

वार्षिक प्रतिवेदन Annual Report 2024



भाकृअनुप-प्याज एवं लहसुन अनुसंधान निदेशालय
पुणे-410 505, महाराष्ट्र, भारत
ICAR-Directorate of Onion and Garlic Research
Pune-410 505, Maharashtra, India

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ICAR-Directorate of Onion and Garlic Research
Pune-410 505, Maharashtra, India

Phone: (02135) 222026, Fax: (02135) 224056
Email: director.dogr@icar.gov.in



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Dr. Vijay Mahajan, Director
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Contact

Phone: 91-2135-222026, 222697
Fax: 91-2135-224056
E-mail: director.dogr@icar.org.in
Website: <http://dogr.res.in>
YouTube: <https://www.youtube.com/@ICAR-DOGR>
Facebook: <https://www.facebook.com/people/ICAR-DOGR/61576206371827/>
Instagram: https://www.instagram.com/icar_dogr/?igsh=MTF2digzaHowcGtqbQ%3D%3D
Twitter (x): <https://x.com/ICARDOGR>

Editors

Dr. Ram Dutta
Dr. A. J. Gupta
Dr. Shailendra S. Gadge
Dr. S. J. Gawande
Dr. A. Thangasamy
Dr. Kalyani Gorrepati
Dr. Karuppaiah, V.
Dr. Rajiv B. Kale
Dr. Pranjali A. Gedam
Mrs. Ashwini P. Benke
Dr. Bhushan R. Bibwe
Dr. Vijay Mahajan

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Preface



Vijay Mahajan
Director

In 2024, the ICAR–Directorate of Onion and Garlic Research, Pune, continued to advance its mandate of strengthening onion and garlic research, development, and technology dissemination. Through integrated efforts in crop improvement, production, protection, post-harvest management, extension, and institutional development, the Directorate addressed key challenges related to climate stress, productivity, quality, sustainability, and market demands.

Significant progress was achieved in germplasm conservation, varietal development, breeding, biotechnology, and genomic research, reinforcing ICAR-DOGR's role as the National Active Germplasm Site for Allium crops. Several high-yielding, stress-tolerant onion and garlic varieties and elite breeding lines were identified and advanced, supported by molecular, physiological, and genomic studies. Research in crop production emphasized climate-resilient technologies, integrated nutrient and water management, precision agriculture tools, and sustainable weed and soil management practices. Advances in crop protection included improved disease and pest management strategies, biocontrol agents, pathogen characterization, pollination studies, and predictive digital models.

Post-harvest and value-chain research focused on reducing storage losses, improving quality, understanding microbial dynamics, and enhancing value addition. Extension and capacity-building activities under schemes such as SCSP, TSP, NEH, MGMG, and ATMA reached a large number of farmers across diverse regions through demonstrations, training programmes, digital advisory tools, and agri-drone applications. Special emphasis was placed on supporting tribal, marginal, and smallholder farmers.

Technology transfer, commercialization, and entrepreneurship were strengthened through licensing agreements, institutional collaborations, and the activities of the Agri-Business Incubation Centre, which supported startups and value-added enterprises. Participation in exhibitions, stakeholder interactions, and institutional initiatives further enhanced outreach and collaboration.

This report presents a brief overview of the research, extension, and institutional achievements of ICAR-DOGR during 2024. I gratefully acknowledge the continued support of ICAR and the invaluable guidance and encouragement provided by Dr. Himanshu Pathak, Secretary, DARE and Director General of the Indian Council of Agricultural Research; Dr. S. K. Singh, Deputy Director General (Horticulture Science); Dr. Sudhakar Pandey, Assistant Director General (Flowers, Vegetables, Spices and Medicinal Plants); and Dr. V. B. Patel, Assistant Director General (Fruits and Plantation Crops). I also place on record my sincere appreciation for the committed efforts of the scientific, technical, administrative, and supporting staff of the Directorate, whose dedication has been instrumental in accomplishing the targets set during the year. It is hoped that the information and outcomes presented in this report will serve as a useful reference for all stakeholders engaged in the onion and garlic sectors.

A handwritten signature in black ink, appearing to read 'Vijay Mahajan', written in a cursive style.

(Vijay Mahajan)

कार्यकारी सारांश

वर्ष 2024 में, भाकृअनुप-प्याज एवं लहसुन अनुसंधान निदेशालय, पुणे में संस्थागत और बाह्य वित्त पोषित परियोजनाओं के माध्यम से अनुसंधान, प्रसार एवं विकास के लिए प्रयास जारी रखा गया। पूरे वर्ष, निदेशालय ने अनुसूचित जाती उप-योजना, जनजातीय उप-योजना, पूर्वोत्तर पर्वतीय योजना, मेरा गाव मेरा गौरव और आत्मा, जैसी अलग-अलग योजनाओं के तहत 121 प्रशिक्षण कार्यक्रम आयोजित किए, जिनसे 5943 किसानों, छात्रों और अन्य हितधारकों को फ़ायदा हुआ। निदेशालयने पाँच प्रमुख कृषि प्रदर्शनियों में भी सक्रियता से भाग लिया, जिनमें प्याज़ एवं लहसुन की नवीनतम प्रजातियाँ, उत्पादन प्रौद्योगिकी और कटाई के उपरांत नवाचार प्रदर्शित किए गए। दिनांक 9 अक्टूबर 2024 को प्याज़ एवं लहसुन की खेती में नैनो-उर्वरकों की क्षमता पर केंद्रित करते हुए उपज और मृदा के स्वास्थ्य को बेहतर बनाने के लिए वैज्ञानिक अंतर्दृष्टि (साइंटिफिक इनसाइट्स) और नीति परिप्रेक्ष्य (पॉलिसी पर्सपेक्टिव्स) को मिलाकर एक विचार मंथन सत्र का आयोजन किया गया। अनुसंधान जागरूकता पहल में डीएसटी-सर्ब परियोजना के तहत एक दिन का वैज्ञानिक सामाजिक जिम्मेदारी कार्यक्रम शामिल था, जिसमें 25 पूर्व स्नातक छात्रों को परागन और प्याज़ के बीज उत्पादन में देसी बिना डंक वाली मधुमक्खियों की भूमिका से परिचित कराया गया। निदेशालयने प्याज की पांच किस्मों (भीमा शक्ति, भीमा सुपर, भीमा रेड, भीमा शुभ्रा, भीमा श्वेता) के लिए तीन किसान उत्पादक कंपनियों समेत आठ बीज कंपनियों के साथ 12 लाइसेंसिंग समझौता ज्ञापनों पर हस्ताक्षर करके अपनी प्रौद्योगिकी प्रसार और व्यवसायीकरण के प्रयासों को बढ़ाया, जिससे ₹ 12 लाख का राजस्व प्राप्त हुआ। इसके अलावा, तीन संस्थानों के साथ समझौता ज्ञापन किए गए, और पांच कॉपीराइट फाइल किए गए। निदेशालय के कृषि व्यवसाय उदभवन केंद्र ने प्याज एवं लहसुन से जुड़े व्यवसाय में उद्यमशीलता को बढ़ावा देने में अहम भूमिका निभाई। वर्ष की शुरुआत 16 जनवरी 2024 को हुए कृषि स्टार्टअप सम्मेलन - 2024 से हुई, जो उद्यमी, शोधकर्ता और कृषि व्यावसायिक हितधारकों के बीच नेटवर्किंग, ज्ञान साझा करने और सहयोग के लिए एक प्लेटफॉर्म के तौर पर काम आया। वर्ष के दौरान कुल 19 अच्छे स्टार्टअप का नामांकन किया गया, जो प्याज और लहसुन मूल्य श्रृंखला के कई भागों में काम कर रहे थे। कृषि व्यवसाय उदभवन केंद्र ने व्यावसायिक प्याज के बीज उत्पादन पर दो विशेष उद्यमशीलता विकास कार्यक्रम भी किए, साथ ही 24 नवंबर 2024 को इनक्यूबेटीज़, उद्यमी और किसानों के लिए 'प्याज एवं लहसुन को फायदेमंद उत्पादों में बदलना' इस विषय पर एक दिन का हैंड्स-ऑन प्रशिक्षण भी दिया गया। वर्ष 2024 के दौरान किए गए अनुसंधान, प्रसार और विकास की गतिविधियों का संक्षिप्त सारांश नीचे प्रस्तुत किया गया है।

फसल सुधार

वर्ष 2024 के दौरान निदेशालयने प्याज एवं लहसुन में जननद्रव्य संरक्षण, प्रजाति विकास, प्रजनन जैव प्रौद्योगिकी और जीनोमिक अनुसंधान में महत्वपूर्ण उन्नति की। राष्ट्रीय सक्रिय जननद्रव्य स्थल (एनएजीएस) के तौर पर, निदेशालयने 495 से ज़्यादा लहसुन प्रामियों को अनुरक्षित करके और 28 एलियम प्रजातियों को संरक्षित करके राष्ट्रीय संग्रह को मजबूत किया, जिसमें 199 सफेद प्याज और लाल प्याज जननद्रव्यों का एक विशाल संग्रहण शामिल है। बड़े पैमाने पर बहु-मौसम मूल्यांकन (खरीफ, पछेती खरीफ, रबी) से बेहतर उपज, कंद गुणवत्ता, जल्दी परिपक्व होने वाली और भण्डारण करने की क्षमता वाली कई अभिजात प्रामियों की पहचान हो पाई। प्रमुख किस्मों की उपलब्धियों में, ज़्यादा उपज और अधिक कुल घुलनशील ठोस पदार्थ (टीएसएस) के लिए तीन सफेद प्याज किस्मों - भीमा उज्वला, भीमा प्रसंस्करण और भीमा निर्जला की सिफारिश शामिल थी। लहसुन में, कई वर्षों के प्रदर्शन के आधार पर ज़ोन II के लिए वंशक्रम डीओजीआर-पीबी-10 की सिफारिश की गई। डीओजीआर-1203, डीओजीआर-1625, और आरजीपी-3 जैसी लाल प्याज की किस्मों को भी जल्दी परिपक्व होने और विक्री लायक पैदावार के लिए खास इलाकों के लिए बेहतर माना गया। प्रजनन कार्यक्रम में 45 पूर्व-प्रजनन वंशक्रम, कई द्वि-पैतृक और पॉली-क्रॉस की संख्या, और सफेद एवं लाल प्याज कार्यक्रम में 150 से ज़्यादा एफ1 संकर के साथ-साथ उच्च टीएसएस मूल्यांकन के लिए 498 नई एफ2 की संख्या के विकास के साथ अच्छी प्रगति हुई। कई संकरों में >20% संकर ओज दिखाई दिया, जिनको अखिल भारतीय प्याज एवं लहसुन नेटवर्क अनुसंधान परियोजना (एआईएनआरपीओजी) बहु स्थानीय परिक्षण में शामिल किया गया। ए. सेपा और ए. फिस्टुलोसम के बीच अंतर प्रजातीय संकरण मानकीकृत भ्रूण बचाव के ज़रिए आगे बढ़ा, जिसमें मनचाही पत्तियाँ और तने की खासियत वाले संकर पौधे सफलतापूर्वक लगाए गए। लहसुन में सुधार के लिए, डीओजीआर-493 (141.71 किं/हे.), डीओजीआर-359, डीओजीआर-534, और खरीफ के लिए

