone spraying demonstrations under the Agri-Drone Project, promoting modern application technology in vineyards.

वार्षिक प्रतिवेदन Annual Report 2025



भाकृअनुप-राष्ट्रीय अंगूर अनुसंधान केंद्र

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Preface



The year 2025 was an important year for ICAR-National Research Centre for Grapes, Pune (ICAR-NRCG), as the Centre continued to strengthen science-based solutions for the sustainable growth and global competitiveness of Indian viticulture. The Indian grape sector, particularly in Maharashtra, faced serious challenges during the year due to prolonged and unseasonal rainfall, cloudy weather, high humidity, cold spells, hailstorms, poor fruitfulness, berry cracking, fungal disease pressure and reduced availability of export-grade grapes. These factors affected productivity, fruit quality and export preparedness, leading to lower vineyard registrations for export, reduced export volumes and increased financial stress among growers. This situation highlighted the urgent need for climate-resilient varieties, improved rootstocks, protected cultivation, residue-compliant plant protection, disease forecasting, digital advisory systems, clean planting material and science-based vineyard management.

In this context, the Centre continued to address the priority needs of the grape sector through research, innovation, analytical services and stakeholder-oriented technology dissemination. During 2025, the Centre maintained 476 grape accessions, of which 467 fruiting accessions were evaluated for important bunch and berry traits. The grape improvement programme made significant progress in developing and evaluating hybrids with mildew resistance, improved fruit quality, loose bunch architecture, bold berries, better colour and superior processing traits. The registration of two newly developed grape varieties, 'Manjari Manjula' and 'Manjari Madhura', by the Protection of Plant Varieties and Farmers' Rights Authority was an important achievement of the year. Research on molecular tools, genomic selection and drought- and salinity-tolerant rootstocks further strengthened the Centre's efforts towards climate-resilient viticulture.

Research on production technologies focused on improving resource-use efficiency, productivity and

fruit quality. Studies on irrigation scheduling, subsurface irrigation, soil moisture-based irrigation, nutrient management, canopy management, propagation techniques, grape physiology and natural viticultural practices generated useful inputs for sustainable vineyard management. Plant protection research emphasized bio-intensive and residue-compliant management of major grape diseases and insect pests. Studies on beneficial microorganisms, bio-rational approaches, pesticide-degrading microorganisms, pathogen diagnostics and precision application technologies contributed to environmentally responsible and export-oriented grape production.

The Centre also made notable progress in digital viticulture through artificial intelligence-based vineyard monitoring, automated bunch detection, yield estimation, online information systems, decision-support tools, drone-assisted spraying and IoT-enabled irrigation management. Food safety remained a major national responsibility, with the National Referral Laboratory supporting pesticide residue monitoring, export certification, proficiency testing, laboratory assessment and regulatory compliance. Research on pesticide dissipation, pre-harvest intervals, residue transfer during processing, food authentication and non-targeted residue screening strengthened consumer protection and the credibility of Indian grape exports.

Collaborative and externally funded projects expanded research in genomic selection, clean planting material production, grapevine virus indexing, smart irrigation, robotics, digital viticulture, foodomics and technology commercialization. The Clean Plant Programme, supported by advances in virus diagnostics, certification systems and propagation technologies, is expected to contribute to the availability of healthy planting material and the long-term sustainability of vineyard production systems.





Technology transfer and stakeholder engagement remained central to the mission of the Centre. Training programmes, demonstrations, advisory services, exhibitions, workshops and farmer interactions facilitated the dissemination of improved technologies. During the year, the Centre undertook 24 consultancy programmes and continued to support growers, exporters, laboratories, entrepreneurs and other stakeholders. The Tribal Sub-Plan, Scheduled Caste Sub-Plan and programmes for the North Eastern Hill region also supported capacity building, technology dissemination and livelihood enhancement among targeted communities.

The Agri-Business Incubation Centre and Institute Technology Management Unit promoted innovation, entrepreneurship, intellectual property management and commercialization of institute-developed technologies. The commercialization of the Decision Support System for Grapes was an important step towards digital advisory-based grape production.

The achievements of 2025 were made possible through the dedicated efforts of the scientific, technical, administrative and supporting staff of ICAR–NRCG. I sincerely acknowledge the guidance and encouragement received from the Indian Council of Agricultural Research and the Department of Agricultural Research and Education. I also place on record my appreciation for the valuable support received from collaborating institutions, funding agencies, grape growers, grower associations, exporters, nurseries, entrepreneurs, industry partners and other stakeholders.

ICAR–NRCG remains committed to advancing scientific excellence, innovation and practical technologies for enhancing the productivity, profitability, sustainability and global competitiveness of Indian viticulture, while contributing to farmer prosperity, environmental sustainability and national agricultural development.

K. V. Prasad
Director

Place : Pune

Date : 23.06.2026

भाकृअनुप-राष्ट्रीय अंगूर अनुसंधान केन्द्र, पुणे ने वर्ष 2025 के दौरान भारतीय अंगूर क्षेत्र की उभरती आवश्यकताओं को पूरा करने के लिए मिशन-उन्मुख अनुसंधान एवं विकास गतिविधियाँ जारी रखीं। केन्द्र ने अंगूर आनुवंशिक संसाधन प्रबंधन, किस्मीय सुधार, उत्पादन तकनीक, पादप स्वास्थ्य प्रबंधन, खाद्य सुरक्षा, कटाई उपरांत प्रबंधन, डिजिटल अंगूर उत्पादन, स्वस्थ रोपण सामग्री, मूल्य संवर्धन और प्रौद्योगिकी हस्तांतरण के प्रमुख क्षेत्रों में कार्य किया। संस्थान-वित्तपोषित अनुसंधान कार्यक्रमों के अतिरिक्त, वर्ष के दौरान कई बाह्य-वित्तपोषित, सहयोगात्मक, परामर्शी और व्यावसायीकरण संबंधी गतिविधियाँ भी संचालित की गईं। वर्ष 2025 के दौरान केन्द्र की प्रमुख उपलब्धियाँ निम्नानुसार हैं।

अंगूर आनुवंशिक संसाधन प्रबंधन

केन्द्र ने अपने प्रक्षेत्र जर्मप्लाज्म भंडार में अंगूर की 476 अभिगमों का रखरखाव किया, जिनमें से 467 फलधारी अभिगमों का महत्वपूर्ण गुच्छा एवं बेरी गुणों के लिए मूल्यांकन किया गया। गुच्छा भार, बेरी भार, बेरी व्यास, बेरी लंबाई, गुच्छा सघनता, प्रति गुच्छा बेरी संख्या, प्रति बेल उपज, टीएसएस, अम्लता, बीजयुक्तता, बेरी रंग, स्वाद और परिपक्वता अवधि में पर्याप्त विविधता दर्ज की गई। प्रति बेल उपज में सर्वाधिक विविधता पाई गई, जो भविष्य के प्रजनन और किस्मीय सुधार के लिए श्रेष्ठ जननद्रव्यों की पहचान की अच्छी संभावना दर्शाती है। विशेषीकृत अंगूर जर्मप्लाज्म भंडार अंगूर विविधता के संरक्षण तथा टेबल अंगूर, किशमिश, रस, वाइन और प्रसंस्करण प्रयोजनों के लिए किस्मों के विकास हेतु एक महत्वपूर्ण आनुवंशिक संसाधन के रूप में कार्य कर रहा है।

आनुवंशिक सुधार और किस्मीय विकास

अंगूर सुधार कार्यक्रम का मुख्य उद्देश्य मिल्ड्यू प्रतिरोध, प्राकृतिक रूप से ढीले गुच्छे, बड़ी बेरियाँ, बेहतर बेरी रंग, उच्च एंथोसायनिन मात्रा, बीजरहितता और बेहतर प्रसंस्करण गुणवत्ता वाले जननद्रव्यों का विकास करना था। वर्ष के दौरान, कैरोलिना ब्लैकरोज × थॉम्पसन सीडलेस तथा सेव विलार्ड × थॉम्पसन सीडलेस से प्राप्त 129 एफ× संकरों का व्यावसायिक दृष्टि से महत्वपूर्ण गुच्छा एवं बेरी गुणों के लिए मूल्यांकन किया गया। इनमें से 14 संकरों में बेरी लंबाई 24 मि.मी. से अधिक, 18 संकरों में बेरी व्यास 20 मि.मी. से अधिक तथा 15 संकरों में ढीले गुच्छे दर्ज किए गए। ये संकर

फल गुणवत्ता और गुच्छा संरचना के आगे के सुधार के लिए उपयोगी पूर्व-प्रजनन सामग्री हैं।

280 एफ × बेलों में फलधारिता का आकलन किया गया। इनमें से 134 बेलों में पुष्पक्रम उद्भव हुआ, जिनमें 102 बेलों में 1-30 पुष्पक्रम, 22 बेलों में 31-50 पुष्पक्रम तथा 10 बेलों में 50 से अधिक पुष्पक्रम दर्ज किए गए। हालांकि, 146 बेलों में पुष्पक्रम उद्भव नहीं हुआ, जिसका मुख्य कारण फाउंडेशन प्रूनिंग के बाद लगातार वर्षा और अत्यधिक मृदा नमी रहा।

वर्ष की एक महत्वपूर्ण उपलब्धि यह रही कि नई विकसित 2 अंगूर किस्मों, 'मांजरी मंजुला' और 'मांजरी मधुरा', का पंजीकरण संरक्षण पौधा किस्म एवं कृषक अधिकार प्राधिकरण, नई दिल्ली द्वारा 3 सितम्बर 2025 को किया गया। 'मांजरी मंजुला' को टेबल अंगूर उपयोग के लिए, जबकि 'मांजरी मधुरा' को किशमिश उत्पादन के लिए विकसित किया गया है। दोनों किस्मों को महाराष्ट्र, कर्नाटक और तमिलनाडु के अंगूर उत्पादक क्षेत्रों में बहु-स्थानीय मूल्यांकन के लिए भी अनुमोदित किया गया।

मिल्ड्यू प्रतिरोधी लोकी के पिरामिडीकरण हेतु एच82.23 को मादा जनक और जेम्स को नर जनक के रूप में उपयोग कर संकरण किया गया। कुल 45 संकरित गुच्छों में से 35 गुच्छों में बेरी सेट प्राप्त हुआ। 182 एफ × बीजों से कुल 19 एफ× बेलें विकसित की गईं, जिनमें से 13 बेलों को प्रक्षेत्र में स्थापित किया गया।

ढीले गुच्छे, बड़ी बेरियाँ और रंगीन अंगूरों के लिए प्रजनन

प्राकृतिक रूप से ढीले गुच्छों और बड़ी बेरियों के विकास कार्यक्रम में बीजयुक्त × बीजरहित संयोजनों में 280 पुष्पक्रमों का परागण किया गया। इनमें से 230 पुष्पक्रमों में बेरी सेट हुआ और 5,972 बीज प्राप्त हुए। फ्लेम सीडलेस × रेड ग्लोब के बीजरहित × बीजयुक्त संयोजन में भ्रूण बचाव तकनीक के माध्यम से 1,260 बीजांडों का संवर्धन किया गया, जिससे 56 भ्रूण प्राप्त हुए। इनमें से 15 भ्रूण अंकुरित होकर एफ × संकरों के रूप में विकसित हुए।

वर्तमान में रेड ग्लोब को मादा जनक के रूप में उपयोग कर विकसित 109 एफ× बेलें प्रक्षेत्र में रखी जा रही हैं, जिनमें रेड ग्लोब × थॉम्पसन सीडलेस की 38 बेलें और रेड ग्लोब × फ्लेम सीडलेस

की 71 बेलें शामिल हैं। इन सामग्रियों का आगे गुच्छा ढीलापन, बेरी आकार, बीजरहितता और अन्य व्यावसायिक रूप से महत्वपूर्ण गुणों के लिए मूल्यांकन किया जाएगा।

रंगीन अंगूर सुधार कार्यक्रम में मधु अंगूर, रेड ग्लोब, फैंटेसी सीडलेस और संबंधित जननद्रव्यों को सम्मिलित करते हुए 331 संकरित अथवा स्व-परागित गुच्छे विकसित किए गए। कुल 92 संकर पौधे प्रक्षेत्र में स्थापित किए गए, जिनमें क्रिसमस रोज × क्रिमसन सीडलेस से प्राप्त 63 संकर तथा मधु अंगूर × फैंटेसी सीडलेस से प्राप्त 29 संकर शामिल हैं। टिंट्यूरियर-प्रकार के अंगूर जननद्रव्यों में ए2-14 ने 2,326.34 मि.ग्रा. कि.ग्रा.छ की सर्वाधिक औसत कुल एंथोसायनिन मात्रा दर्ज की, जिससे उच्च-रंग युक्त अंगूर-आधारित उत्पादों और मूल्य संवर्धन में इसकी संभावनाएँ स्पष्ट होती हैं।

रूटस्टॉक सुधार, जीनोमिक्स और उत्परिवर्तन प्रजनन

रूटस्टॉक प्रजनन कार्यक्रम को सूखा एवं लवणता-सहिष्णु रूटस्टॉक संततियों के विकास हेतु जारी रखा गया। वर्ष के दौरान डॉगरिज × 110आर से 186 संकरित गुच्छे और डॉगरिज × 1103पी से 19 संकरित गुच्छे प्राप्त हुए। इसके अतिरिक्त, आनुवंशिक आधार को व्यापक बनाने के लिए डॉगरिज के 59 खुली-परागित गुच्छे तथा विटिस पार्विफ्लोरा के 30 स्व-परागित गुच्छे एकत्र किए गए। डॉगरिज के कुल 55 खुली-परागित पौधे प्रक्षेत्र स्थापना के लिए तैयार हैं।

आणविक प्रजनन और जीनोमिक्स के अंतर्गत महत्वपूर्ण गुच्छा एवं बेरी गुणों के लिए उम्मीदवार जीनों की पहचान, कार्यात्मक मार्करों के सत्यापन और जीनोमिक चयन पर कार्य जारी रहा। ये उपकरण श्रेष्ठ जननद्रव्यों के चयन को तीव्र करने और भविष्य के अंगूर प्रजनन कार्यक्रमों को सुदृढ़ करने में सहायक होंगे।

उत्परिवर्तन प्रजनन के अंतर्गत 526 उत्परिवर्ती बेलों का विशेष रूप से ढीले गुच्छे और बड़ी बेरी संबंधी आकारिकी गुणों के लिए परीक्षण किया गया। उत्परिवर्ती ए16बी1 ने लगातार 2 वर्षों तक बड़ी बेरी के आशाजनक गुण दर्शाए। अनुपचारित नियंत्रण की तुलना में इसमें बेरी लंबाई, बेरी चौड़ाई और एकल बेरी भार में वृद्धि दर्ज की गई, जिससे वृद्धि नियामक अनुप्रयोग पर कम निर्भरता वाले बड़ी-बेरी उत्परिवर्ती के रूप में इसके आगे सत्यापन की संभावना स्पष्ट होती है।

उत्पादन तकनीक और जलवायु-सहिष्णु अंगूरोत्पादन

उत्पादन तकनीक संबंधी अनुसंधान का मुख्य ध्यान सिंचाई अनुसूची, पोषक तत्व प्रबंधन, कैनोपी प्रबंधन, रूटस्टॉक प्रदर्शन, प्रवर्धन तकनीक, अंगूर शरीरक्रिया, लवणता सहिष्णुता, नमी तनाव, जलभराव सहिष्णुता और प्राकृतिक अंगूरोत्पादन पद्धतियों पर केंद्रित रहा। उप-सतही सिंचाई, मृदा नमी सेंसर-आधारित सिंचाई और

आईओटी-सक्षम सिंचाई प्रबंधन पर किए गए अध्ययनों से अंगूर बागों में जल उपयोग दक्षता सुधारने हेतु प्रक्षेत्र-प्रासंगिक व्यावहारिक जानकारी प्राप्त हुई।

कैनोपी प्रबंधन अध्ययनों से फल गुणवत्ता, उत्पादकता और रोग प्रबंधन में सुधार के लिए केन घनत्व, आधारभूत पत्ती हटाने, गुच्छा भार विनियमन और शूट टॉपिंग पर व्यावहारिक जानकारी प्राप्त हुई। रूटस्टॉक अध्ययनों ने विभिन्न मृदा और जलवायु परिस्थितियों में अंगूर किस्मों को उपयुक्त रूटस्टॉक के साथ मिलाने हेतु उपयोगी अनुशंसाएँ प्रदान कीं। सूखा, जलभराव और लवणता सहिष्णुता पर किए गए अनुसंधान ने तनाव अनुकूलन और बेल प्रदर्शन में सुधार के लिए सहिष्णु रूटस्टॉकों की उपयोगिता की पुष्टि की।

प्राकृतिक अंगूरोत्पादन पर किए गए अध्ययनों ने पारंपरिक प्रणालियों की तुलना में प्राकृतिक खेती इनपुट्स के प्रदर्शन पर वैज्ञानिक जानकारी प्रदान की। कुछ लाभ देखे गए, परंतु उच्च रोग-दबाव की परिस्थितियों में रोग प्रबंधन संबंधी चुनौतियों ने प्राकृतिक खेती पद्धतियों को वैज्ञानिक रूप से प्रमाणित अंगूर बाग प्रबंधन पद्धतियों के साथ सावधानीपूर्वक एकीकृत करने की आवश्यकता को रेखांकित किया।

पादप स्वास्थ्य प्रबंधन

पादप संरक्षण अनुसंधान का मुख्य ध्यान अंगूर के प्रमुख रोगों और कीटों के टिकाऊ, जैव-सघन और अवशेष-अनुपालक प्रबंधन पर केंद्रित रहा। रोग प्रबंधन के लिए लाभकारी अंतःपादपीय और बाह्यपादपीय सूक्ष्मजीवों का पृथक्करण, लक्षण-वर्णन और मूल्यांकन किया गया। कई ट्राइकोडर्मा और बैसिलस-आधारित जैव-संरूपणों ने समेकित रोग प्रबंधन में संभावनाएँ दर्शाईं। विशेष रूप से, आइसोलेट एनआरसीजी-7 के प्रक्षेत्र मूल्यांकन में चूर्णिल आसिता के विरुद्ध 60 प्रतिशत से अधिक नियंत्रण प्रदर्शित हुआ। वर्ष की एक प्रमुख नैदानिक उपलब्धि भारत में अंगूर बेलों में फ्यूजेरियम प्रजातियों से संबंधित बेरी रॉट, पत्ती धब्बा और केन नेक्रोसिस की प्रथम रिपोर्ट रही।

इसके अतिरिक्त, आधारभूत विषाक्तता और अनुकूलता परीक्षणों से यह स्थापित हुआ कि सायजोफेमिड और मैडिप्रोपामिड सहित प्रमुख पंजीकृत कवकनाशक लाभकारी *क्लैडोस्पोरियम* स्ट्रेनों के साथ उच्च अनुकूलता प्रदर्शित करते हैं, जिससे लचीली, जैव-सघन छिड़काव अनुसूचियों के निर्माण के लिए उपयोगी जानकारी प्राप्त हुई। कीटों पर अनुसंधान में कीट जैव-परीक्षण, मिलीबग क्रॉलर के विरुद्ध बुप्रोफेजिन की मात्रा का अनुकूलन और फ्ली बीटल ब्रॉस के विरुद्ध क्लोथियानिडिन की प्रभावशीलता का सत्यापन शामिल रहा। कीटनाशी-अपघटक सूक्ष्मजीवों और सटीक अनुप्रयोग तकनीकों पर कार्य ने सुरक्षित कीटनाशी उपयोग और पर्यावरणीय दृष्टि से उत्तरदायी अंगूर उत्पादन को भी समर्थन दिया।

खाद्य सुरक्षा और राष्ट्रीय संदर्भ प्रयोगशाला

खाद्य सुरक्षा केन्द्र की एक प्रमुख राष्ट्रीय जिम्मेदारी बनी रही। राष्ट्रीय संदर्भ प्रयोगशाला ने अंगूर और अन्य फसलों में कीटनाशी अवशेष निगरानी, निर्यात प्रमाणीकरण, प्रवीणता परीक्षण, प्रयोगशाला मूल्यांकन, नियामकीय अनुपालन और विश्लेषणात्मक विधि विकास में सहयोग प्रदान किया। कीटनाशी अपघटन, कटाई-पूर्व अंतराल, प्रसंस्करण के दौरान अवशेष स्थानांतरण, खाद्य प्रामाणिकता और गैर-लक्षित अवशेष स्क्रीनिंग पर अनुसंधान जारी रहा।

इन गतिविधियों ने सुरक्षित अंगूर उत्पादन, उपभोक्ता संरक्षण और भारतीय अंगूर निर्यात की विश्वसनीयता में प्रत्यक्ष योगदान दिया। अंगूर में कीटनाशी अवशेष निगरानी के 20 वर्षों पर आधारित 1 तकनीकी बुलेटिन राष्ट्रीय अंगूर शिखर सम्मेलन 2025 के दौरान जारी किया गया। यह सम्मेलन भाकृअनुप-एनआरसीजी और बंगाल चैंबर ऑफ कॉमर्स एंड इंडस्ट्री द्वारा 4 मार्च 2025 को पुणे में आयोजित किया गया था। इस बुलेटिन ने खाद्य सुरक्षा और निर्यात सुविधा में केन्द्र के दीर्घकालिक योगदान को रेखांकित किया।

डिजिटल अंगूर उत्पादन और सटीक कृषि

केन्द्र ने एआई-आधारित अंगूर बाग निगरानी, अंगूर गुच्छा पहचान, गुच्छा गणना, उपज अनुमान, ड्रोन-सहायित छिड़काव, आईओटी-सक्षम सिंचाई और निर्णय-सहायक प्रणालियों के माध्यम से डिजिटल अंगूर उत्पादन और सटीक कृषि में प्रगति की। अंगूर बेलों के शरीरक्रियात्मक विकारों से संबंधित ऑनलाइन सूचना प्रणालियों को भी निदान संबंधी जानकारी, चित्रों, लक्षणों, कारण कारकों और प्रबंधन अनुशंसाओं के साथ सुदृढ़ किया गया।

अंगूर के लिए निर्णय-सहायक प्रणाली को पोषक तत्व एवं जल प्रबंधन, रोग जोखिम आकलन तथा कीट एवं माइट परामर्श के लिए और अधिक प्रोत्साहित किया गया। ये तकनीकें वास्तविक समय निगरानी, डेटा-आधारित निर्णय, कुशल इनपुट उपयोग और अंगूर उत्पादकों के लिए बेहतर परामर्श सेवाओं को समर्थन प्रदान करेंगी।

बाह्य-वित्तपोषित और सहयोगात्मक परियोजनाएँ

बाह्य-वित्तपोषित और सहयोगात्मक परियोजनाओं ने केन्द्र के अनुसंधान दायरे को रणनीतिक क्षेत्रों में विस्तारित किया। प्रमुख क्षेत्रों में जीनोमिक चयन, कार्यात्मक मार्कर, विशिष्टता, एकरूपता एवं स्थिरता परीक्षण, स्वस्थ रोपण सामग्री, अंगूर बेल विषाणु अनुक्रमण, आईओटी-सक्षम स्मार्ट सिंचाई, अंगूर बाग निगरानी, रोबोटिक कटाई, फूडोमिक्स, अवशेष विश्लेषण और प्रौद्योगिकी व्यावसायीकरण शामिल रहे। ये परियोजनाएँ सटीक अंगूर उत्पादन, जलवायु-सहिष्णु उत्पादन, स्वस्थ रोपण सामग्री प्रणालियों, रोबोटिक कार्यों, खाद्य सुरक्षा और डिजिटल परामर्श सेवाओं में भविष्य की प्रगति को समर्थन प्रदान करेंगी।

प्रौद्योगिकी हस्तांतरण और क्षमता निर्माण

प्रौद्योगिकी हस्तांतरण गतिविधियाँ प्रशिक्षण कार्यक्रमों, प्रक्षेत्र प्रदर्शनों, किसान संवादों, परामर्श सेवाओं, प्रदर्शनियों, कार्यशालाओं और हितधारक बैठकों के माध्यम से जारी रहीं। अंगूर किस्मों, कैनोपी प्रबंधन, सिंचाई, पोषण, रोग एवं कीट प्रबंधन, अवशेष-अनुपालक उत्पादन, स्वस्थ रोपण सामग्री, खाद्य सुरक्षा और मूल्य संवर्धन से संबंधित तकनीकों का उत्पादकों और हितधारकों तक प्रसार किया गया।

केन्द्र ने वर्ष के दौरान कई प्रदर्शनियों और जनसंपर्क कार्यक्रमों में भाग लिया, जिनसे लगभग 2,100 आगंतुक लाभान्वित हुए। वैज्ञानिकों और कर्मचारियों ने अनुसंधान, नीति, नियामकीय, संस्थागत और हितधारक विषयों से संबंधित 101 कार्यशालाओं और बैठकों में भाग लिया। अंगूर उत्पादकों, विद्यार्थियों, उद्यमियों, नर्सरी हितधारकों, प्रयोगशाला कर्मिकों और निर्यात-संबंधित एजेंसियों के लिए प्रशिक्षण एवं क्षमता निर्माण कार्यक्रम आयोजित किए गए।

उत्तर-पूर्वी पर्वतीय क्षेत्र, जनजातीय उप-योजना और अनुसूचित जाति उप-योजना कार्यक्रम

उत्तर-पूर्वी पर्वतीय क्षेत्र कार्यक्रम, जनजातीय उप-योजना और अनुसूचित जाति उप-योजना के अंतर्गत विशेष-केन्द्रित क्षेत्रों और समुदायों में प्रौद्योगिकी प्रसार तथा क्षमता निर्माण की गतिविधियाँ जारी रहीं। अंगूर छंटाई, प्रबंधन, अंगूर बाग प्रबंधन और फसल प्रदर्शन सुधारने के लिए इनपुट्स के उपयोग पर प्रशिक्षण और प्रदर्शन आयोजित किए गए। इन कार्यक्रमों ने गैर-पारंपरिक क्षेत्रों में अंगूर खेती के प्रसार को समर्थन दिया और लक्षित हितधारकों की आजीविका वृद्धि में योगदान दिया।

प्रमुख कार्यक्रम और हितधारक सहभागिता

राष्ट्रीय अंगूर शिखर सम्मेलन 2025 का आयोजन 4 मार्च 2025 को पुणे में बंगाल चैंबर ऑफ कॉमर्स एंड इंडस्ट्री के सहयोग से किया गया। इस शिखर सम्मेलन ने उत्तम कृषि पद्धतियों, बाजार अवसरों, मूल्य-वर्धित उत्पादों, अंगूर एवं वाइन पर्यटन तथा अंगूर उत्पादन में प्रगति पर चर्चा के लिए 1 मंच प्रदान किया।

केन्द्र ने 20 नवम्बर 2025 को नई दिल्ली में पोषण भारत 2025-खाद्य सुरक्षा और सुरक्षा नेतृत्व शिखर सम्मेलन का सह-आयोजन भी किया। इस कार्यक्रम का मुख्य ध्यान खाद्य सुरक्षा, पोषण, निर्यात बाजारों, नियामकीय तैयारी और डिजिटल ट्रेसबिलिटी पर केंद्रित था।

वर्ष के दौरान भारत सरकार, महाराष्ट्र सरकार, भाकृअनुप, राष्ट्रीय बागवानी बोर्ड और खाद्य प्रसंस्करण उद्योग मंत्रालय के प्रतिनिधियों सहित कई गणमान्य व्यक्तियों और वरिष्ठ अधिकारियों ने केन्द्र का

दौरा किया। इन दौरों ने संस्थान-विकसित अंगूर किस्मों, संरक्षित खेती, स्वस्थ रोपण सामग्री, जैव-सघन उत्पादन, अवशेष-अनुपालक अंगूर उत्पादन, डिजिटल अंगूरोत्पादन और राष्ट्रीय संदर्भ प्रयोगशाला को प्रदर्शित करने के अवसर प्रदान किए।

परामर्श, व्यावसायीकरण और उद्यमिता

जनवरी-दिसम्बर 2025 के दौरान केन्द्र ने 24 परामर्श कार्यक्रम संचालित किए और 6.29 लाख का परामर्श राजस्व अर्जित किया। खाद्य सुरक्षा, अवशेष विश्लेषण, प्रसंस्करण, तकनीकी सत्यापन और अन्य अधिदेश-संबंधित क्षेत्रों में परामर्श सेवाएँ प्रदान की गईं।

अंगूर के लिए निर्णय-सहायक प्रणाली के व्यावसायीकरण हेतु प्रौद्योगिकी लाइसेंस अनुबंध पर हस्ताक्षर किए गए, जिसमें पोषक तत्व एवं जल प्रबंधन, रोग जोखिम आकलन तथा कीट एवं माइट परामर्श शामिल हैं। कृषि-व्यवसाय ऊष्मायन केन्द्र ने अंगूर उत्पादन, प्रसंस्करण, मूल्य संवर्धन और अपशिष्ट-से-संपदा अवधारणाओं में उद्यमियों, स्टार्टअप्स, नवप्रवर्तकों और उद्योग भागीदारों को समर्थन देना जारी रखा।

प्रकाशन

केन्द्र ने 45 शोध-पत्रों, 4 सारांशों, 1 पुस्तक, 5 पुस्तक अध्यायों, 1 वार्षिक प्रतिवेदन और 3 तकनीकी/विस्तार बुलेटिनों एवं पुस्तिकाओं के साथ-साथ विभिन्न सम्मेलन प्रस्तुतियों के माध्यम से वैज्ञानिक और तकनीकी साहित्य में योगदान दिया। अन्य महत्वपूर्ण प्रकाशनों में अंगूर में कीटनाशी अवशेष निगरानी के 20 वर्षों पर आधारित तकनीकी बुलेटिन तथा लघु और सीमांत अंगूर

उत्पादकों के लिए समग्र मार्गदर्शिका शामिल रही, जिसमें प्रवर्धन, कैनोपी प्रबंधन, पोषक तत्व प्रबंधन, जल प्रबंधन, कीट प्रबंधन और रोग प्रबंधन को शामिल किया गया।

वित्तीय प्रदर्शन

जनवरी-मार्च 2025 के दौरान केन्द्र ने 330.09 लाख का उपयोग किया और 88.42 लाख का राजस्व अर्जित किया। अप्रैल-दिसम्बर 2025 के दौरान केन्द्र ने 1,287.76 लाख का उपयोग किया और 97.09 लाख का राजस्व अर्जित किया। इन संसाधनों ने अनुसंधान, विश्लेषणात्मक सेवाओं, प्रौद्योगिकी हस्तांतरण, अवसंरचना विकास और संस्थागत गतिविधियों को समर्थन प्रदान किया।

समग्र प्रभाव

वर्ष 2025 के दौरान भाकृअनुप-एनआरसीजी ने अंगूर आनुवंशिक सुधार, टिकाऊ उत्पादन तकनीक, जलवायु-सहिष्णु अंगूरोत्पादन, अवशेष-अनुपालक पादप संरक्षण, खाद्य सुरक्षा, डिजिटल परामर्श प्रणालियों, स्वस्थ रोपण सामग्री, मूल्य संवर्धन, प्रौद्योगिकी व्यावसायीकरण और हितधारक-उन्मुख विस्तार में महत्वपूर्ण योगदान दिया। वर्ष की उपलब्धियों ने विज्ञान-आधारित और किसान-केंद्रित अनुसंधान के माध्यम से भारतीय अंगूर उत्पादकों, निर्यातकों, प्रसंस्करणकर्ताओं, प्रयोगशालाओं, उद्यमियों और नीति-निर्माताओं को सहयोग प्रदान करने में केन्द्र की भूमिका को सुदृढ़ किया। केन्द्र भारतीय अंगूरोत्पादन की उत्पादकता, लाभप्रदता, स्थिरता और वैश्विक प्रतिस्पर्धात्मकता को बढ़ाने के लिए प्रतिबद्ध है।





Executive Summary

ICAR–National Research Centre for Grapes, Pune (ICAR-NRCG) continued to undertake mission-oriented research and development activities during 2025 to address the emerging needs of the Indian grape sector. The Centre worked in the major areas of grape genetic resource management, varietal improvement, production technology, plant health management, food safety, post-harvest management, digital viticulture, clean planting material, value addition and technology transfer. In addition to institute-funded research programmes, several externally funded, collaborative, consultancy and commercialization activities were implemented during the year. The major achievements of the Centre during 2025 are summarized below.

Grape genetic resource management

The Centre maintained 476 grape accessions in its field repository, of which 467 fruiting accessions were evaluated for important bunch and berry traits. Considerable variability was recorded for bunch weight, berry weight, berry diameter, berry length, bunch compactness, number of berries per bunch, yield per vine, TSS, acidity, seediness, berry colour, flavour and maturity duration. The highest variability was observed for yield per vine, indicating good scope for identifying superior genotypes for future breeding and varietal improvement. The characterized grape germplasm repository continues to serve as an important genetic resource for conservation of grape diversity and development of varieties for table grape, raisin, juice, wine and processing purposes.

Genetic improvement and varietal development

The grape improvement programme focused on development of genotypes with mildew resistance, naturally loose bunches, bold berries, improved berry colour, higher anthocyanin content, seedlessness and better processing quality. During the year, 129 F1 hybrids derived from Carolina Blackrose × Thompson Seedless and Seyve Villard × Thompson Seedless were evaluated for commercially important bunch and

berry traits. Among these, 14 hybrids recorded berry length above 24 mm, 18 hybrids recorded berry diameter above 20 mm, and 15 hybrids had loose bunches. These hybrids are useful pre-breeding material for further improvement of fruit quality and bunch architecture.

Fruitfulness was assessed in 280 F1 vines. Among them, 134 vines showed inflorescence emergence, including 102 vines with 1–30 inflorescences, 22 vines with 31–50 inflorescences and 10 vines with more than 50 inflorescences. However, 146 vines did not show inflorescence emergence, mainly due to continuous rainfall and excessive soil moisture after foundation pruning.

A significant achievement of the year was the registration of two newly developed grape varieties, ‘Manjari Manjula’ and ‘Manjari Madhura’, by the Protection of Plant Varieties and Farmers’ Rights Authority, New Delhi, on 3 September 2025. ‘Manjari Manjula’ has been developed for table grape use, while ‘Manjari Madhura’ has been developed for table and raisin purposes. Both varieties were also approved for multi-locational evaluation in the grape-growing regions of Maharashtra, Karnataka and Tamil Nadu.

For pyramiding mildew resistance *loci*, crossing was carried out using H82.23 as female parent and James as male parent. Out of 45 crossed bunches, berry set was obtained in 35 bunches. A total of 19 F1 vines were developed from 182 F1 seeds, of which 13 vines were established in the field.

Breeding for loose bunches, bold berries and coloured grapes

In the programme for naturally loose bunches and bold berries, 280 inflorescences were pollinated in seeded × seedless combinations. Of these, 230 inflorescences showed berry set and yielded 5,972 seeds. In the seedless × seeded combination of Flame Seedless × Red Globe, 1,260 ovules were cultured through embryo rescue, resulting in recovery of 56

embryos, of which 15 embryos germinated and developed into F1 hybrids.

At present, 109 F1 vines derived from Red Globe as female parent are being maintained in the field, comprising 38 vines of Red Globe × Thompson Seedless and 71 vines of Red Globe × Flame Seedless. These materials will be further evaluated for bunch looseness, berry size, seedlessness and other commercially important traits.

In the coloured grape improvement programme, 331 crossed or selfed bunches were developed using combinations involving Madhu Angoor, Red Globe, Fantasy Seedless and related genotypes. A total of 92 hybrid plants were established in the field, including 63 hybrids from Christmas Rose × Crimson Seedless and 29 hybrids from Madhu Angoor × Fantasy Seedless. Among teinturier-type grape genotypes, A2-14 recorded the highest mean total anthocyanin content of 2,326.34 mg kg⁻¹, indicating its potential for high-colour grape-based products and value addition.

Rootstock improvement, genomics and mutation breeding

The rootstock breeding programme was continued for development of drought- and salinity-tolerant rootstock progenies. During the year, 186 crossed bunches were obtained from Dogridge × 110R and 19 crossed bunches from Dogridge × 1103P. In addition, 59 open-pollinated Dogridge bunches and 30 selfed bunches of *Vitis parviflora* were collected to broaden the genetic base. A total of 55 open-pollinated Dogridge plants are ready for field establishment.

In molecular breeding and genomics, work continued on identification of candidate genes, validation of functional markers and genomic selection for important bunch and berry traits. These tools are expected to accelerate selection of superior genotypes and strengthen future grape breeding programmes.

Under mutation breeding, 526 mutant vines were screened for morphological traits, particularly loose bunch and bold-berry characters. The mutant A16B1 showed promising bold-berry traits during two consecutive years. Compared with untreated control, it showed increases in berry length, berry width and single berry weight, indicating its potential for further validation as a bold-berry mutant with reduced dependence on growth regulator application.

Production technology and climate-resilient viticulture

Research on production technology focused on irrigation scheduling, nutrient management, canopy management, rootstock performance, propagation techniques, grape physiology, salinity tolerance, moisture stress, waterlogging tolerance and natural viticultural practices. Studies on subsurface irrigation, soil moisture sensor-based irrigation and IoT-enabled irrigation management generated field-relevant practical information for improving water-use efficiency in vineyards.

Canopy management studies generated practical inputs on cane density, basal leaf removal, bunch-load regulation and shoot topping for improving fruit quality, productivity and disease management. Rootstock studies provided useful recommendations for matching grape varieties with suitable rootstocks under different soil and climatic conditions. Research on drought, waterlogging and salinity tolerance confirmed the usefulness of tolerant rootstocks for improving stress adaptation and vine performance.

Studies on natural viticulture provided scientific information on the performance of natural farming inputs in comparison with conventional systems. While some benefits were observed, disease management challenges under high disease pressure conditions indicated the need for careful integration of natural farming practices with scientifically validated vineyard management approaches.

Plant health management

Plant protection research remained focused on sustainable, bio-intensive and residue-compliant management of major grape diseases and insect pests. Beneficial endophytic and epiphytic microorganisms were isolated, characterized, and evaluated for disease management. Several *Trichoderma* and *Bacillus*-based bioformulations showed potential for integrated disease management; notably, field evaluations of isolate NRCG-7 demonstrated over 60% control against powdery mildew. A major diagnostic milestone for the year was the first report of berry rot, leaf spot, and cane necrosis associated with *Fusarium* species in grapevines in India. Additionally, baseline toxicity and compatibility assays established that key registered fungicides, including cyazofamid and mandipropamid, exhibit high compatibility with beneficial *Cladosporium* strains, providing actionable insights for designing flexible, bio-intensive spray

schedules. Research on insect pests included pest bioassays, optimization of buprofezin dosing against mealybug crawlers, and the validation of clothianidin efficacy against flea beetle grubs. Work on pesticide-degrading microorganisms and precision application technologies also supported safer pesticide use and environmentally responsible grape production.

Food safety and national referral laboratory

Food safety continued to be a major national responsibility of the Centre. The National Referral Laboratory supported pesticide residue monitoring, export certification, proficiency testing, laboratory assessment, regulatory compliance and analytical method development for grapes and other commodities. Research was continued on pesticide dissipation, pre-harvest intervals, residue transfer during processing, food authentication and non-targeted residue screening.

These activities contributed directly to safe grape production, consumer protection and credibility of Indian grape exports. A technical bulletin on 20 years of pesticide residue monitoring in grapes was released during the National Grape Summit 2025, organized by ICAR-NRCG and Bengal Chamber of Commerce and Industry at Pune on 4 March 2025, highlighting the long-term contribution of the Centre to food safety and export facilitation.

Digital viticulture and precision agriculture

The Centre made progress in digital viticulture and precision agriculture through AI-based vineyard monitoring, grape cluster detection, bunch counting, yield estimation, drone-assisted spraying, IoT-enabled irrigation and decision-support systems. Online information systems for grapevine physiological disorders were also strengthened with diagnostic information, images, symptoms, causal factors and management recommendations.

The Decision Support System for Grapes was further promoted for nutrient and water management, disease risk assessment, and insect and mite pest advisory. These technologies are expected to support real-time monitoring, data-driven decision making, efficient input use and improved advisory services for grape growers.

Externally funded and collaborative projects

Externally funded and collaborative projects expanded the Centre's research portfolio in strategic areas. Important areas included genomic selection,

functional markers, DUS testing, clean planting material, grapevine virus indexing, IoT-enabled smart irrigation, vineyard monitoring, robotic harvesting, foodomics, residue analysis and technology commercialization. These projects are expected to support future advances in precision viticulture, climate-resilient production, clean planting material systems, robotic operations, food safety and digital advisory services.

Technology transfer and capacity building

Technology transfer activities were continued through training programmes, field demonstrations, farmer interactions, advisory services, exhibitions, workshops and stakeholder meetings. Technologies related to grape varieties, canopy management, irrigation, nutrition, disease and pest management, residue-compliant production, clean planting material, food safety and value addition were disseminated to growers and stakeholders.

The Centre participated in several exhibitions and outreach events during the year, through which about 2,100 visitors benefitted. Scientists and staff participated in 101 workshops and meetings related to research, policy, regulatory, institutional and stakeholder matters. Training and capacity-building programmes were organized for grape growers, students, entrepreneurs, nursery stakeholders, laboratory personnel and export-related agencies.

Programme for NEH, TSP and SCSP

Activities under the North Eastern Hill region programme, Tribal Sub-Plan and Scheduled Caste Sub-Plan were continued for technology dissemination and capacity building among special-focus regions and communities. Training and demonstrations were organized on grape pruning, propagation, vineyard management and use of inputs for improving crop performance. These programmes supported the promotion of grape cultivation in non-traditional areas and contributed to livelihood enhancement among targeted stakeholders.

Major events and stakeholder engagement

The National Grape Summit 2025 was organized at Pune on 4 March 2025 in collaboration with the Bengal Chamber of Commerce and Industry. The summit provided a platform for discussion on good agricultural practices, market opportunities, value-added products, grape and wine tourism, and advances in viticulture.

The Centre also co-hosted Nourish India 2025 – Food Safety and Security Leadership Summit at New Delhi on 20 November 2025. The event focused on food safety, nutrition, export markets, regulatory preparedness and digital traceability.

Several dignitaries and senior officials visited the Centre during the year, including representatives from the Government of India, Government of Maharashtra, ICAR, National Horticulture Board and Ministry of Food Processing Industries. These visits provided opportunities to showcase institute-developed grape varieties, protected cultivation, clean planting material, bio-intensive production, residue-compliant grape production, digital viticulture and the National Referral Laboratory.

Consultancy, commercialization and entrepreneurship

During January–December 2025, the Centre undertook 24 consultancy programmes and generated consultancy revenue of Rs. 6.29 lakh. Consultancy services were provided in food safety, residue analysis, processing, technology validation and other mandate-related areas.

A Technology Licence Agreement was signed for commercialization of the Decision Support System for Grapes, covering nutrient and water management, disease risk assessment, and insect and mite pest advisory. The Agri-Business Incubation Centre continued to support entrepreneurs, startups, innovators and industry partners in grape production, processing, value addition and waste-to-wealth concepts.

Publications

The Centre contributed to scientific and technical

literature through 45 research papers, 4 abstracts, 1 book, 5 book chapters, 1 annual report and 3 technical/extension bulletins and manuals, besides conference presentations. Important other publications included the technical bulletin on 20 years of pesticide residue monitoring in grapes and the Comprehensive Guide for Small and Marginal Grape Growers, covering propagation, canopy management, nutrient management, water management, pest management and disease management.

Financial performance

During January–March 2025, the Centre utilized Rs. 330.09 lakh and generated revenue of Rs. 88.42 lakh. During April–December 2025, the Centre utilized Rs. 1,287.76 lakh and generated revenue of Rs. 97.09 lakh. These resources supported research, analytical services, technology transfer, infrastructure development and institutional activities.

Overall impact

During 2025, ICAR–NRCG made important contributions to grape genetic improvement, sustainable production technology, climate-resilient viticulture, residue-compliant plant protection, food safety, digital advisory systems, clean planting material, value addition, technology commercialization and stakeholder-oriented extension. The achievements of the year strengthened the Centre's role in supporting Indian grape growers, exporters, processors, laboratories, entrepreneurs and policymakers through science-based and farmer-centric research. The Centre remains committed to enhancing the productivity, profitability, sustainability and global competitiveness of Indian viticulture.





Introduction

ICAR-National Research Centre for Grapes, Pune, has developed strong research infrastructure, experimental vineyards, technical expertise and state-of-the-art analytical facilities to address the emerging needs of the Indian grape sector. Since its establishment, the Centre has contributed significantly to research and development in viticulture, grape improvement, production technology, plant protection, post-harvest processing, food safety and technology transfer. The Centre continues to provide science-based solutions for improving productivity, quality, sustainability and export competitiveness of Indian grapes.

During 2025, the Centre maintained 476 grape accessions in its field repository, of which 467 fruiting accessions were evaluated for bunch and berry traits. The germplasm evaluation programme generated useful information on yield, berry size, bunch characters, seediness, berry colour, flavour, bunch compactness and maturity duration. This repository continues to serve as an important genetic resource for varietal improvement, trait discovery and future grape breeding programmes.

The grape improvement programme focused on development of hybrids with mildew resistance, naturally loose bunches, bold berries, improved berry colour, higher anthocyanin content and better processing quality. Promising hybrids and mutant lines were identified for commercially important traits. Progress was also made in registration and evaluation of newly developed grape varieties, development of functional markers for berry-size traits, genomic selection, DUS testing and genetic improvement of grape rootstocks for drought and salinity tolerance.

Research on production technologies addressed irrigation scheduling, nutrient management, canopy management, rootstock evaluation, propagation techniques, moisture stress, salinity tolerance and natural viticultural practices. Studies on subsurface

irrigation, soil moisture sensor-based irrigation and crop water-use efficiency generated useful information for improving water productivity in vineyards. Canopy management and rootstock studies provided practical insights for improving yield, berry quality and vine performance under changing climatic conditions.

Plant protection research continued to focus on bio-intensive, residue-compliant and sustainable management of major grape diseases and insect pests. Promising endophytic and epiphytic microbial isolates were evaluated for management of powdery mildew, anthracnose and other diseases. Studies on *Fusarium*-associated diseases, *Cladosporium* management, pesticide-degrading microorganisms, drone-based spraying, pest bioassays and biodiversity-based conservation biocontrol strengthened the integrated plant protection programme of the Centre. AI-based vineyard monitoring, grape cluster detection, bunch counting and bunch weight estimation also progressed during the year.

The food safety programme of the Centre remained a major national strength. The National Referral Laboratory continued to support residue monitoring, proficiency testing, laboratory assessment, export certification and regulatory compliance for grapes and other commodities. During the year, the laboratory strengthened its analytical scope and continued to generate data on pesticide dissipation, pre-harvest intervals, residue transfer during processing, food authentication and non-targeted residue screening. These activities contributed directly to safe grape production, export facilitation and consumer protection.

Externally funded and collaborative projects further strengthened research in genomic selection, clean planting material, grapevine virus indexing, robotic harvesting, smart irrigation, digital viticulture, foodomics, residue analysis and technology

commercialization. The Clean Plant Programme, IoT-based vineyard monitoring, robotic harvesting and AI-enabled vineyard advisory systems are expected to support the future transition towards precision and climate-resilient viticulture.

The Centre also continued its activities under technology transfer, consultancy, capacity building, NEH, TSP and SCSP programmes. Trainings, field demonstrations, farmer interactions, advisory services, exhibitions and outreach programmes were organized for grape growers, students, entrepreneurs, laboratories and other stakeholders. The Agri-Business Incubation Centre and Institute Technology Management Unit supported entrepreneurship, intellectual property protection and commercialization of institute-developed technologies.

Overall, the research and development activities undertaken during 2025 strengthened the Centre's contribution to sustainable grape production, varietal improvement, residue-compliant crop protection, food safety, digital viticulture, value addition and stakeholder-oriented technology dissemination. The Centre remains committed to supporting the Indian grape industry through science-led, farmer-centric and export-oriented research.

Mandate

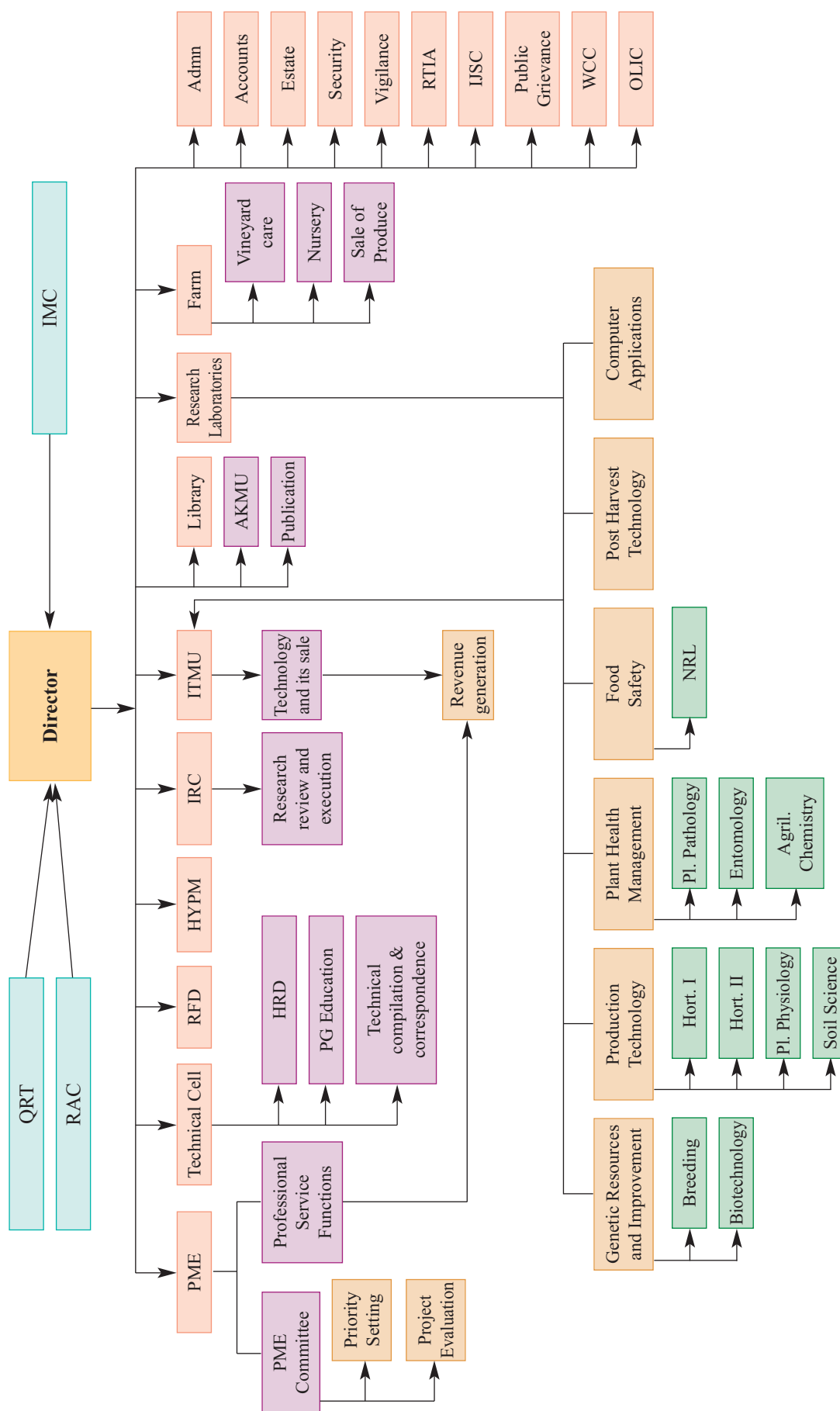
- Strategic and applied research on safe grape production and productivity.

- Transfer of technology and capacity building of stakeholders for enhanced and sustained production of grapes.
- National Referral Laboratory for food safety and pesticide residue in fruits.

Thrust areas of research

1. Conservation, characterization and utilization of grape.
2. Genetic improvement of grape.
3. Development and refinement of production technologies for enhancing quality, productivity and sustainability in grape.
4. Development and refinement of integrated protection technologies in grape.
5. Development of pre- and post-harvest technologies for processing of grapes and value addition.
6. Food safety in grapes and its processed products
7. Improving knowledge and skill of stakeholders for increasing area, production and quality of grapes and sustaining its productivity.

Organizational Set-up





Financial Statement

A. Jan – Mar 2025 (F.Y. 2024-25)

(Rs. in lakhs)

Sl. No.	Heads	RE 2024-25	Utilization during the year 2024-25 (Jan 2025 – Mar 2025)					Revenue generated
			ONEH	NEH	TSP	SCSP	Total	
1	2	3	4	5	6	7	8 (4+5+6+7)	
1.	GIA-Capital	100.00	39.60	0.00	0.00	0.00	39.60	88.42
2.	GIA-Salary	859.63	149.52	0.00	0.00	0.00	149.52	
3.	GIA-General							
	(1) Others	430.00	115.63	0.00	0.00	24.33	139.96	
	(2) Pension	1.57	1.01	0.00	0.00	0.00	1.01	
	Total	1391.20	305.76	0.00	0.00	24.33	330.09	

B. Apr – Dec 2025 (F.Y. 2025-26)

(Rs. in lakhs)

Sl. No.	Heads	RE 2025-26	Utilization during the year 2025-26 (Apr 2025 – Dec 2025)					Revenue generated
			ONEH	NEH	TSP	SCSP	Total	
1	2	3	4	5	6	7	8 (4+5+6+7)	
1.	GIA-Capital	190.01	74.82	0.00	0.00	0.00	74.82	97.09
2.	GIA-Salary	919.41	736.23	0.00	0.00	0.00	736.23	
3.	GIA-General							
	(1) Others	416.00	320.23	2.95	3.75	5.31	332.24	
	(2) Pension	181.73	144.47	0.00	0.00	0.00	144.47	
	Total	1707.15	1275.75	2.95	3.75	5.31	1287.76	

Revenue Generation: Targets and Achievements

Financial Year	Target	Revenue Generated
2024-25	Rs. 88.00 lakhs	Rs. 88.42 lakhs

Staff position

Sl. No.	Post	Number of posts		
		Sanctioned	Filled	Vacant
1.	Research and Management Personnel	1	1	0
2.	Scientific	17	17	0
3.	Technical	7	6	1
4.	Administrative	13	7	6
5.	Supportive	7	3	4
	Total	45	34	11



Research Achievements

I. Conservation, Characterization and Utilization of Grape

Grape genetic resource management

A total of 476 grape accessions were established and maintained in the grape repository of the Centre. Out of these, 467 accessions were in fruiting stage and were evaluated for bunch and berry parameters. Although considerable variability was recorded for the bunch and berry parameters, the highest variation

was recorded for yield/vine (81.55%) and minimum variation was recorded for days to harvest (7.49%) (Tables 1 to 3). The characterized grape germplasm repository provides a broad genetic base for conserving diversity and identifying promising accessions for future grape breeding, varietal development and trait improvement.

Table 1. Variation recorded for berry and bunch traits in grape accessions

Parameters	Mean	Range	SD	CV (%)
Bunch weight (g)	195.75	13.50-520.50	104.54	53.40
50-berry weight (g)	125.90	15.50-446.0	67.46	53.58
Number of berries/ bunch	74.78	13.67-170.20	28.84	38.57
Berry diameter (mm)	14.74	6.07-23.80	2.89	19.62
Berry length (mm)	17.25	7.70-27.07	3.42	19.86
TSS (°Brix)	17.82	5.00-31.00	3.26	18.31
Acidity (%)	0.60	0.40-1.65	0.22	36.68
Bunch length (cm)	12.45	2.83-37.33	4.13	33.15
Bunch compactness	4.41	0.57-17.31	1.96	44.51
Yield/vine (kg)	5.43	0.05-32.79	4.43	81.55
Days to harvest (days)	120.81	105.00-153.00	9.05	7.49

Table 2. Classification based on berry characters

Berry Diameter (mm)	Coloured/Colourless	Seediness	Flavour	Teinturier
>18 mm (62)*	Black (180)	Seeded (378)	Flavoured (178)	(10)
16.1–18 mm (92)	Red (60)	Seedless (92)		
14.1–16 mm (123)	White (230)			
12.1–14 mm (112)				
≤12 mm (81)				

* The figures given in the parentheses are number of accessions for the respective category.

Table 3. Classification based on number of bunches per vine, bunch compactness and harvesting duration

Categories for number of bunches per vine	Number of accessions	Categories for bunch compactness	Number of accessions
≤ 10 Number of bunches per vine	44	Very loose < 2.0	26
11 to 30 Number of bunches per vine	257	Loose (2.1 to 4.0)	190
31 to 60 Number of bunches per vine	146	Medium (4.1 to 6.0)	180
> 60 Number of bunches per vine	23	Dense	52
Categories for harvesting duration	Number of accessions	Very dense	22
Early (110-120 days)	289		
Medium (121-140 days)	158		
Late (> 140 days)	23		

II. Genetic Improvement of Grape

Breeding for mildew resistance (Phase-II): Evaluation of promising hybrids and gene pyramiding

Evaluation of F1 hybrids for bunch and berry traits: During the period, 129 F1 hybrids were evaluated for commercially important bunch and berry traits. These included 69 hybrids of Carolina Blackrose × Thompson Seedless (CBR×TS) and 60 hybrids of Seyve Villard × Thompson Seedless (SV×TS). In the Carolina Blackrose × Thompson Seedless population, berry length ranged from 10.0 to 27.7 mm, berry diameter from 10.0 to 23.0 mm and

bunch compactness from 2.03 to 11.10 berries/cm. In the Seyve Villard × Thompson Seedless population, berry length ranged from 13.3 to 27.0 mm, berry diameter from 12.0 to 23.0 mm and bunch compactness from 1.64 to 13.20 berries/cm. High heritability was observed for berry firmness, berry length, berry diameter and bunch compactness, indicating good scope for selection and genetic improvement.

Identification of F1 hybrids with traits of interest: Observations were recorded for commercially important traits, particularly berry size and bunch

Table 4. Identification of hybrids for traits of interest

Traits	Cross	No. of accessions	Hybrids
Berry length (>24 mm)	CBR×TS	10	H08.21, H119.23, H29.21, H33.21, H44.21, H45.23, H101.23, H24.21, H44.23, H56.23
	SV×TS	4	H123.24, H84.24, H68.24, H65.24
Berry diameter (>20 mm)	CBR×TS	12	H77.23, H94.23, H44.21, H08.21, H119.23, H101.23, H49.22, H85.23, H98.23, H29.21, H24.21, H56.23
	SV×TS	6	H123.24, H76.24, H68.24, H58.24, H84.24, H65.24
Bunch compactness (<3.0 berries/cm)	CBR×TS	9	H93.23, H01.23, H118.22, H44.21, H57.23, H103.22, H68.23, H85.23, H61.21
	SV×TS	7	H84.24, H86.24, H85.25, H121.25, H78.24, H68.24, H76.24

compactness. Potential F1 hybrids were identified using Best Linear Unbiased Prediction (BLUP) analysis in the CBR × TS and SV × TS populations. Berry length above 24.00 mm and berry diameter above 20.00 mm were recorded in 14 and 18 F1 hybrids, respectively, while 15 F1 hybrids had loose bunches. These hybrids can serve as useful pre-breeding material for trait improvement (Table 4).

Screening of F1 hybrids for fruitfulness: The crop experienced excessive moisture stress due to continuous rains from May onwards till mid of October 2025 after foundation pruning. This adversely affected the fruitfulness of vines. Inflorescence emergence was recorded in 280 F1 vines derived from Carolina Blackrose × Thompson Seedless and Seyve Villard × Thompson Seedless. Among the 280 F1 vines screened for inflorescence emergence, 134 vines showed inflorescence emergence, including 102 vines with 1–30 inflorescences, 22 vines with 31–50 inflorescences and 10 vines with more than 50 inflorescences, while 146 vines did not show inflorescence emergence.

Progress in newly developed grape varieties ‘Manjari Manjula’ and ‘Manjari Madhura’: Developments related to the newly developed grape varieties ‘Manjari Manjula’ and ‘Manjari Madhura’ progressed significantly during the year. The two varieties, Manjari Manjula (REG/2024/0434) and Manjari Madhura (REG/2024/0435), were granted registration by the Protection of Plant Varieties and Farmers’ Rights Authority, New Delhi, on 3 September 2025. Further, proposals for multi-locational evaluation of Manjari Manjula, developed for table grape purpose, and Manjari Madhura, developed for table and raisin purposes, were presented during the XII Group Discussion Meeting, 2025 of the ICAR-All India Coordinated Research Project on Fruits. Both varieties were approved for evaluation in grape-growing regions of Maharashtra, Karnataka and Tamil Nadu. In addition, both varieties are currently under the release process through the State Variety Release Committee, and the proposals have been submitted to Mahatma Phule Krishi Vidyapeeth, Rahuri, Maharashtra.

Progeny development: Crossing was conducted using H82.23 as female parent and James as male parent with the objective to combine mildew resistance *loci* (Rpv3, Rpv1, Rpv2, Run1). Total 45 bunches were crossed and berry setting was obtained

in 35 bunches. Nineteen F1 vines were developed from the 182 F1 seeds and 13 are established in the field.

Nutrient analysis of Manjari Manjula and Manjari Madhura: Nutrient analysis of both varieties was conducted using berry and petiole samples, recording levels of K, Ca, Mg, Mn, P, Zn, and Fe. The analysis will be repeated in the second year for confirmation. Soil analysis was also performed to assess key parameters, including pH, EC, organic carbon, CaCO₃, and nutrients (N, P, K, Ca, Mg, Na, Fe, Mn, Zn, Cu, S, B). These results will guide optimization of fertilizer schedules to enhance varietal performance.

Breeding for naturally loose bunches and bold berries in grapes

Crossing programme during November, 2025: The crossing programme was undertaken to develop grape hybrids with naturally loose bunches and bold berries. Four parental combinations were used, including three seeded × seedless crosses and one seedless × seeded cross. In the seeded × seedless crosses, Red Globe and H44.21 were used as female parents with Thompson Seedless or Flame Seedless as male parents. A total of 280 inflorescences were pollinated in these combinations, of which 230 showed berry set, resulting in the recovery of 5,972 seeds. In the seedless × seeded combination, Flame Seedless was crossed with Red Globe. Since seedless genotypes generally require embryo rescue for hybrid recovery, 1,260 ovules were cultured on ER medium. This resulted in the recovery of 56 embryos, of which 15 embryos germinated and developed into F1 hybrids. The developed hybrids will be further evaluated for bunch looseness, berry size, seedlessness and other commercially important traits.

Progeny development and field establishment: Thirteen newly developed F1 hybrids were transferred and established in the field during the period. At present, 109 F1 vines derived from Red Globe as the female parent are being maintained, comprising 38 vines of Red Globe × Thompson Seedless and 71 vines of Red Globe × Flame Seedless.

Development of F1 progeny through embryo rescue: During the period, 15 F1s were developed from Flame Seedless × Red Globe combination using embryo rescue protocol (Figure 1).



Figure 1. F1 progeny of Flame Seedless x Red Globe developed using embryo rescue

Field establishment of embryo rescued vines: Sixteen embryo rescued (Flame Seedless × Red Globe = 11 and Open pollinated Flame Seedless = 5) F1 vines were established in the field.

Evaluation of Red Globe × Flame Seedless for berry characters: Six F1 vines of Red Globe × Flame Seedless achieved bearing and were evaluated for berry characters. Of these, three vines had rudimentary seeds. All evaluated vines produced round berries. Three vines recorded berry diameter above 17 mm, while four vines produced coloured berries and two vines produced white berries. Among the evaluated vines, RGFS-22, RGFS-40 and RGFS-35 were notable for berry diameter above 17 mm, while RGFS-22, RGFS-29 and RGFS-41 had loose bunches.

Genetic improvement of coloured grapes

Crossing was undertaken to develop coloured grape hybrids with improved berry quality, bunch characters, yield potential and market-preferred traits. Madhu Angoor × Red Globe was attempted using 53 bunches to combine desirable berry quality and bunch traits. Red Globe × Fantasy Seedless was attempted using 49 bunches to integrate the large berry size and market preference of Red Globe with the seedlessness and eating quality of Fantasy Seedless. In addition, 30 selfed bunches of Red Globe were collected to generate genetically diverse progenies for evaluation. The reciprocal cross, Fantasy Seedless × Red Globe, was attempted using 199 bunches and was used for embryo rescue studies. A total of 331 crossed/selfed bunches were developed during the programme.

Progeny development and field establishment: A total of 92 hybrid plants were established in the field, comprising 63 hybrids from Christmas Rose × Crimson Seedless and 29 hybrids from Madhu Angoor × Fantasy Seedless.

Embryo rescue in Fantasy Seedless: A total of 1,060 selfed ovules of Fantasy Seedless and 1,170 hybrid ovules from Fantasy Seedless × Red Globe, sampled at 35-45 days after flowering, were cultured on modified Nitsch medium for embryo rescue. The cultured ovules are presently in the germination phase.

Comparative analysis of total anthocyanin content in teinturier-type grape genotypes: The newly identified teinturier-type grape genotype A2-14, along with other teinturier genotypes available at the institute, was evaluated for total anthocyanin content. A2-14 recorded the highest mean anthocyanin content (2,326.34 mg kg⁻¹), followed by Pusa Navrang (934.40 mg kg⁻¹) and Manjari Medika (869.23 mg kg⁻¹). Considerable variation was observed among the genotypes for total anthocyanin content (Table 5). A2-14 has consistently recorded the highest anthocyanin accumulation among the evaluated genotypes for the last three consecutive years.

Genetic improvement of grape rootstocks for drought & salinity tolerance (Phase-I)

Genetic improvement of grape rootstocks for drought and salinity tolerance: The rootstock breeding programme was undertaken to develop drought- and salinity-tolerant rootstock progenies. Dogridge × 110R was the major cross, with 186 crossed bunches, followed by Dogridge × 1103P with 19 crossed bunches. In addition, 59 open-pollinated Dogridge bunches were collected to broaden genetic variability, while 30 selfed bunches of *Vitis parviflora* were collected to generate inbred material for trait analysis and identification of stable lines. Overall, the programme generated diverse breeding material for selection of grape rootstocks with improved tolerance to drought and salinity stress.