डीओजीआर-100 और डीओजीआर-555 जैसी ज़्यादा पैदावार देने वाली वंशक्रमों की पहचान की गई। एसएसआर मार्कर का इस्तेमाल करके 32 लहसुन जीनप्रारूपों की आणविक और जैव रासायनिक रूपरेखा से काफी विविधता का पता चला, जिससे कुल घुलनशील ठोस पदार्थ, गंधक यौगिक, एंटीऑक्सीडेंट और कलियों की गुणवत्ता के लिए लक्षित प्रजनन को सहायता मिली। जैवप्रौद्योगिकी अनुसंधान में उल्लेखनीय प्रगति हुई। इन विट्रो गाइनोजेनेसिस से 193 अगुणित और 52 द्विगुणित प्राप्त हुए, जिससे दोहरे अगुणित विकास में मदद मिली। CRISPR/Cas9 का इस्तेमाल करके जीनोम एडिटिंग की कोशिशों से विशेष जीनों-*AcCENH3*, *AcMYB1*, *AcCHS*, और *AcMSH1* को लक्षित किया गया, जिससे कई कंस्ट्रक्ट में संपादित किए गए पौधों का सफल कैलस परिवर्तन और पुनर्जनन हुआ। लवणता और रोगजनक तनाव के तहत ट्रांसक्रिप्टोम विश्लेषण सहित आणविक अध्ययन से तनाव प्रतिक्रियाशीलता के लिए ज़रूरी नियामक जीन और पथमार्ग की पहचान की गई। एक अतिरिक्त अनुसंधान परिणाम में *ए. फिस्टुलोसम* में चर्म संबंधी मोम संयोजन का लक्षणवर्णन, उच्च-जल-अवरोध प्राप्ति की पहचान, और तोर सहनशीलता, भंडारण क्षमता और गुणवत्ता लक्षणों के लिए प्याज के वंशक्रमों के मूल्यांकन भी शामिल थे। भाकृअनुप-एनबीपीजीआर के साथ पंजीकरण के लिए कई यूनिक आनुवंशिक स्टॉक तैयार किए गए।

कुल मिलाकर, वर्ष 2024 में निदेशालय के अनुसंधान कार्य ने भारत की प्याज एवं लहसुन सुधार में महत्वपूर्ण योगदान दिया। एकीकृत प्रजनन, जैव प्रौद्योगिकी और जीनोमिक तरीकों से, निदेशालयने नई किस्में, बेहतर उच्च सुस्पष्ट प्रजनन साधन दिए जो उत्पादकता, जलवायु परिवर्तन और किसानों की लाभप्रदता की सहायता करते हैं।

फसल उत्पादन

निदेशालय ने अजैविक तनाव में और बेहतर फसल प्रबंधन तरीकों से प्याज एवं लहसुन की उत्पादकता बढ़ाने पर अनुसंधान कार्य जारी रखा। सूखे के तनाव ने सभी प्याज जीनप्रारूपों में वृद्धि, प्रकाश संश्लेषण और कंद की उपज को काफी कम कर दिया, साथ ही तनाव सहनशीलता में भी काफी अंतर देखा गया। भीमा शुभ्रा जैसे जीनप्रारूप में कैनोपी के तापमान में अधिक गिरावट और बेहतर कायिक प्रदर्शन दिखाई दिया, जबकि भीमा राज, भीमा डार्क रेड और भीमा सुपर के उपज में कम कमी दिखी, जो बेहतर सूखे सहनशीलता को दर्शाता है। सूखे के तनाव में प्याज (*एलियम सेपा* एल.) प्रजाति भीमा शक्ति पर पादप वृद्धि नियामकों (पीजीआर) और पादप वृद्धि को बढ़ानेवाले सूक्ष्मजीवों (पीजीपीएम) के पत्तियों पर इस्तेमाल के प्रभाव का पता लगाने के लिए एक प्रक्षेत्र अध्ययन किया गया। नतीजों से पता चला कि पीजीआर और पीजीपीएम, दोनों के पत्तियों पर इस्तेमाल से सामान्य और सूखे दोनों तरह की स्थितियों में पौधों की वृद्धि और और कंदों की उपज में काफी बढ़ोतरी हुई। पीजीआर उपचार में, काइनेटिन (25 पीपीएम) ने प्रकाश संश्लेषण, तनाव सहनशीलता और एंटीऑक्सीडेंट गतिविधियों को बढ़ाया, जिससे सामान्य और सूखे दोनों तरह की स्थितियों में कंद की सबसे ज़्यादा उपज हुई। इसी तरह, परिक्षण किए गए सूक्ष्मजीवों में *एज़ोस्पिरिलम ब्रासिलेंस* सबसे असरदार था। इसने सूखे की स्थिति में ऑक्सीडेटिव नुकसान को कम करके और कायिक गुणों को बेहतर बनाकर प्रकाश संश्लेषण, तनाव सहनशीलता तंत्र और कंद की उपज को बढ़ाया। उच्च तापमान (35° से. से अधिक) तनाव ने प्याज की वृद्धि और कायिक गुणों को काफी कम कर दिया, जिससे क्लोरोफिल मात्रा, मेम्ब्रेन स्थिरता, पर्ण क्षेत्र और एंटीऑक्सीडेंट गतिविधियां कम हो गईं, जबकि आरओएस का संचयन होने लगा। तापमान 42° से. के संपर्क में आने से नियंत्रित पौधों की तुलना में प्याज की दोनों किस्मों में गंभीर नुकसान हुआ तथा उगाही और उत्तरजीविता खराब रही।

एक लंबे समय के अध्ययन से पता चला कि केंचुए की खाद के साथ खनिज खाद मिलाने से प्याज की उपज और मिट्टी की उपजाऊ शक्ति बनी रही, जिससे सिर्फ खनिज खाद के बराबर उपज हुई, और मक्का-प्याज प्रणाली में बेहतर प्रदर्शन पाया गया। एकीकृत पोषक तत्व प्रबंधन (आईएनएम) से पोषक तत्व का अवशोषण और मिट्टी का जैविक कार्बन बढ़ा, जबकि सिर्फ जैविक उपचार से दोनों फसल प्रणालियों में उपज और पोषक तत्व का अवशोषण कम हुआ। एक और लंबे समय के अध्ययन से पता चला कि एकीकृत पोषक तत्व प्रबंधन से प्याज की सबसे ज़्यादा उपज प्राप्त हुई, जो सिर्फ खनिज खाद और जैविक / प्राकृतिक खेती से क्रमशः 21.0% और 51.5% बेहतर थी। जैविक और प्राकृतिक खेती से कंद की गुणवत्ता और मिट्टी का जैविक कार्बन बेहतर हुआ, जबकि आईएनएम और खनिज खाद से पोषक तत्व का अवशोषण बढ़ा और कटाई उपरांत भण्डारण में नुकसान कम हुआ। नत्रजन स्तर और सिंचाई के तरीके ने प्याज की वृद्धि, उपज और भण्डारण गुणवत्ता पर काफी असर डाला। सौ प्रतिशत अनुशासित नत्रजन के साथ टपक सिंचाई से सबसे ज़्यादा उपज, बेहतर कंद आकार और भण्डारण में कम नुकसान हुआ, जबकि नत्रजन की अधिकता (150%) से कंद की गुणवत्ता बढ़ी लेकिन कटाई उपरांत नुकसान भी ज़्यादा हुआ। पानी जमा होने की वजह से प्याज की वृद्धि और उपज में काफी कमी आई, और सहनशीलता में जीनप्रारूप अंतर भी साफ था। प्राप्ति 1666 और भीमा डार्क रेड ने बेहतर कायिक स्थिरता और एंटीऑक्सीडेंट गतिविधि बनाए रखी, जिससे उपज नुकसान कम हुआ (~29%), और इन्हें पानी जमा होने वाले इलाकों में, खासकर चौड़ी ऊंची क्यारियों में लगाने के लिए

अनुशंसित किया जाता है। लवणता की वजह से चिकनी दोमट मिट्टी में उगाए गए प्याज के जिनप्रारूपों में वृद्धि, कायिकी और आयन संतुलन में काफी बदलाव आया। भीमा शक्ति और भीमा रेड ने हल्की लवणता ($0.5-0.85 \text{ dS m}^{-1}$) में बेहतर प्रदर्शन किया, जबकि 1.85 dS m^{-1} से ज़्यादा लवणता की वजह से जिनप्रारूपों में वृद्धि और उपज में $>30\%$ की कमी आई, जिससे पता चलता है कि लवणता वाले क्षेत्रों में प्याज की खेती बढ़ाने के लिए सहनशील किस्म की आवश्यकता है। स्मार्ट-एसएनडब्ल्यूएम में आईओटी पर आधारित सौर शक्ति वाले संभव (SAMBHAV™) सेंसर लगाए गए, ताकि प्याज में सिंचाई और फर्टिगेशन को अनुकूलित करने के लिए मिट्टी की नमी, पोषक तत्व, मौसम और फसल की स्थिति की वास्तविक समय पर निगरानी की जा सके। सेंसर सहयोगिता अध्ययन से संभव नमी ($\pm 5\%$) और एनपीके सेंसर ($R^2 0.96$ तक) की उच्च यथार्थता एवं सुसंगति दिखाई दी, जिससे प्रिसिजन कृषि में कुशल, डेटा-संचालित पोषक तत्व और जल प्रबंधन के लिए उनकी क्षमता पर ज़ोर डाला गया। खेत अध्ययनों से पता चला कि पॉलीहैलाइट (पॉली 4), विशेषकर जब पूरक पोटाश के साथ मिलाया जाता है, तो पारंपरिक एमओपी उपचार की तुलना में प्याज एवं लहसुन की वृद्धि, उपज, पोषक तत्व अवशोषण और गुणवत्ता में सुधार हुआ। इस तरीके से पोषक तत्व के इस्तेमाल की प्रभावात्मकता बढ़ी। इसलिए, इसे प्याज एवं लहसुन उत्पादन के लिए एक टिकाऊ, कम-क्लोराइड विकल्प के तौर पर अनुशंसित किया जाता है। एकीकृत खरपतवार प्रबंधन से प्याज की उपज में काफी सुधार आया, खरपतवार मुक्त प्रक्षेत्र में खरपतवार नियंत्रक की तुलना में 98.2% की बढ़ोतरी देखी गई। खरपतवार-आधारीय उपचार में, पेंडीमेथालिन के बाद प्रोपेक्लिज़ाफॉप + ऑक्सीफ्लोरफेन और पॉलीथीन पलवार के साथ पेंडीमेथालिन से सबसे ज़्यादा उपज प्राप्त हुई, जो रासायनिक और कल्चरल तरीकों को मिलाने के प्रभाव को दर्शाता है। खरपतवार रहित स्थिति में लहसुन की सबसे ज़्यादा उपज (7.33 टन/हे) हुई, जबकि खरपतवार-आधारीय उपचार में, पेंडीमेथालिन और उसके बाद प्रोपेक्लिज़ाफॉप + ऑक्सीफ्लोरफेन से सबसे ज़्यादा उपज (6.26 टन/हे) प्राप्त हुई। पूर्व-उद्भव खरपतवार नाशक को पलवार के साथ मिलाने से भी लहसुन की उपज में असरदार बढ़ोतरी हुई।