Table 5. Total anthocyanin content of ‘teinturier’ grape genotypes

S. No.	Genotype	Avg. total anthocyanin (mg/kg)	Standard Deviation (SD)	Relative Standard Deviation (RSD)	Range (mg/kg)
1	A2-14	2326.34	302.14	12.99	2070.67 - 3055.06
2	Alicante Bouschet	385.94	178.30	46.18	84.57 - 612.14
3	E 26-5	509.64	116.37	22.83	376.94 - 747.29
4	Pusa Navrang	934.40	193.93	20.75	766.23 - 1373.70
5	Rubi Red	196.05	38.60	19.69	147.75 - 248.01
6	PN × RG	142.06	35.85	25.23	88.07 - 215.28
7	Manjari Medika	869.23	306.73	35.29	339.51 - 1469.72

Progeny development and field establishment: A total of 55 open-pollinated plants developed from Dogridge are ready for field establishment. Transplanting will be taken up during the coming season in 2026.

Creating gene and ploidy variations for desired traits in grapes using physical and chemical agents

Creating gene and ploidy variations for desired traits in grapes using physical and chemical agents: A total of 526 mutant vines were screened for morphological traits, with particular emphasis on loose bunch and bold-berry characters. Among the evaluated mutants, A16B1 consistently exhibited promising bold-berry traits during the last two

consecutive years. Compared with the untreated control, A16B1 showed an increase of 18% and 27% in berry length, 34% and 17% in berry width, and 24% and 61% in single berry weight during 2023–24 and 2024–25, respectively (Table 6). The mutant will be further evaluated to confirm the stability of these traits. A16B1 was also compared with the untreated control and gibberellic acid (GA)-treated bunches. The mutant recorded higher 50-berry weight, single berry weight, berry length and berry width than the untreated control, even without GA application. Although the values were slightly lower than those recorded under GA treatment, A16B1 showed comparable bold-berry characters, indicating its potential for reducing dependence on growth regulator application after further validation.

Table 6. Performance of mutant A16B1 for bold-berry traits in comparison with untreated and GA-treated controls

Trait	Improvement over untreated control in 2023–24 (%)	Improvement over untreated control in 2024–25 (%)	Untreated control	GA-treated control	A16B1 mutant
50-berry weight (g)	-	-	67	121	108
Single berry weight (g)	24	61	1.34	2.42	2.16
Berry length (mm)	18	27	14.20	19.48	18.15
Berry width (mm)	34	17	11.27	15.10	13.17
Reduction in bunch compactness (%) / bunch compactness	44	49	12.40	6.30	11.80

Evaluation of grape genotypes for processability

Evaluation of teinturier-type grape genotypes for wine quality: Nine teinturier-type grape genotypes were evaluated for bunch and berry traits and wine quality parameters. Among the evaluated genotypes, ARI (H-27) recorded the highest bunch weight (322.67 g), while Pusa Navrang × Red Globe recorded the lowest bunch weight (102.66 g). ARI-239 recorded the thinnest berry skin (0.18 mm). The lowest berry diameter was recorded in E26/5 IIHR Hybrid, whereas the highest berry diameter was observed in Manjari Medika. Rubired recorded the

highest juice recovery (66.01%), while Pusa Navrang × Chardonnay recorded the lowest juice recovery (51.42%); however, the differences for juice recovery were non-significant (Table 7). The wine quality data indicated that the wines were of super-dry type, with comparatively lower acidity levels. Ethanol content ranged from 11.40 to 11.50%. Considerable variation was observed in colour intensity among the wines. The lowest colour intensity was recorded in Pusa Navrang × Chardonnay (2.71%), whereas ARI (H-27) recorded the highest colour intensity (11.16%). Colour intensity differed significantly among the wines (Table 8).

Table 7. Bunch and berry parameters of teinturier-type grapes

Name of Genotype	Bunch weight (g)	Skin Thickness (mm)	Bunch length (cm)	Berry diameter (mm)	TSS °Brix	50 berry weight (g)	pH	Juice recovery (%)
E26/5 IIHR Hybrid	198.66	0.21	12.50	11.26	23.25	73.33	3.26	58.39
ARI (H-27)	322.67	0.22	16.76	15.36	23.32	127.67	3.32	53.69
Pusa Navrang x Red Globe	102.66	0.32	12.47	13.53	23.30	102.67	3.26	54.68
Manjari Medika	295.33	0.20	14.90	15.78	23.56	129.33	3.55	60.79
Pusa Navrang x Chardonnay	191.33	0.21	12.50	12.3	23.11	118.00	3.22	51.42
Alicante Bouschet	295.66	0.21	14.83	14.74	23.26	130.67	3.26	62.91
Pusa Navrang	130.00	0.21	11.50	12.98	22.36	84.00	3.28	55.81
Rubi Red	190.67	0.21	12.50	12.40	24.36	77.00	3.23	66.01
ARI-239	235.66	0.18	15.83	11.83	23.13	141.33	3.24	55.52
C.D. 5%	113.311	NS	2.141	2.073	NS	27.177	0.124	NS
SE(m)±	37.473	0.041	0.708	0.686	0.432	8.988	0.041	6.299

Identification and validation of candidate genes and development of functional markers for bunch and berry quality traits in grape (*Vitis vinifera* L.) (ANRF partially funded)

Morphological observations: The data on bunch and berry traits were recorded for eight selected grape genotypes with contrasting traits during fruiting

season 2024-25. The berry length varied from 14.05 (Viognier) to 25.10 (Red Globe), berry diameter varied from 13.1 (Pusa Navrang) to 23.2 (Manjari Naveen). Similar variability was observed for all the traits

Expression analysis of candidate genes: The expression of 10 candidate genes was analysed at five stages of bunch development (EL-12, EL-23, EL-27,

Table 8. Wine quality parameters of wines prepared from teinturier-type grapes

Name of Genotype	Sugar (g/l)	Total acidity (g/l)	Ethanol (%)	Volatile acidity (g/l)	Colour intensity (%)
E26/5 IIHR Hybrid	1.00	3.53	11.40	1.08	9.68
ARI (H-27)	1.48	3.20	11.50	1.21	11.16
Pusa Navrang X Red Globe	1.76	3.93	11.40	1.14	10.46
Manjari Medika	2.21	4.53	11.47	1.24	9.24
Pusa Navrang X Chardonnay	2.03	4.16	11.43	1.15	2.71
Alicante Bouschet	1.99	6.33	11.40	1.24	10.82
Pusa Navrang	1.79	3.50	11.50	1.16	8.29
Rubi Red	1.19	3.96	11.43	1.27	10.94
ARI-239	1.76	3.33	11.50	1.23	9.78
C.D. 5%	0.159	0.37	0.06	0.032	2.055
SE(m)±	0.053	0.122	0.02	0.01	0.68

EL-35, EL-38). Gene PP2A was used as reference gene for data normalisation. Transcription abundance was estimated. The expression of all the analysed genes varied across different stages. For several genes genotype-stage-specific significantly differential expression was obtained. Higher expression level was

observed for many genes in Red Globe, a bold berry variety, at inflorescence stage. In Manjari Naveen, a self-thinning variety, the expression of chromatin modelling gene was significantly higher at EL-27 stage, whereas Ca^{2+} ATPase gene expression was observed at very low level at EL-35 stage (Figure 2).

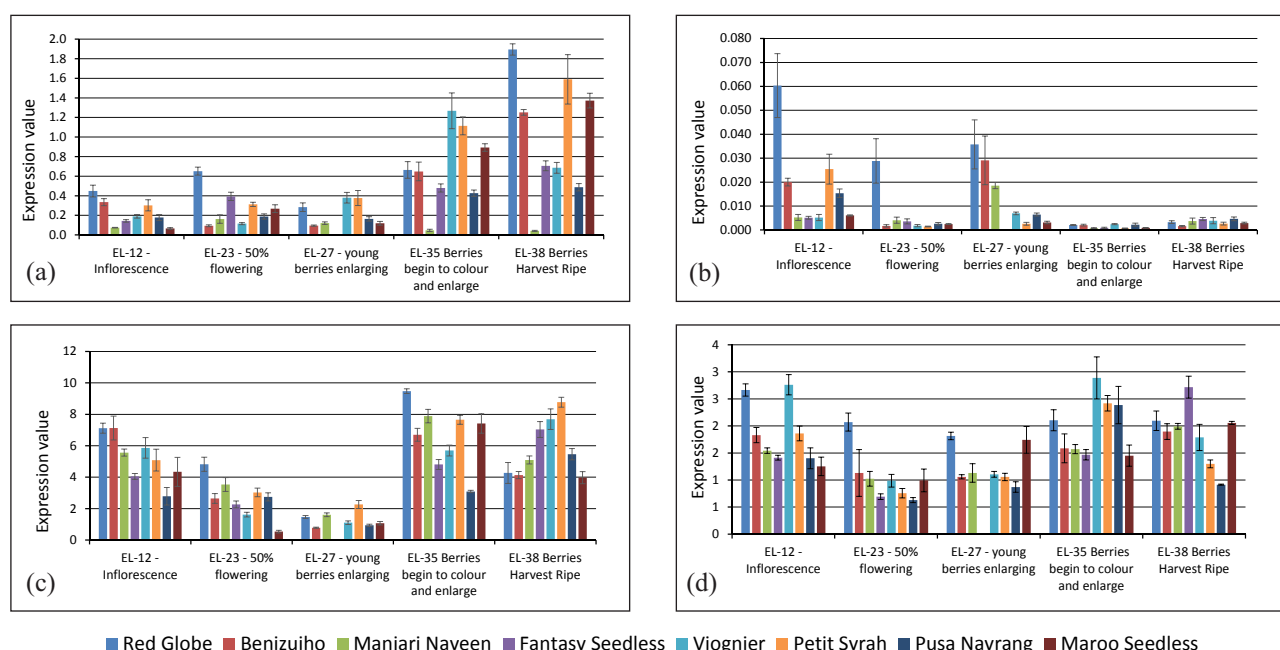


Figure 2. Genotype and stage-specific differential expression of candidate genes (a) Chromosome remodelling, (b) Ca^{2+} ATPase Plasma Protein II, (c) bHLH077, (d) Myosin VII

Development of functional markers for berry size:

Primers were designed for 54 microsatellite repeat regions identified in 25 candidate genes. Twenty primer pairs were analysed with ten selected grape genotypes. Fourteen primer pairs were polymorphic. Analysis of 50 hybrids of a segregating population derived from a cross of Seyve Villard 12375 and Thompson Seedless with these primers were performed. Single marker analysis using non-parametric Mann-Whitney U Test revealed significant association of two marker alleles with berry size

related traits. The presence of marker allele VviKAS09 (approximately 170bp size) was significantly associated with increased grape berry diameter, length, and weight, suggesting that this allele may be linked to a genomic region positively regulating berry development (Figure 3). On the contrary, the presence of marker allele VviKAS19 (approximately 192bp size) was associated with reduced berry size traits, indicating a possible negative regulatory role or linkage with alleles contributing to smaller berry phenotypes.

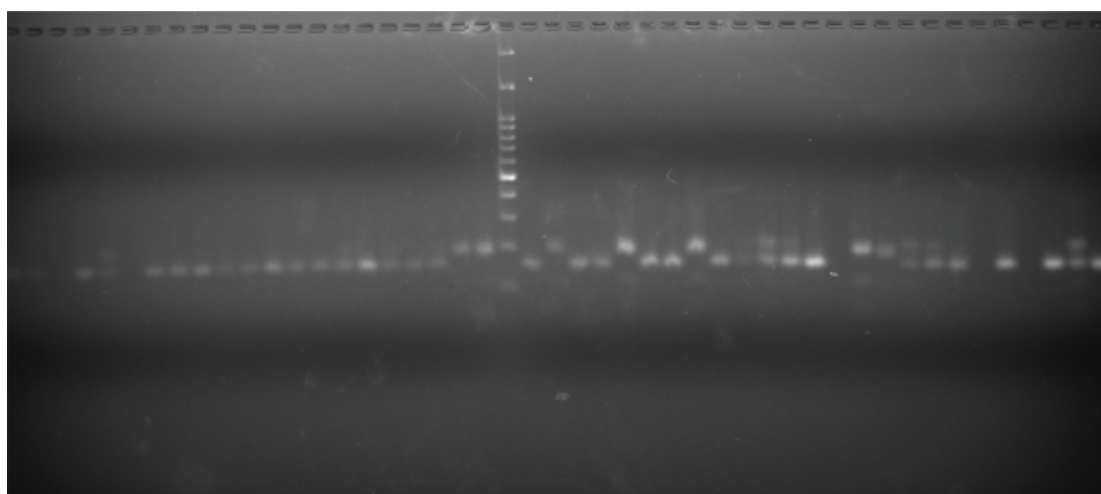


Figure 3. Co-segregation of microsatellite marker allele with berry size

III. Development and Refinement of Production Technologies for Enhancing Quality, Productivity and Sustainability in Grape

Evaluation of natural viticultural practices for production of Thompson Seedless grapes

The project was undertaken to evaluate natural farming practices for Thompson Seedless grapes grafted on Dogridge rootstock and to compare their performance with organic and modern grape-growing practices in established as well as newly planted vines. During the second year of study, 19 applications of natural inputs, including Jeevamrut, Dashparni, Khatli Lassi, Brahmastra and Neemastra, were given as per the treatment schedule. High disease pressure was observed during the season under the prevailing weather conditions. The natural inputs alone were not sufficient to suppress disease incidence effectively. In the newly established vines, poor canopy health affected cane maturation before October pruning and resulted in poor fruitfulness.

Even under modern practices, no bunches were obtained in the new block.

In established vines, disease incidence remained high, particularly under natural farming practices. Downy mildew affected all treatments, with the highest disease severity under natural farming, recording 53.08% PDI on 20 January 2025 (Figure 4). A similar trend was observed for powdery mildew, which exceeded 81% PDI by 15 March 2025. The available bunches showed poor marketable quality due to smaller berry size, lower sugar content and heavy powdery mildew infection. The results indicate that, under high disease pressure, natural farming inputs alone may not be adequate for successful production of Thompson Seedless grapes. Further refinement and integration with validated disease management interventions are required for developing a practical and sustainable natural viticulture module.

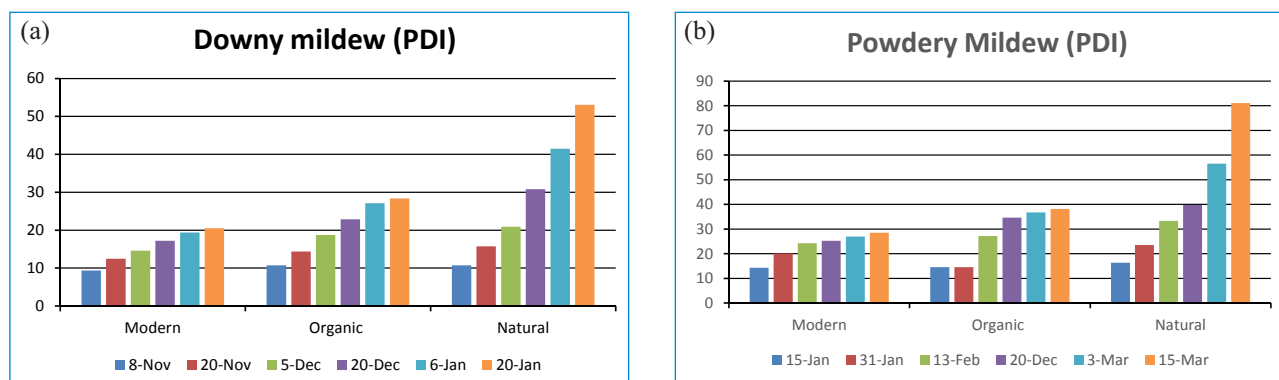


Figure 4. Incidences of (a) Downy mildew and (b) Powdery mildew in terms of PDI (%)

An online information system for physiological disorders of grapevines under Indian agro-climatic conditions

The project was undertaken to develop and update an online information system for identification and management of physiological disorders of grapevines under Indian agro-climatic conditions. During the year, the existing software modules were improved for better functionality, consistency and user access. The homepage and disorder information pages were redesigned, and a media gallery, FAQ section, contact page and user-support features were incorporated. A comprehensive database of 22 physiological disorders of grapevines was developed. The database includes diagnostic images, symptom descriptions, causal

factors, economic impact and preventive measures for important disorders such as dead arm, berry splitting, pink berry, berry cracking, sunburn and lightning injury. Relevant images and publications were collected, curated, uploaded and verified to ensure accuracy and practical utility. An admin interface was developed for uploading and managing content in different formats, while the user interface was designed to facilitate easy search, viewing and access to disorder-specific information. An e-book-based help document and user manual were also prepared. The system is expected to serve as a useful digital advisory tool for grape growers, extension personnel, students and researchers for diagnosis and management of physiological disorders in grapevines (Figure 5).



Figure 5. Updated homepage and media gallery of the online information system for physiological disorders

Studies on estimation of light compensation and saturation points of grape varieties

This project was initiated in May 2024 and completed

in April 2025 with an objective to quantify the light compensation and saturation point of grape varieties under field conditions. The study was conducted to quantify light compensation point (LCP), light saturation point (LSP), maximum net photosynthesis

rate (P_{nmax}), dark respiration rate (R_d), apparent quantum yield (AQY), chlorophyll content and biomass production in seven grape varieties under field conditions. Mature fifth to sixth leaves were used for gas-exchange measurements under varying light

intensities to generate light-response curves (Figure 6). Significant varietal differences were observed for photosynthetic performance and light-use efficiency.

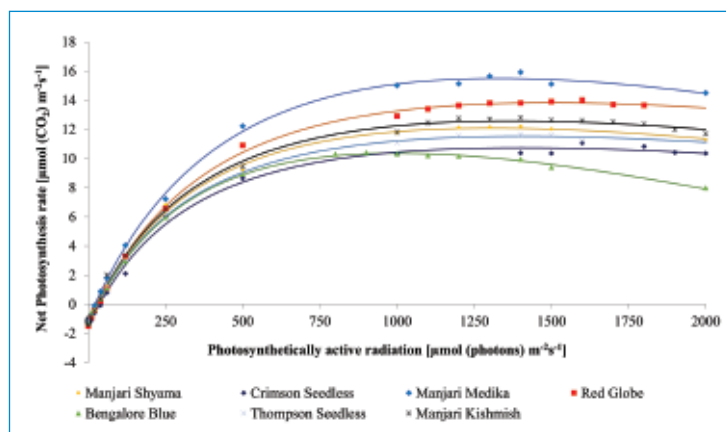


Figure 6. Light response curve of grape varieties

Among the evaluated varieties, Manjari Medika recorded the highest P_{nmax} ($16.56 \mu\text{mol CO}_2 \text{ m}^{-2} \text{ s}^{-1}$), followed by Red Globe ($15.35 \mu\text{mol CO}_2 \text{ m}^{-2} \text{ s}^{-1}$), whereas Bangalore Blue recorded the lowest P_{nmax} ($11.59 \mu\text{mol CO}_2 \text{ m}^{-2} \text{ s}^{-1}$). Red Globe recorded the highest LSP ($1497.60 \mu\text{mol m}^{-2} \text{ s}^{-1}$), followed by Thompson Seedless ($1405.04 \mu\text{mol m}^{-2} \text{ s}^{-1}$), indicating their ability to utilize higher light intensity. Bangalore Blue recorded the lowest LSP ($996.74 \mu\text{mol m}^{-2} \text{ s}^{-1}$). The LCP was highest in Crimson Seedless ($36.39 \mu\text{mol m}^{-2} \text{ s}^{-1}$) and lowest in Manjari Medika ($21.83 \mu\text{mol m}^{-2} \text{ s}^{-1}$), suggesting better photosynthetic efficiency of Manjari Medika under low-light conditions.

Chlorophyll content and biomass production also differed among varieties. Manjari Medika recorded the highest chlorophyll a (19.16 mg ml^{-1}), chlorophyll b (5.80 mg ml^{-1}) and biomass ($2.31 \text{ kg vine}^{-1}$). Red Globe was comparable, with chlorophyll a of 18.14 mg ml^{-1} , chlorophyll b of 6.09 mg ml^{-1} and biomass of $2.21 \text{ kg vine}^{-1}$. Bangalore Blue and Crimson Seedless recorded comparatively lower chlorophyll content and biomass. Correlation analysis indicated that biomass and yield were positively associated with AQY, photosynthetic traits, stomatal conductance and chlorophyll content. Hierarchical clustering grouped Manjari Medika and Red Globe together as physiologically efficient varieties, while Crimson Seedless and Bangalore Blue formed a low-efficiency group. Overall, the study identified Manjari Medika

and Red Globe as promising varieties with superior photosynthetic efficiency, biomass accumulation and light-use capacity under field conditions.

Standardising irrigation and nutrient schedule for Crimson Seedless vines raised on Dogridge rootstock

The project was initiated in September 2021 to standardise growth stage-wise irrigation and nutrient requirements of Crimson Seedless on Dogridge rootstock. The study was conducted in factorial RBD with 4 irrigation and 4 nutrient treatments. Irrigation treatments I1–I3 were applied through surface drip irrigation, while I4 represented subsurface irrigation using inline drippers placed at 9-inch depth (Table 9). During 2024–25, total pan evaporation was 1,355.5 mm and rainfall was 733.2 mm. Due to rainfall, no irrigation was applied for 150 days.

Grapevine yield varied significantly with irrigation treatments, whereas nutrient treatments and their interaction effects were non-significant. Subsurface irrigation treatment I4 recorded the highest yield (18.13 t/ha) with the lowest irrigation water application (191.8 mm) and the highest water-use efficiency ($94.5 \text{ kg grapes/mm irrigation water applied}$). In comparison, I1 recorded a comparable yield of 18.00 t/ha but required 267.4 mm irrigation water, resulting in lower water-use efficiency ($67.3 \text{ kg grapes/mm}$). Thus, I4 saved 75.6 mm irrigation water compared with I1 without reducing yield (Table 10).

Among nutrient treatments, N2 recorded the highest yield (17.72 t/ha), which was on par with the reduced nutrient dose N4 (17.68 t/ha). The treatment combination I4N4 produced 18.2 t/ha, comparable with I1N2, indicating the possibility of combining subsurface irrigation with reduced nutrient application (50% N, 60% of P₂O₅ and 75% of K₂O of N2). Petiole nutrient status, leaf water potential and

biochemical stress indicators suggested that reduced irrigation under I4 did not adversely affect vine health. The results indicate that subsurface irrigation with N4 treatment, comprising 50% N, 60% P₂O₅ and 75% K₂O of N2, can improve water-use efficiency and nutrient-use efficiency in Crimson Seedless grapes without compromising yield.

Table 9. Irrigation and nutrient treatments

Growth stage	Irrigation treatments			
	I1	I2	I3	I4
Foundation pruning				
Shoot growth	40	30	40	30
Fruit bud differentiation	15	15	15	15
Cane maturity and fruit bud development	15	15	15	15
121 days - fruit pruning	15	15	0	0
Fruit pruning				
Shoot growth	40	30	30	30
Bloom to Shatter	15	15	15	15
Berry growth and development	40	30	30	30
Veraison to Harvest	40	30	20	20
Rest period	-	--	--	--
Nutrient treatments				
	N (kg/ha)	P ₂ O ₅ (kg/ha)	K ₂ O (kg/ha)	
N1	266.6	222	266.6	
N2	266.6	177.6	266.6	
N3	200	133.3	200	
N4	133.3	106.6	200	

Table 10. Effect of irrigation treatments on yield and water-use efficiency of Crimson Seedless grapes

Irrigation treatments	Irrigation water applied (mm)	Yield (t/ha)	WUE (kg grapes/mm of irrigation water applied)
I1	267.4	18.00	67.3
I2	203.4	17.18	84.5
I3	213.3	17.04	79.9
I4	191.8	18.13	94.5

Studies on canopy management practices in different varieties of grape

Canopy management practices involving cane density, basal leaf removal, bunch load and shoot topping were evaluated in Manjari Shyama and Crimson Seedless during 2024-25. The treatments were designed to regulate canopy density, improve light interception, balance vegetative and reproductive growth, and reduce disease incidence. Among the evaluated treatments, T2 comprising 0.5 cane sq. ft⁻¹, removal of four basal leaves, 30 bunches vine⁻¹ and shoot topping at 18 leaves, produced the most balanced vegetative growth and superior physiological performance in both varieties.

In Manjari Shyama and Crimson Seedless, respectively, T2 recorded higher cane diameter (7.2 and 7.7 mm), leaf area (210.91 and 200.63 cm²), and moderate internodal length, indicating balanced vine vigour. The treatment also improved physiological activity, recording higher net assimilation rate (13.89 and 13.25 $\mu\text{mol CO}_2 \text{ m}^{-2} \text{ s}^{-1}$) and transpiration rate (5.28 and 5.04 $\text{mmol H}_2\text{O m}^{-2} \text{ s}^{-1}$). Yield and berry parameters were also superior under T2, with higher bunch weight (395.46 and 379.51 g), 50-berry weight (253.00 and 158.00 g), berry length (25.63 and 22.40 mm), berry diameter (19.23 and 17.24 mm) and yield per vine (11.86 and 11.39 kg) in Manjari Shyama and Crimson Seedless, respectively.

The same treatment improved berry biochemical quality, recording higher TSS (18.00 and 19.70 °Brix), total carbohydrates (230.40 and 222.23 mg g⁻¹), anthocyanins (48.50 and 44.89 mg 100 g⁻¹), protein (8.36 and 6.35 mg g⁻¹), proline (6.28 and 5.86 $\mu\text{mol g}^{-1}$) and flavonoids (5.76 and 5.28 $\mu\text{g mg}^{-1}$) in Manjari Shyama and Crimson Seedless, respectively. Disease incidence was also lowest under T2, with downy mildew (11.35 and 11.36%), powdery mildew (10.50 and 9.11%) and anthracnose (10.16 and 8.34%) in the two varieties. In contrast, higher disease incidence was recorded in denser or less balanced canopy treatments. The results indicate that moderate cane density, basal leaf removal and shoot topping can improve canopy microclimate, yield, berry quality and disease management in table grapes.

Production of quality planting material of grape

Effect of different concentrations of IBA on shoot growth and rooting behaviour of Dogridge and 110R rootstock cuttings: During 2024–25, a study

was conducted to evaluate the effect of different concentrations of Indole-3-butyric acid (IBA) on rooting behaviour of four month old hardwood cuttings of Dogridge and 110R rootstocks under net house conditions. Six treatments comprising IBA at 2000 ppm (T1), 2500 ppm (T2), 3000 ppm (T3), 3500 ppm (T4), 4000 ppm (T5) and control (T6) were evaluated for morphological and biochemical traits. Results indicated that IBA significantly improved shoot and root parameters over control. Among treatments, T4 proved optimal, recording early sprouting (10.30 and 11.60 days), higher rooting percentage (91.10 and 86.84%), more root primordia (17.98 and 16.84), higher root diameter (2.20 and 1.98 mm), maximum number of roots per cutting (10.86 and 9.80), highest fresh root weight (5.72 and 5.35 g), longest root length (22.49 and 21.39 cm) and highest survival percentage (91.33 and 86.37%) and better cutting survival in Dogridge and 110R, respectively as compared to T1 and T6. Increasing IBA concentration from 2000 to 3500 ppm progressively improved all rooting parameters, whereas a further increase to 4000 ppm (T5) caused a slight decline, though values remained significantly higher than lower concentrations and control. T6 recorded the lowest values for all root growth and survival parameters in both rootstocks. Overall, Dogridge exhibited comparatively better rooting performance than 110R across all treatments.

Effect of scion maturity on growth parameters and success of graft: During 2024–25, the study revealed that scion wood maturity significantly influenced grafting success and plant vigour in Thompson Seedless grafted on Dogridge rootstock. Four treatments comprising, T1: Soft Wood Scion (120 DAP), T2: Semi Hard Wood Scion (150 DAP), T3: Hard wood Scion (180 DAP) and T4-Extra Hard Wood Scion (210 DAP) were evaluated for grafting success and plant vigour. Hard wood scions collected at 180 DAP (T3) recorded the best performance with minimum days to sprouting (16.50), highest sprouting (90.45%), maximum graft survival (85.20%) and superior vegetative growth traits, including number of leaves (64.50), longest shoot length (65.28 cm), shoot diameter (6.70 mm), leaf area (121.78 cm²), and graft height (127.68 cm). The superior performance at 180 DAP indicated an optimum physiological balance of stored reserves and cambial activity for successful graft union and vigorous growth. Semi-hard wood scions at 150 DAP ranked next best, while juvenile

soft wood and over-mature scions performed poorly. Thus, hard wood scions at 180 DAP were found ideal for maximizing grafting efficiency.

Evaluation of rootstocks for released and commercially promising grape varieties

Rootstocks were evaluated for commercially important grape varieties to identify suitable scion–rootstock combinations for improved vine growth, yield, berry quality and physiological performance. The varieties evaluated included Crimson Seedless, Manjari Medika, Manjari Naveen, Manjari Kishmish and Thompson Seedless grafted on different rootstocks, including 110R, 140Ru, 1103P and Dogridge.

In Crimson Seedless, 1103P performed best for reproductive traits, recording the highest fruitful canes (89.30%), bunches per vine (34.80) and yield (9.79 kg vine⁻¹). Dogridge, however, improved berry-related traits, recording higher bunch weight (290.40 g), 50-berry weight (170.70 g), berry size (22.70 × 17.00 mm) and juice pH (3.48). Thus, 1103P was identified as the most suitable rootstock for Crimson Seedless under the experimental conditions.

In Manjari Medika, Dogridge was the best-performing rootstock, recording the highest pruning weight (1.28 kg vine⁻¹), fruitful canes (96.00%), bunch weight (362.60 g), 50-berry weight (133.20 g), yield (17.35 kg vine⁻¹), berry size (16.30 × 16.60 mm) and juice recovery (70.20%). Vines grafted on 1103P recorded higher TSS (19.30 °Brix), but overall yield and juice recovery were superior on Dogridge. In Manjari Naveen, Dogridge recorded the highest bunch weight (460.30 g), 50-berry weight (280.60 g), yield (13.57 kg vine⁻¹) and TSS (19.00 °Brix), while 1103P produced more bunches per vine (35.60).

In Manjari Kishmish, Dogridge enhanced bunch weight (345.30 g), 50-berry weight (192.30 g), yield (12.13 kg vine⁻¹), berry diameter (18.00 mm) and raisin recovery (27.00%). In Thompson Seedless, Dogridge recorded superior vegetative and yield performance, with the highest pruning weight (1.31 kg vine⁻¹), bunches per vine (36.40), bunch weight (335.20 g), 50-berry weight (148.60 g) and yield (12.25 kg vine⁻¹). Own-rooted vines recorded lower yield and weaker growth. Overall, 1103P was found suitable for Crimson Seedless, whereas Dogridge was identified as the preferred rootstock for Manjari Medika, Manjari Naveen, Manjari Kishmish and

Thompson Seedless.

Response of grape rootstocks under moisture stresses

Impact of drought on physiological, biochemical and root morphology parameters in grape rootstocks: Rootstock 110R maintained higher relative water content (RWC, 75.0%) under drought, indicating better tolerance, while Freedom and Salt Creek were more affected. Grafted vines showed higher chlorophyll content than own-rooted plants under both conditions, with TS+Dogridge (4.430 mg/g) recording the highest values under control. Under drought, phenol content increased in grafted vines, with TS+Dogridge (17.88 mg/g in CTG to 19.91 mg/g in DTG) showing the highest levels. Proline accumulation was also highest in TS+Dogridge (16.54 µmol/g) and TS+110R (15.99 µmol/g) indicating better stress adaptation and suitability for drought conditions. Rootstock combinations TS+1103P and TS+Freedom showed superior root development (total number of roots) under non-stress conditions. Under drought, root growth declined overall, but TS+1103P (total roots: 48.4, mean: 31.0) and TS+SO4 (total roots: 41.9, mean: 26.9) maintained relatively strong root systems, indicating better tolerance. Overall, drought significantly affected physiological, biochemical, and root traits. However, grafting Thompson Seedless onto tolerant rootstocks, 110R, Dogridge, 1103P, and 140Ru clearly improved drought tolerance and plant performance.

Impact of water-logging condition on physiological, biochemical and root morphology parameters in grape rootstocks: Water-logging significantly reduced RWC in grapevines across rootstocks and five developmental stages of grapevines. The experiment considered two main treatments as Factor A: Own Rootstock and Thompson Grafted Rootstock, under both Control (COR/CTR) and Water-logging (WLOR/WLTG) conditions. Factor B included different rootstocks such as Dogridge, 110R, 140Ru, 1103P, SO4, Salt Creek, and Freedom, along with their grafted combinations with Thompson Seedless (TS). Compared to control (COR), all rootstocks showed a decline in RWC under water-logging (WLOR), with the most pronounced reductions in 110R and SO4, indicating higher sensitivity. Overall, water-logging adversely affected physiological water status and water retention in own-rooted vines, likely due to root hypoxia and disrupted water transport.

Grafted vines showed greater resilience to water-logging than own-rooted vines. TS+Dogridge maintained high RWC with minimal reduction, while TS+140Ru and TS+Salt Creek also retained relatively higher RWC under stress. In contrast, TS+110R and TS+SO4 showed notable declines, indicating sensitivity. Overall, grafting improved water retention under water-logging, likely due to better rootstock–scion synergy, enhanced water uptake and retention efficiency under hypoxic conditions.

Determination of salinity tolerance threshold for Thompson Seedless grafted on Dogridge, 110R and 1103P rootstocks (Completed project)

The project was initiated in 2020 to determine the salinity tolerance threshold for Thompson Seedless grafted on Dogridge, 110R and 1103P and the impact of varying salinity levels on physiological, biochemical and nutritional parameters of grape.

The salinity tolerance of Thompson Seedless grafted on Dogridge was evaluated. Vines were subjected to increasing NaCl levels (0% NaCl, 0.25% NaCl, 0.5% NaCl, 0.75% NaCl, 1% NaCl and 2% NaCl) designated as T1, T2, T3, T4, T5 and T6 respectively, which raised EC from 0.93, 5.22, 9.38, 13.38, 17.32 and 31.10 dS m⁻¹. Sodium (Na⁺) and chloride (Cl⁻)

accumulation in leaves, stems, and roots increased significantly with salinity, accompanied by reduced K⁺ levels due to ionic antagonism. Higher salinity led to increased phenol and proline content, but reduced chlorophyll and root volume. Overall tolerance declined with increasing salinity, and 0.25% NaCl was identified as the threshold level for Thompson Seedless on Dogridge.

In the second experiment, salinity tolerance threshold for Thompson Seedless grafted on Dogridge, 110R and 1103P was studied. One additional treatment of 0.1% NaCl was included in addition to above six treatments. The salinity treatments led to significantly higher accumulation of Na⁺ and Cl⁻ in vines grafted on Dogridge followed by 110R and 1103P rootstocks at all the salinity levels. Other nutrients analysed viz. K, Mg and Ca accumulation was significantly higher in 110R and 1103P rootstocks compared to Dogridge. Increasing salinity levels led to increase in phenol and proline content in all the rootstocks, however, higher accumulation was observed from 0.25% NaCl level.

Based upon the second study, the treatment 0.1% salinity level of NaCl was the tolerance threshold value for Thompson Seedless vines raised on Dogridge rootstock. Overall, tolerance decreased with increasing salinity, with 110R and 1103P showing better tolerance than Dogridge.

IV. Development and Refinement of Integrated Protection Technologies in Grape

Identification and characterization of fungal and bacterial endophytes from grapevines and their evaluation as a biocontrol agent against major pathogens of grapevines in India

Field evaluation of endophytic *Trichoderma* and *Bacillus* bioformulations: During 2024-2025, six foliar sprays of *Trichoderma* and *Bacillus* formulations were applied from berry setting to the harvesting stage of the vine, @ 5 g/L of water at a weekly interval for management of powdery mildew. The vines treated with three *Trichoderma* formulations viz., CSBY4, DRRS1, and MCBY2) showed 66%, 30.8%, and 56.4% disease control on leaves, respectively, compared to the untreated control. The vines treated with three *Bacillus* formulations (SB5, SB2 and RF1) showed 48.75%, 48.7% and 41.7% disease control on leaves,

respectively, compared to the untreated control. During 2025-2026, the MCBY2 and SB5 showed a significant percentage of powdery mildew control, 60.85% and 56.88%, respectively, on leaves in the Manik Chaman variety. The MCBY2 and SB5 showed a significant percentage of powdery mildew control, 63.52% and 60.05%, respectively, on bunches in the same variety. Three bioformulations, viz., DRRS1, MCBY2 and SB5, are in MLT under AICRP on Fruits. Instead of a consortium, a single bioformulation was found effective for the management of powdery mildew.

Morphological and molecular characterization of grapevine endophytic *Trichoderma asperellum* and *in vitro* bioefficacy against *Colletotrichum gloeosporioides* and *Xanthomonas citri* pv. *viticola* originated from different grapevine varieties and plant parts: A total of ten *Trichoderma* isolates were

purified from different plant parts of grapevine cultivars for their antagonistic potential. All ten *Trichoderma* isolates exhibited light green to dark green coloured colony characteristics. The PCR amplification of the ITS region yielded amplicons of ~ 600 bp. Likewise, translation elongation factor (*TEF-1 α*) and actin (*ACT*) genes of these isolates yielded ~507 bp and ~480 bp amplicons, respectively. Sequence information of the ITS region, *TEF-1 α* and *ACT* genes showed 98-100% similarity with available sequences of *Trichoderma asperellum*. Additionally, *in vitro* bioefficacy of these isolates was evaluated against *Xanthomonas citri* pv. *viticola* and *Colletotrichum gloeosporioides*. Results showed the maximum inhibition of Xcv and *C. gloeosporioides* achieved by NRCG-7 with 81.34-94.44% and 31.27-66.11%, respectively, followed by NRCG-3 (78.87-92.22%); (28.86-60.55%), and NRCG-5 (76.49-93.33%); (26.45-58.33%) isolates. BLASTn analysis and identity matrix of the ITS sequences of ten isolates revealed 99%-100% homology with the other isolates from the NCBI GenBank. Similarly, BLASTn analysis and identity matrix of the *TEF-1 α* (7 isolates) and actin (6 isolates) genes revealed the 98%-100% and 97% - 100% homology, respectively, with the available isolates of *T. asperellum* in the NCBI GenBank. The phylogenetic analysis based on ITS, *TEF-1 α* and *ACT* genes revealed the close clustering with *T. asperellum*. Field evaluation of these bioformulations for the management of powdery mildew, downy mildew, anthracnose and bacterial leaf spot was carried out during the 2024-25 and 2025-26 crop seasons. NRCG-7 isolate showed more than 60% powdery mildew disease control than the untreated control.

Survey on root rot and vascular wilt, and molecular characterization of the *Fusarium* species associated with the disease: The survey of wilt disease in grape vineyards revealed that disease incidence ranged from 10% to 15%. Higher incidences were observed in vineyards with poor soil drainage and prolonged waterlogging periods. Vineyards with better drainage and no waterlogging recorded low disease incidence (<2%). Based on colony characteristics, spore morphologies and PCR amplification and multi-locus sequence typing, the presence of *Fusarium acutatum*, *F. falciforme* and *F. annulatum* was found to be associated with the root rot and vascular wilt disease of the grapevine samples were collected from different locations in Maharashtra.

Molecular confirmation of *Fusarium* species associated with berry rot, leaf spot and cane necrosis disease in grapevine: Berry rot, leaf spot, and cane necrosis were observed for the first time in grapevine in Maharashtra. The *F. pernamhucanum* and *F. irregulare* were found to be associated with berry rot, whereas *F. lacertarum*, *F. irregulare*, and *F. annulatum* were associated with leaf spot and *F. nanum* with cane necrosis diseases in grapevine. Spore and colony morphologies, molecular identification based on the ITS region, *TEF1- α* , *RPB2*, *TUB2* genes and pathogenicity confirmed the presence of five *Fusarium* species in grapevine. PCR amplification of different genes and the ITS region of the total 22 fungal isolates was carried out. Amplification of (*RPB2*) in twelve isolates showed ~1150 bp size amplicon. Amplification of *Actin* (*ACT*) in nine isolates showed ~300 bp size amplicon. Amplification of *TEF1* gene in eleven isolates showed ~272 bp size amplicon. Amplification of β -*tubulin* (*TUB2*) in ten isolates showed ~333 bp size amplicon. Berry isolates showed 98-100% identity with *F. pernamhucanum* and *F. irregulare*. Leaf spot isolates showed 99-100% identity with *F. irregulare*, *F. lacertarum*, and *F. annulatum*, and cane isolates showed 100% identity with *F. nanum*.

Studies on management of major diseases of grapevine using bio-rationale chemicals, bio-control agents, alternative chemicals and botanicals

Effect of registered fungicides on spore germination, and vegetative growth of *Cladosporium cladosporioides*: Fungicides mentioned in Annexure 5 of ICAR-NRCG, Pune, were analyzed for their effect on spore germination, and vegetative growth of the *Cladosporium cladosporioides*. Maximum fungicides showed complete inhibition of mycelium growth, sporulation and spore germination. Significantly high germination of conidia was shown by sulphur 66.16 SC. *Cladosporium* sporulation significantly increased in the presence of dimethomorph 50 WP, copper hydroxide 53.8 DF, Sulfur 80 WP & WDG. *Cladosporium* sp. sporulation was strongly reduced by kresoxim methyl 44.3 SC.

Fungicidal toxicity: Fungicide toxicity research demonstrated that about half of the fungicides tested were extremely hazardous to the studied fungus. A total of twenty-six fungicides were found to be very

toxic to the fungus, whereas cyazofamid 34.5% SC, mandipropamid 23.4% SC, amisulbrom 17.7% SC w/w Sulfur 55.16 SC, meptyldinocap 35.7% EC, Sulfur 80 WP and metrafenone SC combined with cyflufenamid were all highly compatible with *Cladosporium* sp.

In vitro evaluation of antagonistic action of *Bacillus* and *Trichoderma* against *Cladosporium cladosporioides*: *In vitro* evaluation revealed that *Bacillus* and *Trichoderma* controlled *C. cladosporioides* growth. *Trichoderma* had the strongest inhibition (75.12 %), while *Bacillus* had the lowest (69.83%). *Trichoderma* outgrew *C. cladosporioides* mycelium after mycelium contact, displaying significant sporulation and hyphae lysis. *Trichoderma* emitted non-volatile and volatile chemicals that inhibited *C. cladosporioides* growth considerably (61.76 and 64.74 %). However, *Bacillus* non-volatile and volatile metabolites did not affect *C. cladosporioides* growth (27.38 and 16.66 %).

Development of a bio-intensive disease management schedule for production of disease-free and residue-compliant grapes (AMAAS partially funded)

Diversity analysis of grapevine epiphytes isolated from different stages of grape berry development of a table variety: Diversity analysis of grapevine-associated epiphytes from Thompson Seedless table grape berries was carried out. Within the vineyard, the grape berry developmental stages influenced the microbial community. There were microbes that were common to all the stages, whereas many were unique to the specific stage. A total of 29 bacteria, 19 fungi and 3 yeast isolates were obtained and identified.

Evaluation of the field efficacy of potential antagonistic epiphytic bacteria against anthracnose of grapevine: The three bacteria, viz. SB5, SB13 and SB15 were evaluated for their biocontrol ability against anthracnose on vines in an experimental plot of the Centre. The difference in PDI of all the test treatments and fungicide control was non-significant. Isolate SB13 and SB15 showed more than 40% control of the disease as compared to carbendazim, which was 38%.

Production of biosurfactant: Screening of effective epiphytic bacteria, viz. SB5, SB13 and SC 15 for biosurfactant production was carried out by following different methods like drop collapse technique, oil

displacement assay, emulsification ability assay, hemolysis test and CTAB agar plate method. Experimental results showed that all the bacterial isolates produced the biosurfactant. The production was highest in the isolate SB13. After extraction, the biosurfactant produced was brown and sticky. During biochemical characterisation, the ninhydrin test showed the formation of Ruhemann's purple complex, indicating the presence of protein or an amino group. In the anthrone test, which denotes the presence of carbohydrate, a bluish green colour formation was observed. Saponification with sodium hydroxide confirmed the presence of lipid. Antimicrobial activity of biosurfactant produced by all three bacteria showed inhibition of growth of *C. gloeosporioides* and *Xanthomonas campestris* pv *viticola*. The maximum inhibition of mycelium growth of *C. gloeosporioides* was observed when treated with biosurfactant from the SB13 isolate.

Biodegradation of pesticides: Among the epiphytic isolates, *Bacillus inaquosorum* and *Bacillus spizizenii* were identified as bacteria capable of degrading lambda cyhalothrin, while *Kocuria sediminis* was capable of acephate biodegradation.

Screening for antifungal activity of epiphytes: Screening of thirty epiphytic isolates from the fructosphere of wine grapes was done against 10 plant pathogenic fungi. Out of thirty isolates, four bacterial isolates inhibited the growth of *Macrophomina phaseolina*, while nine inhibited the growth of *Pythium* sp. Sixteen bacterial isolates were inhibitory to the growth of *Sclerotium rolfsii*, and twenty-four to *Colletotrichum gloeosporioides*. Three bacterial isolates were inhibiting *Mycosphaerella musicola*. Similarly, four bacterial isolates inhibited the *Stemphylium* sp., while seven isolates of bacteria were inhibitory to *Fusarium oxysporum*. Seventeen bacterial isolates were found to inhibit the *Exserohilum turcicum*, and twelve isolates tend to inhibit the growth of fungus *Alternaria* sp. Among all the thirty bacterial isolates studied, CB7 was found to be most inhibiting bacterial isolate against certain plant pathogens, followed by Viognier14 and Charak18.

Compatibility of grapevine epiphytic isolates with registered fungicides against powdery mildew in grapes: A total of five isolates were taken for study. Epiphytes SB1, SB2 and SB3 were highly compatible with all the registered fungicides.

Isolation and characterization of grapevine epiphytes from the phyllosphere of table varieties:

A total of 61 isolates were obtained from the phyllosphere of 16 table varieties. Morphological, biochemical characterization and enzyme assay were carried out. The majority of the colonies were whitish in colour (55.7%), circular in shape (50.8%) and moist in texture. Thirty-nine isolates showed the Gram-positive reaction, and twenty-two isolates were Gram-negative.

CIB-RC submission of microbial bioformulation:

The submission of *Bacillus subtilis* DR39 bioformulation to CIB-RC has been completed. *Trichoderma asperelloides* 5R bioformulation reports of bioefficacy, toxicology and chemistry have been generated from a GLP lab. Data scrutiny is in process.

Integrated pest management for sustainable vineyard protection

During 2025, a series of laboratory and field-oriented experiments were conducted to strengthen evidence-based pest management for sustainable viticulture, with emphasis on mealybug, flea beetle, thrips, and conservation of natural enemies. The work generated actionable insecticide bioassay outputs and established/validated experimental systems for ongoing studies.

Optimizing buprofezin dose against mealybug

crawlers: A concentration-mortality bioassay was performed with buprofezin 25 SC (1.0 to 2.5 ml/L; water control) to determine the lowest effective concentration and time-dependent toxicity. Probit analysis showed a declining LC_{50} with increasing exposure time in terms of hours after treatment (HAT): 2.99 ml/L (24 HAT) $\rightarrow$ 2.12 ml/L (48 HAT) $\rightarrow$ 1.85 ml/L (72 HAT), indicating improved efficacy with longer exposure. Corrected mortality increased with both dose and time; the highest dose, 2.5 ml/L, produced the maximum mortality, reaching 85.16% at 72 HAT, and was statistically superior (ANOVA $p < 0.0001$; LSD separation). Overall, buprofezin exhibited strong residual activity against crawler stages, supporting its use where mealybug pressure warrants higher-dose interventions.

Clothianidin bioassay against flea beetle grubs: In a Petri-plate bioassay (20 grubs/plate; 3 replications), clothianidin 50% WDG @ 200 g acre⁻¹ achieved 100% grub mortality within 24 hours in all

replications, while the water control showed gradual mortality over 4 days.

Feeding behaviour and survival of flea beetle grubs on different media:

Newly hatched grubs fed on moist dried leaves for 1–2 days, then shifted preference toward roots. Grub survival was highly moisture-sensitive; both excess and deficit moisture caused mortality, suggesting an optimum moisture range that will be refined under field-capacity conditions. EPF pathogenicity (Koch's postulates approach) against flea beetle grubs: Using a standard EPF (*Beauveria bassiana* / *Metarhizium anisopliae*; 5 ml/100 ml), treated first-instar grubs were incubated for mycosis and attempted isolation on PDA. No fungal growth was obtained from cadavers, preventing continuation beyond the isolation stage.

Biodiversity plot for conservation biocontrol:

A biodiversity plot of medicinal/flowering/aromatic plants was established and monitored monthly. From September–December 2025, key natural enemies/pollinators recorded included coccinellids on multiple host plants, tachinids, syrphids, bees, *Chrysoperla* eggs, praying mantids, and *Anagyrus* sp., demonstrating utility for ecological services mapping in vineyard-adjacent habitats. Pot experiment on plant species influence on pests/natural enemies: In an RBD (six plant species + no-plant control; three replications), thrips were higher on gaillardia/chilli/cockscorn; red mites on gaillardia/cape honeysuckle; aphids mainly on cape honeysuckle/cowpea. Few natural enemies were observed (*Chrysoperla* eggs). Interim inference was that there is no significant impact on grapevine pest levels versus control.

Mealybug management practice trials in blocks:

Field evaluations were initiated comparing (i) standard practice vs spot application vs control, and (ii) free-hanging bunches vs control. In the demo block, mealybug incidence was low; cultivar-specific actions included stem washing in Red Globe (about 5% infestation) and preventive buprofezin stem washing in Thompson Seedless/Crimson Seedless, while sprays were avoided in some Manjari cultivars due to PHI constraints; yield observations are pending completion of harvest.

Standardization and demonstration of spraying using drones in vineyards (ICAR Agri-Drone Project)

Drone-based application of insecticides for thrips management in grapevine: A field experiment was

conducted to evaluate the efficacy of different insecticides applied using a drone for the management of thrips in grapevines. Three drone spray applications were carried out at different intervals, with the drone maintained at a height of 3 m above the canopy. The results showed that all insecticidal treatments significantly reduced thrips population compared to the untreated control at all observation intervals (1, 3 and 5 days after spray). Among the treatments, spinetoram 11.7% SC consistently recorded the lowest thrips population across all sprays, indicating superior and sustained effectiveness. Fipronil 80 WG was the next most effective treatment, maintaining comparatively low pest incidence. Cyantraniliprole 10% OD, spinosad 45% SC, and emamectin benzoate 5 SG showed moderate effectiveness in reducing the thrips population. In contrast, the untreated control maintained a significantly higher pest population throughout the experimental period. The results demonstrated that drone-based application of suitable insecticides can effectively manage thrips infestation in vineyards.

Comparative efficacy of drone and tractor-mounted spraying systems for grapevine disease management: A field experiment was conducted during November-December 2025 to compare the efficacy of drone-based spraying with tractor-mounted spraying for the management of downy mildew and anthracnose diseases in grapevines. Six fungicidal sprays were applied to manage downy mildew. The results indicated that disease intensity increased progressively in the untreated control plots, whereas both spraying methods effectively reduced disease incidence. The tractor-mounted spraying system consistently recorded lower percent disease index (PDI) compared to drone spraying. By the final observation date, the tractor spray treatment recorded 22.43 PDI with 56.12% disease control, whereas drone spraying recorded 25.09 PDI with 45.77% disease control, while the untreated control recorded the highest disease intensity (31.18 PDI). For anthracnose disease, both spraying methods significantly reduced disease incidence compared to untreated control. The tractor-mounted sprayer recorded 54.83% disease control, while the drone spraying system recorded 43.33% disease control. Although tractor-mounted spraying showed slightly better disease suppression, drone spraying proved to be an effective alternative for disease management in vineyards, particularly in situations where ground-based spraying is difficult or impractical.

Physiological effects of Ethephon application using drone and tractor-mounted sprayers: A comparative study was conducted to evaluate the physiological response of grapevines to Ethephon 39% SL applied through drone and tractor-mounted sprayers in two grape varieties, Manjari Kishmish and Manjari Shyama. Treatments were applied at doses of 1.5 L acre⁻¹ and 3.0 L acre⁻¹, and observations on Chlorophyll Concentration Index (CCI) and number of leaves per cane were recorded at different intervals after spraying. In the Manjari Kishmish variety, all treatments were statistically similar for CCI at 5 days after spraying. At 15 days after spraying, the tractor-mounted sprayer at 3.0 L acre⁻¹ showed comparatively better performance and was at par with drone spraying at the same dose. For the number of leaves per cane, tractor spraying treatments generally showed better response during the early observation period, although most treatments became statistically comparable at later stages. In the Manjari Shyama variety, the CCI values at 15 days after spraying were statistically similar among both drone and tractor spraying treatments. The number of leaves per cane indicated relatively better performance with tractor-mounted spraying at the higher dose. Overall, the results demonstrated that drone-based application of ethephon can produce physiological responses comparable to conventional tractor-mounted spraying systems.

Drone-based foliar nutrient application and demonstrations: Drone-based foliar nutrient application was evaluated for zinc and other micronutrient sprays in vineyards. Foliar zinc sprays are commonly applied during the initial shoot growth stage after foundation pruning as well as fruit pruning. During the fruit pruning season, rains during September–October are becoming frequent, and in the heavy soils of major grape-growing tracts of Maharashtra, conventional foliar application of zinc and other micronutrients is often constrained. Therefore, drone-based zinc application was evaluated during the fruit pruning season. Five treatments comprising zinc sulphate applied through tractor and drone, and zinc EDTA, zinc oxide and CaZBo applied through drone were evaluated. Zinc sulphate applied through tractor spraying recorded the highest zinc concentration in leaves (190.70 ppm) and petioles (68.90 ppm). Among the drone-applied treatments, zinc oxide and CaZBo performed better than zinc EDTA. Although conventional spraying resulted in slightly higher zinc accumulation, drone

spraying offered clear operational advantages, including reduced water requirement, faster field coverage, lower labour demand and better accessibility under difficult field conditions. The study indicates that drone-assisted foliar nutrient application can serve as an efficient alternative for macro- and micronutrient management in vineyards.

Drone-based spraying demonstrations: During 2025, the demonstrations were also conducted in 214 ha of vineyards with the participation of 1,587 farmers and with this the target of 500 ha demonstration programme under the project was completed.

Automated monitoring and advisory system for intelligent viticulture

Vineyard rover platform for vineyard monitoring: During 2025, end-to-end development of an autonomous rover tailored for vineyard conditions was carried out covering iterative mechanical redesign, subsystem fabrication/assembly, and field-readiness testing. Key engineering refinements included torque/speed optimization, custom wheel hub design for durability and load handling, power system re-configuration for efficiency, and optimized camera placement to support reliable grape detection under occlusion. The build cycle progressed through chassis/hub/mount fabrication, full mechanical–electrical–electronics integration, and on-field testing under stressed/uneven terrain to validate mobility, hub performance and power efficiency.

Grape cluster detection and counting (real-time vision pipeline): A robust grape counting pipeline was developed using real vineyard video. Approximately 5,000 frames were extracted using Python and manually annotated in Roboflow to represent variability in cluster size, angle, occlusion and lighting. A YOLOv11 object detection model was trained (train/val/test split) and achieved about 93% accuracy, selected for its real-time single-stage performance and suitability for edge deployment in agricultural environments. To mitigate double-counting due to repeated detections and occlusions, the workflow integrates SAM-2 to mask already-detected clusters so that YOLO detects only new instances. Successive script versions improved region-of-interest handling, mask persistence, cropped-mask storage, and GPU acceleration; the final CUDA-based implementation delivered the lowest latency and highest throughput. Further

upgrades converted the system into a spatio-temporal tracking engine using feature-based re-identification, multi-frame confirmation, parallax split detection and heuristic mask validation, reducing false positives and segmentation artefacts while improving stability under occlusion.

Bunch weight estimation: A regression-based bunch weight estimation module was built using a “mask ratio” feature (2D mask area / tight bounding box area) together with bunch dimensions. Using the D1 Yield dataset (height/width of 58 bunches) plus corresponding mask-ratio data, the trained model achieved ≤ 50 g error for 84.7% of test cases (maximum overestimation 123.3 g, maximum underestimation 83.18 g) and was validated on a test video tracking 19 grape clusters. Current limitations arise from reliance on 2D imagery (no depth/volume/density); planned integration of a depth camera and secondary viewpoint is expected to improve accuracy via volumetric estimation.

Sensor farm: A Sensor Farm communication module demonstrated reliable grape image transfer using LoRa via a chunk-based protocol: images are split into fixed-size binary chunks, CRC-tagged for error detection, transmitted sequentially, and reconstructed at the receiver after end-of-transmission signalling. Tests showed lossless transmission (no corrupted pixels; identical image sizes), but transmission time scaled linearly: 11 minutes for 28 KB and 47 min for 363 KB images, highlighting LoRa throughput constraints for multi-node hourly image reporting. Consequently, the architecture was updated to use Raspberry Pi 4 for computing and shift image transmission to Wi-Fi for higher data rates and scalability.

NS-3 sensor farm simulation: To evaluate the LoRa image-transfer protocol without full physical deployment, an NS-3.45 simulation was implemented with an external LoRaWAN module to emulate PHY/MAC behaviour (spreading factors, bandwidth, power, interference, packet loss). A custom sender–receiver application transmitted chunked images with sequence numbers and acknowledgements, enabling selective retransmission of missing data. Channel/propagation models and NS-3 logging/tracing supported validation and performance analysis of the reliable protocol under controlled “real-world-like” network conditions.

V. Food Safety in Grapes and its Processed Products

Phytochemical profiling and development of nutraceuticals and value-added products from grapes

Grape pomace of Manjari Medika was evaluated under shade and sun drying methods to study drying behaviour and retention of bioactive compounds. The study compared drying efficiency, moisture loss, biochemical quality and metabolomic profile of fresh, shade-dried and sun-dried pomace. Sun drying was faster, completing drying in 68 hours compared with 168 hours under shade drying. Moisture content declined from $79.85 \pm 0.60\%$ to $4.33 \pm 0.22\%$ under sun drying, and from $79.50 \pm 1.05\%$ to $4.62 \pm 0.35\%$ under shade drying. Drying occurred mainly in the falling-rate period, indicating that internal moisture diffusion was the dominant mechanism of moisture removal.

Mathematical modelling showed that the Approximation of Diffusion model provided the best fit for shade drying, whereas the Midilli et al. model best described sun drying. Although sun drying was more rapid, it caused greater degradation of phytochemicals. Total phenolic content declined from $83.15 \text{ mg GAE } 100 \text{ g}^{-1}$ in fresh pomace to $27.04 \text{ mg GAE } 100 \text{ g}^{-1}$ under shade drying and $21.09 \text{ mg GAE } 100 \text{ g}^{-1}$ under sun drying. Similar trends were observed for flavonoids, anthocyanins and antioxidant activity, indicating better preservation of bioactive compounds under shade drying.

LC-Orbitrap-MS profiling confirmed the superior retention of bioactive compounds under shade drying. The total relative concentration of bioactive compounds decreased from $27,432 \text{ mg kg}^{-1}$ catechin equivalents in fresh pomace to $18,952 \text{ mg kg}^{-1}$ under shade drying and $13,543 \text{ mg kg}^{-1}$ under sun drying. Malvidin-3-O-glucoside was the dominant anthocyanin in fresh pomace, with a concentration of $25,824 \pm 213 \text{ mg kg}^{-1}$ catechin equivalents. Anthocyanins, flavan-3-ols, hydroxybenzoic acids, hydroxycinnamic acids, flavonols and flavones showed better retention under shade drying than sun drying. The study demonstrated a clear trade-off between processing speed and phytochemical retention. Sun drying may be suitable for rapid and low-cost drying, whereas shade drying is preferable when preservation of phenolics, anthocyanins, antioxidant activity and nutraceutical quality is the priority.

Non-target impact of pesticide residues in vineyard ecosystem and its residual impact on grape and wine quality

In-vitro assessment of degradation mechanism of CAP residues in soil by potential bacteria isolated from rhizosphere soil: Twenty bacterial isolates exhibiting diverse morphological characteristics were isolated from chlorantraniliprole (CAP)-enriched grape rhizosphere soil. Among these, fifteen isolates demonstrated active growth and were selected for further evaluation of their CAP degradation potential. Of the fifteen isolates screened, four strains CAP02, CAP05, CAP07, and CAP10 showed significant degradation efficiency, achieving more than 50% (50–81%) degradation of CAP residues in minimal salt medium (MSM) within 15 days of incubation. Molecular identification based on NCBI BLAST analysis revealed that CAP02 and CAP05 were identified as *Priestia megaterium*, CAP07 as *Peribacillus huizhouensis*, and CAP10 as *P. aryabhatai*.

An Orbitrap Q-Exactive mass spectrometer (MS) paired with an ultrahigh-performance liquid chromatograph (UHPLC) was employed for targeted analysis to identify CAP metabolites. A comprehensive in-house database was created, containing 8 reported metabolites of CAP, along with their molecular formulas, exact masses $[(M+H)^+]$, and data-dependent acquisition (MS/MS) information. Chlorantraniliprole dissipation and transformation product formation were assessed in four selected isolates (CAP02, CAP05, CAP07, and CAP10) and in their combined consortium over 15 days of incubation. CAP residues declined progressively across all treatments. Initial concentrations ($9.3\text{--}10.7 \text{ mg kg}^{-1}$) decreased to $2.26\text{--}4.25 \text{ mg kg}^{-1}$ by day 15, with CAP02 showing the highest degradation rate, followed by CAP10 and CAP07. In contrast, the untreated control retained nearly the entire initial concentration. Among the transformation products, IN-LEM10 (2-[5-Bromo-2-(3-chloro-pyridin-2-yl)-2H pyrazol-3-yl]-6-chloro-3,4-dihydro-3-methyl-4-oxo-8-quinazolinecarboxylic acid) (m/z 473.01; fragments 283.92, 130.00) was the predominant metabolite across all treatments, with the highest accumulation recorded in CAP02 on day 1 (4.26 mg kg^{-1}). Overall, the results suggest that CAP degradation in bacterial systems proceeds primarily

through hydrolysis, oxidation, and dechlorination, resulting in the stable accumulation of IN-LEM10, while microbial consortia favour the generation of further conjugated metabolites.

Assessment of chlorpyrifos (CPF) degradation using bacterial isolates from grape and vegetable rhizosphere soil:

Organic soil samples from the grape rhizosphere (collected at the institute) and vegetable fields (collected from farmers) were used for the isolation of chlorpyrifos (CPF)-degrading bacteria. A total of eleven isolates were obtained using the spread plate method. These isolates were characterized based on colony morphology, Gram's reaction, and biochemical and enzyme production assays following standard protocols. All eleven isolates were circular, rod-shaped, and tested positive for both catalase and oxidase. Further characterization revealed that isolates CPFG1, CPFG2, CPFG3, CPFG6, CPFG7, and CPFG8 produced acid from glucose, sucrose, and fructose, whereas isolates CPFV4, CPFV5, CPFV9, and CPFV10 showed contrasting fermentation profiles. The eleven selected bacterial isolates were screened for plant growth-promoting traits. All isolates tested positive for IAA and ammonia production. Ammonia-producing PGPR typically supply nitrogen to the host plant, thereby supporting root and shoot elongation. The consistent production of IAA across all isolates suggests their potential to enhance host growth. IAA production by bacteria can increase overall root biomass, improving water and mineral uptake, which in turn facilitates bacterial colonization in the rhizosphere. Phosphate solubilization and siderophore production assays were not observed in any of the isolates.

The eleven bacterial isolates were evaluated for their chlorpyrifos (CPF) degradation activity in minimal salt medium (MSM) by GC-MS/MS. Confirmatory analysis revealed that five isolates achieved complete (100%) degradation of CPF within five days. Biodegradation studies demonstrated that isolates CPFG1, CPFG2, CPFG3, CPFV4, and CPFV5 exhibited rapid degradation kinetics compared to the control medium containing pesticide only (CMP) (Figure 7). The initial CPF concentration on Day 1 was consistent across treatments (approximately 9–10 mg kg⁻¹). By Day 3, a marked reduction in CPF residues was observed in all isolates, with CPFG1–CPFV5 showing sharper declines relative to CMP. By Day 5, CPF residues were reduced to negligible levels in CPFG1–CPFV5, whereas CMP retained substantially higher concentrations. Percentage degradation confirmed these trends, with CPFG1–CPFV5 achieving ~98–100% degradation, while CMP showed only ~30% degradation. Molecular identification of the efficient isolates was performed using 16S rRNA gene sequencing. The results identified CPFG1 and CPFG2 as *Enterobacter cloacae*, CPFG3 as *Enterobacter cloacae* subsp., CPFV4 as *Stenotrophomonas maltophilia*, and CPFV5 as *Atlantibacter hermannii*. The 16S rRNA sequences of these strains were submitted to NCBI GenBank and assigned accession numbers OR816053 (CPFG1), OR816054 (CPFG2), OR816110 (CPFG3), OR816055 (CPFV4), and OR884079 (CPFV5). Overall, these findings demonstrate that selected CPFG and CPFV isolates possess strong CPF-degrading potential and represent promising candidates for bioremediation of chlorpyrifos-contaminated environments.

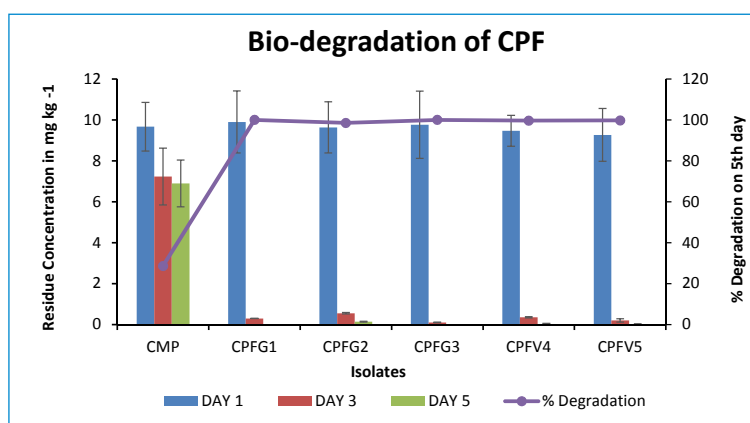


Figure 7. Degradation potential of five bacterial isolates isolated from CPF-enriched grape and vegetable soil checked for CPF degradation

Phylogenetic analysis based on 16S rRNA gene sequences was conducted to determine the taxonomic relationships of the chlorpyrifos-degrading bacterial isolates. The isolate CPFG3 (OR816110) clustered closely with *Enterobacter cloacae* subsp., showing high sequence similarity (97–99%) with strong bootstrap support. Similarly, CPFG1 (OR816053) grouped with *Enterobacter cloacae* strains. The isolate CPFV5 (OR884079) formed a distinct cluster with *Atlantibacter hermannii* and related species, supported by a bootstrap value of 91%, validating its identification as *Atlantibacter hermannii*. In addition, CPFV4 (OR816055) clustered with *Stenotrophomonas maltophilia* and related *Stenotrophomonas* species, with strong bootstrap support (97%).