फसल सुरक्षा

वर्ष 2024 के दौरान, प्याज एवं लहसुन की प्रमुख फफूंदीय रोगों के प्रबंधन रणनीति के विकास, परिशोधन और मान्यकरण पर अध्ययन किया गया। रोगों के नमूने इकट्ठा किए गए और उनका विश्लेषण किया गया, जिसमें प्याज के प्रमुख फफूंदीय रोगजनकों, जिनमें कोलेटोट्राइकम, फ्यूजेरियम, अल्टरनेरिया और स्टेमफिलियम एसपीपी शामिल हैं, की पहचान की गई और रूपात्मक एवं आणविक साधनों का इस्तेमाल करके उनकी खासियत बताई गई। कल्चरों को एनसीबीआई और एनएआईएमसीसी में जमा किया गया। लहसुन में फसल की वृद्धि के लिए और बारह ट्राइकोडर्मा आइसोलेट्स को स्टेमफिलियम ब्लाइट और पर्पल ब्लाच के विरुद्ध जांचा गया। पर्पल ब्लाच में ज़्यादा से ज़्यादा 49% की कमी और कंद की उपज में 30% तक की बढ़ोतरी दर्ज की गई, जिसमें आइसोलेट जीआरडीटी 5 ने सबसे ज़्यादा रोग को कम किया और जीआरडीटी 7 ने सबसे ज़्यादा पौधों की वृद्धि की। आणविक लक्षणवर्णन से *tef1 α* अनुक्रमण और वंशावली विश्लेषण के द्वारा ट्राइकोडर्मा एस्परेलम की पुष्टि की गई। एकीकृत रोग प्रबंधन (आईडीएम) मॉड्यूल का परिक्षण किया गया और पाया गया कि यह प्रमुख फफूंदीय रोगों के अवरोध में परिणामकारक हैं, जिसमें आईपीडीएम मॉड्यूल 2 ने सबसे ज़्यादा रोगों को अवरोध किया और 27% उपज बढ़ाई। अमृतपानी-आधारीय जैविक फॉर्मूलेशन, रोगों की घटनाओं को कम करने और उपज को बढ़ाने में असरदार थे, जिसमें डीओजीआरओएफ3 फॉर्मूलेशन ने बेहतर परिणाम दिखाए। इन तरीकों के प्रभाव की एआईएनपीआरओजी के केंद्रों पर कई जगहों पर मान्यकरण के ज़रिए और पुष्टि की गई। प्याज की पत्तियों और कंदों के रोगों से जुड़े प्रमुख रोगजनक फफूंद, जिनमें कोलेटोट्राइकम, अल्टरनेरिया, स्टेमफिलियम और फ्यूजेरियम एसपीपी शामिल हैं, को भी आईटीएस-आधारित जाँच सहित रूपात्मकता, रोगजनकता और आणविक पद्धतियों का इस्तेमाल करके अलग, शुद्ध और चिन्हित किया गया। वन्य और खेती की जाने वाली एलियम प्रजातियों के राइज़ोस्फीयर माइक्रोबायोम को पूरे जीनोम मेटाजीनोमिक्स का इस्तेमाल करके लक्षणवर्णन किया गया, जिससे सूक्ष्मजीवों के सामुदायिक संयोजन में काफी अंतर पाया गया। प्रचुरता, एकरूपता, शैलन एवं सिम्पसन इंडेक्स समेत विविधता के विश्लेषण से वन्य और खेती की जाने वाली एलियम राइज़ोस्फीयर के बीच साफ फर्क दिखा, जिससे पता चलता है कि, सुधारने के और खेती के तरीके सूक्ष्मजीवों के सामुदायिक संरचना पर महत्वपूर्ण प्रभाव डालते हैं। रोग एवं तनाव की स्थिति में प्याज में एमआईआरएनए से होने वाले जीन विनियमन की जांच की गई। ग्यारह बचाव से जुड़े जीन मार्कर का इस्तेमाल करके 30 प्याज जननद्रव्य वंशक्रमों की आणविक जाँच से रोग के प्रतिरोध की आनुवांशिक क्षमता में बदलाव का पता चला। आरटी-पीसीआर एवं क्यूआरटी-पीसीआर के ज़रिए आरएनए-आधारित अभिव्यक्ति विश्लेषण से स्वस्थ और एन्थेक्नोज से संक्रमित ऊतकों के बीच विशेष बचाव जीन (MYCA, PR-5 और RGA) के अलग-अलग अभिव्यक्ति की पुष्टि की गई। यह अध्ययन रोगजनक विविधता, पोषिता बचाव तंत्र और रोग के प्रतिरोध में राइज़ोस्फीयर माइक्रोबायोम की भूमिका के संबंध में जानकारी देता है।

लंबे समय के अध्ययन (1998-2022) और वर्तमान समय के सर्वेक्षण में महाराष्ट्र के प्याज उगाने वाले प्रमुख जिलों में फ्यूजेरियम बेसल रॉट (एफबीआर) की 11-50% घटनाओं का पता चला है। बेसल रॉट उत्पन्न करने वाले फ्यूजेरियम आइसोलेट्स की पहचान विशेषकर एफ. एक््यूटेम और एफ. फाल्सीफॉर्म के रूप में की गई, जिसमें रोगजनकता परीक्षण कोच के सिद्धांतों को पूरा करते हैं। भारत में बेसल रॉट पैदा करने वाले फ्यूजेरियम इक्विसेटी की पहली रिपोर्ट प्रलेखित की गई। रबी 2024 के दौरान लहसुन में फ्यूजेरियम ड्राई रॉट की घटनाएं अलग-अलग जगहों पर अलग-अलग पाई गई, पुणे और अहिल्यानगर जिलों में इसकी गंभीरता ज्यादा देखी गई। लहसुन ड्राई रॉट से जुड़ी कई फ्यूजेरियम उपजातियों को अलग किया गया, उनकी पहचान की गई और उन्हें राष्ट्रीय संग्रह में जमा किया गया। रोगजनकता एसेज़ ने एफ. सोलानी, एफ. ऑक्सीस्पोरम, एफ. इनकार्नेटम, और एफ. इक्विसेटी को लहसुन ड्राई रॉट के कारण के तौर पर पुष्टि की, जिसमें एफ. इनकार्नेटम, और एफ. इक्विसेटी के लिए पहली वैश्विक रिपोर्ट शामिल हैं। स्टैंडर्ड चैलेंज इनोक्यूलेशन प्रोटोकॉल से फ्यूजेरियम बेसल रॉट के कृत्रिम प्रेरण के लिए कॉटन स्वैब और पिनप्रिक-डिपिंग तरीकों को सबसे असरदार पाया गया। कम्पैरेटिव विरुलेंस अध्ययनों से पता चला कि एफ. फाल्सीफॉर्म, एफ. एक््यूटेम से ज्यादा आक्रामक होते हैं। हिस्टोपैथोलॉजिकल अध्ययनों से पता चला कि एफ. फाल्सीफॉर्म संक्रमण में ऊतकों को बहुत ज्यादा नुकसान होता है। इन-विट्रो संवेदनशील एसेज़ में फफूंदनाशी, खासकर टेबुकोनाज़ोल और कार्बेन्डाजिम का उच्च प्रभाव दिखाई दिया, जबकि ट्राइकोडर्मा हार्जियानम और टी. लॉन्गिब्राचिएटम असरदार जैवनियंत्रक एजेंट थे। कटाई उपरांत के अध्ययनों में 16 एसआर-आरएनए और आईटीएस सीक्वेंसिंग का इस्तेमाल करके स्वस्थ, थोड़े और बहुत ज्यादा सड़े प्याज के कंद में सूक्ष्मजीवों के समुदायों की रूपरेखा (प्रोफाइल) बनाई गई। स्वस्थ कंदों में अलग-अलग जीवाणुओं के समुदाय थे, जिनमें प्रोटियोबैक्टीरिया, फर्मिक्यूट्स, बैक्टीरॉइडोटा और प्लैक्टोमाइसीटोटा ज्यादा पाए गए, साथ ही एसिनेटोबैक्टर और स्ट्रेप्टोमोनास जैसे फायदेमंद जेनेरा भी थे। हल्के सड़े हुए कंदों में शुरुआती सूक्ष्मजीव बदलाव दिखाई दिए, जिसमें प्रोटियोबैक्टीरिया बढ़ा और एक्टिनोबैक्टीरियोटा और डेसल्फोबैक्टीरोटा का उद्भव पाया गया। बहुत ज्यादा सड़े हुए कंदों में प्रोटियोबैक्टीरिया और फर्मिक्यूट्स ज्यादा थे, जो ऊतकों के बहुत ज्यादा खराब होने का संकेत देते हैं। फफूंद समुदाय में अधिकतर एस्कोमाइकोटा ज्यादा मात्रा में पाया गया। एस्परजीलस स्वस्थ कंदों की ग्रीवा और बाहरी स्तर में सबसे अधिक पाया गया, जबकि यीस्ट कैंडिडा ऊतकों के मध्य में बहुत अधिक पाया गया। खराब होने के दौरान, मेयरोज़ाइमा, ब्लास्टोबोट्रिस और पेनिसिलियम बढ़ गए, जिससे प्याज के कंदों का न्हास होने के दौरान फफूंद का बढ़ना दिखाई दिया। प्याज एवं लहसुन में कीड़ों के प्रबंधन के लिए जैव-सघन आईपीएम रणनीति का मूल्यांकन किया गया। कोकिनेलिड भृंग चेइलोमेनेस सेक्समैकुलाटा थ्रिप्स और एफिड्स का एक अहम भक्षक बनकर उभरा, जिसकी संख्या जनवरी में सबसे अधिक देखी गई। प्रयोगशाला अध्ययनों से पता चला कि वयस्क हर दिन 18-50 थ्रिप्स खाते हैं, और 45 दिन वाली प्याज की फसल में भृंग छोड़ने वाले अर्ध-क्षेत्र परीक्षणों में एक सप्ताह के अंदर थ्रिप्स की संख्या 71% कम हो गई। अंतरफसल के रूप में प्याज को लोबिया और धनिया के साथ लगाने से भक्षकों की गतिविधियां बढ़ गई, जिससे थ्रिप्स 35% कम हो गए। कटाई उपरांत के अध्ययनों से भण्डारण के कीड़ों की पहचान हुई, जिनमें एस्परजीलस नाइजर और ए. ओस्टियानस शामिल हैं। नीम, करंज, सीताफल, यूकेलिप्टस, विटेक्स, मोरिंगा और लेमनग्रास के साथ वानस्पतिक उपचार से भण्डारण में नुकसान कम हुआ, नीम से उपचारित किए गए कंदों में सबसे कम 38.39% नुकसान दिखाई दिया। परागण अध्ययन में बिना डंक वाली मधुमक्खियों (टेट्रागोनूला इरिडिपेनिस) पर लक्ष्य केंद्रित किया गया, जिसमें आकृति विज्ञान और डीएनए बारकोडिंग का इस्तेमाल करके उपजातियों का प्रलेखन और भोजन ढूंढने के लिए भ्रमण के व्यवहार का आकलन शामिल था। भोजन ढूंढने के लिए भ्रमण सबसे ज्यादा सुबह के 10:30 बजे से दोपहर के 2:30 बजे के बीच हुआ, जिसमें पराग संकलन के लिए 72% शीर्ष कार्य व्यवहार पाया गया। हर एकड़ में आठ छत्ते लगाने से प्याज के बीज बेहतर हुए। परागण क्षमता के मूल्यांकन से पता चला कि प्याज के परागण में टी. इरिडिपेनिस ने हाथ से परागण से बेहतर काम किया। एपिस फ्लोरिया की गट माइक्रोबायोम अध्ययनों से पता चला कि सूक्ष्मजीव प्रतिजैविकों, फफूंदनाशकों और कीटनाशकों के प्रति सहिष्णु हैं, जो मधुमक्खी के स्वास्थ्य प्रबंधन के लिए संभावित अनुप्रयोग का संकेत देते हैं। प्याज के कीटों, रोगों और अजैविक तनाव की वास्तविक समय में निगरानी के लिए आईओटी-आधारित रोग एवं कीट पूर्व-अनुमान मॉडल्स विकसित किए गए। स्वचालित प्याज गुणवत्ता श्रेणीकरण के लिए YOLOv8-seg का इस्तेमाल किया गया, जिससे पांच श्रेणियों के जैसे कि, स्वीकार्य (स्वस्थ), अमान्य, जोड़ वाले, सड़े हुए, और अंकुरित कंदों की पहचान करने में 91% की मध्यमान औसत परिशुद्धता (mAP@0.50) पाई गई। रैंडम फॉरैस्ट रिग्रेशन का इस्तेमाल करने वाले मौसम-आधारित थ्रिप्स मॉडल्स ने 0.752 का R² हासिल किया, और रोग पूर्व-अनुमान मॉडल्स ने मौसम की आवश्यक सीमा की पहचान की। यूएवी-आधारित बहु वर्णक्रमीय इमेजिंग ने वृद्धि, रोग और तनाव निगरानी के लिए एरियल फिनोटाइपिंग की सहायता की। क्रॉस-वैलिडेशन वाले मशीन अधिगम मॉडल्स ने उपज और रोग का सही-सही अनुमान लगाया, जिससे प्रिसिजन खेती और बेहतर फसल प्रबंधन के लिए साधन मिले।