Development of a bacterial consortium using selected strains for the degradation of targeted insecticide residues in grapes: A total of 19 bacterial strains isolated from rhizosphere soil of grape/vegetables having pre-established potential for degradation of targeted pesticides are being considered for evaluation and development of bacterial consortia for enhanced pesticide degradation. The selected bacterial strains include, five cyantraniliprole-degrading isolates identified as *Priestia megaterium* (CY3, CY4, CY11), *Exiguobacterium* sp. (CY9), and *Niallia nealsonii* (CY20), four chlorantraniliprole-degrading isolates identified as *Priestia megaterium* (CAP2, CAP5), *Peribacillus huizhouensis* (CAP7), and *Priestia aryabhatai* (CAP10), five isolates degrading imidacloprid identified as *Pseudomonas anuradhapurensis* (IM28), *Bacillus safensis* (IM29), and *Priestia megaterium* (IM32) *Bacillus subtilis* IM 23 (ON715435) *Bacillus vallismortis* IM 09 (ON715120) and five chlorpyrifos-degrading bacteria isolated from grape and vegetable soils identified as *Enterobacter cloacae* (CPFG1, CPFG2), *Enterobacter cloacae* (CPFG3), *Stenotrophomonas maltophilia* (CPFV4), and *Atlantibacter hermannii* (CPFV5). After initial screening based on pesticide degradation efficiency, thirteen strains showing higher degradation CY20, CAP02, CAP07, CAP10, IM09, IM23, IM28, IM29, IM32, CPFV4, CPFV5, CPFG2, and CPFG1 potential were selected for further evaluation and development of a bacterial consortium.

In-vitro compatibility analysis of pesticide-degrading bacteria for bioremediation applications: The 13 pesticide-degrading bacterial

isolates were selected for a compatibility test. For compatibility testing, bacterial culture in nutrient broth was incubated at 30°C for 24 h, and OD measured at 650 nm. A lawn was prepared on sterile agar, wells made, each filled with 50 µL culture, and incubated again at 30°C for 24 h. Zones of inhibition were then observed. Bacterial isolates that did not show zones of inhibition were considered compatible. All isolates were found to be compatible with each other and were selected for further experimentation.

In-Vitro toxicity evaluation of selected isolates against target pesticide residues: Thirteen test bacterial isolates were inoculated in nutrient broth and incubated at 30°C for 24 h at 120 rpm. Sterile agar plates were prepared, lawns created, and wells filled with 50 µL neonicotinoid solutions (0.1–20 mg kg⁻¹). Plates were incubated at 30°C for 24 h, and zones of inhibition were recorded. Bacteria tolerating up to 20 ppm without inhibition were selected for further pesticide degradation studies. No zone of inhibition was observed at any concentration, indicating that the isolates were non-toxic to target pesticides.

Liquid culture assay for evaluation of pesticide degradation: Thirteen pesticide-degrading bacterial isolates (CAP02, CAP07, CAP10, CY20, IM09, IM23, IM28, IM29, IM32, CPFV4, CPFV5, CPFG2, and CPFG1) were found to be compatible. These isolates tolerated insecticides up to 20 mg kg⁻¹, as confirmed by the well diffusion method, and were therefore selected for evaluation for degradation of broad-spectrum insecticide residues in a liquid culture assay conducted at 10 mg kg⁻¹, in minimal salt medium. The degradation profiles of individual isolates and consortia for imidacloprid, acetamiprid, clothianidin, thiacloprid, dinotefuran, flupyradifurone, spinosad, thiamethoxam, sulfoxaflor, and nitenpyram residues over a 40-day incubation period. The control exhibited very low degradation percentages for all insecticides, indicating limited natural dissipation and confirming that microbial activity was the primary factor responsible for pesticide breakdown in the treated samples. In contrast, all bacterial treatments showed substantially higher degradation levels. The microbial consortium demonstrated consistently high degradation efficiency across all insecticides, generally ranging between 75–99%. Notably, spinosad showed the highest degradation among all compounds, approaching nearly complete degradation (about 98–100%) by most isolates and the consortium. This indicates that spinosad is highly susceptible to microbial degradation under the given conditions.

Among the neonicotinoid insecticides, degradation percentages were generally high for most isolates, particularly for imidacloprid, thiacloprid, dinotefuran, and flupyradifurone, where values frequently ranged between 85% and 92%. Clothianidin and sulfoxaflor exhibited comparatively lower degradation percentages, typically around 50-60% for several isolates, suggesting relatively greater persistence of these compounds. With respect to individual bacterial degradation, isolates such as CAP07, IM23, IM28, CPFV4, and CPFV5 consistently showed high degradation across multiple insecticides, often exceeding 85%. CAP07 and IM23 demonstrated

broad-spectrum degradation capability. Overall, Figure 8 clearly demonstrates that the selected bacterial isolates possess strong biodegradation potential, with the microbial consortium exhibiting the most comprehensive and efficient degradation across the tested insecticides by the 40th day. Based on their non-pathogenic nature, consistently high degradation efficiency and tolerance to pesticides, nine isolates (CAP02, CAP07, CAP10, CY20, IM09, IM23, IM28, IM29, and CPFV2) were selected for the development of a multi-strain consortium formulation for field application.

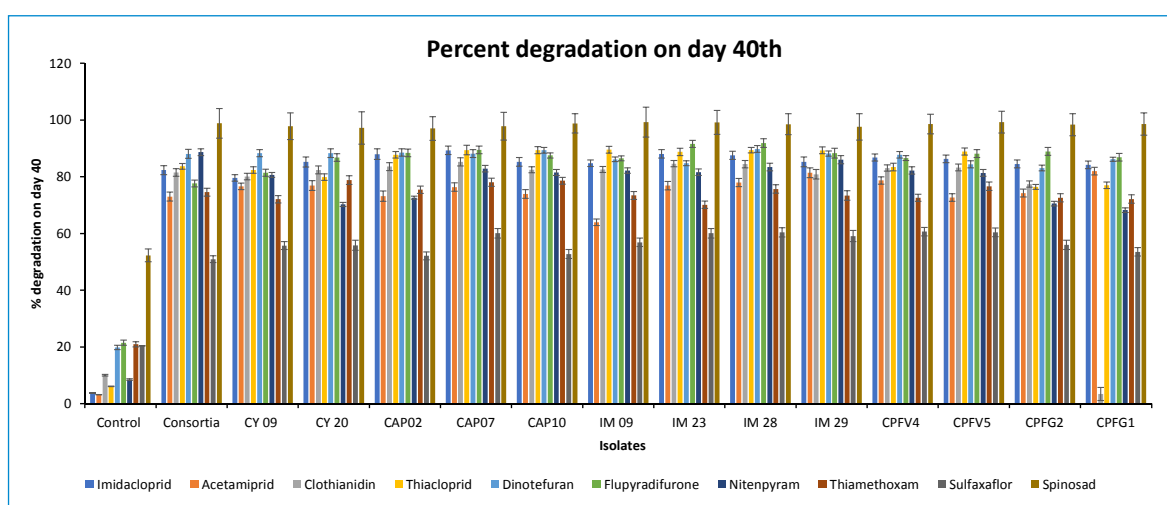


Figure 8. Pesticide degradation capability of selected individual bacterial isolates and consortium for the targeted insecticide residues in a liquid culture medium on the 40th day of incubation





Collaborative, Externally Funded, Contract Research and Consultancy Projects

National Referral or Reference Laboratory for control of pesticide residues and mycotoxins in products of plant origin (APEDA funded)

Residue monitoring plan in table grapes for export season 2024-25

This was the 22nd year of the Residue Monitoring Plan for controlling agrochemical residues in table grapes for export to the EU and other countries. In this season, a list of 76 pesticides (Annexure 5), with label claim with CIB&RC was recommended and 274 pesticides (+ their metabolites and isomers of toxicological significance) (Annexure 9) were monitored in all export samples. SOPs were harmonized for all the nominated laboratories on grape for multiresidue and single residue analysis of pesticides and other contaminants. A total of 42,678 grape plots were registered on GrapeNet from Maharashtra and Karnataka for export to EU countries.

Based on the reports of the MRL exceedances in context of export to the European Union Countries, a total of 113 Internal Alerts were issued. This accounts for only 0.89% of the total analyzed samples (12,662). The highest number of alerts due to EU-MRL non-compliance was issued for 4-bromo-2-chlorophenol (metabolite of profenophos with 16 detections) and chlormequat chloride (CCC) (PGR analyte with 13 detections), followed by famoxadone (10 detections), abamectin (7), and Ethepon (7). The other detected pesticides included profenofos (5) and pyraclostrobin (4).

Proficiency Testing Programme

A proficiency testing round on pesticide residues in grape homogenate was organized on 1 October 2025 for 84 commercial testing laboratories, of which 83 submitted results within the stipulated time. Based on PT performance, 33 laboratories were recommended to APEDA for GrapeNet access for the 2025–26

season. Another PT round on pesticide residues in apple homogenate was conducted on 25 July 2025 for 84 laboratories, all of which submitted results on time, with 60 laboratories achieving satisfactory z-scores for all target pesticides. A PT round on aflatoxin analysis in peanut homogenate was also organized on 23 December 2025 for 70 laboratories, and all participating laboratories achieved satisfactory performance.

Assessment of Nominated Laboratories

On-site and virtual assessments of nominated laboratories were carried out during the year. Counter samples collected from these laboratories were analysed at the National Referral Laboratory for comparative evaluation, and the results were found to be comparable. Based on overall performance, 33 laboratories were recommended to APEDA for grape residue testing.

Support to Organic Product Testing

To strengthen pesticide residue testing infrastructure for export of organic commodities, 76 laboratories across India were recommended to APEDA based on their satisfactory performance in grape and apple proficiency testing rounds.

Scope of Accreditation

The National Referral Laboratory successfully underwent NABL ISO/IEC 17025:2017 renewal assessment on 11-12 October 2025 and obtained accreditation for the period from 26 October 2025 to 25 October 2027. During this renewal, the accredited scope of pesticide residue analysis was substantially expanded from 351 to 779 pesticides across a wide range of agricultural and food commodities. This enhanced scope has significantly strengthened the laboratory's capacity to support food safety surveillance, regulatory compliance and export certification.

Dissipation Studies for Residue Management

Field dissipation studies were carried out on selected agrochemical formulations in grapes to determine

dissipation pattern, half-life and pre-harvest interval (PHI) with reference to EU-MRL compliance. The studies generated scientific data for oxathiapiprolin, ethephon, hexaconazole + carbendazim, picoxystrobin and copper hydroxide under field conditions. Based on residue dissipation behaviour, PHIs of 60 days were established for oxathiapiprolin,

hexaconazole + carbendazim, and picoxystrobin, while ethephon required a PHI of 30 days. These studies provide scientific support for safe pesticide use and generation of label claim data in grapes. The half-life and pre-harvest interval and dissipation pattern of these pesticides are depicted in Table 11.

Table 11. Half-life and pre-harvest intervals of selected agrochemical formulations in grapes

S. No.	Formulation	Matrix	Agrochemical	Dose	Half-life (Days)	EU-MRL (mg kg ⁻¹)	Pre-harvest interval (Days)
1.	Oxathiapiprolin 10% OD	Grape berries	Oxathiapiprolin	x	11.5-12	0.70	60
				1.25 x	11.5-16		
2	Ethephon 39% w/w SL	Grape berries	Ethrel	x	10.5-14.5	1.00	30
				1.25 x	10.5-15.0		
3	Hexaconazole 4% + Carbendazim 16% SC	Grape berries	Hexaconazole	x	8.0	0.01	60
				1.25 x	8.0		
			Carbendazim	X	9.0	0.30	
				1.25 x	8.50		
4	Picoxystrobin 22.52% SC	Grape berries	Picoxystrobin	X	6.50	0.01	60
				1.25 x	9.00		
5	Copper hydroxide 61.41%WG	Grape leaf	Copper Hydroxide	x	6.0	NA*	NA
				1.25 x	6.5		
6	Copper hydroxide 61.41%WG	Grape berries	Copper Hydroxide	x	9.5	NA	NA
				1.25 x	14.5		

*NA- EU-MRL is not established, hence PHI is not applicable.

National Reference Laboratory Scheme (FSSAI funded)

A study was undertaken to evaluate the effect of on-field decontamination treatments on the transfer rate and processing factor of selected insecticide residues during raisin preparation. Selected pesticides were applied at recommended doses, followed by foliar application of different decontamination treatments prior to harvest. Grapes were then processed into raisins and analysed using a validated LC-MS/MS method following SANTE guidelines.

The study showed that pesticide residues persisted

substantially during raisin preparation in untreated grapes. However, on-field decontamination treatments significantly reduced residue carry-over into raisins. Among the treatments evaluated, 2% citric acid was found to be the most effective, followed by 4% acetic acid, in reducing both transfer rate and processing factor across the tested pesticides (Figure 9). Triple-spray application of decontaminants proved more effective than single- or double-spray schedules. The findings demonstrate the practical utility of on-field decontamination as an effective risk-mitigation strategy for reducing pesticide residues in raisins and improving consumer safety.

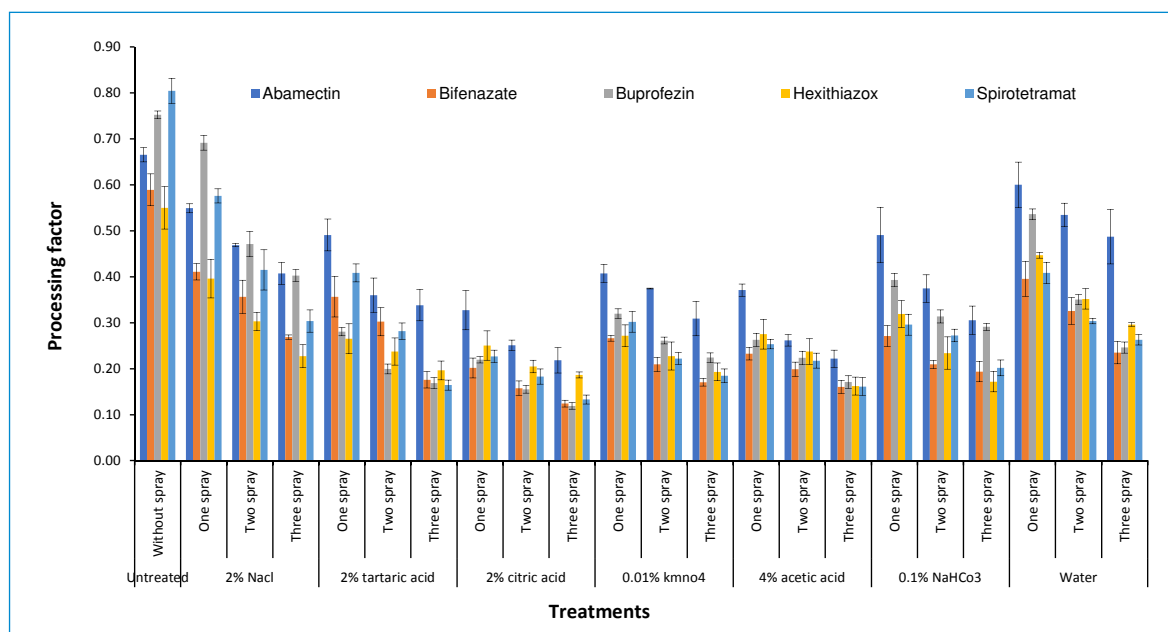


Figure 9. Processing Factor (PF) of pesticide from selected decontaminants treated and untreated grapes to raisin

Developing genomic selection strategy for accelerating breeding program in perennial fruit crops grape, guava and mango (NASF funded in collaboration with ICAR-IARI, New Delhi and ICAR-CISH, Lucknow)

The project was sanctioned in March 2024 with the following objectives (1) To generate high density SNP genotyping data of training and test populations in target crops viz. grape, mango and guava and (2) To develop and evaluate genomic prediction models for target fruit traits in breeding populations of grape, mango and guava.

The raw GBS data for train population (107 germplasm accessions), test population (122 - hybrids of SV x TS and CBR x TS crosses) and validation population (99 hybrids of Red Globe x Thompson Seedless and Red Globe x Flame Seedless) and raw data of 250 samples from earlier project were used for SNP detection after preprocessing. A total of 5,06,05,204 SNPs were detected. 91,137 high-quality SNPs were retained after filtering for missing data and minor allele frequency. Functional annotation revealed that a substantial proportion of SNPs were located in intergenic and intronic regions, with missense mutations being the predominant class among coding-region variants.

Phenotyping of important berry and bunch traits was carried out during the 2024–25 fruiting season in the training and test populations. Wide variation was observed for berry length (10-27.8 mm), berry width (9-24 mm), 20 berry weight (12-137 g), number of berries (15-320), berry firmness (19-99), bunch length (60-230 mm) and bunch compactness-related traits. Distribution analysis revealed that berry firmness followed normal distribution in all the three populations. Besides this, berry width and bunch length followed normal distribution in CBR x TS population, whereas berry length, berry width and bunch length followed normal distribution in SV x TS population.

The heritability data of target traits in two segregating populations indicated that all the selected traits are mainly influenced by genetic factor as indicated by moderate to high heritability (0.48 for bunch length and 0.97 for berry firmness).

The genotyping and phenotyping data of 208 grape accessions (training population) were analysed to identify the significantly associated markers. At a significance value of 10⁻⁵, large number of significantly associated markers were identified for each target trait. The number of significant markers for berry length, width, weight and firmness was 43, 30, 31 and 35 respectively. Some of these markers were significant with more than two models and

explained large proportion of phenotypic variation indicating presence of major QTLs in these genomic regions.

The phenotyping and genotyping data of training population (208 genotypes) were used to estimate prediction accuracies using RRBLUP software. Prediction accuracies were estimated using different proportions as train and test data sets (70% train data, 30% test data and 60% train data, 40% test data). However, it was observed that proportion of train and test populations did not significantly affect the prediction accuracy which varied from 0.42 (berry firmness) to 0.84 (first ramification length) for different traits.

RRBLUP was used to estimate the prediction accuracies in test population of CBR x TS (83 hybrids) with germplasm population (208 genotypes) as train population. The prediction accuracies for different target traits ranged from -0.009 to 0.374.

Validation of DUS descriptors for Indian Grapes (*Vitis* spp.) (PPVFRA funded)

A total of 26 candidate grape varieties were evaluated through on-site DUS testing at different growth stages in accordance with the prescribed guidelines (Table 12). The consolidated DUS data of 18 candidate varieties were compiled and submitted to the PPV&FR Authority, while second-year on-site evaluation of the remaining varieties is in progress.

Table 12. Detail of on-site DUS testing of candidate grape varieties

Entries from	Number of entries	Name of candidate varieties
Foreign countries	12	ARRA29, ARRA30, ARRA32, ARRA33, ARRA34, ITUM2, ITUM5, ITUM6, ITUM8, ITUM9, ITUM13, ITUM17
Farmers	11	Nath Jambo Seedless, Anishka, BP Seedless, Govind Seedless, Joti Seedless, SSN, Viraj Seedless, Yashwant Seedless, Armani, Kavur, Bate Kavur
Private institute	1	MACS-516, H 516/ARI 516
Public institute	2	Manjari Manjula, Manjari Madhura

Eighteen candidate grape varieties were registered with PPV&FRA, New Delhi based on the DUS data collected and documented by the institute. The details of these varieties are given in Table 13.

Agri CRP on Water- IoT Enabled Sensor Based Smart Irrigation Management System (ICAR funded in collaboration with MPKV Rahuri, ICAR-NRCG, ICAR-IIHR and ICAR-IIWM)

During the fruit pruning season of 2024–25, an experiment was conducted in Thompson Seedless grafted on Dogridge rootstock to compare the existing recommended irrigation schedule based on pan evaporation and crop growth stage with alternative schedules based on crop evapotranspiration (ETc) and soil moisture sensor-guided irrigation. Six irrigation treatments were evaluated (Table 14).

The results showed significant differences in yield and irrigation water use among treatments. The highest

yield of 27.62 t/ha was recorded under the ETc-based irrigation schedule, though it remained statistically at par with the recommended pan evaporation-based schedule, which produced 26.61 t/ha. However, the ETc-based schedule required substantially higher water use, consuming 24.08 lakh litres/ha, which was 6.37 lakh litres/ha more than the recommended schedule (17.71 lakh litres/ha).

Soil moisture sensor-assisted schedules linked with ET-based irrigation and pan evaporation-based irrigation saved up to 17.67% and 36.15% irrigation water, respectively, over the currently recommended pan evaporation and crop growth stage-based schedule. Under these soil moisture sensor-assisted treatments, yields ranged from 25.70 to 26.09 t/ha in the better-performing treatments, indicating that substantial water could be saved while maintaining yields close to the currently recommended pan evaporation and crop growth stage-based schedule. The lowest irrigation water use was recorded in the more deficit-oriented sensor-based treatments, which

Table 13. Registration granted by PPV&FR Authority, New Delhi

S. No.	Variety	Registration no.	Categories
1.	ARRA32	REG/2018/713 (03.04.2025)	New
2.	INIAGRAPE-1	REG/2017/2269 (09.06.2025)	New
3.	BATE KAVUR	REG/2024/0087 (04.08.2025)	Farmer
4.	KAVUR	REG/2024/0088 (04.08.2025)	Farmer
5.	ARMANI	REG/2024/0089 (04.08.2025)	Farmer
6.	SSN	REG/2024/1085 (04.08.2025)	Farmer
7.	ARRA30	REG/2022/0133 (03.09.2025)	New
8.	ARRA33	REG/2022/0134 (03.09.2025)	New
9.	ARRA29	REG/2022/0135 (03.09.2025)	New
10.	ARRA34	REG/2023/0040 (03.09.2025)	New
11.	VIRAJ SEEDLESS	REG/2024/0260 (03.09.2025)	Farmer
12.	BP ROSY SEEDLESS	REG/2024/0261 (03.09.2025)	Farmer
13.	MANJARI MANJULA	REG/2024/0434 (03.09.2025)	New
14.	MANJARI MADHURA	REG/2024/0435 (03.09.2025)	New
15.	ANISHKA	REG/2024/0552 (03.09.2025)	Farmer
16.	YASHWANT SEEDLESS	REG/2024/0553 (03.09.2025)	Farmer
17.	GOVIND SEEDLESS	REG/2024/0923 (03.09.2025)	Farmer
18.	JOTI SEEDLESS	REG/2024/0924 (03.09.2025)	Farmer

Table 14. Treatment details

S. No.	Treatment detail
T1	Recommended irrigation schedule based upon pan evaporation applied through surface drip irrigation
T2	Irrigation schedule based upon ET _c applied through surface drip irrigation (Grape factor)
T3	Soil moisture sensor-based Irrigation schedule – soil moisture maintained at field capacity except at flowering stage, where it is given at 50% of available water. If soil moisture reduced, then irrigated based upon ET _c values
T4	Soil moisture sensor-based Irrigation schedule - soil moisture content was maintained at 75% of the available water except at flowering stage, where it is given at 60% of available water. If soil moisture reduced, then irrigated based upon ET _c values
T5	Soil moisture sensor-based Irrigation schedule – soil moisture maintained at field capacity except at flowering stage, where it is given at 50% of MAD. If soil moisture reduced, then irrigated based upon recommended pan evaporation values
T6	Soil moisture sensor-based Irrigation schedule - soil moisture content will be maintained at 75% of the available water except at flowering stage, where it is given at 60% of available water. If soil moisture reduced, then irrigated based upon recommended pan evaporation values

also produced the highest water use efficiency values of 2.50 to 2.61 t/lakh L, compared with 1.50 t/lakh L under the recommended schedule and 1.15 t/lakh L under ETc-based irrigation.

Fruit quality did not differ significantly among treatments, indicating that sensor-based irrigation can improve irrigation efficiency without adversely affecting grape quality. Overall, the study demonstrated that soil moisture sensor-based irrigation scheduling has strong potential to reduce irrigation water use and enhance WUE in grapes under field conditions. Based on the encouraging results obtained during the 2024–25 fruit pruning season, the trial was refined and expanded to eight treatments from the foundation pruning season of 2025–26 for further validation and optimization of smart irrigation schedules.

IoT-based Vineyard monitoring system for Micro-climate and Soil moisture Sensing system (DST funded)

The project was initiated in collaboration with TIH foundation for IoT and IoE, IIT, Mumbai during April 2024, to develop the IoT-based Vineyard monitoring system for micro-climate and Soil moisture sensing. This will be used to understand the impact of microclimate factors on grapevine growth, health, berry quality, and overall vineyard productivity.

The solar powered automatic weather station (SAMBHAV-1 no.) and canopy microclimate systems (SAMADHAN-15 nos.) were installed at experimental farm of ICAR-NRCG and also at two farmers' fields for monitoring soil and canopy

microclimate in vineyard. The relationship was studied between weather parameters and the risk of major grapevine diseases, leveraging both historical and high-resolution weather data from August 2003 to March 2018. The disease trigger conditions, specifying critical thresholds for parameters such as temperature, relative humidity, rainfall, and leaf wetness were finalized for diseases like Downy Mildew, Anthracnose, and Powdery Mildew. The model was developed to identify High Risk Window based on how pathogens have historically behaved under identical conditions. The alert is generated when all the conditions are satisfied in the previous 24 hours cycle.

The irrigation water requirement of the grape crop depends on the growth stage of the crop, soil type, rainfall and evapotranspiration (ET). Studies with soil moisture sensor and its replenishment with pan evaporation factor led to 18-20% saving in irrigation water over the recommended irrigation scheduled based upon pan evaporation and crop growth stage. The current I-SARTHI app being developed for irrigation scheduling for providing irrigation advisories hence a farmer select irrigation scheduling based upon crop growth stage in conjunction with any of the three namely pan evaporation, ET, soil moisture sensor.

Development and evaluation of robotic harvester for grape bunches (ICAR-NASF funded)

For vision-based ripeness detection, image datasets were generated for three grape varieties, namely Panner (1021 images), Thompson Seedless (1028



Figure 10. Vision-based ripeness detection of grape bunches

images) and Crimson Seedless (1056 images), under diverse field conditions. After quality screening, augmentation, annotation and partitioning into training, validation and testing sets, YOLO-based models were trained and evaluated. YOLOv8 performed best for Panner and Crimson Seedless, while YOLOv11 gave the best results for Thompson Seedless (Figure 10). Overall, YOLOv8 emerged as the most robust model across varieties for ripeness detection in grape bunches.

An unmanned electric vehicle was also designed and developed as the carrier platform for the robotic harvesting system. The vehicle includes a lightweight chassis, transmission system, electronic control unit, remote-control interface, robotic arm mounting provision and grape tray carrier. It is powered by a 24 V battery system and is designed for stable movement and reliable field performance under vineyard conditions. The platform will enable seamless integration of the robotic arm for selective and damage-free harvesting of grape bunches. A design registration (487374-001) has been filed for the unmanned mobile vehicle developed under the project.

Clean Plant Programme for Grapes (ADB funded)

As part of capacity building, visits were undertaken to advanced laboratories and biotechnology institutions in Maharashtra, and technical interactions were held with national and international experts, including Prof. Arun K. Dhar, University of Arizona, USA, and Dr. Maher Al Rwahnih, Foundation Plant Services, UC Davis, USA. These activities contributed to strengthening the technical framework for implementation of the programme in India.

Hazard analysis was planned to detect a 1% infection rate with more than 95% confidence, and a nationwide collection of 578 grapevine samples representing 48 varieties and four rootstocks was undertaken. High-quality nucleic acid extraction followed by high-throughput sequencing (HTS) on the Illumina platform enabled identification of known as well as novel viruses from major grape-growing regions. HTS data for 575 samples have been generated and analysed.

Protocols for production of virus-free in vitro plants through meristem culture have been standardized for

Dogridge and Thompson Seedless, and the technology was approved by the Institute Technology Release Committee on 06.05.2025. Multiplication and maintenance of virus-free plants are currently underway under polyhouse conditions. In addition, a Detailed Project Report, Project Administration Manual, standard operating procedures and tentative layouts for tissue culture, virology and nursery facilities have been prepared, and a five-acre site has been identified for programme implementation.

Hazard analysis of grapevine under the Clean Plant Programme (NHB funded)

Extensive surveys were carried out in Maharashtra, Karnataka, Tamil Nadu, Andhra Pradesh, Jammu and Kashmir and Mizoram by ICAR-NRCG and ICAR-IARI to understand the virus-profile in Indian vineyards. A total of 575 samples (representing 48 varieties, more than 130 germplasm, 4 rootstocks) of grapes were collected through comprehensive coordinated surveys as per the global standards and analyzed using the HTS approach by the ICAR-IARI. Analysis of all 575 samples has been completed. The findings are expected to provide a scientific basis for disease indexing, source plant selection and development of clean planting material under the national clean plant framework.

Impact assessment of grapevine viruses on yield and quality of grape production (MIDH funded)

A total of 224 samples were analysed for GLRaV-1, GLRaV-3, GLRaV-4, GfKv, GFLV and GPGV. Among the leaf samples tested, GLRaV-1 was detected in 10.7% and GLRaV-4 in 82.6% of samples, while mixed infection of GLRaV-1 and GLRaV-3 was recorded in 5.56% of the samples. An additional 53 samples were tested for GfKv, GFLV and GPGV, but none of these viruses were detected. The results indicated that GLRaV-1, GLRaV-3 and GLRaV-4 were the predominant viruses present in leaf samples. Further studies on the physical and biochemical characterization of leaves and berries from virus-infected vineyards are in progress.

A detailed Foodomics study for food authentication and exploration of nutraceutical potential (NASF funded)

An LC-HRMS-based analytical method was developed for metabolite profiling and authentication

of six grape juice varieties, namely Arka Shyama, Bangalore Blue, Concord, Gulabi × Bangalore Purple, H-516 and Manjari Medika. Chemometric models based on OPLS-DA and PLS-DA enabled accurate varietal authentication, with a prediction accuracy of 98%. Flavonoid biomarker ions were also identified, indicating significant variation in flavonoid composition among the juice varieties.

An LC-HRMS-based targeted analytical method was also developed for detection of beetroot adulteration in pomegranate juice, along with preparation of a marker compound database. Adulteration was simulated by blending beetroot juice with pomegranate juice at levels ranging from 0 to 100%. The method showed a proportional increase in betanin intensity and a corresponding decrease in punicalagin intensity with increasing adulteration, demonstrating that the method is rapid, sensitive, accurate and robust for juice adulteration analysis.

Another LC-HRMS-based metabolite profiling method was developed to authenticate organically grown grapes and pomegranates in comparison with conventionally produced samples. OPLS-DA and PLS-DA models were successfully used for prediction of authenticity, and epicatechin and catechin were identified as marker compounds for organic pomegranate and grape samples, respectively.

In addition, an LC-HRMS-based pesticide screening method was developed and validated for verification of organically grown grapes and pomegranates. Screening of 104 grape samples revealed 25 non-target pesticides in 18 samples, including oxamyl-oxime and acetochlor metabolite in organically labelled grapes. No pesticide residues were detected in the 20 pomegranate samples analysed, confirming their organic status. In contrast, about 17% of the grape samples were found to be falsely labelled as organic. Among the detected residues, carbofuran, 3-keto and acetochlor were the most frequent, while ethoxyquin and pyrimethanil, which are not included in Annexure 9, were also detected. Ethoxyquin was found in 57% of the screened grape samples, whereas pyrimethanil was detected in 1.9% of the total samples tested.

Intellectual Property Management and Transfer / Commercialization of Agricultural Technology (ICAR-NAIF Scheme)

During the year, the Institute Technology

Management Unit (ITMU) continued to facilitate intellectual property (IP) protection, maintenance and commercialization of institute-developed technologies. A total of five patents were maintained, and efforts were made to promote technology transfer through licensing and wider dissemination of information on available technologies. The institute website was updated with details of saleable technologies, commercialized technologies and intellectual property assets to improve visibility and outreach. One technology licence agreement was signed during the year for the Decision Support System for Grapes (DSS) with AgriPilot Tech Pvt. Ltd. on a non-exclusive basis on 25 February 2025, generating revenue of Rs. 1.05 lakh. Significant progress was also made in copyright protection. A total of 11 copyright applications were filed, of which four copyrights were granted to ICAR (Table 15).

Agri-Business Incubation (ABI) Centre Component-II of the XII Plan 'National Agriculture Innovation Fund (NAIF)'

The ABI Centre continued to promote entrepreneurship, innovation and technology-based agribusiness development through training, sensitization, stakeholder interaction and technology showcasing activities.