कटाई- उपरांत प्रौद्योगिकी

एलियम ट्यूबरोसम पर कटाई-उपरांत अनुसंधान वृद्धि अवस्था, भंडारण, और जैव सक्रिय संयोजनों के निष्कर्षण को अनुकूलित करने पर केंद्रित था। वृद्धि के चार सप्ताह पर अधिकतम फिनोलिक (6.8 mg GAE/g) और एंटीऑक्सीडेंट सामग्री (9.36 TEAC $\mu\text{mol/g}$) दर्ज की गई, जबकि फ्लेवोनोइड और क्लोरोफिल का स्तर वृद्धि काल के दौरान अलग-अलग रहा। एलियम ट्यूबरोसम की पत्तियों के भंडारण अध्ययन से पता चला कि प्रशीतित परिस्थितियों (4°C) और क्लिंग फिल्म रैपिंग ने पत्तियों की ताजगी को प्रभावी ढंग से संरक्षित किया और वजन के नुकसान को कम किया, जबकि परिवेशी परिस्थितियों में पत्तियां तेजी से खराब हो रही थीं। अल्ट्रासोनिक और माइक्रोवेव- सहाय्य विधियों सहित उन्नत निष्कर्षण तकनीकों से पता चला कि विलायक के प्रकार, विलायक-से-ठोस अनुपात और भिगोने के समय ने फिनोलिक्स, फ्लेवोनोइड्स और एंटीऑक्सीडेंट्स की पुनर्प्राप्ति को महत्वपूर्ण रूप से प्रभावित किया, जिसमें मेथनॉल और 30 मिनट तक भिगोना सबसे प्रभावी रहा। यह निष्कर्ष खाद्य और औषधीय इस्तेमाल के लिए पोषण संबंधी और कार्यात्मक गुणवत्ता बढ़ाने हेतु एलियम ट्यूबरोसम की कटाई, भंडारण और प्रसंस्करण के लिए व्यावहारिक सिफारिशें प्रदान करते हैं।

प्रसार

महाराष्ट्र में खरीफ, पछेती खरीफ और रबी मौसमों में आयोजित कुल 320 अग्रिम पंक्ति के प्याज प्रदर्शनों ने स्थानीय किस्मों की तुलना में निदेशालय की किस्मों-भीमा सुपर, भीमा राज, भीमा रेड, भीमा श्वेता और भीमा पर्पल के बेहतर प्रदर्शन का पता चला, जिनमें उच्च अंकुरण, कंद का वजन और उपज शामिल है। पारंपरिक (पश्चिमी महाराष्ट्र) और गैर-पारंपरिक (विदर्भ) क्षेत्रों में आकलन से पता चला कि निदेशालय की प्रौद्योगिकियों को मजबूत तरीके से अपनाया जा रहा है, जिसमें निदेशालय की किस्में, रीतियों का पैकेज, सूक्ष्म सिंचाई के साथ चौड़ी ऊँची क्यारियां, और संशोधित भंडारण संरचनाएं शामिल हैं। निदेशालय की प्रौद्योगिकियों को अपनाने का महत्वपूर्ण प्रभाव किसानों के सामाजिक-आर्थिक पहलुओं पर पाया गया, जैसे कि वार्षिक आय में वृद्धि, ऋण चुकौती, कृषि सुधार, गृह सुधार, घरेलू खर्च में वृद्धि और किसानों की सामाजिक भागीदारी में वृद्धि।

निदेशालय ने प्रौद्योगिकी हस्तांतरण और उसे अपनाने को बढ़ावा देने के लिए नवीन डिजिटल उपकरणों का लाभ उठाया। 'गार्लिक न्यूट्री प्लानर' विज्ञान पर आधारित पोषक तत्वों के संबंध में सुझाव देता है, 'गार्लिक डॉक्टर' लक्षित प्रबंधन सलाह के साथ प्रारंभिक कीड़ों और रोगों का जल्दी पता लगाने में मदद करता है, 'गार्लिक वैरायटी गाइड' स्थान-विशिष्ट किस्म चयन में मदद करती है, और 'गार्लिक क्रॉप एडवाइजर' मोबाइल ऐप व्यावहारिक मार्गदर्शन और परामर्श देने के लिए इन उपकरणों को एकीकृत करता है। एग्री-ड्रोन परियोजना के तहत, पुणे और अहिल्यानगर के 58 गांवों में 314 हेक्टेयर प्याज के खेतों पर 223 ड्रोन-आधारित छिड़काव प्रदर्शनों से 2,532 किसान लाभान्वित हुए, जिससे श्रम और समय कम हुआ और उपज भी बेहतर हुई। कुल 450 किसानों के एक सर्वेक्षण में छिड़काव में चुनौतियां और ड्रोन सेवाओं के लिए भुगतान करने की किसानों की इच्छा का आकलन किया, जो उच्च-मूल्य और ज्यादा मेहनत वाली फसलों के लिए इसे अपनाने की संभावनाओं को उजागर करता है।

वर्ष 2024 में, निदेशालय ने महाराष्ट्र और पूर्वोत्तर पर्वतीय क्षेत्र में प्याज एवं लहसुन की उपज को बेहतर बनाने, किसानों की जानकारी बढ़ाने और टिकाऊ तरीकों को बढ़ावा देने के प्रयासों को जारी रखा। पूर्वोत्तर पर्वतीय राज्यों-अरुणाचल प्रदेश, नागालैंड, मणिपुर, त्रिपुरा और सिक्किम में 124 क्षेत्रीय प्रदर्शनों और 47 प्रशिक्षण कार्यक्रमों का आयोजन किया गया, जिनसे 4060 किसान लाभान्वित हुए। इनमें, स्थानीय कृषि विज्ञान केंद्रों के सहयोग से निदेशालय द्वारा बेहतर प्याज के बीज और जैविक उत्पादन सामग्री किसानों में वितरित की गई। जनजाति उप-योजना के तहत, महाराष्ट्र और उत्तर प्रदेश में 247 क्षेत्रीय प्रदर्शनों और चार प्रशिक्षण/क्षेत्र दिवसों में 2470 आदिवासी किसानों ने भाग लिया, जिससे उन्नत किस्मों को अपनाने में और किसानों की क्षमता निर्माण में बढ़ावा मिला। इसी तरह, 'मेरा गाँव मेरा गौरव' ग्राम अपनाने के कार्यक्रम के माध्यम से 20 अपनाने गए गाँवों में 63 गतिविधियों के माध्यम से निदेशालय की प्रौद्योगिकियों को 1,594 किसानों तक पहुंचाया गया। इन में, निदेशालय द्वारा विकसित प्याज की किस्मों के 60 प्रदर्शन और 39 प्रशिक्षण कार्यक्रम शामिल थे, साथ ही निदेशालय की वेबसाइट, मोबाइल ऐप और एग्रोवन अखबार के माध्यम से मृदा स्वास्थ्य विश्लेषण और सलाहकार सेवाएँ प्रदान की गईं। निदेशालय ने 'प्याज बीज ग्राम' मॉडल को भी मजबूत किया, जिससे छोटे किसानों के बीच शाश्वत प्याज बीज उत्पादन और उन्नत किस्मों के प्रसार को बढ़ावा मिला। अनुसूचित जाति उप-योजना के तहत, अहिल्यानगर, पुणे और छत्रपति संभाजीनगर जिलों के 460 से अधिक अनुसूचित जाति के किसानों को बेहतर प्याज और लहसुन के बीज, उर्वरक, सूक्ष्म पोषक तत्व और कीटनाशक दिए गए। कुल ग्यारह प्रशिक्षण कार्यक्रम आयोजित किए गए, जिनमें 636 किसानों ने भाग लिया। इन प्रशिक्षण कार्यक्रमों में बेहतर उत्पादन, कटाई, कटाई-उपरांत प्रबंधन और उद्यमिता विकास पर किसानों का ध्यान केंद्रित किया गया।

कुल मिलाकर, वर्ष 2024 में निदेशालय की एकीकृत विस्तार, डिजिटल उपकरण, प्रदर्शन और क्षमता-निर्माण पहलों ने प्याज एवं लहसुन की उत्पादकता में सुधार, प्रौद्योगिकी अपनाने और आदिवासी एवं पिछड़े किसान समुदायों के सामाजिक-आर्थिक सशक्तिकरण में महत्वपूर्ण योगदान दिया।

संस्थागत गतिविधियाँ

वर्ष 2024 में, भाकृअनुप-प्याज एवं लहसुन अनुसंधान निदेशालय, पुणे ने कार्यक्रमों, समारोहों और आउटरीच पहलों के माध्यम से अनुसंधान, नवाचार और सामुदायिक सहभागिता को सक्रिय रूप से बढ़ावा दिया। निदेशालय ने कर्मचारियों के बीच हिंदी के उपयोग को प्रोत्साहित करने के लिए 13-25 सितंबर 2024 तक हिंदी पखवाड़ा मनाया, जिसमें तात्कालिक भाषण, निबंध लेखन, प्रश्नोत्तरी और वाद-विवाद जैसी प्रतियोगिताएं आयोजित की गईं। हिंदी पखवाड़े का समापन 26 सितंबर 2024 को पुरस्कार समारोह और एक दिवसीय कार्यशाला के साथ हुआ। वैश्विक अभियान #एक पेड़ मां के नाम #Plant4Mother के तहत, 5 जून 2024 और 29 अगस्त 2024 को वृक्षारोपण कार्यक्रम आयोजित किए गए, जिनमें वृक्ष संरक्षण और पारिस्थितिकी तंत्र सेवाओं को बढ़ावा देने के लिए निदेशालय परिसर में लगभग 125 पौधे लगाए गए और कर्मचारियों को 200 पौधे वितरित किए गए, जिससे पर्यावरणीय स्थिरता को कृषि परिवर्तन के साथ जोड़ा जा सके। निदेशालय ने 26 जनवरी 2024 को 75वां गणतंत्र दिवस और 15 अगस्त 2024 को 78वां स्वतंत्रता दिवस 'हर घर तिरंगा' अभियान के साथ मनाया। कर्मचारियों के मेधावी बच्चों को सम्मानित किया गया और फ्लैग मार्च पास्ट का आयोजन किया गया। निदेशालय द्वारा 28 अक्टूबर से 3 नवंबर 2024 तक सतर्कता जागरूकता सप्ताह 'राष्ट्र की समृद्धि के लिए ईमानदारी की संस्कृति' विषय के साथ मनाया गया, जिसमें शपथ ग्रहण, संवेदीकरण कार्यक्रम, कार्यशालाएं और कर्मचारियों एवं उनके बच्चों के लिए प्रतियोगिताएं शामिल थीं। इसी तरह, कृषि नवाचारों में बौद्धिक संपदा की भूमिका को उजागर करने के लिए 25 अप्रैल 2024 को 'विश्व बौद्धिक संपदा दिवस' मनाया गया। 'स्वच्छता पखवाड़ा' 15 सितंबर-2 अक्टूबर 2024, और फिर 16-31 दिसंबर 2024 (23 दिसंबर 2024 को किसान दिवस सहित) के दौरान आयोजित किया गया, साथ ही विशेष स्वच्छता अभियान 4.0 के माध्यम से स्वच्छता, सफाई, वृक्षारोपण, स्वास्थ्य जांच आदि को बढ़ावा दिया गया। निदेशालय ने 29 जून 2024 को टाटा समूह के अध्यक्ष डॉ. एन. चंद्रशेखरन की मेजबानी की, जिसमें किसानों, उद्यमियों और विशेषज्ञों के साथ 'प्याज मूल्य श्रृंखला प्रबंधन' पर चर्चा की गई। चर्चाओं में भंडारण, विपणन, प्रसंस्करण और प्याज क्षेत्र को मजबूत करने की रणनीतियों पर प्रकाश डाला गया, जिसमें डॉ. चंद्रशेखरन ने निदेशालय के अनुसंधान की सराहना की और भविष्य में सहयोग करने का वादा किया। इन एकीकृत गतिविधियों के माध्यम से, निदेशालय द्वारा वर्ष 2024 में प्याज एवं लहसुन उत्पादन को आगे बढ़ाने, सामुदायिक भागीदारी को मजबूत करने और शाश्वत कृषि पद्धतियों को बढ़ावा देने के लिए अनुसंधान, नवाचार, किसान प्रशिक्षण, पर्यावरणीय स्थिरता, उद्यमिता और उद्योग सहयोग को सफलतापूर्वक जोड़ा गया।

Executive Summary

In 2024, the ICAR-Directorate of Onion and Garlic Research (ICAR-DOGR), Pune, continued its efforts in research, extension, and development through a combination of institutional and externally funded projects. Throughout year, the Directorate organized 121 training programs under various schemes such as SCSP, TSP, NEH, MGMR, and ATMA, benefiting 5943 farmers, students, and other stakeholders. ICAR-DOGR also actively participated in five major agricultural exhibitions, showcasing its latest onion and garlic varieties, production technologies, and post-harvest innovations. A brainstorming session was organized on 9 October 2024 focused on the efficiency of nano-fertilizers in onion and garlic cultivation, combining scientific insights and policy perspectives to improve yield and soil health. Research awareness initiatives included a one-day Scientific Social Responsibility program under a DST-SERB project, which introduced 25 undergraduate students to the role of native stingless bees in pollination and onion seed production. The Directorate enhanced its technology transfer and commercialization efforts by signing 12 licensing MoUs with eight seed companies, including three Farmer Producer Companies (FPCs), for five onion varieties (Bhima Shakti, Bhima Super, Bhima Red, Bhima Shubhra, Bhima Shweta), generating ₹12 lakh in revenue. Additionally, MoUs were executed with three institutions, and five copyrights were filed. The Agri-Business Incubation (ABI) Centre at ICAR-DOGR played a key role in promoting entrepreneurship in onion and garlic-based enterprises. The year began with the *Agri Startups Conclave – 2024* held on 16th January 2024, which served as a platform for networking, knowledge sharing, and collaboration among entrepreneurs, researchers, and agribusiness stakeholders. A total of 19 promising startups were enrolled during the year, working across multiple segments of the onion and garlic value chain. The ABI Centre also conducted two specialized Entrepreneurship Development Programmes on commercial onion seed production, along with a one-day hands-on training on 24 November 2024 titled 'Transforming Onion and Garlic into Profitable Products' for incubatees, entrepreneurs, and farmers. A brief overview of the research, extension, and development activities undertaken during the year 2024 is presented below.

Crop Improvement

During 2024, ICAR-DOGR achieved significant advancements in germplasm conservation, varietal development, breeding, biotechnology, and genomic research in onion and garlic. As the National Active Germplasm Site (NAGS), the institute strengthened the national repository by maintaining over 495 garlic accessions and conserving 28 *Allium* species, including 199 white onion and a large collection of red onion germplasm. Extensive multi-season evaluations (*kharif*, late *kharif*, *rabi*) enabled the identification of several elite accessions with superior yield, bulb quality, earliness, and storability. Major varietal achievements included the recommendation of three white onion varieties—*Bhima Ujjwala*, *Bhima Prasanskaran*, and *Bhima Nirjala*—for high yield and high TSS. In garlic, the line DOGR-Pb-10 was recommended for Zone II based on multi-year performance. Red onion entries such as DOGR-1203, DOGR-1625, and RGP-3 were also identified as superior for specific zones, particularly for earliness and marketable yield. Breeding programs demonstrated strong progress with the development of 45 pre-breeding lines, numerous bi-parental and poly-cross populations, and more than 150 F₁ hybrids across white and red onion programs as well as 498 new F₂ population bred for high TSS evaluation. Several hybrids showed >20% heterosis and have entered AINRPOG multi-location testing. Interspecific hybridization between *A. cepa* and *A. fistulosum* advanced through standardized embryo rescue, with successful establishment of hybrid plants possessing desirable foliage and stem traits. In garlic improvement, high-yielding accessions such as DOGR-493 (141.71 q/ha), DOGR-359, DOGR-534, and *Kharif*-suitable lines DOGR-100 and DOGR-555 were identified. Molecular and biochemical profiling of 32 garlic genotypes using SSR markers revealed substantial diversity, supporting targeted breeding for TSS, sulfur

compounds, antioxidants, and clove quality. Biotechnological research made notable strides. *In vitro* gynogenesis yielded 193 haploids and 52 diploids, advancing doubled haploid development. Genome editing efforts using *CRISPR/Cas9* targeted key genes—*AcCENH3*, *AcMYB1*, *AcCHS*, and *AcMSH1*—resulting in successful callus transformation and regeneration of edited plants across multiple constructs. Additional molecular studies, including transcriptome analysis under salinity and pathogen stress, identified regulatory genes and pathways critical for stress responsiveness. Additional research outputs included characterization of cuticular wax composition in *A. fistulosum*, identification of high-water-barrier accessions, and evaluation of onion lines for bolting tolerance, storability, and quality traits. Several unique genetic stocks were prepared for registration with ICAR-NBPGR.

Overall, ICAR–DOGR's work in 2024 significantly strengthened India's onion and garlic improvement pipelines. Through integrated breeding, biotechnology, and genomic approaches, the institute delivered new varieties, enhanced genetic resources, and advanced precision breeding tools that support productivity, climate resilience, and farmer profitability.

Crop Production

ICAR-DOGR continued its comprehensive research on enhancing onion and garlic productivity under abiotic stresses and through improved crop management practices. Drought stress significantly reduced growth, photosynthesis, and bulb yield across all onion genotypes, with notable variation in stress tolerance. Genotypes such as Bhima Shubhra exhibited higher canopy temperature depression and better physiological performance, while Bhima Raj, Bhima Dark Red, and Bhima Super showed the less yield reduction, indicating superior drought tolerance. A field study was conducted to evaluate the effects of foliar application of plant growth regulators (PGRs) and plant growth-promoting microbes (PGPMs) on onion (*Allium cepa* L.) cv. Bhima Shakti under drought stress, studied separately. The results revealed that foliar application of both PGRs and PGPMs significantly enhanced plant growth and bulb yield under normal as well as drought conditions. Among the PGR treatments, kinetin (25 ppm) enhanced photosynthesis, stress tolerance, and antioxidant activity, resulting in the highest bulb yield under both normal and drought conditions. Likewise, Among the tested microbes, *Azospirillum brasilense* was most effective, enhancing photosynthesis, stress tolerance mechanisms, and bulb yield by reducing oxidative damage and improving physiological traits under drought conditions. High temperature stress above 35°C significantly impaired growth and physiological traits of onion, reducing chlorophyll content, membrane stability, leaf area, and antioxidant activity while increasing ROS accumulation. Exposure to 42°C caused severe damage with poor recovery and survival in both onion varieties compared to control plants.

A long-term study showed that integrating mineral fertilizers with vermicompost sustained onion yield and soil fertility, producing yields comparable to mineral fertilizers alone, with better performance in the maize–onion system. Integrated nutrient management enhanced nutrient uptake and soil organic carbon, while sole organic treatments resulted in lower yields and nutrient uptake in both cropping systems. Another long-term study showed that integrated nutrient management (INM) produced the highest onion yield, outperforming mineral fertilizers alone and organic/natural farming by 21.0% and 51.5%, respectively. Organic and natural farming improved bulb quality and soil organic carbon, whereas INM and mineral fertilization enhanced nutrient uptake and reduced post-harvest storage losses. Nitrogen level and irrigation method significantly influenced onion growth, yield, and storage quality. Drip irrigation with 100% recommended nitrogen produced the highest yield, superior bulb size, and minimum storage losses, while excess nitrogen (150%) increased bulb quality traits but also led to higher post-harvest losses. Waterlogging stress caused significant reductions in growth and yield of onion, with clear genotypic differences in tolerance. Accession 1666 and Bhima Dark Red maintained better physiological stability and antioxidant activity, resulting in lower yield losses (~29%), and are recommended for cultivation in waterlogged areas, especially with raised bed and furrow planting. Salinity stress significantly altered growth, physiology, and ion balance in onion genotypes grown in clay loam soils. Bhima Shakti and Bhima Red performed better under mild salinity (0.5–0.85 dS m⁻¹), whereas salinity above 1.85 dS m⁻¹ caused

>30% reductions in growth and yield across genotypes, indicating the need for tolerant varieties to expand onion cultivation in saline areas. Smart-SNWM integrates IoT-based, solar-powered SAMBHAV™ sensors for real-time monitoring of soil moisture, nutrients, weather, and crop status to optimize irrigation and fertigation in onion. Sensor calibration studies showed high accuracy and consistency of SAMBHAV moisture ($\pm 5\%$) and NPK sensors (R^2 up to 0.96), highlighting their potential for efficient, data-driven nutrient and water management in precision agriculture. Field studies showed that polyhalite (POLY4), especially when combined with supplemental K, improved onion and garlic growth, yield, nutrient uptake, and quality compared to conventional MOP treatments. This approach enhanced nutrient use efficiency and is recommended as a sustainable, low-chloride alternative for onion and garlic production. Integrated weed management significantly improved onion yield, with weed-free plots showing a 98.2% increase over the weedy check. Among herbicide-based treatments, Pendimethalin followed by Propaquizafop + Oxyfluorfen and Pendimethalin with polythene mulching achieved the highest yield gains, highlighting the effectiveness of combining chemical and cultural practices. Weed-free conditions produced the highest garlic clove yield (7.33 t/ha), while among herbicide-based treatments, Pendimethalin followed by Propaquizafop + Oxyfluorfen achieved the highest yield (6.26 t/ha). Combining pre-emergence herbicides with mulching also effectively enhanced garlic productivity.

Crop Protection

During 2024, studies on the development, refinement, and validation of management strategies for major fungal diseases of onion and garlic were conducted. Disease samples were collected and analyzed, with major fungal pathogens of onion, including *Colletotrichum*, *Fusarium*, *Alternaria*, and *Stemphylium* spp., identified and characterized using morphological and molecular tools. Cultures were further deposited in NCBI and NAIMCC. Twelve *Trichoderma* isolates were evaluated against *Stemphylium* blight and purple blotch and for crop growth in garlic. A maximum of 49% reduction in purple blotch and up to 30% increase in bulb yield were documented, with isolate GRDT5 showing the highest disease suppression and GRDT7 producing maximum plant growth. Molecular characterization confirmed *Trichoderma asperellum* through *tefla* sequencing and phylogenetic analysis. Integrated disease management (IDM) modules were tested and found effective in suppressing major fungal diseases, with IPDM Module 2 providing the highest disease suppression and a 27% yield increase. *Amritpani*-based organic formulations were effective in reducing disease incidence and improving yield, with the DOGROF3 formulation showing superior performance. The efficacy of these interventions was further confirmed through multi-location validation at AINPROG centres. Major pathogenic fungi associated with foliar and bulb diseases of onion, including *Colletotrichum*, *Alternaria*, *Stemphylium*, and *Fusarium* spp., were also isolated, purified, and characterized using morphological, pathogenicity, and molecular methods, including ITS-based assays. The rhizosphere microbiome of wild and cultivated *Allium* species was characterized using whole-genome metagenomics, revealing significant differences in microbial community composition. Diversity analyses including richness, evenness, Shannon, and Simpson indices demonstrated clear distinctions between wild and cultivated *Allium* rhizospheres, indicating that domestication and agronomic practices significantly influence microbial community structure. miRNA-mediated gene regulation in onion in response to disease and stress conditions was investigated. Molecular screening of 30 onion germplasm lines using eleven defense-related gene markers highlighted variation in genetic potential for disease resistance. RNA-based expression analyses via RT-PCR and qRT-PCR confirmed differential expression of key defense genes (MYC A, PR-5, and RGA) between healthy and anthracnose-infected tissues. These studies provide insights into pathogen diversity, host defense mechanisms, and the role of rhizosphere microbiomes in disease resistance.