Programs Organized

1. ABI Draksha and ITMU of ICAR-NRCG, Pune jointly organized a National Workshop on "From Ideas to Assets: Demystifying IPR for Innovators" on 25.07.2025 in hybrid mode. The workshop was attended by 32 scientists from ICAR and UHS Bagalkot. The programme highlighted the importance of IPRs, branding, copyrights and geographical indications (GIs).
2. ABI Draksha and ITMU of ICAR-NRCG, Pune organized an IPR awareness programme on the occasion of World IP Day on 01.05.2025.
3. ABI Draksha celebrated National Startup Day 2025 on 15.01.2025. On this occasion, Dr Partha Das Gupta delivered a talk on "Scope and Challenges of Technology-Based Startups in Agribusiness" and shared insights on the startup ecosystem in agriculture and the adoption of innovations for farmers' welfare.

Table 15. Details of copyrights granted to ICAR

Copyright title	Author/Inventor Name & Designation	Application No./ Diary No.	Date of grant
GIS-based Thematic Map of Grape Cultivating Districts in India with Grape Production (2022-2023)	Mrs. K. Y. Mundankar, Dr. K. Banerjee	5778/2025-CO/L	16.05.2025
GIS-based Thematic Maps of Soil Suitability for Grape Cultivation in Maharashtra State At 30-meter Resolution	Dr. G.P. Obi Reddy, Mrs. K. Y. Mundankar, Dr. Ajay Kumar Upadhyay	5732/2025-CO/L	16.05.2025
GIS-based Thematic Maps of Soil Suitability for Grape Cultivation in Madhya Pradesh State At 30-meter Resolution	Dr. G.P. Obi Reddy, Mrs. K. Y. Mundankar, Dr. Ajay Kumar Upadhyay	5496/2025-CO/L	16.05.2025
GIS-based thematic map on climatic constraint for grape production across various regions of India considering average annual precipitation in the region with a spatial resolution of 2.5 arc minutes	Mrs. K. Y. Mundankar	2504/2025-CO/L	08.04.2025

Sensitization programmes

1. A sensitization programme on agri-entrepreneurship for ensuring livelihood in tribal areas was organized for tribal farmers of the Bhimashankar region of Pune district, on 12.11.2025. The aims and support services of ABI Draksha were explained, and business opportunities in the grape sector were discussed.
2. A group of five representatives from KrushiVikas, an NGO, visited on 18.08.2025. They were briefed on technologies developed by ICAR-NRCG, Pune, as well as the incubation facilities and support available through ABI Draksha.
3. A group of 35 students from Agriculture Polytechnic College, Baramati, visited on 30.07.2025. The students were sensitized to the objectives and activities of ABI Draksha and its role in supporting the startup ecosystem in agriculture.
4. A group of 63 students along with two faculty members from the University of Agricultural Sciences, Dharwad, Karnataka, visited ICAR-NRCG, Pune on 20.02.2025. They were sensitized to technologies developed under the waste-to-wealth concept and briefed on the objectives and

activities of ABI Draksha. Success stories of women-led startups were also shared.

5. A group of 59 students and three staff members from the College of Horticulture, Kolar, under the aegis of UHS, Bagalkot, Karnataka, visited ICAR-NRCG on 10.02.2025. The group was sensitized to the objectives and activities of ABI Draksha and encouraged to adopt innovative ideas for establishing startups.
6. A group of 48 students along with two faculty members from Tuljaram Chaturchand College, Baramati, visited on 07.02.2025. Technologies developed in the area of food science were discussed, and the visitors were sensitized to the objectives and activities of ABI Draksha.

Technology discussion

1. Mr Bhushan Darekar from AgMove Robo Ind Pvt. Ltd. visited ABI Draksha on 30.04.2025 and shared his expertise and future plans.
2. Representatives from Sakhi Agrotech, Kota visited ABI Draksha on 06.03.2025. Discussions were held on available technologies, the importance of innovation, and business opportunities in grape cultivation and processing in the region.

3. A technology discussion was held with innovator Ms Rashmitha Chittimalli on 06.01.2025. The discussion focused on the utilization of Manjari Medika pomace for developing high-value bakery products, and possible areas of collaboration were explored.
4. Mr Sairaj Kusekar from Shirur, Pune, visited ABI Draksha on 18.02.2025. He expressed interest in establishing a startup based on the utilization of agri-waste for biofertilizer production and was briefed on the support extended by ABI Draksha.
5. A group of four progressive farmers from Pune district visited ABI Draksha on 21.02.2025. They

had established an FPC and were working on grapes and bananas. The group expressed interest in precision agriculture and the production of high-value products from bananas.

Showcasing

1. The contribution of ABI Draksha in promoting agribusiness was highlighted during National Grape Summit 2025, organized by BCC&I and ICAR-NRCG, Pune, on 04.03.2025.
2. Incubatees of ABI Draksha displayed their food products on 25.02.2025 at ICAR-NRCG on Grape Day which were appreciated by the visitors.



Programme for NEH, TSP and SCSP

North-Eastern Hill Region (NEH)

Training, demonstration and agri-input distribution: Under the NEH programme, a two-day training programme on “Scientific Training, Pruning and Propagation of Grapes in Non-Traditional Areas” was organized at KVK-Unakoti, Tripura, during 25-26 September 2025. After the training, demonstrations on training and pruning, grapevine propagation techniques and use of Dormex in canes for fruitfulness in grapes were conducted. Agri-inputs, including pesticides (7.5 kg), were distributed to 25 farmers at KVK-Unakoti, Tripura, on 25 September 2025. The programme was coordinated by Dr. Ratan Das, SMS, KVK-Unakoti, Tripura, and Dr. N.A. Deshmukh, Nodal Officer (NEH), ICAR-NRCG, Pune.



Training and demonstration on vineyard establishment: A two-day training programme on “Vineyard Establishment and Management Techniques under Agro-Climatic Conditions of Tripura” was organized under the NEH programme at KVK-Unakoti, Tripura, during 23–24 December 2025. Demonstrations on installation of Y-trellis and nutrient management in grapes were conducted after the training programme. A total of 25 farmers participated. The programme was coordinated by Dr. Ratan Das, SMS, KVK-Unakoti, Tripura, and Dr. N.A. Deshmukh, Nodal Officer (NEH), ICAR-NRCG, Pune.



Tribal Sub Plan (TSP)

Training, demonstration and agri-input distribution: Under the Tribal Sub Plan (TSP), a training programme on “Organic Farming Practices in Vegetables and Fruit Crops” was organized at Ugalewadi, Taluka Ambegaon, District Pune, on 24 September 2025. After the training, demonstrations on the use of decomposers, biopesticides and

micronutrients were conducted. Agri-inputs including biopesticides (58 L), biofertilizers (58 kg), micronutrients (50 kg) and decomposer culture (29 L) were distributed to 29 tribal farmers for use in strawberry and vegetable crops. The programme was coordinated by Dr. N.A. Deshmukh, Nodal Officer (TSP), ICAR-NRCG, Pune, and Dr. Dattatray B. Gawade, SMS, KVK, Narayangaon, Pune.



Scheduled Caste Sub Plan (SCSP)

Distribution of fertilizers and fungicides at Ranjankhol village: ICAR-NRCG organized an agricultural input distribution-cum-interaction meeting at Ranjankhol village, Taluka Rahata, District Ahmednagar, under the SCSP Scheme of the Government of India on 16 January 2025. Fertilizers and fungicides were distributed to 34 SCSP beneficiaries, including 30 male and 4 female farmers. Dr. Somnath Holkar, Senior Scientist and Nodal Officer (SCSP), ICAR-NRCG, interacted with the farmers and provided information on the SCSP

programme and disease management approaches. Shri Krushna Abhang, village representative, shared feedback on the benefits of the scheme in improving crop production and livelihood of SC farmers. The programme was attended by SCSP beneficiaries and senior citizens of the village. The procurement and receipt of inputs at the institute were facilitated by Dr. D.N. Gawande, Shri P.P. Kalbhor, Shri B.J. Phalke and Shri Eknath Kamble, ICAR-NRCG, Pune. Dr. Kaushik Banerjee, Director, ICAR-NRCG, provided guidance and support for organizing the programme.



Residential training programme on protected cultivation: ICAR-NRCG organized a three-day residential training programme on "Cultivation of Vegetables, Ornamentals and Other Short-Duration Crops under Protected Conditions" for SCSP beneficiaries at the National Institute of Post-Harvest Technology, Talegaon Dabhade, Pune, during 10–12 March 2025. A total of 26 farmers from Ranjankhol village participated in the programme. The training focused on modern agricultural technologies for improving yield and quality, cultivation of crops under greenhouse conditions, post-harvest



technologies, cultivation methods, pest management, fertilizer management and water management. Dr. Somnath Holkar organized the programme based on the request received from SCSP farmers. The participants appreciated the exposure to protected cultivation technologies and expressed their willingness to adopt the knowledge gained for profitable and quality crop production. Dr. Kaushik Banerjee, Director, ICAR-NRCG, provided guidance and support for organizing the training programme.

Distribution of fertilizers at Nandapur village:

ICAR-NRCG organized an agricultural input distribution programme at Nandapur village, Taluka Jalna, District Jalna, under the Scheduled Caste Sub Plan (SCSP) Scheme of the Government of India on 11 March 2025. Essential fertilizers required for crop cultivation were distributed to 124 SCSP beneficiaries from Nandapur and Kadwanchi villages. The beneficiaries included 83 grape growers, 29 non-grape growers and 12 women beneficiaries, including widows. Five fertilizers, namely 24:24:00, DAP, 13:40:13, 12:61:00 and 00:52:34, amounting to 127.72 quintals, were distributed to the beneficiary



farmers. The programme was planned by Dr. Somnath Holkar and the fertilizers were distributed by Shri Eknath Kamble, Assistant Chief Technical Officer, ICAR-NRCG. Procurement and receipt of fertilizers at the institute were facilitated by Dr. D.N. Gawande, Shri P.C. Noble, Shri Munish Ganti, Shri P.P. Kalbhor and Shri B.J. Phalke. Dr. Kaushik Banerjee, Director, ICAR-NRCG, provided guidance and support for organizing the programme.

Distribution of fertilizers at Tandulwadi village:

ICAR-NRCG organized an agricultural input distribution programme at Tandulwadi village, Taluka Jalna, District Jalna, under the Scheduled Caste Sub Plan (SCSP) Scheme of the Government of India on 25 March 2025. Essential fertilizers required for crop cultivation were distributed to 53 SCSP beneficiary farmers of Tandulwadi village. Nine fertilizers, namely 19:19:19, 24:24:00, DAP, SOP, ammonium sulphate, SSP, magnesium sulphate, ferrous sulphate and zinc sulphate, amounting to 164.30 quintals, were distributed. The programme was attended by beneficiary farmers and senior citizens of the village. The programme was planned by Dr. Somnath Holkar and the fertilizers were distributed by Shri Eknath Kamble, Assistant Chief Technical Officer, ICAR-NRCG. Procurement and receipt of fertilizers were facilitated by Dr. D.N. Gawande, Shri P.C. Noble, Shri Munish Ganti, Shri P.P. Kalbhor and Shri B.J. Phalke. Dr. Kaushik Banerjee, Director, ICAR-NRCG, provided guidance and support for organizing the programme.



Technology Assessed and Transferred

Technologies Developed

1. **Marker-assisted selection for berry traits in grapes:** Two functional microsatellite markers associated with grape berry diameter, length and weight were identified. These markers will help in early-stage selection of grape hybrids with desirable berry size and improve breeding efficiency.
2. **Soil moisture sensor-based irrigation scheduling:** Soil moisture sensors were evaluated for irrigation scheduling in Thompson Seedless grapevines on Dogridge rootstock. Sensor-based irrigation from berry development to harvest saved up to 18% irrigation water without affecting yield and fruit quality.
3. **Preservation of grape pomace through drying:** A drying method was standardized for preservation of grape pomace with better retention of phenolics and anthocyanins. Drying at 50–60°C was found suitable for maintaining bioactive compounds while improving drying efficiency.
4. **Grape pomace powder as a functional carrier:** Grape pomace powder was developed as a functional carrier for microencapsulation of dopamine and its precursors from banana peel extract through spray drying, indicating its potential use in nutraceutical applications.
5. **Bioformulations for disease management:** Liquid bioformulation of *Bacillus subtilis* isolate SB2 and formulations of endophytic *Trichoderma asperellum* isolates NRCG-7 and NRCG-3 were developed for management of anthracnose and powdery mildew in grapes.
6. **Drone spraying technology for thrips management:** Drone-based spraying technology was standardized for thrips management in vineyards during the foundation pruning season. Five insecticides and their application doses were standardized for precision pesticide application.
7. **Green synthesis of zinc nanoparticles:** A process was developed for green synthesis of zinc nanoparticles functionalized with Manjari Medika pomace extract for improving micronutrient content, yield and quality of Thompson Seedless grapes.
8. **Microbial isolate for bioremediation:** A microbial isolate was identified for potential bioremediation of chlorantraniliprole residues in grape rhizosphere soil. The isolate will be further evaluated for residue degradation and nutrient mineralization.
9. **Strengthening of NRL accreditation and analytical scope:** The National Referral Laboratory renewed its NABL ISO/IEC 17025:2017 accreditation for 26 October 2025 to 25 October 2027 and expanded its accredited scope to 779 pesticides across diverse agricultural and food matrices, strengthening food safety surveillance and export certification support.

Field Days Organised

Grape Day: ICAR-NRCG organised Grape Day on 25 February 2025 to create awareness about grapes and grape-based products among the general public. The programme was graced by Dr. Sudhir Hiremath, DIG-CBI, Pune, and Dr. Bikash Mandal, Assistant Director General (International Relations), ICAR, New Delhi. Dr. Kaushik Banerjee, Director, ICAR-NRCG, welcomed the participants and highlighted the significance of the event. Dr. K.V. Prasad, Director, ICAR-DFR, Pune, emphasized the need to develop grape varieties with low glycaemic index to enhance consumer acceptance. Dr. Bikash Mandal highlighted sustainable grape cultivation and the use of biopesticides and biostimulants. He also appreciated the institute's work in food safety and pesticide residue management. Dr. Sudhir Hiremath shared his experience with grapes and appreciated the institute's efforts in enhancing farmers' income through diversification and commercialization of grape-

derived products. The vineyards were opened for visitors to observe grape varieties, cultivation practices and grape-based products. ABI-Draksha incubatees displayed and sold grape-based products



through stalls. More than 400 participants attended the programme and interacted with ICAR-NRCG staff.



Biointensive Field Day for pest management at Nashik: ICAR-NRCG organised a Biointensive Field Day on 21 March 2025 at Nashik in collaboration with IPL Biologicals, New Delhi. More than 100 grape growers participated in the programme. The event highlighted strategies adopted by growers for production of residue-free grapes through weather-based advisories and intensive use of biological inputs for management of insect pests and diseases. Inputs such as *Trichoderma*, *Bacillus*, *Beauveria* and *Ampelomyces* species were used on a need-based

basis, resulting in reduction in cost of grape production and improvement in harvest quality. Pesticide application safety kits were distributed by the Pesticide Manufacturers and Formulators Association of India. Officials from the Department of Agriculture, Government of Maharashtra, ICAR-NRCG and IPL Biologicals participated in the programme. Dr. Sujoy Saha, Principal Scientist and Project Leader, conveyed the institute's commitment to promoting safe and residue-free grapes for domestic and export markets.



Viksit Krishi Sankalp Abhiyan: Viksit Krishi Sankalp Abhiyan was launched on 29 May 2025 by Shri Shivraj Singh Chouhan, Hon'ble Union Minister of Agriculture and Farmers Welfare, from Puri, Odisha. Under this campaign, scientists from ICAR institutes, KVKs and SAUs visited farmers' fields to address current agricultural problems and disseminate information on new technologies. Scientists from ICAR-NRCG, Pune, were attached to KVKs at

Narayangaon, Nashik-I, Nashik-II and Dhule. They visited villages in Nashik, Dhule and Narayangaon regions and interacted with farmers on water scarcity, judicious irrigation, soil and water testing, use of soil health cards, natural farming, high-yielding climate-resilient varieties, crop diversification, safe pesticide use, soil moisture and NPK sensors, AI-enabled technologies, drones and modern farm machinery. The campaign concluded on 12 June 2025.



Grape expansion programme in Jammu and Kashmir: As part of the institute's ongoing efforts to expand grape cultivation in non-traditional areas, Dr. Kaushik Banerjee, Director, and Dr. Sharmistha Naik, Scientist, interacted with farmers from Ganderbal and Baramulla districts of Kashmir. ICAR-NRCG supplied grape planting material to these farmers. More than 90% success in plant establishment was observed at the farm of the Centre of Excellence, Zawoora, Department of Horticulture, Kashmir

Division, Government of Jammu and Kashmir. ICAR-NRCG signed an MoU with the Department of Horticulture, Kashmir Division, Government of Jammu and Kashmir, on 21 April 2025 for collaborative promotion of grape cultivation and capacity building in the Union Territory of Jammu and Kashmir. On 22 April 2025, the team visited ICAR-CITH, where a grape demonstration block has recently been included under AICRP-Fruits (Grapes).



Participation in Charchasatra and seminars organised by MRDBS

ICAR-NRCG scientists actively participated in Charchasatras, technical seminars and farmer outreach programmes organized by Maharashtra State Grape Growers' Association (MRDBS) during 2025. The MRDBS organized its Annual Grape Seminar at Pune during 24–26 August 2025. The programme was inaugurated by Shri Ajit Pawar, Hon'ble Deputy Chief

Minister, Government of Maharashtra, and Shri Dattatraya Bharane, Hon'ble Minister of Agriculture, Government of Maharashtra. The first technical session on "Grape Varieties and Trade Facilitation" was chaired by Prof. S.K. Singh, Deputy Director General (Horticultural Science), ICAR, and co-chaired by Dr. Kaushik Banerjee, Director, ICAR-NRCG. Scientists of ICAR-NRCG delivered following technical lectures in the Seminar.

Name of the scientist	Topic
Dr. R.G. Somkuwar	Problems faced in vineyards due to unseasonal rains and possible solutions
Dr. A.K. Upadhyay	Nutrient and water – The key pillars
Dr. S.D. Ramteke	Effects of herbicides on grapevines and possible solutions
Dr. A.K. Sharma	Quality raisin production for international market and scenario of Indian and worldwide raisins
Dr. Sujoy Saha	Integrated disease management and climate change
Dr. D.S. Yadav	Recent strategies for management of major insect pests in grapes
Dr. Roshni R. Samarth	Efforts in grape varietal development by ICAR-NRCG
Dr. N.A. Deshmukh	Use of new sensors in grape production according to changing weather conditions
Dr. S.K. Holkar	Biological disease control (anthracnose, downy mildew, wilt, etc.)
Dr. P.H. Nikumbhe	Use of crop cover and different rootstocks in changing climate

- Dr. A.K. Sharma, Dr. Sujoy Saha, Dr. D.S. Yadav, Dr. Roshni Samarth and Dr. P.H. Nikumbhe guided the grape growers in the foundation pruning charchasatra in Sangli on 04 April 2025.
- Dr. R.G. Somkuwar, Dr. A.K. Upadhyay, Dr. Sujoy Saha and Dr. D.S. Yadav guided the grape growers in the foundation pruning charchasatra in Solapur on 08 April 2025.
- Dr. R.G. Somkuwar, Dr. A.K. Upadhyay and Dr. Sujoy Saha guided the grape growers in charchasatra at Nashik on 06 June 2025.
- Dr. Sujoy Saha and Dr. D.S. Yadav guided the grape growers in the forward pruning charchasatra held at Nashik on 23 September 2025.
- Dr. R.G. Somkuwar, Dr. Sujoy Saha and Dr. D.S. Yadav guided the grape growers in the forward pruning charchasatra held at Solapur on 10 October 2025.
- Dr. R.G. Somkuwar, Dr. A.K. Upadhyay, Dr. Sujoy Saha and Dr. D.S. Yadav guided the grape growers in the forward pruning charchasatra held at Baramati, Pune on 14 October 2025.

Participation in Charchasatra and seminars organised by other agencies

- ICAR-NRCG, Pune, participated in the grape field

day programme jointly organised by SML Limited and Sumil Chemical Industries Pvt. Ltd. at Mohadi, Nashik. Grape growers shared their experiences on the use of fertilizers and their impact on berry development, cane maturity, canopy growth, bunch development and disease pressure. The programme was attended by representatives of SML Limited and Sumil Chemical Industries, grape growers, and scientists from ICAR-NRCG, including Dr. S.K. Holkar and Dr. Sharmistha Naik.

- Dr. N.A. Deshmukh guided grape growers on good agricultural practices during a seminar organized by Jivagro Ltd. under the CSR project “Jivodaya” for grape growers. The programme was organized by Mahalaxmi Farmer Producer Company (FPO) and PI Foundation at Kavathe Mahankal, District Sangli, on 6 March 2025.
- Dr. A.K. Upadhyay guided grape growers on “Nutrient and Water Management in Grapes” during the fruit pruning seminar organized at Indapur on 12 September 2025.
- Dr. P.H. Nikumbhe and Dr. P.V. Sawant guided DMR farmers’ group at Pandharpur, district Solapur on different aspects of grape cultivation on 20 June 2025.



- Dr. P.V. Sawant guided the farmers on 'Grapes Crop Management' in the farmers meeting organized by Green TV at Nasik on 15 October 2025.

Field visits

- Dr. S.K. Holkar visited wilt-affected vineyards in the Sangli region on 11 January 2025 and guided grape growers on remedial measures.
- Dr. Sujoy Saha visited powdery mildew and berry cracking affected vineyards in the Nashik region on 23 January 2025 and advised grape growers on remedial measures.
- Dr. A.K. Sharma participated in NHB inspection visits to nurseries in Pune and Sangli regions during 29–30 January 2025.
- Dr. A.K. Upadhyay and Dr. Sujoy Saha visited vineyards at Shirwade Phata, Nashik division, on 6 June 2025 in collaboration with MRDBS and guided grape growers on canopy, nutrient and water management, and disease management strategies.
- Dr. A.K. Upadhyay and Dr. S.K. Holkar visited wilt-affected vineyards at Narayangaon on 10 July 2025 and advised grape growers on the management of wilt through drenching with biological formulations.
- Dr. S.D. Ramteke inspected grape plots affected by unfruitfulness in Junnar and Ambegaon blocks on 17 October 2025.
- Mr. B.B. Khade inspected vineyards affected by excess rainfall in Indapur taluka on 18 October 2025. Incidence of downy mildew, powdery mildew, anthracnose and rust was observed in different fruit crops, including grape, guava and pomegranate.

- Dr. Sujoy Saha visited vineyards affected by excess rainfall in the Sangli region on 28 November 2025 and guided grape growers on remedial measures for powdery mildew.

Laboratory visits

- Dr. Kaushik Banerjee visited the State Food Testing Laboratory, Shillong, and imparted training on pesticide residue analysis on 26 March 2025.
- Dr. Kaushik Banerjee conducted laboratory assessment of Aashvi PT LLP, Hyderabad, during 5–6 April 2025.
- Dr. Kaushik Banerjee visited FirstSource Laboratory Solutions LLP, Secunderabad, on 7 April 2025 to evaluate their grape testing facilities for export.
- Dr. Kaushik Banerjee conducted NABL assessment of the National Institute of Plant Health Management, Hyderabad, during 10–11 May 2025.
- Dr. Kaushik Banerjee visited the Pesticide Residue Laboratory of ICAR-IIHR, Bengaluru, on 7 November 2025.

Participation in Horticulture Fair/Krishi Mela/Exhibitions

ICAR-NRCG arranged stalls in different events organized in Maharashtra and Karnataka, during the year 2025. Developed technologies were displayed through posters and displayed products based on developed technologies. Important publications of NRCG were also available on stalls for sale. About two thousand one hundred visitors were benefitted by stalls of NRCG in the various exhibitions/events.



S. No.	Name of event	Place	Duration
1.	Global Krushi Mahotsav-Live Demos, Agri Exhibition & Crop Conference 2025,	KVK Narayangaon, Pune	9-12 January 2025
2.	35th Farm-Fest-cum-Flower, Fruit, and Vegetable Show, organized by the Department of Agriculture and Farmers Welfare, Puducherry	Botanical Garden, Puducherry	7-9 February 2025
3.	17th Agricultural Science Congress (ASC)	GBPUAT, Pantnagar	20 to 22 February 2025
4.	National Horticulture Fair	ICAR-IIHR, Bengaluru	27 Feb-1 March, 2025
5.	National Grape Summit-2025 organized by Bengal Chamber of Commerce, Industry and Agriculture and ICAR-NRCG	Pune	4 March 2025
6.	Annual Seminar of MRDBS at Pune	TipTop Hotel, Pune	24-27 August 2025
7.	KRISHITHON 2025	Nashik	13-17 November 2025
8.	Pragatishil Maharashtra 2025 - एक उन्नत राष्ट्र की ओर	Jalgaon	3-5 November 2025
9.	11th Indian Horticulture Congress	UAS, Bangalore	6-9 November 2025





Training and Capacity Building

Training and Capacity Building of ICAR Employees

Deputation abroad

- Dr. Kaushik Banerjee participated in the workshop “Mancozeb Summit”, organized by UPL in partnership with the Centre of Excellence for Regulatory Science in Agriculture at NC State University, Rothamsted Enterprises, United Kingdom, during 3–5 June 2025.
- Dr. Kaushik Banerjee participated as Lead Instructor in a capacity-building programme organized by the United Nations Development Programme and the Government of Saudi Arabia at a government laboratory of the Saudi Food and Drug Authority, Riyadh, during 21–22 July 2025.
- As part of a delegation led by the Joint Secretary (Horticulture), Department of Agriculture and Farmers Welfare, Dr. Kaushik Banerjee was deputed to the United States of America during 17–20 November 2025 for signing an MoU with the University of Arkansas and for studying the Clean Plant Programme and nursery systems.

Training acquired

- Dr. Sujoy Saha participated in the training programme on “Introduced and Emerging Pest Threats to India” organized by the National Institute of Plant Health Management, Hyderabad, during 24–26 February 2025.
- Mrs. Kavita Y. Mundankar participated in the online training programme on “IoT and IIoT Security” organized by the Indian Computer Emergency Response Team under the Ministry of Electronics and Information Technology on 21 January 2025. She also completed a six-month online training programme on “Machine Learning Specialization” through Coursera.
- Dr. Roshni R. Samarth participated in the training programme on “Analysis Tools for Association

and QTL Mapping in Fruit Crops” organized by ICAR-NRCG, Pune, during 10–14 February 2025. Dr. Roshni R. Samarth and Dr. D.N. Gawande participated in the DBT-sponsored training on “Biosecurity and Biosafety: Policies, Diagnostics, Phytosanitary Treatments and Issues” organized by ICAR-NBPGR, New Delhi, during 19–28 August 2025.

- ICAR-NRCG staff also completed various courses on the iGOT-Karmayogi platform on stress management, service rules, procurement, climate change, digital transformation, generative AI, office procedures, etc.
- Dr. N.A. Deshmukh completed GLOBALG.A.P. IFA v6 courses during 20–25 April 2025, QMS and Internal Auditor Training v6 during 18–19 June 2025, GRASP Add-on v2 during 25–26 August 2025 and SPRING Add-on v2 during 4–5 September 2025. These courses were organized by GIZ and MIDH Division, Department of Agriculture and Farmers Welfare, New Delhi, to strengthen export-oriented compliance advisory. He also participated in the Global G.A.P. Farm Mentorship Training Programme organized by MIDH, Ministry of Agriculture and Farmers Welfare, in collaboration with GIZ during 8–9 October 2025.
- Dr. Lavanya A.K. participated in the National Training on “Decoding Microbial Genomics: From Sequencing to Functional Insights” organized by ICAR-National Bureau of Agriculturally Important Microorganisms, Mau, during 18–24 December 2025.
- Shri P.S. Jagdale participated in the training programme on “Office Procedures and Noting and Drafting” organized by the Institute of Secretariat Training and Management, New Delhi, during 1–3 September 2025.
- Dr. Sharmistha Naik participated in the Value

Links 2.0 training programme organized by the Ministry of Agriculture and Farmers Welfare, MIDH Division, during 28 April–5 May 2025. She also attended the training-cum-brainstorming programme on DUS testing held at ICAR-NRCG,

Pune, during 24–27 February 2025, and the workshop on “Assessment of Grapevine Planting Material Demand and Nursery Accreditation Awareness” on 9 April 2025.

Seminar/Symposium/Conference/Meeting/Workshop attended by employees

International Seminars/Symposia/Conferences/ Webinars

Name of the scientists	Title of Seminar / Symposium / Conference	Period	Organizer and place
Dr. Kaushik Banerjee	MISSION 2047: MIONP - Make India Organic, Natural & Profitable, an International Conference and Workshop	19/03/2025	NASC Complex, New Delhi
Dr. Kaushik Banerjee	The 2025 AOAC International Annual Meeting & Exposition	23/08/2025 to 28/08/2025	AOAC International (Online)
Dr. A.K. Sharma	Global Conference: Innovations to Impact'	08/03/2025 to 10/03/2025	ICAR-CIWA, Bhubaneswar
Dr. A.K. Sharma	7th International Symposium on Innovative Global Technology Trends	20/03/2025	SOFT, MITADT, Pune
Dr. Roshni R. Samarth	11th International conference on 'Recent Advances in Agricultural, Biological & Applied Sciences for Eco-Friendly Development'	25/07/2025 to 27/07/2025	CIHG, Palampur; CAU, Pasighat; MDU, Dehradun and AEDS, Rampur
Dr. Lavanya A.K.	International Conference on Sustainable Innovations in Agriculture, Veterinary and Allied Sciences (SIAVAS-2025)	29/12/2025 to 31/12/2025	UAS, Raichur and NADCL Baramulla held at UAS, Raichur

National Seminars / Symposia / Conferences / Webinars

During 2025, scientists of ICAR-NRCG participated in 20 national seminars, symposia, conferences and webinars organized by ICAR, FSSAI, NABL, CII, agricultural universities, scientific societies and industry bodies.

- Dr. Kaushik Banerjee participated in the technical seminar “Hive to Home: Building a Scientific and Sustainable Honey Industry” on 29 January 2025; National Stakeholder Consultation on Challenges in Monitoring Pesticide Residues in Food Commodities on 13 February 2025; XII Group Discussion of ICAR-AICRP on Fruits on 14 February 2025; AIM B2B Conclave 2025 on 3 March 2025; Regional Stakeholder Conclave on Food Safety on 27 March 2025; Annual Meet of

Vice-Chancellors of Agricultural Universities and Directors' Conference of ICAR Institutes on 20 May 2025; Soluble and Organic Fertilizer, Micronutrients and Stimulants Conference on 3 July 2025; National Seminar on Advanced Technologies of Sugarcane Production in Relation to Climate Resilience on 31 July 2025; CII-FSSAI State Connect on 12 September 2025; Global Food Regulators Summit on 26 September 2025; Stakeholder Consultation on Speciality Crop Protection on 9 October 2025; and the webinar “The Future of Mancozeb: Science, Stewardship and Food Security” on 14 October 2025.

- Dr. Kaushik Banerjee, Dr. Sujoy Saha, Dr. A.K. Sharma, Dr. N.A. Deshmukh and Dr. Sharmistha Naik participated in the National Grape Summit, “From Vines to Value: Transforming the Grape

Industry”, held on 4 March 2025 at Pune. Dr. Kaushik Banerjee, Dr. A.K. Upadhyay and Dr. A.K. Sharma participated in the National Seminar on “Recent Trends in Production and Processing of Grapes for Raisin” held on 27 July 2025 at Vijayapur, Karnataka. Dr. Kaushik Banerjee and Dr. N.A. Deshmukh participated in the 9th PTP RMP Conclave 2025 held during 21–22 August 2025 at Chandigarh. Dr. Kaushik Banerjee, Dr. Anuradha Upadhyay, Dr. A.K. Upadhyay and Dr. A.K. Sharma participated in the 11th Indian Horticulture Congress on “Horticulture for Inclusive, Equitable and Sustainable Growth” held during 6–9 November 2025 at Bengaluru.

- Dr. A.K. Upadhyay participated in the National Seminar on “Recent Advances in Micronutrient Research in Horticultural Crops in India” on 11 August 2025 at Pune. Dr. N.A. Deshmukh participated in the National Seminar on “Progressive Agriculture – Viksit Bharat: Preparedness for Eastern Region (PAVER-2025)” held during 21–23 February 2025.
- Dr. Dhananjay Gawande attended the Orientation Workshop on Mission Karmayogi organized by DARE/ICAR for HRD Nodal Officers at NASC Complex, New Delhi, on 27 February 2025. He also attended the National Workshop on IPR titled “From Ideas to Assets: Demystifying IPR for Innovators” on 25 July 2025. Further, he participated in a brainstorming session on “Draft Seed Bill-2025: Impact and Opportunities for Floriculture Sector” organized by ICAR-Directorate of Floricultural Research, Pune, on 10 December 2025.
- Dr. Sharmistha Naik participated in Nourish India 2025 – Food Safety and Security Leadership Summit, organized by ICAR-NRCG and the Bengal Chamber of Commerce and Industry at India Habitat Centre, New Delhi, on 20 November 2025; the 3rd Global Food Regulators Summit, organized by FSSAI, New Delhi, during 26–27 September 2025; and the National Workshop on “Evolving a Traceability Framework for the Fisheries Value Chain”, organized by ICAR-CIFT at ICAR-CIFT, Cochin, on 26 June 2025.