Long-term analysis (1998-2022) and recent surveys revealed *Fusarium* basal rot (FBR) incidence of 11–50% in major onion-growing districts of Maharashtra. *Fusarium* isolates causing basal rot were identified mainly as *F. acutatum* and *F. falciforme*, with pathogenicity tests fulfilling Koch's postulates. A first report of *Fusarium equiseti* causing basal rot in India was documented. *Fusarium* dry rot incidence in garlic during Rabi 2024 was variable, with higher severity observed in Pune and Ahilyanagar districts. Multiple *Fusarium* species associated with garlic dry rot were isolated, characterized, and deposited in national repositories. Pathogenicity assays confirmed *F. solani*, *F. oxysporum*, *F. incarnatum*, and *F. equiseti* as causal agents of garlic dry rot, with first

global reports for *F. incarnatum* and *F. equiseti*. Standardized challenge inoculation protocols identified cotton swab and pinprick-dipping methods as the most effective for artificial induction of *Fusarium* basal rot. Comparative virulence studies showed *F. falciforme* to be more aggressive than *F. acutatum*. Histopathological studies revealed extensive tissue damage under *F. falciforme* infection. *In vitro* sensitivity assays showed high efficacy of fungicides, particularly tebuconazole and carbendazim, while *Trichoderma harzianum* and *T. longibrachiatum* were effective biocontrol agents. Post-harvest studies profiled microbial communities in healthy, mildly rotten, and severely rotten onion bulbs using 16S rRNA and ITS sequencing. Healthy bulbs contained diverse bacterial communities dominated by Proteobacteria, Firmicutes, Bacteroidota, and Planctomycetota, with beneficial genera such as Acinetobacter and Pseudomonas. Mildly rotten bulbs showed early microbial shifts, with increased Proteobacteria and emergence of Actinobacteriota and Desulfobacterota. Severely rotten bulbs were dominated by Proteobacteria and Firmicutes, indicating advanced tissue degradation. Fungal communities were largely dominated by Ascomycota. Aspergillus was most abundant in the neck and outer scales of healthy bulbs, whereas the yeast Candida was abundant in central tissues. During spoilage, Meyerozyma, Blastobotrys, and Penicillium increased, demonstrating fungal succession during onion bulb deterioration. Bio-intensive IPM strategies were evaluated for insect pest management in onion and garlic. The coccinellid beetle *Cheilomenes sexmaculata* emerged as an important predator of thrips and aphids, with peak populations in January. Laboratory studies showed adults consumed 18–50 thrips per day, and semi-field trials releasing beetles in 45-day-old onion crops reduced thrips populations by 71% within a week. Intercropping onion with cowpea and coriander enhanced predator activity, reducing thrips by 35%. Post-harvest studies identified storage pests, including *Aspergillus niger* and *A. ostianus*. Botanical treatments with neem, karanj, custard apple, eucalyptus, vitex, moringa, and lemongrass reduced storage losses, with neem-treated bulbs showing the lowest losses at 38.39%. Pollination studies focused on stingless bees (*Tetragonula iridipennis*), including species documentation using morphology and DNA barcoding, and assessment of foraging behavior. Peak foraging occurred between 10:30 AM and 2:30 PM, with 72% top-working behavior for pollen collection. Optimal hive placement at eight hives per acre improved onion seed set. Pollination efficiency assessment revealed that *T. iridipennis* significantly contributed to onion pollination, outperforming hand pollination. Gut microbiome studies of *Apis florea* revealed microbes tolerant to antibiotics, fungicides, and insecticides, indicating potential applications for bee health management. IoT-based disease and pest prediction models were developed for real-time monitoring of onion pests, diseases, and abiotic stresses. YOLOv8-seg was applied for automated onion quality grading, achieving a mean Average Precision (mAP@0.50) of 91% across five classes viz., acceptable (healthy), discard, double, rot and sprout. Weather-based thrips models using Random Forest regression achieved an R² of 0.752, and disease prediction models identified critical weather thresholds. UAV-based multispectral imaging supported aerial phenotyping for growth, disease, and stress monitoring. Machine learning models with cross-validation accurately predicted yield and disease, providing tools for precision farming and improved crop management.

Post-Harvest Technology

Research on *Allium tuberosum* focused on optimizing growth stage, storage, and extraction of bioactive compounds. Maximum phenolic (6.8 mg GAE/g) and antioxidant content (9.36 TEAC μ mol/g) were recorded at four weeks of growth, while flavonoid and chlorophyll levels varied across the growth period. Storage studies *Allium tuberosum* leaves demonstrated that refrigerated conditions (4°C) and cling film wrapping effectively preserved leaf freshness and minimized weight loss, compared to rapid spoilage under ambient conditions. Advanced extraction techniques, including ultrasonic and microwave-assisted methods, revealed that solvent type, solvent-to-solid ratio, and soaking time significantly influenced the recovery of phenolics, flavonoids, and antioxidants, with methanol and 30-minute soaking being most effective. These findings provide practical recommendations for harvesting, storage, and processing of *Allium tuberosum* to enhance their nutritional and functional quality for food and medicinal applications.

Extension

A total of 320 frontline onion demonstrations conducted in Maharashtra across kharif, late *kharif* and *rabi* seasons revealed superior performance of ICAR-DOGR varieties-Bhima Super, Bhima Raj, Bhima Red, Bhima Shweta, and Bhima Purple over local cultivars, with higher germination, bulb weight, and yields. Impact assessments in traditional (Western Maharashtra) and non-traditional (Vidarbha) regions showed strong adoption of ICAR-DOGR technologies, including varieties, package of practices, BBF with micro-irrigation, and modified storage structures. The significant impact of adoption of ICAR-DOGR technologies was found on socio-economic aspects viz., increase in annual income, loan repayment, farm improvement, home improvement, increase in domestic spending and increase in social participation of farmers.

ICAR-DOGR leveraged innovative digital tools to enhance technology transfer and adoption. 'Garlic Nutri Planner' provides science-based nutrient recommendations, 'Garlic Doctor' enables early pest and disease diagnosis with targeted management advice, 'Garlic Variety Guide' supports location-specific variety selection, and 'Garlic Crop Advisor' mobile app integrates these tools to deliver practical guidance and advisories. Under the Agri-Drone Project, 223 drone-based spraying demonstrations on 314 hectares of onion fields across 58 villages in Pune and Ahilyanagar benefitted 2,532 farmers, reducing labour and time while improving yields. A survey of 450 farmers assessed spraying challenges and willingness to pay for drone services, highlighting potential for scaling up adoption for high-value, labour-intensive crops.

In 2024, ICAR-DOGR continued its focused efforts on improving onion and garlic production, enhancing farmers' knowledge, and promoting sustainable practices across Maharashtra and the North Eastern Hill (NEH) region. In the NEH states—Arunachal Pradesh, Nagaland, Manipur, Tripura, and Sikkim—124 field demonstrations and 47 training sessions benefitted 4060 farmers, with ICAR-DOGR providing improved onion seeds and organic input kits in collaboration with local KVKs. Under the TSP scheme, 2470 tribal farmers participated in 247 field demonstrations and four training/field days across Maharashtra and Uttar Pradesh, promoting adoption of improved varieties and capacity building. Similarly, The 'Mera Gaon Mera Gaurav' Village Adoption Programme reached 1,594 farmers in 20 adopted villages through 63 activities, including 60 demonstrations of ICAR-DOGR onion varieties and 39 training programs, along with soil health analysis and advisory services via the Directorate's website, mobile app, and Agrowon newspaper. ICAR-DOGR also strengthened the Onion Seed Village model, promoting sustainable onion seed production and improved variety dissemination among small-scale farmers. Under the SCSP, over 460 Scheduled Caste farmers across Ahilyanagar, Pune and Chhatrapati Sambhajnagar districts received improved onion and garlic seeds, fertilizers, micronutrients, and pesticides. Eleven training programmes reached 636 farmers, focusing on improved production, harvesting, post-harvest management, and entrepreneurship development. Overall, ICAR-DOGR's integrated extension, digital tools, demonstration, and capacity-building initiatives in 2024 contributed significantly to improve onion and garlic productivity, enhance technology adoption, and socio-economic empowerment of tribal and marginalized farming communities.

Institutional Activities

In 2024, ICAR-Directorate of Onion and Garlic Research (ICAR-DOGR), Pune, actively promoted research, innovation, and community engagement through a series of programs, celebrations, and outreach initiatives. The Directorate celebrated Hindi Fortnight from 13–25 September 2024 to encourage the use of Hindi among staff, with competitions such as extempore speech, essay writing, quizzes, and debates, culminating in an award ceremony and a one-day workshop on 26 September 2024. As part of the global campaign #एक पेड़ मां के नाम #Plant4Mother, plantation events were organized on 5 June 2024 and 29 August 2024, where around 120 saplings were planted on-site and 200 distributed to staff to promote tree conservation and ecosystem services, linking environmental sustainability with agricultural resilience. ICAR-DOGR also celebrated the 75th Republic Day on

26 January 2024 and the 78th Independence Day on 15 August 2024 with '*Har Ghar Tiranga*' campaign. Meritorious children of staff were felicitated, and a flag march past was organized. Vigilance Awareness Week from 28 October–3 November 2024 was observed with the theme “Culture of Integrity for Nation's Prosperity,” including pledge-taking, sensitization programs, workshops, and competitions for staff and their children. Similarly, World Intellectual Property Day on 25 April 2024 was celebrated to highlight the role of IP in agricultural innovations. Swachchhata Pakhwara, held from 15 September–2 October 2024 and again during 16–31 December 2024 (including Kisan Diwas on 23 December 2024), along with Special Sanitation Campaign 4.0, promoted hygiene, cleanliness, plantation, health check-ups, etc. The Directorate also hosted Dr. N. Chandrasekaran, Chairman of Tata Group, on 29 June 2024 for a discussion on Onion Value Chain Management with farmers, entrepreneurs, and experts. Discussions highlighted storage, marketing, processing, and strategies to strengthen the onion sector, with Dr. Chandrasekaran appreciating ICAR-DOGR's research and pledging future support. Through these integrated activities, ICAR-DOGR successfully linked research, innovation, farmer training, environmental sustainability, entrepreneurship, and industry collaboration to advance onion and garlic production, strengthen community engagement, and promote sustainable agricultural practices in 2024.

A. Introduction

The Directorate

Realizing the importance of onion and garlic in the country, the Indian Council of Agricultural Research (ICAR) established National Research Centre for Onion and Garlic in VIII Plan at Nashik in 1994. Later, the Centre was shifted to Pune on 16 June 1998. Due to the expansion of R&D activities of onion and garlic, the center was rechristened and upgraded to ICAR-Directorate of Onion and Garlic Research (DOGR) in December 2008 along with All India Network Research Project on Onion and Garlic with 26 participating centers across the country.

Location and weather

The Head Quarter of the Directorate located at Pune, Maharashtra on Pune-Nashik Highway. It is 18.32'N and 73.5'E at 553.8m above m.s.l. with a temperature range of 5.5-42.0 °C and having annual average rainfall of 669mm.

Infrastructure

The centre has 52 acres of research farm with perennial irrigation facilities at Rajgurunagar, 55 acres at Kalus, 10 acres at Manjari and 4 acres at Baner. The centre has research laboratories for biotechnology, soil science, plant protection, seed technology and post-harvest technology with modern state of the art equipment. The library at the centre has extensive collection of books, journals, e-sources on *Allium*. The internet and e-mail connectivity has been strengthened for easy literature access. The centre has its own website: www.dogr.icar.org.in, which provides rapid updates and all relevant information on onion and garlic and administrative matters of ICAR-DOGR.

Vision

To improve production, productivity, export and add on value of onion and garlic.

Mission

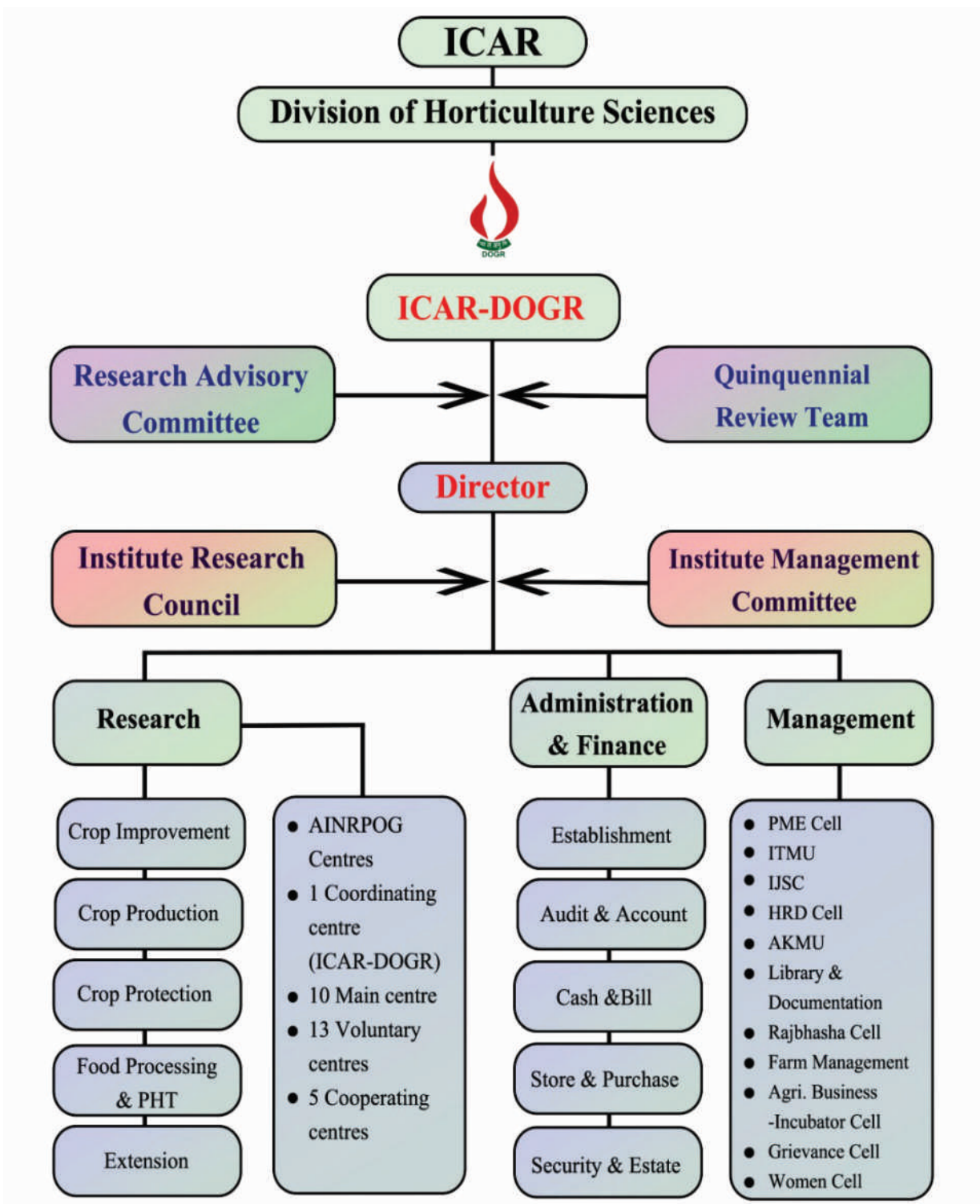
To promote overall growth of onion and garlic in terms of enhancement of quality production, export and processing.

Mandate

- ★ Basic, strategic and applied research on genetic resource management, crop improvement and production technologies for enhancing and sustaining production of onion and garlic
- ★ Transfer of technology and capacity building of stakeholders for enhancing productivity of onion and garlic
- ★ Coordinate research and validation of technologies through AINRP on onion and garlic



Organogram



B. RESEARCH ACHIEVEMENTS

1. Crop Improvement

1.1 Genetic improvement of white and yellow onion including *Allium* species

Collection, evaluation, conservation and maintenance of onion germplasm

As the National Active Germplasm Site (NAGS), ICAR-DOGR collaborates with NBPGR to maintain a diverse gene pool of onion and garlic collected domestically and imported from the USA, Taiwan, and Germany. The institute currently conserves 28 *Allium* species, including 199 white onion accessions characterized for yield, storability, and biotic/abiotic stress resistance. Elite lines, particularly those with high Total Soluble Solids (TSS), are rigorously selected for use in biparental and poly-cross breeding programs. Additionally, nearly 100 long-day accessions are preserved at ICAR-CITH, Srinagar, with all entries assigned IC numbers for long-term storage.

1.1.1 Variety/genetic stock development

The Variety Identification Committee (VIC) for onion and garlic under AINRPOG in its meeting held on 21 August 2024 at ICAR KAB-II, PUSA New Delhi, recommended three white onion varieties for release. The proposed variety Bhima Ujjwala (DOGR-361) has been identified for higher marketable yield, while other two varieties viz., Bhima Prasanskaran (DOGR HT-3 and Bhima Nirjala (DOGR HT-4) have been identified for higher TSS and suitability for processing purpose.



Bhima Ujjwala
(DOGR-361)



Bhima Prasanskaran
(DOGR HT-3)



Bhima Nirjala
(DOGR HT-4)

Fig.1.1 Recommended white varieties for release

1.1.2 Maintenance of released varieties

All the three released varieties of white onion (Bhima Safed, Bhima Shweta and Bhima Shubhra) were maintained as per the principles of maintenance breeding. The true-to-type bulbs of each variety were selected and used for production of nucleus seeds. Nearly 1.1 kg seeds of Bhima Shubhra, 0.9 kg of Bhima Shweta and 0.8 kg seeds of the variety Bhima Safed were produced during the period.

1.1.3 Development of breeding population

Crosses (14 nos.) between released varieties (Bhima Shweta, Bhima Shubhra and Bhima Safed) and elite lines (W 355, W 125, W 448 BR-11, W 208, F6 × L-12(Y)) were attempted in line × tester design. The seeds were harvested and raised in *Kharif* and late-*Kharif* 2024. In addition, 14 other biparental crosses were attempted for improvement of various traits. In addition, 10 poly-crosses were developed by intercrossing five elite lines.

Table 1.1 List of biparental crosses attempted for improvement of traits

| S. No. | Crosses | S. No. | F ₁ seed quantity |
|--------|---------------------|--------|------------------------------|
| 1. | W 398 AD-6 × W 448 | 8. | W 009 EL-12 × W 344 |
| 2. | W 009 EL-12 × W 448 | 9. | W 398 AD-6 × Bhima Shweta |
| 3. | W 398 AD-6 × W 361 | 10. | W 009 EL-12 × Bhima Shweta |
| 4. | W 009 EL-12 × W 361 | 11. | W 398 AD-6 × Bhima Shubhra |
| 5. | W 398 AD-6 × W 355 | 12. | W 009 EL-12 × Bhima Shubhra |
| 6. | W 009 EL-12 × W 355 | 13. | W 398 AD-6 × Bhima Safed |
| 7. | W 398 AD-6 × W 344 | 14. | W 009 EL-12 × Bhima Safed |

Table 1.2 List of poly-crosses attempted for improvement of traits

| Crosses | Parents involved |
|---------|---|
| PC1 | Bhima Shweta, W 009 EL-11, W 448, W 361, W 398 AD-6 |
| PC2 | Bhima Shubhra, W 344, W 355, W 408, W 498 |
| PC3 | Bhima Safed, W 009 EL-11, W 125 M-2, W 453, W 398 AD-7 |
| PC4 | Bhima Shweta, W 217 M-3, W 453 M-9, W 043 AD-5, W 177 |
| PC5 | Bhima Shubhra, W 408, W 147 M-7, W 353 M-5, W 418, W 459 M-10 |
| PC6 | W 344, W 177, W 043 AD-5, W 009 EL-11, W 045 |
| PC7 | Bhima Shweta, Bhima Shubhra, Bhima Safed, W 448, W 361 |
| PC8 | W 448, W 361, W 344 |
| PC9 | W 009 EL-11, W 398 AD-7 |
| PC10 | Bhima Shweta, Bhima Shubhra, Bhima Safed |

1.1.4 Evaluation of white onion germplasm and breeding lines in different seasons

Late *kharif*

Evaluation of white onion germplasm

In late *kharif* 2023-2024, twenty-four white onion germplasm accessions were evaluated along with a check Bhima Shubhra. There were serious issues of anthracnose disease incidence, which led to poor yield. None of the accessions performed better than the check for marketable yield. The marketable yield varied from 1.90 to 24.47 t/ha. The accession 'White Gene pool' recorded maximum marketable yield (24.47 t/ha) and was at par to the check Bhima Shubhra (19.64 t/ha). The storage-losses (after two months) in the tested accessions ranged from 11.08 to 54.79%. The accession W-519 recorded the lowest storage loss (11.08%) while the check Bhima Shubhra recorded storage-loss of 40.01%. Among the tested accessions, 18 accessions were free of bolters and 7 accessions were free of doubles. The TSS in the germplasm accession ranged from 10.53 to 13.27 °Brix, while the check recorded TSS of 11.82 °Brix.

Table 1.3 Evaluation of white onion germplasm during late *kharif*

| Germplasm accessions evaluated (No.) | Superior accessions for MY (No.) | Marketable Yield (t/ha) Range | SL2M (%) Range | Bolter (%) Range | TSS °Brix range (%) |
|--------------------------------------|----------------------------------|-------------------------------|----------------|------------------|---------------------|
| 24 | 0 | 1.90-24.47 | 11.08-54.79 | 0.00-5.21 | 10.53-13.27 |

(TY: Total Yield; MY: Marketable Yield; TSS: Total Soluble Solid; SL2M: Storage Loss in 2 Months)

Evaluation of white onion breeding lines

A total of 34 breeding lines were evaluated for various yield traits against the check Bhima Shubhra. None of the tested lines were found better than the check for marketable yield. However, the lines W-340 EL-9 and W 308 M-8 recorded slightly higher marketable yield (21.69 and 21.88 t/ha, respectively) when compared to the check (19.64 t/ha). The storage losses (after two months of storage) in the tested lines varied from 23.47 to 62.76%. The line W-174 EL-9 recorded the least storage loss (23.47%) followed by the lines W-396 AD-7 (28.51%) and W-340 M-10 (29.37%). All lines were free of bolters, and 22 lines were free of doubles. The TSS in the tested lines ranged from 10.27 to 15.60 °Brix. The line W-043 AD-6 recorded highest TSS (15.60 °Brix) followed by W-009 EL-12 (14.13), while the check recorded TSS of 11.82 °Brix.

Table 1.4: Evaluation of white onion breeding lines during late *kharif*

| Breeding lines evaluated (No.) | Superior lines for MY (No.) | Marketable Yield (t/ha) Range | SLM2 (%) Range | TSS (°Brix) Range (%) |
|--------------------------------|-----------------------------|-------------------------------|----------------|-----------------------|
| 34 | - | 2.26-21.88 | 23.47-62.76 | 10.27-15.60 |

(MY: Marketable Yield; TSS: Total Soluble Solid; SLM2: Storage Loss in 2 Months)

Evaluation of white onion bolting tolerant lines

In late *kharif* 2023-24, four bolting tolerant lines were evaluated and compared to check Bhima Shubhra. Three lines had similar marketable yield as that of the check variety. The marketable yield ranged between 10.88 and 18.74 t/ha. All the three lines i.e. W-448 LG-209-7, White Gene pool LG-107-7 and White GP comp LG-209-7 were free of bolters. All the tested lines recorded lower (30.10 to 42.07%) storage loss (after 2 months) against 54.79% noted for the check variety. Among the entries tested, White GP comp LG-209-7 recorded maximum TSS (13.80 °Brix) while the check recorded TSS of 11.82 °Brix.