These participations contributed to professional capacity building and strengthened the institute’s engagement in grape production, food safety, pesticide residue monitoring, horticultural

development, regulatory compliance, export facilitation and stakeholder-oriented research.

Papers Presented at Symposia / Workshops / Meetings

I. International

Oral presentation:

1. Sharma A.K. Support of ABI Draksha to women led startups. Oral presentation in ‘Global Conference: Innovations to Impact’, organized by ICAR-CIWA, Bhubaneswar during March 8-10, 2025.
2. Roshni R. Samarth, Anuradha Upadhyay, Vidya Mane¹, Madhavi Khapare, Komal Thorat (2025). ‘Manjari Madhura’, a new promising grape hybrid for table and raisin purpose. 11th International conference on ‘Recent Advances in Agricultural, Biological & Applied Sciences for Eco-Friendly Development’ organized by Centre for Indian Himalayan Grasslands, Palampur; College of Horticulture and Forestry Central Agricultural University, Pasighat; School of Agriculture and Technology Maya Devi University, Dehradun and Agro Environmental Development Society, Rampur during 25-27 July, 2025.

Poster presentation:

3. Samiksha R. Chavhan, Komal D. Thorat, Aishwarya Pardhi, Roshni R. Samarth, Prashant H. Nikumbhe and Anuradha Upadhyay (2025). “Effect of population size and marker density on genomic prediction accuracy in grape (*Vitis vinifera* L.)” in the theme of Horticulture and Tree Physiology in the 6th International conference on Plant Physiology held during 15-18 December, 2025 jointly organized by TNAU, Coimbatore and Indian Society of Plant Physiology, New Delhi.

II. National

Oral presentation:

1. Deshmukh N.A. 2025. Advancing Viticulture-Wine & Grape-Tourism. Oral presentation (in) National Grape Summit 2025 organised by Bengal Chamber of Commerce and Industry and ICAR-National Research Centre for Grapes at Pune on 4th March 2025.
2. Deshmukh N.A. 2025. Expanding export horizons of horticultural crops: A success story of food safety traceability system in grapes. Oral

- presentation (in) National Seminar entitled “Progressive Agriculture - Viksit Bharat: Preparedness for Eastern Region (PAVER-2025)” at the ICAR-Research Complex for Eastern Region (ICAR-RCER), Patna and Indian Society of Agronomy (ISA), BAU Chapter, Sabour during February 21-23, 2025.
3. Thorat K.D, R M Devarumath and Anuradha Upadhyay (2025) Expression analysis of candidate genes for berry size in grape (*Vitis vinifera* L.) Presented at 6th international conference on plant physiology held at TNAU during 15-18th December 2025.
 4. Samiksha R. Chavhan, Komal D. Thorat, Aishwarya Pardhi, Roshni R. Samarth, Prashant H. Nikumbhe and Anuradha Upadhyay (2025). Effect of Population Size and Marker Density on Genomic Prediction Accuracy in Grape (*Vitis vinifera* L.). Presented at 6th international conference on plant physiology held at TNAU during 15-18th December 2025.
 5. Upadhyay A.K. Oral talk on ‘Adaptive Strategies for Nutrient and Water Management in Grapevines in India amidst Climate Change’. In 11th Indian Horticulture Congress-2025 ‘Horticulture for Inclusive, Equitable and Sustainable Growth’ during 6-9th November 2025.
 6. Sharma A.K. Oral presentation on ‘Processability of grape varieties: Tapping the untapped potential’ in the technical session on ‘Breeding horticulture crops and plant variety protection’. In 11th Indian Horticulture Congress-2025 ‘Horticulture for Inclusive, Equitable and Sustainable Growth’ during 6-9th November 2025.
 7. Saha Sujoy. National conference on Emerging Issues and sustainable strategies in Plant Health management: A global perspective. 19-21 January 2025, Nagpur, Maharashtra, India.
 8. Saha Sujoy. National Grapes Summit 2025 on NRCG’S contribution in implementing GAP at Pune on 4th March 2025.
 9. Vashisht, A., Tekade, I., Shah, J., Sawarn, A., Yadav, D. S., Sontakke, P., & Patil, R. (2025). Effective segmentation of grape leaves using Segment Anything Model-2. Proceedings of the Ninth International Conference on Smart Trends in Computing and Communications. 29-31 January 2025, SmartCom - 2025 - Pune, India.
- ### Poster presentation
1. Yadav DS and Banerjee Kaushik (2025). Advancements in Digital Viticulture through Decision Support System, AI-Driven Stress Identification and Smart Monitoring. National Conference on Digital Technologies for Transforming the Horticulture Sector, 28-30 Jan 2025, New Delhi.
- ### Workshops / Meetings
- ICAR-NRCG scientists and staff participated in 101 workshops and meetings related to research, policy, regulatory, institutional and stakeholder matters. The participating employees were Dr. Kaushik Banerjee, Dr. Anuradha Upadhyay, Dr. A.K. Upadhyay, Dr. Sujoy Saha, Dr. A.K. Sharma, Dr. S.D. Ramteke, Dr. N.A. Deshmukh, Dr. Roshni R. Samarth, Dr. Lavanya A.K., Dr. Dhananjay Gawande and Ms. Shailaja V. Satam. These engagements covered the Clean Plant Programme, CPC planning, AICRP-Fruits, FSSAI and NABL scientific panels, pesticide residue monitoring, traceability, grape value chain development, nursery systems, plant metabolomics, smart pesticide management, agri-startups, IPR, DUS testing, biotechnology safety, ABI activities, collaborative research projects, and stakeholder consultation on transforming food, land and water systems to combat the climate crisis.





Training and Capacity Building Programmes Organized for Other Stakeholders

Training Programmes Organised

For grape growers and export stakeholders

- ICAR-NRCG collaborated with the Directorate of Marketing and Inspection (DMI), Government of India, in a training programme on “Grading and Marking of Fruits and Vegetables under Agmark for Exports to European Union Countries”, organized at Navi Mumbai on 11 February 2025. Dr. N.A. Deshmukh highlighted the role of the National Referral Laboratory in residue monitoring and sensitized participants on revised maturity standards for early-season export grapes. The revision of TSS and TSS ratio standards by DMI, based on ICAR-NRCG’s technical inputs, facilitated export of early-harvest grapes during 2024 and 2025.
- The National Referral Laboratory of ICAR-NRCG also organized a training programme on “Pre-harvest Sampling of Grapes for Pesticide Residue Analysis and Field Demonstration” on 17 February 2025 at NHRDF, Nashik, as per APEDA GrapeNet guidelines. More than 110 samplers from 20 nominated laboratories participated. The statistically validated sampling procedure was demonstrated in a grower’s vineyard, and its role in minimizing laboratory-to-laboratory variation in pesticide residue analysis was emphasized.

For technical personnel

S. No.	Training programme	Duration	Participants	Coordinator / Programme Director
1	Proficiency testing programme in peanut homogenate for aflatoxin analysis	5 December 2024 -7 February 2025	63 laboratories	Dr. Ahammed Shabeer T.P.
2	ICAR-approved training programme on analysis tools for association mapping and QTL mapping in fruit crops	24–28 February 2025	29 participants from 12 ICAR and 2 non-ICAR institutes	Dr. Anuradha Upadhyay
3	Training programme on implementation of ISO/IEC 17043 and ISO 13528	15-17 April 2025	-	Dr. N.A. Deshmukh
4	Protection technologies and residue management in grapevines for quality grape production	7-8 July 2025	20 officials of New Gen Crop Solutions Pvt. Ltd.	Dr. A.K. Sharma and Dr. D.S. Yadav
5	Production technologies for improving grapevine productivity for resource persons of Bayer CropScience Ltd.	18-19 August 2025	50 participants	Dr. Anuradha Upadhyay and Dr. S.K. Holkar
6	Training programme on grape physiology, nutrition and biologicals	18-19 September 2025	20 officials of Corteva Agriscience India Pvt. Ltd.	Dr. Sujoy Saha, Dr. P.H. Nikumbhe and Dr. Sharmistha Naik

S. No.	Training programme	Duration	Participants	Coordinator / Programme Director
7	Proficiency testing programme for pesticide residue analysis in apple homogenate	25 July-31 October 2025	40 laboratories	Dr. N.A. Deshmukh and Dr. Sharmistha Naik
8	Proficiency testing programme for pesticide residue analysis in grapes	1 October - 31 December 2025	50 laboratories	Dr. N.A. Deshmukh and Dr. Sharmistha Naik
9	Training on 'Grape Variety Protection'	24 to 27.02.2025	ICAR-NRCG scientist	Dr. Dhananjay Gawande and Dr. Roshni Samarth

Training Imparted as Resource Persons

ICAR-NRCG scientists served as resource persons in several academic, training and capacity-building programmes during 2025. Scientists contributed to the viticulture course of the M.Sc. (Wine Brewing and Alcohol Technology) programme of Pune University, offered through Vasantdada Sugar Institute, Pune, by conducting lectures, practical sessions, examinations, student presentations and assignment assessments. Dr. Kaushik Banerjee served as resource person in the FSSAI training programme on “Rapid Analytical Food Testing” at New Delhi on 2 July 2025 and as lead instructor in a UNDP–Government of Saudi Arabia capacity-building programme at the Saudi Food and Drug Authority laboratory, Riyadh, during 21–22 July 2025.

- Dr. A.K. Upadhyay guided farmers on “Plastic Cover for Grape Crop” in an MIDH–National Horticulture Mission training programme at the Pomegranate Research Centre, Lakhmapur, Nashik, on 6 January 2025. Dr. A.K. Sharma delivered a lecture on “Support of ABI Draksha to the Startup Ecosystem” during the 21-day Summer School Programme for agri-startups organized by ICAR-DOGR, Pune, during 6–26 March 2025, and mentored seven RAWE students from the College of Agriculture, Baramati, on 19 August 2025. Mrs. Kavita Y. Mundankar delivered lectures for the Agri-Informatics course of B.Sc. (Agriculture) Honours at the IARI-NIASM Baramati Hub during 2024–25.
- Dr. Roshni R. Samarth delivered a lecture on “Innovative Approaches in Grape Breeding” for Ph.D. students of IARI-IIHR and also taught “Wide Hybridization and Pre-breeding”,

“Polyploidy in Relation to Plant Breeding” and “Maintenance of Breeding Records and Data Collection” under the IARI-NIASM Baramati Hub. Dr. N.A. Deshmukh delivered a lead talk on “Good Agricultural Practices for Food Quality and Safety Improvement” in a capacity-building programme on regulatory compliance in agri-food sectors at Rani Lakshmi Bai Central Agricultural University, Jhansi, on 18 March 2025.

- Dr. Dhananjay Gawande coordinated a five-day RAWE training-cum-attachment programme for B.Sc. (Agri.) students of the College of Agriculture, Baramati, at ICAR-NRCG, Pune, during 18–22 August 2025; organized an exposure visit of technical staff to John Deere Tractor Ltd., Pune, on 6 August 2025; organized an awareness programme on “Seed Bank to Preserve Indigenous Crop Varieties” at Rahuri Bk., Ahilyanagar, on 6 November 2025 under Jan Jatiya Gaurav Varsh Pakhwada; conducted an on-site DUS testing visit at a farmer’s field in Sangli on 17 January 2025 along with the DUS Nodal Officer; and served as Observer for the CBT Combined NET-2025 and preliminary examination for ARS, SMS (T6) and STO (T6) at Pune during 12–13 November 2025. Dr. Sharmistha Naik provided technical support to officials of the Central/Referral Food Laboratory, Pune, for establishing an organic testing facility during their visit to ICAR-NRCG on 11–12 November 2025.
- Dr. Sharmistha Naik served as the resource person and delivered lectures on “Post-harvest Handling Practices in Grapes” on 8 July 2025 during the training programme on “Protection Technologies and Residue Management in Grapevine for

Quality Grape Production”, and on “Grape Phenology and Growth Stages” on 19 September 2025 during the training programme on “Grape Physiology, Nutrition and Biologicals”, organized by ICAR-NRCG for Corteva Agriscience Limited.

Guiding Doctoral, Post-graduate and Under-graduate Students

Ph.D. Students

During the year, ICAR-NRCG provided doctoral research guidance to one Ph.D. student. Dr. Sharmistha Naik guided Ms. Chandni Rajkumar Jiwtani from Rajiv Gandhi Institute of IT and Biotechnology, Bharati Vidyapeeth Deemed University, Pune, for the project entitled “Profiling and Extraction of Secondary Metabolites in Grapes Using Advanced Analytical Techniques”. The project duration is from 1 April 2025 to 31 March 2028.

Post-graduate and Under-graduate Students

During the year, scientists of ICAR-NRCG guided 68 post-graduate and under-graduate students from different agricultural, biotechnology and science institutions. The student projects covered diverse areas such as grape rootstock characterization, molecular marker development, *in vitro* regeneration and micropropagation, somatic embryogenesis, tissue culture, winemaking, grape fermentation, grapevine-associated microbes, biocontrol potential, pesticide residue analysis, nano-formulations, patent analysis, plant breeding, grape diseases, rootstock physiology and fruit quality improvement.

- Dr. R.G. Somkuwar guided a project on morphological and physicochemical characterization of grape rootstock cuttings. Dr. Anuradha Upadhyay guided work on molecular markers for berry traits in grape. Dr. S.D. Ramteke

guided projects on *in vitro* regeneration, shoot induction, micropropagation and use of plant growth regulators in different grape varieties and rootstocks. Dr. A.K. Sharma guided students on winemaking, grape fermentation and wine quality.

- Dr. Sujoy Saha guided projects on nano-formulations, antimicrobial resistance, plasmid profiling and grapevine-associated microbes. Mrs. Kavita Y. Mundankar guided a project on patent analysis and patentability related to ICAR-NRCG technologies. Dr. Roshni R. Samarth guided projects on *in vitro* multiplication, somatic embryogenesis, callus induction and plant breeding-related aspects in grapes.
- Dr. Ahammed Shabeer T.P. guided projects on phytochemical extraction from agrowaste and pesticide residue transfer from grapes to raisins. Dr. S.K. Holkar guided projects on grape pathogens, berry spot, trunk diseases, endophytes and field evaluation of *Trichoderma* isolates. Dr. D.N. Gawande guided students on hybridization and tissue culture techniques in grapes. Dr. P.H. Nikumbhe guided projects on rootstock enzymatic activities, leaf removal, berry thinning and rooting behaviour of grape rootstocks. Dr. Sharmistha Naik guided projects on tissue culture, callus induction, somatic embryogenesis, low-input-cost media, microbial contamination, direct organogenesis, pesticide residue extraction methods and cell suspension culture in grapes.

Overall, the guidance provided by ICAR-NRCG scientists strengthened student capacity in viticulture science, biotechnology, plant protection, post-harvest processing, residue analysis and allied areas.





Awards and Recognitions

Awards

- ICAR-NRCG secured the highest rank in centre performance, without staff-position marks, with a score of 91.94/100 during the XII Group Discussion of ICAR-AICRP on Fruits held at Bihar Agricultural University, Sabour, during 11-14 February 2025.
- Dr. Kaushik Banerjee, Director, ICAR-NRCG, received the CHAI-Padma Bhushan Dr. R.S. Paroda Award 2025 for excellence in research on residue-management technologies for safe fruits.
- Dr. Roshni R. Samarth won two gold medals in the 100 m and 200 m races, and a silver medal in women's singles badminton, at the ICAR West Zone Sports Tournament held at ICAR-CICR, Nagpur, during 1-4 February 2025.
- Dr. Roshni R. Samarth won a bronze medal in the women's 100 m race at the ICAR Inter-Zonal Sports Tournament held at Lucknow during 4-7 November 2025.
- Dr. Lavanya A.K. received the Young Scientist Award in Agricultural Microbiology at the International Conference SIAVAS-2025 at UAS, Raichur held during 29-31 December 2025.
- Dr. Lavanya A.K. received Certificates of Excellence in Reviewing from the Journal of Advances in Biology & Biotechnology and the International Journal of Environment and Climate Change for the academic year 2025–26.
- The paper entitled “Horticulture for Inclusive, Equitable and Sustainable Growth” by Dr. A.K. Upadhyay received the Best Oral Paper Presentation Award in the faculty category at the 11th Indian Horticulture Congress 2025.
- The paper entitled “Expanding Export Horizons of Horticultural Crops: A Success Story of Food Safety Traceability System in Grapes” by N.A. Deshmukh, S.C. Ekatpure, B.S. Taynath and K.

Banerjee received the Best Oral Presentation Award at National Seminar PAVER-2025 held at ICAR-RCER, Patna during 21-23 February 2025.

- Dr. Kaushik Banerjee and Dr. Sharmistha Naik received a Certificate of Appreciation from the Director of Horticulture, Kashmir, Government of Jammu and Kashmir, for conducting a series of training programmes on expansion and development of grape cultivation in Jammu and Kashmir.

Recognitions and Invited Roles

- Dr. Kaushik Banerjee participated as Guest of Honour in the AIM B2B Conclave 2025 organized by the Agro Input Manufacturers Association on 3 March 2025.
- Dr. Kaushik Banerjee participated as Guest of Honour in “Mission 2047: MIONP – Make India Organic, Natural and Profitable”, an International Conference and Workshop held at NASC Complex, New Delhi on 19 March 2025.
- Dr. Kaushik Banerjee participated as Guest of Honour in the Eighth Institute Foundation Day programme of ICAR-ATARI, Pune on 3 April 2025.

Chairperson / Moderator / Panelist in Technical Sessions

- Dr. Kaushik Banerjee participated as Chief Moderator for the technical seminar “Hive to Home: Building a Scientific and Sustainable Honey Industry”, organized by the National Institute of Food Technology Entrepreneurship and Management, Kundli, at India International Centre, New Delhi, on 29 January 2025.
- Dr. Kaushik Banerjee chaired the technical session on “Grape Processing for Raisin Production” during the National Seminar on “Recent Trends in Production and Processing of Grapes for Raisin”, organized by the Grape Growers Federation of



India in collaboration with the Karnataka Grape Growers' Association, on 27 July 2025 at Vijayapura, Karnataka.

- Dr. Kaushik Banerjee co-chaired the technical session on "Sugarcane Crop Protection" during the National Seminar on "Advanced Technologies of Sugarcane Production in Relation to Climate Resilience", organized by VSI, Pune on 31 July 2025.
- Dr. A.K. Sharma chaired the session on "Transforming Agri-Food Value Chains: Digital Innovation, Sustainability and Global Collaboration" during the 7th International Symposium on Innovative Global Technology Trends organized by SOFT, MIT-ADT University, Pune on 20 March 2025.
- Dr. N.A. Deshmukh was nominated as Theme Presenter and Panelist for Technical Session IV, "Advancing Viticulture: Wine and Grape Tourism", during the National Grape Summit 2025 organized by the BCCI and ICAR-NRCG on 4 March 2025 at Hotel Amanora, Pune.
- Dr. Sharmistha Naik served as a panellist in the session on "Unlocking Sectoral Opportunities: Boosting Domestic and Export Markets" during Nourish India 2025 – Food Safety and Security Leadership Summit, organized by the Bengal Chamber of Commerce and Industry and ICAR-National Research Centre for Grapes, Pune, at New Delhi on 20 November 2025.

Invited/lead/keynote lectures

- Dr. Kaushik Banerjee delivered a keynote lecture at the National Conference on "Digital Technologies for Transforming the Horticultural Sector" held at ICAR-IARI, New Delhi, on 29 January 2025.
- Dr. Kaushik Banerjee delivered the inaugural lecture at the II National Workshop on "Plant Metabolomics: From Sample Preparation to Data Analysis" held at the School of Life Sciences, University of Hyderabad, Hyderabad, on 3 February 2025.
- Dr. Kaushik Banerjee delivered a guest lecture on "Evolution of Multi-residue Methods for Pesticide Analysis Using GC-MS and LC-MS" in the workshop on "Applications of Advanced Analytical Techniques in Research and Industry" held at IIT Bombay, Mumbai, on 19 February 2025.
- Dr. Kaushik Banerjee delivered a lecture on "Export Facilitation of Table Grapes by On-farm Pesticide Management: A Holistic Approach" in the workshop on "Smart Pesticide Management" held at Jadavpur University, Kolkata, on 24 February 2025.
- Dr. Kaushik Banerjee delivered an online lecture entitled "Research and Development on Pesticide Residue Analysis and Farm-to-Table Approach" in the NCPAC Conference held at the National Institute of Plant Health Management, Hyderabad, on 6 March 2025.
- Dr. Kaushik Banerjee delivered an invited talk on "Promotion of Pomegranate and Grape Export through Residue Management" in the Stakeholders' Meet on Production, Value Addition and Export of High-Value Horticulture Crops held at NASC Complex, New Delhi, on 20 March 2025.
- Dr. Kaushik Banerjee delivered an invited lecture on "Evolution of Pesticide Residue Analysis Methods for Organic Food in India" at the Regional Stakeholder Conclave on Food Safety held at Shillong on 27 March 2025.
- Dr. Kaushik Banerjee delivered a keynote address on "APEDA-NRL's Contribution to Traceability Standards for Plant-Origin Products" at the National Workshop on Evolving a Traceability Framework for the Fisheries Value Chain held at ICAR-CIFT, Cochin, on 26 June 2025.
- Dr. Kaushik Banerjee was invited as the Chief Guest for the inaugural function of the One District One Product (ODOP) national webinar on "Grapes Processing and Value Addition" held by the National Institute of Food Technology, Entrepreneurship and Management, Thanjavur, on 30 July 2025.
- Dr. A.K. Upadhyay delivered an expert talk on "Decision Support System-based Smart Viticulture" in a workshop held at IISER Pune on 10 March 2025.
- Dr. A.K. Upadhyay participated in the National Seminar on "Recent Advances in Micronutrient Research in Horticultural Crops in India" on 11 August 2025 and delivered a lecture on "Trends in Micronutrient Usage in Grapes".

- Dr. Sujoy Saha delivered a lead lecture on “Eco-friendly Shields: Bio-intensive Strategies for Grape Disease Management” in the National Conference on “Emerging Issues and Sustainable Strategies in Plant Health Management: A Global Perspective” held during 19-21 January 2025.
- Dr. N.A. Deshmukh delivered an invited talk on Good Agricultural Practices for promoting the safe use of pesticides in the GLOBALG.A.P. Orientation Workshop for SMART Departments, Government of Maharashtra, held at Pune on 14 July 2025.
- Dr. A.K. Upadhyay delivered an invited talk on “OMICS Approaches for Improvement of Fruit Crops” at “AgriHub: One-day Industry-Academia Workshop on Research Innovation for Commercialization” held at IISER Pune on 10 March 2025.
- Samiksha Chavhan, Komal D. Chavan, Rivi Verma, Kashmir Singh, Amit Kumar Goswami, Chavlesh Kumar, Anju Bajpai, Dr. Roshni R. Samarth and Dr. Anuradha Upadhyay delivered a lead presentation on “Harnessing Genomic Selection for Superior Fruit Varieties: Case Studies” in the 11th Indian Horticulture Congress 2025 on “Horticulture for Inclusive, Equitable and Sustainable Growth” held at the University of Agricultural Sciences, Bengaluru, during 6–9 November 2025.
- Dr. A.K. Sharma delivered a lecture on “ICAR-NRCG’s Contributions in Promoting Agribusiness of Grapes” in the National Grape Summit, “From Vines to Value: Transforming the Grape Industry”, held at Pune on 4 March 2025.
- Dr. A.K. Sharma delivered a lecture on “Appraisal on Package of Practices of Raisins” in the National Seminar on “Recent Trends in Production and Processing of Grapes for Raisin” held at Vijayapur, Karnataka, on 27 July 2025.
- Dr. D.S. Yadav delivered a lecture on “Precision Digital Decision Support System for Sustainable and Safe Grape Production” in the 11th Indian Horticulture Congress 2025 held at Bengaluru on 8 November 2025.
- Dr. Anuradha Upadhyay served as outside expert in the Institutional Biosafety Committee of ICAR-NIASM, Baramati; DBT nominee in the Institutional Biosafety Committee of ICAR-DOGR, Pune; Subject Expert in Biotechnology in the Departmental Promotion Committee of VNMKV, Parbhani, for promotion of Assistant/Associate Professors; and Subject Expert in Biotechnology for the CAS of scientists at CAZRI, Bikaner.
- Dr. A.K. Upadhyay was nominated by ICAR as Expert in the assessment for CAS of scientist for promotion at ICAR-CIAH, Bikaner, on 3 February 2025. He also served as a member of the Maharashtra State Level Committee for Grape Cover Technology and visited grape growers in Nashik district on 4 December 2025 to recommend inclusions in the items to be covered under plastic-cover subsidy for grape growers.
- Dr. A.K. Sharma served as Member of the Institute Management Committee of ICAR-ATARI, Pune; panel member for conducting CAS interviews at MIT Art, Design and Technology University, Pune; and Member of RAC of MRDBS.
- Dr. Roshni R. Samarth served as Chairperson of the question-bank preparation committee for the ninth semester course Genetics (24BBT201) of MIT-ADT University, Pune; and Chairperson of the question-bank preparation committee for the ninth semester course Agribiotechnology (211MBT901) of MIT-ADT University, Pune.
- Dr. N.A. Deshmukh served as Chairman of the crop-specific sub-committee on grapes for the Restructured Weather-Based Crop Insurance Scheme. He also served as Member of the State Level Horticulture Traceability Review Committee, Department of Horticulture, Government of Maharashtra.

Membership of Committees

- Dr. Kaushik Banerjee served as ICAR Representative on the Executive Council of Vasantrao Naik Marathwada Krishi Vidyapeeth,

Linkages and Collaboration Including Externally Funded Projects

Collaboration and Externally funded projects

- i. National Referral or Reference Laboratory for control of pesticide residues and mycotoxins in products of plant origin (APEDA funded)
- ii. National Reference Laboratory Scheme (FSSAI funded)
- iii. Developing genomic selection strategy for accelerating breeding programme in perennial fruit crops grape, guava and mango (NASF funded in collaboration with ICAR-IARI, New Delhi and ICAR-CISH, Lucknow)
- iv. Validation of DUS descriptors for Indian Grapes (*Vitis* spp.) (PPVFRA funded)
- v. Agri CRP on Water- IoT Enabled Sensor Based Smart Irrigation Management System (ICAR funded in collaboration with MPKV Rahuri, ICAR-NRCG, ICAR-IIHR and ICAR-IIWM)
- vi. IoT-based Vineyard monitoring system for Micro-climate and Soil moisture Sensing system (DST funded)
- vii. Development and evaluation of robotic harvester for grape bunches (ICAR-NASF funded)
- viii. Clean Plant Programme for Grapes (ADB funded)
- ix. Hazard analysis of grapevine under the Clean Plant Programme (NHB funded)
- x. Impact assessment of grapevine viruses on yield and quality of grape production (MIDH funded)
- xi. A detailed Foodomics study for food authentication and exploration of nutraceutical potential (NASF funded)
- xii. Intellectual Property Management and Transfer / Commercialization of Agricultural Technology (ICAR-NAIF Scheme)
- xiii. Agri-Business Incubation (ABI) Centre Component-II of the XII Plan 'National Agriculture Innovation Fund (NAIF)'
- xiv. Automated monitoring and advisory system for intelligent viticulture (Collaboration with MIT-ADT University, Pune & IIT-TIH, Mumbai)

MoU/MoA signed

Sl. No.	Title	MoA / MoU	Collaborating Institute	Signed on date
I. MoA/MoU Signed for Transfer of Technology				
1.	Commercialization of Decision Support System Application Programming Interface for (i) Nutrient and water management (ii) Disease risk assessment and advisory (iii) Insect and mite pest risk assessment and advisory	Technology License Agreement	Agripilot Tech. Pvt. Ltd., Nagpur	25.02.2025
2.	For distribution of revenue from commercialized Technology 'Decision Support System for Grapes'	MoA	Shivrai Technologies Pvt. Ltd., Pune	28.08.2025
3.	Technical support for preservation of product (verjuice) as well as product validation, capacity building, assisting in marketing linkage and promotion	MoA	Rajyog Agro	17.01.2025

Sl. No.	Title	MoA / MoU	Collaborating Institute	Signed on date
4.	Technical support for preservation of product as well as product validation, capacity building, assisting in marketing linkage and promotion	MoA	One Stop Digital Agrisolutions Pvt Ltd	17.01.2025
5.	Collaborative capacity building of stakeholders of the grapes' value chain	MoU	Indo Fruits Development Council, Pune	07.02.2025
6.	Collaborative promotion of grape cultivation and capacity building in UT of Jammu & Kashmir	MoU	Department of Horticulture, Kashmir Division	21.04.2025
II. MoA/MoU signed for Collaborative research				
7.	Collaboration on organizing 'Proficiency Testing program in Sampling of Food, Training and Sustainability'	MoA	Green Economy Initiatives Pvt. Ltd., Mohali	31.07.2025
8.	Collaborative research in method development for agro-chemical residues and contaminants, including methods for the analysis of MOSH and MOAH in food commodities.	MoU	SGS India Private Limited, Mumbai	04.07.2025
9.	Collaborative research for method development towards honey authentication using LC-HRMS techniques for identification of adulteration in honey.	MoA	Dabur India Limited, New Delhi	07.07.2025
10.	Training, development of advanced analytical methods and serve as industry interface – technical resource in food industry	MoA	Agilent Technologies India Pvt. Ltd., New Delhi and Peak Scientific Instruments India Pvt. Ltd., New Delhi	08.09.2025
III. MoU signed for Contract Research				
11.	Contract Research Project 'To evaluate bio-efficacy and phytotoxicity of FF2101 against powdery of grapes for first season'. (CR22/2024-25)	MoA	FMC India Private Limited	23.04.2025
12.	Contract Research Project 'To evaluate the bio-efficacy and phytotoxicity of IIF 123 against downy mildew disease in grapes after fruit pruning for first season'. (CR13/2023-24)	MoA	Indofil Industries Limited	04.06.2025
IV. MoU signed with Universities / Institutes for facilitating Students' Training/Postgraduate Research				
13.	For facilitating students' training/postgraduate research	MoU	Annasaheb Magar Mahavidyalaya, Pune	29.04.2025
14.	For facilitating students' training/postgraduate research	MoU	Dr. Vishwanath Karad MIT World Peace University, Pune	07.05.2025
V. CSR Activities				
15.	Provision of Corporate Social Responsibility (CSR) Contribution in connection with Project on "Diversification of Horticulture / Agriculture Ecosystem by Including Viticulture for Nutritional and Economic Security of Economically Challenged Farmers	Letter of Agreement	Indofil Industries Limited	18.09.2025



Publications



Research papers

1. Deshmukh NA, Patil NM, Gat SD, Takale SR, Nikumbhe PH, Ramteke SD, Langote AR, Banerjee K. 2025. Photosynthetic performance of grape varieties in the tropical climate of India. *Vitis* 64, Art. 19, 13 pp. <https://doi.org/10.5073/vitis.2025.64.19>.
2. Deshmukh NA, Ekatpure S, Taynath B, Gavali AH, Ramteke SD, Bhagwat SR and Banerjee K. 2025. Establishing good agricultural practices for the use of Chloromequat Chloride in grapes to improve vine vigour, fruitfulness, and revision of MRL. *South African Journal of Enology and Viticulture*, 46, 113–121. <https://doi.org/10.21548/46-6926>
3. Natta S, Shaikh N, Sachin E, Kassouf A, Deshmukh N, Das SP, Banerjee K. 2025. Unfolding the nutraceutical potentials of *Dendrobium nobile* Lindl orchid flowers based on their color variation: a high-resolution mass spectrometry-based untargeted metabolomics study. *J AOAC Int.* 19:qsaf025. doi: 10.1093/jaoacint/qsaf025. Epub ahead of print. PMID: 40106708.
4. Deshmukh NA, Gat S D, Takale S R, Sinhasane S R, Nikumbhe P H and Somkuwar R G 2025. Study on the effect of different rootstocks on cane biochemical composition in grape varieties The Indian Journal of Agricultural Sciences 95 (5): 547–553, <https://doi.org/10.56093/ijas.v95i5.153549>
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8. Dhananjay N. Gawande and Prashant Nikumbhe. 2025. Cultivating Innovation: The role of Indian grape growers in grape breeding. *International journal of Advanced Biochemistry Research*. Vol. 9, Issue 7, pg. 856-860.
9. Mahesh S, Shabeer ATP, Haldankar P, Kadam P, Godase V, Ekatpure S, Shaikh N, Pawar CD, Dalvi V, Kasture M and Sawant S. 2025. Assessment of kokum (*Garcinia indica* Choisy) germplasm for its nutraceutical potential with special emphasis on anthocyanins by LC-Orbitrap-MS analysis. *Journal of Food Composition and Analysis*, 140: 107257. <https://doi.org/10.1016/j.jfca.2025.107257>
10. Somnath Kadappa Holkar, Sagar B. Bhondave, Sakshi J. Patil, Shweta C. Nanekar, Rushikesh K. Bhosale, Yogesh Khade, Kiran S. Khandagale, Auji Radhakrishna, Pawan Mainkar, Sujoy Saha, and Kaushik Banerjee. 2025. First Report of *Fusarium acutatum* Causing Root Rot and Vascular Wilt Disease in Grapevine (*Vitis vinifera* L.) in India. *Plant Disease* 0 0:ja. <https://doi.org/10.1094/PDIS-03-25-0621-PDN>
11. Yadav, A., Singh, N., Bhatia, A., Varghese, E., Banerjee, K., & Khandelwal, A. 2025. Effect of biosurfactant on degradation of polyaromatic hydrocarbons in different agricultural soils under different environments. *Current Science*, 129(1).
12. Ganguly, P., & Banerjee, K. 2025. Pesticide in

- food chain: Impact and regulation. In Food Toxicity and Safety (pp. 59–76).
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 14. Athira, A. S., Nazar, N., Haridas, P. C., Panda, S. K., Banerjee, K., & Chatterjee, N. S. 2025. Comparative evaluation of large volume injection and splitless injection techniques with conventional and high throughput SPE clean-up for GC-MS/MS analysis of persistent pesticides. *Journal of Chromatography A*, 466081.
 15. Naik, S., Deshmukh, R. S., Dhawale, R. N., Patole, P. B., & Yanbhure, P. B. 2025. Optimization of Somatic Embryogenesis in a Seedless Grape Cultivar. *Journal of Advances in Biology & Biotechnology*, 28(8), 899-907
 16. Holkar, S.K., Nanekar, S.C., Bhondave, S.B., Patil, S.J., Markad, H.N., Taynath, B., Gat, S.D., Deshmukh, N.A. and Banerjee, K. 2025. Characterization of Grapevine Endophytic Microbes and Field Evaluation of Bioformulations Against Powdery Mildew Disease with Residue Compliantgrape Production. Available at SSRN 5141840.
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Meetings of QRT, RAC, IMC, IRC with Significant Decisions

Institute Research Committee meeting

The 30th meeting of the Institute Research Committee (IRC) of ICAR-NRCG, Pune, was held on 16 September 2025 under the chairmanship of Dr. Kaushik Banerjee, Director, ICAR-NRCG. Dr. M.K. Verma, Director, ICAR-Central Institute of Temperate Horticulture, Srinagar, attended the meeting as the external expert.

The committee reviewed the progress of ongoing research programmes covering germplasm management, genetic improvement, production technologies, plant protection, post-harvest processing and food safety. The progress of grape germplasm conservation and evaluation was reviewed, including the maintenance of 493 grape accessions, of which 470 were at fruiting stage. The committee noted the evaluation of accessions for key horticultural traits and pest resistance.

Under genetic improvement, the committee reviewed the progress made in the development of hybrids for loose bunches, bold berries and disease resistance. The identification of high-anthocyanin genotypes and the use of genomic tools, including SNP analysis and marker development, were also discussed. In production technology, the committee noted the

performance of rootstock-scion combinations, improvement in water-use efficiency through subsurface and IoT-based irrigation systems, and progress in tissue culture protocols for production of virus-free planting material.

In plant protection, the committee reviewed the work on biocontrol agents, botanical extracts, drone spraying and AI-based pest detection systems. Mechanization-related activities, including robotic harvesting and smart vineyard monitoring systems, were also discussed. Post-harvest research focused on value addition and nutraceutical extraction, while food safety programmes covered residue analysis protocols and metabolomics-based authentication methods.

The committee recommended that greater emphasis should be placed on extension of promising projects, commercialization of technologies, external funding and strengthening of integrated approaches in grape breeding and vineyard management. The committee appreciated the progress made by the institute and emphasized continued efforts towards sustainable, technology-driven and farmer-centric grape production.



Consultancy, Patents and Commercialization of Technology

Consultancy Projects

During January–December 2025, ICAR-NRCG undertook 24 consultancy programmes for different organizations, generating total consultancy revenue of Rs. 6.29 lakhs. The major consultancy services included online and offline demonstrations on pack-house sampling of peanut and peanut products for aflatoxin analysis, pre- and post-harvest sampling of fruits and vegetables for pesticide residue analysis, proficiency testing for sampling of peanut products and vegetables, and grape advisory services. Most consultancy programmes were handled by Dr. N.A. Deshmukh and were conducted for analytical laboratories and inspection agencies across Gujarat, Maharashtra, Tamil Nadu, Rajasthan, West Bengal and New Delhi, including Aarav Laboratory LLP, Gujarat Testlab Pvt. Ltd., Interstellar Testing Centre Pvt. Ltd., Doctors' Analytical Lab, Equinox Labs, Eurofins Analytical Services India Pvt. Ltd., Microchem Siliker Pvt. Ltd., MATS India Pvt. Ltd.,

Accurate Universal Laboratories Pvt. Ltd., VJS Phytosanitary Service Pvt. Ltd., QSS Inspection and Testing Pvt. Ltd., Vimta Labs Ltd., IRCLASS Systems & Solutions Pvt. Ltd., Dr. Amin Controllers Pvt. Ltd., QAU Inspector Krish Biotech Research Pvt. Ltd. and FICCI Research and Analysis Centre.

In addition, grape disease and insect pest management advisories were provided through audio advisories produced and broadcast by Amicus Agri Services, with Dr. Sujoy Saha and Dr. D.S. Yadav as consultants. A proficiency testing programme on sampling of peanut products for aflatoxin analysis and vegetable sampling for pesticide residue analysis was also organized for Green Economy Initiatives Pvt. Ltd. under the consultancy of Dr. Ahammed Shabeer T.P. These consultancy activities strengthened the institute's role in residue analysis, sampling quality assurance, aflatoxin monitoring and stakeholder-oriented grape advisory services.

Commercialization of Technology

Name of the technology	Firm / Client	Agreement type	Date of signing	Technology transfer cost (Rs.)
Decision Support System for Grapes	AgriPilot Tech Pvt. Ltd., Narendra Nagar, Nagpur, Maharashtra	Technology Licensing Agreement for one year	25 February 2025	1.05 lakh

Patents

Title of work	Inventor(s)	Date of filing	Application number	Status
A process for producing zinc oxide nanoparticles	Dr. Yukti Verma, Dr. Ajay Kumar Upadhyay and Dr. Ahammed Shabeer T.P.	28 March 2025	202511030115	Filed



Approved Ongoing Institute Programmes

I. Conservation, Characterization and Utilization of Grape

1. Management of grape genetic resources of table, wine, raisin, juice and rootstock varieties – Phase III

II. Genetic Improvement of Grape

2. Breeding for mildew resistance – Phase II: Evaluation of promising hybrids and gene pyramiding
3. Breeding for naturally loose bunches and bold berries in grapes
4. Genetic improvement of coloured grapes
5. Genetic improvement of grape rootstocks for drought and salinity tolerance – Phase I
6. Creating genetic and ploidy variations for desired traits in grape using physical and chemical agents
7. Evaluation of grape genotypes for processability
8. Identification and validation of candidate genes and development of functional markers for bunch and berry quality traits in grape (*Vitis vinifera* L.)
9. Development of tissue culture techniques for production of quality planting material in grape

III. Development and Refinement of Production Technologies for Enhancing Quality, Productivity and Sustainability in Grape

10. Evaluation of natural viticultural practices for production of Thompson Seedless grapes
11. An online information system for physiological disorders of grapevines under Indian agro-climatic conditions
12. Studies on estimation of light compensation and saturation points of grape varieties
13. Standardising irrigation and nutrient schedule for Crimson Seedless vines raised on Dogridge rootstock
14. Studies on canopy management practices in different grape varieties

15. Production of quality planting material of grape

16. Evaluation of rootstocks for released and commercially promising grape varieties

17. Response of grape rootstocks under moisture stress

18. Determination of salinity tolerance threshold for Thompson Seedless grafted on Dogridge, 110R and 1103P rootstocks

IV. Development and Refinement of Integrated Protection Technologies in Grape

19. Identification and characterization of fungal and bacterial endophytes from grapevines and their evaluation as biocontrol agents against major grapevine pathogens in India

20. Studies on management of major grapevine diseases using biorational chemicals, biocontrol agents, alternative chemicals and botanicals

21. Development of a bio-intensive disease management schedule for production of disease-free and residue-compliant grapes (AMAAS partially funded)

22. Integrated pest management for sustainable vineyard protection

23. Standardization and demonstration of spraying using drones in vineyards (ICAR Agri-Drone Project)

24. Automated monitoring and advisory system for intelligent viticulture

V. Food Safety in Grapes and its Processed Products

25. Phytochemical profiling and development of nutraceuticals and value-added products from grapes

26. Non-targeted impact of pesticide residues in vineyard ecosystem and its effect on grape and wine quality

Visitors



Visit of the Hon'ble Minister of Agriculture, Government of Maharashtra

Shri Manikrao Shivajirao Kokate, Hon'ble Minister of Agriculture, Government of Maharashtra, visited ICAR-NRCG on 22 January 2025. He was accompanied by Shri Kailas Bhosale, President, and Shri Abhishek Kanchan, Chairman, Central Research Committee, Maharashtra State Grape Growers' Association. Dr. Kaushik Banerjee, Director, ICAR-NRCG presented the recent achievements of the institute. During the visit, the Hon'ble Minister appreciated the institute's contributions to the grape industry, particularly in the areas of institute-developed varieties, protected cultivation, climate-resilient grape production, bio-intensive agriculture and residue-compliant grape production. He emphasized the need to expand the cultivation of 'Manjari Medika' and 'Manjari Naveen' across Maharashtra and assured support in addressing challenges related to import of patented climate-resilient grape varieties. The Hon'ble Minister also urged the institute to strengthen research on protected cultivation for mitigating climatic risks such as hailstorm damage and to organize targeted training programmes for grape growers, farmers' children and women farmers. On this occasion, he released the information brochure of ABI Draksha to support agri-startups and agro-industry stakeholders.



Visit of Secretary, MoFPI, Govt. of India

Dr. Subrata Gupta, Secretary, Ministry of Food

Processing Industries (MoFPI), Govt. of India and Shri. S. Dave, former Chairman, Codex Alimentarius Commission visited ICAR-NRCG on 4 March 2025. Dr. Kaushik Banerjee, Director briefly explained about institute's ongoing research activities, expansion of area under grape in non-traditional areas, introduction of institute's varieties in NEH region, implementation of Clean Plant Programme etc. The dignitaries also visited the National Referral Laboratory and experimental vineyards. Dr. Subrata Gupta appreciated the efforts in maintaining well-equipped National Referral Laboratory and suggested that ICAR-NRCG collaborate with the MoFPI institutes, viz., National Institute of Food Technology, Entrepreneurship and Management, in the field of grape processing. Shri. Dave recollected the memories of 2003 and felt proud of the institute's achievements so far.



Visit of Managing Director, NHB and Joint Secretary (Horticulture), MIDH

Shri Priya Ranjan, Managing Director, National Horticulture Board (NHB) and Joint Secretary (Horticulture), MIDH, Government of India, visited ICAR-NRCG, on 5 March 2025 to review preparations for establishing the Clean Plant Centre under the Clean Plant Programme. He visited the tissue culture laboratory, glasshouse and proposed GTC area, where scientists briefed him on tissue culture protocols, clean scion production, virus-free Dogridge rootstocks, hardened planting material,

hazard analysis and site suitability. He appreciated the preparatory work undertaken by ICAR-NRCG for implementation of the programme.



Visit of Hon'ble GB member of ICAR Society Padma Shri Shri Kanwal Singh Chauhan

Hon'ble GB member of ICAR Society Padma Shri Shri Kanwal Singh Chauhan ji visited the institute during June 7-9, 2025. Hon'ble GB member visited vineyards, National Active Germplasm Site for Grapes, nursery, and other available facilities like grape drying sheds, research winery, biocontrol lab, National Referral Laboratory, water storage tanks, etc. He was impressed by the ongoing research activities, technologies developed, close association with stakeholders especially grape growers and NRL activities for not only export grapes but support to other commodities as well.

Farmer Visits

During 2025, ICAR-NRCG received farmer groups and educational tour groups from different states and provided exposure to the Centre's research, field and laboratory activities. A total of 175 farmers and trainees visited the institute, including 120 farmers from Madhya Pradesh, 25 trainees from Maharashtra during January–March 2025, and 30 farmers during July–December 2025. The visits were coordinated by Dr. Prasad Sawant and Mr. B.J. Phalke. The participants were briefed on grape varieties, recommended package of practices, production of quality grapes, and important do's and don'ts in vineyard management.

Educational Tours

During the year, 2,388 students and staff members from agricultural colleges and institutions across India visited the Centre as part of educational tours. These included participants from Maharashtra, Karnataka, Tamil Nadu, Manipur, Rajasthan and Madhya Pradesh. The educational visits provided an overview of the Centre's laboratories, farm activities, ongoing research projects, vineyard establishment methods and training systems. Students were also sensitized on canopy management, irrigation and fertigation, stage-specific use of pesticides and fungicides, plant growth regulator application, raisin production and machinery used in vineyard operations.



Personnel



Research Management Personnel

1. Dr. Kaushik Banerjee, Director

Scientific

2. Dr. A. Upadhyay, Principal Scientist (Biotechnology)
3. Dr. A. K. Upadhyay, Principal Scientist (Soil Science)
4. Dr. S. D. Ramteke, Principal Scientist (Plant Physiology)
5. Dr. A. K. Sharma, Principal Scientist (Horticulture)
6. Dr. Sujoy Saha, Principal Scientist (Plant Pathology)
7. Dr. D. S. Yadav, Principal Scientist (Agricultural Entomology)
8. Mrs. K. Mundankar, Scientist (Computer applications in Agriculture)
9. Dr. Roshni R. Samarth, Senior Scientist (Plant Breeding)
10. Dr. Ahammed Shabeer TP, Senior Scientist (Agricultural Chemistry)
11. Dr. N.A. Deshmukh, Senior Scientist (Fruit Science)
12. Dr. Somnath K. Holkar, Senior Scientist (Plant Pathology)
13. Dr. D.N. Gawande, Senior Scientist (Plant Breeding)
14. Dr. P.H. Nikumbhe, Senior Scientist (Fruit Science)
15. Dr. Sharmistha Naik, Scientist (Fruit Science)
16. Dr. Gajanan Gundewadi, Scientist (Fruit Science)
17. Dr. Sushmitha B.H., Scientist (Fruit Science)
18. Dr. Lavanya A.K., Scientist (Agricultural Microbiology)

Technical

19. Shri. U. N. Borse, Assistant Chief Technical Officer
20. Kum. Shailaja Satam, Senior Technical Officer
21. Shri. B. B. Khade, Technical Officer
22. Shri. B. J. Phalke, Technical Officer
23. Shri. E. G. Kamble, Technical Officer
24. Shri. P. V. Sawant, Sr. Technical Assistant

Administrative

25. Shri. P. C. Noble, Administrative Officer
26. Shri. M. N. Ganti, Finance and Accounts Officer
27. Shri. N. S. Pathan, Assistant Administrative Officer
28. Shri. P. P. Kalbhor, Assistant
29. Shri. Pradip Jagdale, Assistant
30. Ms. Vandana, Assistant
31. Shri. A. D. Fulsundar, L.D.C.

Skilled Supporting Staff

32. Shri. K. G. Raskar, Skilled Supporting Staff
33. Shri. B. R. Chakankar, Skilled Supporting Staff
34. Mrs. Lata Pawar, Skilled Supporting Staff

Promotion

1. Ms. Shailaja Satam, Technical Officer (Pay Level 7) to Senior Technical Officer (Pay Level 10) w.e.f. 23.04.2022

2. Dr. P. H. Nikumbhe, Scientist (Pay Level 11) to Senior Scientist (Pay Level 12) w.e.f. 01.07.2023
3. Dr. D. N. Gawande, Senior Scientist (Pay Level 12) to Senior Scientist (Pay Level 13A) w.e.f. 15.09.2023
4. Dr. D. S. Yadav, Senior Scientist (Pay Level 13A) to Principal Scientist (Pay Level 14) w.e.f. 10.02.2024

Transfer

1. Ms. Samiksha Jain, Assistant, relieved on 11.08.2025 to join at ICAR-Indian Institute of Soil Science, Bhopal
2. Dr. Lavanya A. K., Scientist (Agricultural Microbiology) joined on 30.10.2025 after being relieved from ICAR-Central Research Institute for Jute and Allied Fibres, Kolkata

New Joining

1. Dr. Gajanan Gundewadi, Scientist (Fruit Science) on 07.07.2025
2. Dr. Sushmitha B. H., Scientist (Fruit Science) on 07.07.2025

Superannuation

1. Mr. Prakash Jadhav, Technical Assistant on 30.06.2025
2. Dr. R. G. Somkuwar, Principal Scientist on 31.10.2025

Obituary

Mr. Sham Bhoite, Technical Officer, 28.10.2025



Infrastructure Development



Website development

The GIGW (Guidelines for Indian Government Websites)-compliant CMS-based institutional website has been developed through the National Informatics Centre Services Inc. (NICSI). It provides a Content Management System (CMS) to enable content updates, review processes, and management using the latest web technologies. For an institute's website, a CMS is a critical technology that enables staff to maintain and update content efficiently, ensuring the site remains current and relevant. Designed to enhance digital outreach, the website ensures accessibility, security, and user-friendliness while adhering to GIGW standards, which mandate compliance with accessibility (WCAG 2.0), security, and usability for government-affiliated websites. The system facilitates industry collaboration, promotes

technology transfer, and provides stakeholders with easy access to research outputs and institute-developed innovations. Built with scalable technologies (e.g., HTML5, CSS3, JavaScript, PHP-based CMS framework viz. Drupal), it integrates advanced features for dynamic content delivery.

Antivirus software

Endpoint protection of computers connected to the institute's LAN was strengthened through procurement of SEQRITE EPP Total antivirus software for a period of three years.

Backup internet connection

A backup internet facility using a Jio AirFiber router was also established to ensure uninterrupted internet access.



Other Activities

Official Language Implementation

The institute continued to implement the Official Language Policy of the Government of India during the year. Hindi was used progressively in official correspondence, reports, meetings, notices and other administrative activities. The Parliamentary Committee on Official Language inspected the institute on 25 April 2025 and expressed satisfaction over the use and implementation of Hindi at the institute.

Hindi Pakhwada was organized at the institute on the occasion of Hindi Diwas. The programme was inaugurated on 15 September 2025 under the chairmanship of Dr. Kaushik Banerjee, Director, ICAR-NRCG, by administering the Hindi pledge to the staff. During the fortnight, various competitions such as Hindi essay writing, self-composed Hindi poetry recitation, Hindi typing in Unicode and Hindi draft writing were organized to promote the use of Hindi in official work.



Important Meetings and Stakeholder Interactions

Shri Shivraj Singh Chouhan, Hon'ble Union Minister of Agriculture and Farmers Welfare, interacted with the Directors and scientists of ICAR-NRCG, ICAR-DFR, ICAR-DOGR and ICAR-ATARI during his visit to Pune on 7 January 2025. Dr. Kaushik Banerjee, Director, ICAR-NRCG, briefed the Hon'ble

Minister on grape area expansion in non-traditional regions, institute-developed varieties, the Clean Plant Programme and residue monitoring activities. The Hon'ble Minister appreciated the institute's contributions to grape research, food safety, export facilitation and quality improvement, and suggested strengthening research on climate-resilient and market-preferred grape varieties.



Shri Sanjay Garg, Additional Secretary, DARE and Secretary, ICAR, visited ICAR-NRCG, Pune, on 8 January 2025 and interacted with scientists and administrative officers. He was briefed on ongoing research programmes, grape cultivation in non-traditional areas, introduction of institute-developed varieties in the North-Eastern Hill region and the implementation of the Clean Plant Programme. He advised the institute to collaborate with regional authorities, strengthen training of KVK staff and submit project proposals to national funding agencies for technology development and grape area expansion.

The Bengal Chamber of Commerce and Industry and ICAR-NRCG jointly organized the National Grape Summit 2025 at Pune on 4 March 2025 to promote Indian grapes in the global market and popularize grape and wine tourism. The summit was attended by policymakers, researchers, industry representatives, exporters and grape growers. The programme

included deliberations on Good Agricultural Practices, market intelligence, value-added products and advances in viticulture. A technical bulletin of the National Referral Laboratory on 20 years of pesticide residue monitoring in grapes was also released.

A national workshop on Plant Metabolomics was organized at ICAR-NRCG on 18 March 2025 under the NASF-funded project on foodomics, food authentication and nutraceutical exploration. The workshop covered metabolomics-based disease diagnostics, sample preparation, instrumental identification of biomarkers and multivariate statistical data analysis. About 40 participants, including ICAR scientists and young professionals, attended the programme.

A one-day workshop on “Assessment of Grapevine Planting Material Demand and Nursery Accreditation Awareness” was organized on 9 April 2025 under the Clean Plant Centre for Grapes. The programme focused on the importance of clean planting material, nursery accreditation and the role of nursery owners in ensuring production and distribution of healthy grape planting material.

PM Kisan Diwas Utsav was organized at ICAR-NRCG on 2 August 2025. Live streaming of the release of the 20th instalment of PM Kisan Samman Nidhi was arranged. Scientists interacted with 62 farmers, including 41 male and 21 female participants, on vineyard operations required for fruitful cane development. Farmers were advised on canopy management for minimizing disease incidence during the rainy season. Videos prepared by the institute on different aspects of grape cultivation were also screened.

ICAR-NRCG and the Bengal Chamber of Commerce and Industry co-hosted “Nourish India 2025 – Food Safety and Security Leadership Summit” on 20 November 2025 at India Habitat Centre, New Delhi. The programme brought together policymakers, scientific leaders and industry representatives to deliberate on food safety, nutrition, export markets and regulatory preparedness. Discussions emphasized harmonized regulatory processes, adoption of new chemistries, wider farmer training networks and digital traceability from farm to export.

Celebrations and Commemorative Events

The 76th Republic Day was celebrated at the institute on 26 January 2025. Dr. Kaushik Banerjee,

Director, ICAR-NRCG, hoisted the National Flag and addressed the staff on constitutional values, institutional commitment and scientific service to the nation. Scientists, technical, administrative and supporting staff participated in the celebration.



The 79th Independence Day was celebrated on 15 August 2025 with patriotic fervour. Dr. Kaushik Banerjee hoisted the National Flag and highlighted the importance of dedication, integrity and scientific contributions towards nation-building.



ICAR-NRCG celebrated its 29th Foundation Day on 17 January 2025. Dr. Kaushik Banerjee highlighted the institute's journey and contributions to grape research and development. Dr. Ashok P. Giri, Chief Scientist, CSIR-National Chemical Laboratory, Pune, delivered the Foundation Day Lecture on “Linking Fruit Chemistry to Biology through OMICS”. Dr. K.V. Prasad, Director, ICAR-Directorate of Floricultural Research, Pune, delivered the keynote address and emphasized the institute's role in supporting farmers, the grape industry and grape exports. The new institute website was also launched on this occasion.

National Science Day was celebrated on 28 February 2025 on the theme “Empowering Indian Youth for Global Leadership in Science and Innovation for Viksit Bharat”. Dr. Shraddha Amol Khuspe, Head, Department of Nutrition and Dietetics, Vishwaraj Multispeciality Hospital, delivered a lecture on “Health Benefits of Grape Consumption”. Dr. N.A. Deshmukh, Senior Scientist, ICAR-NRCG, delivered a lecture on “Benefits of Healthy Snacks in Sustaining Good Health”. Staff and students participated in poster-making and one-minute competitions.

International Women’s Day was observed on 7 March 2025. Dr. Yogini Soregaonkar Patil, Obstetrician and

Gynaecologist, delivered a special lecture on “What Women’s Health Means in 2025!”. The session focused on women’s health and well-being, including balanced diet, exercise, stress management, early detection of cancers affecting women and regular health check-ups.

Vigilance Awareness Week 2025 was observed at ICAR-NRCG through activities promoting integrity, transparency, cyber awareness and responsible citizenship. A total of 42 employees undertook the integrity e-pledge. Competitions including elocution, poster-making and debate were organized for staff and students.



Meteorological Data



Year and Month	Air temperature (°C)		Relative humidity (%)		Pan evaporation (mm)	Total rainfall (mm)	No. of rainy days
	Min.	Max.	Min.	Max.			
January 2025	15.32	31.05	39.24	81.79	115.6	0.00	0
February 2025	16.57	34.65	28.46	75.39	145.9	0.00	0
March 2025	17.35	37.87	22.00	68.60	210.9	0.00	0
April 2025	22.67	38.84	24.73	68.95	242.1	1.20	0
May 2025	23.21	33.39	55.07	86.34	101.8	318.13	14
June 2025	23.35	30.15	72.40	91.31	77.5	170.63	9
July 2025	22.96	28.66	77.24	92.22	44.8	57.89	10
August 2025	22.53	28.56	76.75	92.58	64.9	95.96	6
September 2025	22.03	27.72	79.12	93.91	53.7	188.67	7
October 2025	20.34	31.11	62.65	96.62	84.9	118.00	7
November 2025	13.90	30.03	48.05	96.19	99.1	4.6	1
December 2025	10.86	29.04	40.74	93.02	107.5	0.00	0
Total					1348.7	955.08	54

Source: Weather station, ICAR-NRCG, Pune



Abbreviations

ABA	Absciscic acid	CR	Contract Research
ABI	Agri-Business Incubation	CRC	Cyclic Redundancy Check
ADB	Asian Development Bank	CSR	Corporate Social Responsibility
AEDS	Agro Environmental Development Society	CTAB	Cetyltrimethylammonium Bromide
AI	Artificial Intelligence	CV	Coefficient of Variation
AICRP	All India Coordinated Research Project	DAP	Days After Pruning
AIM	Agro Input Manufacturers Association	DBT	Department of Biotechnology
AMAAS	Application of Microorganisms in Agriculture and Allied Sectors	DIG	Deputy Inspector General
ANRF	Anusandhan National Research Foundation	DMI	Directorate of Marketing and Inspection
AOAC	Association of Official Analytical Chemists	DMR	Draksha Mandal Research
APEDA	Agricultural and Processed Food Products Export Development Authority	DOGR	Directorate of Onion and Garlic Research
AQY	Apparent Quantum Yield	DPC	Departmental Promotion Committee
ARI	Agharkar Research Institute	DPR	Detailed Project Report
ATARI	Agricultural Technology Application Research Institute	DST	Department of Science and Technology
BCC&I	Bengal Chamber of Commerce, Industry and Agriculture	DUS	Distinctness, Uniformity and Stability
BLAST	Basic Local Alignment Search Tool	EC	Electrical Conductivity
BLUP	Best Linear Unbiased Prediction	EPF	Entomopathogenic Fungi
BOD	Board of Directors	ER	Embryo Rescue
CAU	Central Agricultural University	ET	Evapotranspiration
CAS	Career Advancement Scheme	ETc	Crop Evapotranspiration
CAP	Chlorantraniliprole	EU	European Union
CBI	Central Bureau of Investigation	FAQ	Frequently Asked Questions
CBR	Carolina Blackrose	FICCI	Federation of Indian Chambers of Commerce and Industry
CCI	Chlorophyll Concentration Index	FMC	FMC India Private Limited
CIB&RC / CIB-RC	Central Insecticides Board and Registration Committee	FPC	Farmer Producer Company
CIFT	Central Institute of Fisheries Technology	FPO	Farmer Producer Organisation
CII	Confederation of Indian Industry	FS	Flame Seedless
CIHG	Centre for Indian Himalayan Grasslands	FSSAI	Food Safety and Standards Authority of India
CISH	Central Institute for Subtropical Horticulture	GA	Gibberellic Acid
CITH	Central Institute of Temperate Horticulture	GAE	Gallic Acid Equivalent
CIWA	Central Institute for Women in Agriculture	GAP	Good Agricultural Practices
CMP	Control medium containing pesticide	GBPUAT	Govind Ballabh Pant University of Agriculture and Technology
CPC	Clean Plant Centre	GBS	Genotyping-by-Sequencing
CPF	Chlorpyrifos	GC-MS	Gas Chromatography-Mass Spectrometry
		GC-MS/MS	Gas Chromatography-Tandem Mass Spectrometry
		GfKv	Grapevine Fleck Virus

GFLV	Grapevine Fanleaf Virus	MoA	Memorandum of Agreement
GIS	Geographic Information System	MoFPI	Ministry of Food Processing Industries
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit	MoU	Memorandum of Understanding
GLP	Good Laboratory Practice	MPKV	Mahatma Phule Krishi Vidyapeeth
GLRaV	Grapevine Leafroll-associated Virus	MRDBS	Maharashtra Rajya Draksha Bagaitdar Sangh
GPGV	Grapevine Pinot Gris Virus	MRL	Maximum Residue Limit
GRASP	GLOBALG.A.P. Risk Assessment on Social Practice	MS	Mass Spectrometry
HAT	Hours After Treatment	MSM	Minimal Salt Medium
HTS	High-Throughput Sequencing	NABL	National Accreditation Board for Testing and Calibration Laboratories
IAA	Indole-3-Acetic Acid	NAAS	National Academy of Agricultural Sciences
IARI	Indian Agricultural Research Institute	NAIF	National Agriculture Innovation Fund
IBA	Indole-3-Butyric Acid	NAIP	National Agricultural Innovation Project
ICAR	Indian Council of Agricultural Research	NASC	National Agricultural Science Centre
IIHR	Indian Institute of Horticultural Research	NASF	National Agricultural Science Fund
IIoT	Industrial Internet of Things	NCBI	National Center for Biotechnology Information
IISER	Indian Institute of Science Education and Research	NEH	North-Eastern Hill Region
IMC	Institute Management Committee	NGO	Non-Governmental Organisation
IoT	Internet of Things	NHB	National Horticulture Board
IP	Intellectual Property	NHRDF	National Horticultural Research and Development Foundation
IPL	Indian Potash Limited	NIASM	National Institute of Abiotic Stress Management
IPR	Intellectual Property Rights	NIPHM	National Institute of Plant Health Management
IRC	Institute Research Committee	NPK	Nitrogen, Phosphorus and Potassium
ISO	International Organization for Standardization	NRL	National Referral Laboratory
IT	Information Technology	NS	Non-significant
ITMU	Institute Technology Management Unit	NS-3	Network Simulator-3
KVK	Krishi Vigyan Kendra	ODOP	One District One Product
LAI	Leaf Area Index	ONEH	Other than NEH
LC-HRMS	Liquid Chromatography-High Resolution Mass Spectrometry	OPLS-DA	Orthogonal Partial Least Squares-Discriminant Analysis
LC-MS	Liquid Chromatography-Mass Spectrometry	PAR	Photosynthetically Active Radiation
LC-MS/MS	Liquid Chromatography-Tandem Mass Spectrometry	PAVER	Progressive Agriculture – Viksit Bharat: Preparedness for Eastern Region
LCP	Light Compensation Point	PBTi	Punjab Biotechnology Incubator
LoRa	Long Range	PCR	Polymerase Chain Reaction
LoRaWAN	Long Range Wide Area Network	PDA	Potato Dextrose Agar
LSP	Light Saturation Point	PDI	Percent Disease Index
MAC	Medium Access Control	PF	Processing Factor
MACS	Maharashtra Association for the Cultivation of Science	PFAS	Per- and Polyfluoroalkyl Substances
MAD	Maximum Allowable Depletion	PGPR	Plant Growth-Promoting Rhizobacteria
MDU	Maya Devi University	PHI	Pre-Harvest Interval
MIDH	Mission for Integrated Development of Horticulture	PLS-DA	Partial Least Squares-Discriminant Analysis
MIONP	Make India Organic, Natural and Profitable	PM	Prime Minister
MLT	Multi-Location Trial	Pnmax	Maximum Net Photosynthesis Rate

PN	Pusa Navrang	SE	Standard Error
PPV&FR	Protection of Plant Varieties and Farmers' Rights	SFDA	Saudi Food and Drug Authority
PPV&FRA	Protection of Plant Varieties and Farmers' Rights Authority	SIAVAS	Sustainable Innovations in Agriculture, Veterinary and Allied Sciences
PT	Proficiency Testing	SML	SML Limited
QAU	Quality Assurance Unit	SMS	Subject Matter Specialist
QMS	Quality Management System	SNP	Single Nucleotide Polymorphism
QRT	Quinquennial Review Team	SOP	Standard Operating Procedure
QTL	Quantitative Trait Locus	SPRING	Sustainable Program for Irrigation and Groundwater Use
RAC	Research Advisory Committee	SSP	Single Super Phosphate
RAWE	Rural Agricultural Work Experience	SV	Seyve Villard
RBD	Randomized Block Design	TNAU	Tamil Nadu Agricultural University
Rd	Dark Respiration Rate	TSP	Tribal Sub Plan
RE	Revised Estimate	TS	Thompson Seedless
RG	Red Globe	TSS	Total Soluble Solids
RMP	Residue Monitoring Plan	TUB2	Beta-Tubulin Gene
RPB2	RNA Polymerase II Second Largest Subunit	UAS	University of Agricultural Sciences
RRBLUP	Ridge Regression Best Linear Unbiased Prediction	UHPLC	Ultra-High Performance Liquid Chromatography
RSD	Relative Standard Deviation	UHS	University of Horticultural Sciences
RWC	Relative Water Content	UNDP	United Nations Development Programme
SAM	Segment Anything Model	UPL	UPL Limited
SANTE	Directorate-General for Health and Food Safety	UT	Union Territory
SAU	State Agricultural University	VNMKV	Vasandra Naik Marathwada Krishi Vidyapeeth
SC	Scheduled Caste	VSI	Vasandra Sugar Institute
SCSP	Scheduled Caste Sub Plan	WUE	Water-Use Efficiency
SD	Standard Deviation	YOLO	You Only Look Once





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