Evaluation of white onion high-TSS lines

In late *Kharif* 2023-2024, a total of four high-TSS lines were evaluated and compared with the check variety Bhima Shubhra. The yield was relatively low due to the significant anthracnose incidence. However, TSS in these lines varied from 11.82 to 16.02 °Brix. The WHTS-15-18-M-10-SC had the highest TSS (16.02 °Brix), followed by the lines WHTB-GT-18-M-10-MC, WHT-9I-LT-15-SMC-M-8 and WHTS-7G-GT-15-MC-M-7 each having 15.87 °Brix, while the check variety Bhima Shubra recorded TSS of 11.82 °Brix. All four lines were free of bolters.

Rabi

Evaluation of white onion germplasm

Fifty-seven white onion germplasm were multiplied and evaluated along with check Bhīma Shweta during *Rabi* 2023-24. The marketable yield ranged in the germplasm ranged between 20.04 to 55.35 t/ha. The check variety Bhīma Shweta recorded marketable yield of 36.98 t/ha and total yield of 42.21 t/ha. Eight accessions showed

significant superiority for marketable yield and total yield over the check. The germplasm accession W-439 exhibited highest marketable yield (55.35 t/ha) and total yield (55.35 t/ha), followed by W-396 with marketable and total yield of 52.07 t/ha. The percentage of bolters in the germplasm collection ranged from 0 to 32.76%. Fourteen lines were found to be bolter-free. Storage losses ranged between from 39.72 to 90.05% after 4 months of storage. None of the accessions exhibited superior storability when compared to the check. However, least storage-loss was observed in the accessions White GP Comp-7 (39.72%), W 175 (40.73%) and W-146 (41.09%). The TSS (Total Soluble Solids) in the germplasm ranged between 10.13 to 15.27 °Brix. The accession W-310 recorded the maximum TSS (15.27 °Brix) followed by W-218 (14.20 °Brix), W-203 (13.80 °Brix), W-401 (13.80 °Brix) and W-498 (13.80 °Brix).

Table 1.5 Evaluation of white onion germplasm during rabi

| Germplasm accessions evaluated (No.) | Superior accessions for MY (No.) | Marketable Yield (t/ha) Range | SL4M (%) Range | Bolter (%) Range | TSS (°Brix) Range (%) |
|--------------------------------------|----------------------------------|-------------------------------|----------------|------------------|-----------------------|
| 57 | 8 | 20.04-55.35 | 39.72-90.05 | 0.00-32.76 | 10.13-15.27 |

(MY: Marketable Yield; TSS: Total Soluble Solid; SL4M: Storage Loss in 4 Months)

Table 1.6 List of superior germplasm accessions for important traits

| Trait | Germplasm accessions |
|------------------|--|
| Marketable yield | W -439, W- 396, W- 418, W- 497, W- 419, W -157, W -385 and W- 208 |
| Non-bolter | W- 055, W -146, W -208, W -217, W- 328, W- 385, W- 390, W -396, W- 398, W -401, W- 418, W -439, W- 455, W- 497 |
| TSS | W -310, W- 218, W -203, W- 498, W- 401 |

(MY: Marketable Yield; TSS: Total Soluble Solid; SL4M: Storage Loss in 4 Months)



A. White onion germplasm accessions with superior marketable yield



B. Bolter-free Germplasm accessions of white onion

Fig. 1.2 Best performing white onion germplasm accessions during rabi

Evaluation of yellow onion germplasm

Three accessions of yellow onion along with the variety Phule Suvarna (check) were evaluated during *Rabi* in 2023-24. None of them exhibited significant superiority over the check for marketable and total yield. The marketable yield of the accessions ranged between 35.01 to 43.43 t/ha which was lesser than that of the check variety (49.95 t/ha). The percentage bolting in the accession ranged from 2.53 to 7.18 % against 0.95% in the check variety. None of the accessions was found bolter-free. Storage losses (after 4-month of storage) in the tested accessions varied from 54.39 to 59.23% against 53.44% in the check. Total soluble solids in the accession ranged between 13.65 to 15.48 °Brix, while the check recorded TSS of 10.18 °Brix.

Evaluation of white onion breeding lines

In *Rabi* 2023-2024, Seventy-seven white onion breeding lines were evaluated along with the variety Bhima Shweta as check. The marketable yield in the tested lines ranged between 23.11 to 66.46 t/ha. Ten lines were found to be significantly superior to the standard Bhima Shweta for both total yield and marketable yield. The maximum marketable yield was observed in the entry W-353 M-5 (66.46 t/ha), followed by the entry W-439 M-9 (52.31 t/ha) and W-418 M-3 (51.24 t/ha). The entries revealed a wide range of bolters ranging from 0 to 34.30%, while the check variety recorded no bolters. A total of 22 lines were found bolter-free. The storage-loss in the tested lines ranged between from 38.37 to 88.81% after 4 months of storage. None of the lines exhibited superiority for storability when compared to the check. However, 12 entries recorded less storage loss when compared to the check with minimum loss recorded for the entry W 147 M-7 (38.37%) followed by W 232 M-2 (42.26%). Total soluble solids in the breeding lines ranged between 10.07 and 16.07 °Brix. The check variety recorded TSS of 12.60 °Brix. The line W-441 EL-9 recorded highest TSS (16.07 °Brix), followed by W-397 EL-9 (14.93) and W-402 AD-6 (14.27 °Brix).

Table 1.7 Evaluation of white onion breeding lines during rabi

| Breeding lines evaluated (No.) | Superior lines for MY (No.) | Marketable Yield (t/ha) Range | SL4M (%) Range | Bolter (%) Range | TSS (%) (°Brix) Range |
|--------------------------------|-----------------------------|-------------------------------|----------------|------------------|-----------------------|
| 77 | 10 | 23.11-66.46 | 38.37-88.81 | 0.00-34.30 | 10.07-16.07 |

(MY: Marketable Yield; TSS: Total Soluble Solid; SL4M: Storage Loss in 4 Months)

Table 1.8 Best performing white onion breeding lines during rabi

| Trait | Germplasm accessions |
|------------------|--|
| Marketable yield | W 009 AD-5, W 127 AD-8, W 172 AD-6, W 172 AD-7, W 402 AD-6, W 353 M-5, W 418 M-3, W 439 M-9, W 543 M-2, W 408 EL-10 |
| Non-bolter | W 078 AD-5, W 172 AD-6, W 172 AD-7, W 355 AD-7, W 396 AD-6, W 402 AD-6, W 419 AD-7, W 141 M-1, W 203 M-5, W 353 M-5, W 414 M-4, W 418 M-3, W 448 M-5, W 477 M-5, W 543 M-2, W 174 EL-11, W 361 EL-9, W 397 EL-7, W 397 EL-9, W 408 EL-10, W 440 EL-9, W 444 EL-8 |
| TSS | W 441 EL-9, W 397 EL-9, W 402 AD-6, W 104 M-5, W 477 M-6 |

Evaluation of white onion inbred lines

In *Rabi* 2023-24, twenty-five (I₁) white onion inbred lines were assessed in comparison to the check, Bhima Shweta. Four lines were found to be significantly superior for both marketable yield and total yield when compared to the check Bhima Shweta. The maximum marketable yield was observed in the line W-261 GP-2 (42.66 t/ha), followed by W-385 GP-4 (42.43 t/ha), W-418 GP-5 (39.92 t/ha) and W-418 GP-5 (39.02 t/ha), while the check Bhima Shweta recorded marketable yield of 30.10 t/ha. A total of 14 lines were found bolter-free. Two inbred lines WM 356 GP-2 and W 408 GP-3 marked their significant superiority for TSS over the check variety.

None of the inbred lines indicated significant superiority for storage when compared to the check. However, the entry W 534 GP-5 recorded the least storage-loss of 38.05% after 4 months of storage.

Evaluation of white onion high-TSS lines

In *Rabi* 2023–2024, a total 27 high-TSS lines were evaluated along with the standard check Bhima Shweta. The TSS in the tested lines varied from 12.60 to 17.80 °Brix with the highest TSS of 17.80 °Brix recorded by the entry WHTB-1A-GT-18-M-9-SC, WHTB-15-18-M-9-MC (17.73 °Brix), WHTB-GT-18-M-11-SC (16.93 °Brix) and WHTS-8H-GT-15-MC-M-8 (16.73 °Brix). With the exception of two lines (WHT-12-LT-15-M-8 and WHTB-LT-15-M-12-SC), all other lines recorded significant superiority for TSS over the check. The check recorded TSS of 12.60 °Brix. With respect to yield, none of the high-TSS lines performed better than the check. However, the marketable yield of two entries i.e. WHTB-6F-GT-15-SMC-M-8 (26.75 t/ha) and WHTB-9I-LT-15-SMC-M-8 (25.87 t/ha) was on par with that of the check (30.10 t/ha). A total of 15 lines recorded no bolting. The percentage of bolters in the tested entries varied from 0 to 14.02 %. After four months of storage, storage losses range from 40.45 to 74.17 %, respectively in the tested entries while the check variety recorded storage loss of 52.99%. Though none of the entries detected superiority for storability over the check, nine lines recorded lesser storage loss than the check.

Table 1.9 Evaluation of white onion high TSS lines during *rabi*

| Entries | % of bulbs in population having TSS >15 °Brix (%) | Average population TSS (°Brix) (%) |
|----------------------|---|------------------------------------|
| WHTB-1A-GT-18-SC-M-9 | 44.00 | 18.12 |
| WHTB-1A-GT-18-M-9-SC | 60.00 | 17.84 |
| WHTB-15-18-M-9-MC | 53.45 | 17.72 |
| WHTB-GT-18-M-12-SC | 40.00 | 17.52 |
| WHTS-8H-GT-15-MC-M-8 | 61.82 | 16.71 |
| WHT-23A-1 | 53.33 | 16.75 |
| HT-GR-2A-M-8-SGT-18 | 72.73 | 16.90 |

Evaluation of white onion backcrosses

During *Rabi* 2023-24, 6 backcross populations (4BC1 & 2BC4) were evaluated and compared with the check Bhima Shweta. One population recorded significantly superior performance as compared to the check. The population MS-100 × W-172 × W-172 (BC-4) recorded highest marketable yield (53.39 t/ha) against the check Bhima Shweta (36.98 t/ha). The maximum heterosis for marketable yield was noted for the population MS-100 × W-172 × W-172 (BC-4) (44.36%) followed by MS-100 × W-453 × W-453 (BC-4) (17.58%), and MS-100 × W-408 × W-408 BC-1 (12.33%) over the check Bhima Shweta. Two populations were found bolter-free.

Table 1.10 Evaluation of white onion hybrids during *rabi*

| Crosses | MY (t/ha) | Heterosis (%) | TY (t/ha) | Heterosis (%) | Bolters (%) | TSS (%) | SL4M (%) |
|-------------------------------|-----------|---------------|-----------|---------------|-------------|---------|----------|
| (MS-100 × W-172) × W-172 BC-4 | 53.39 | 44.36 | 53.39 | 26.50 | 0.00 | 12.28 | 71.00 |
| (MS-100 × W-453) × W-453 BC-4 | 43.48 | 17.58 | 46.55 | 10.29 | 0.38 | 13.20 | 64.12 |
| (MS-100 × W-408) × W-408 BC-1 | 41.54 | 12.33 | 43.34 | 2.69 | 0.31 | 13.80 | 72.28 |
| Bhima Shweta (C) | 36.98 | | 42.21 | | 0.00 | 12.60 | 54.39 |

(TY: Total Yield; MY: Marketable Yield; TSS: Total Soluble Solid; SL4M: Storage Loss in 4 Months)

Evaluation of white and yellow populations raised through crosses between long day and short-day onion in 7th generation

At ICAR-DOGR, the eight generation is now evaluating all five populations of long-day and short-day white and yellow onions following purification. None of the populations was found significantly superior to the check Arka Pitamber. The maximum heterosis for marketable yield was recorded by the population I-9 X E-5 (W) F7M6 (26.27%) followed by the population F-6 X J-10 (W) F8 M7 (5.31 %) as compared to check Arka Pitamber. Two hybrids were found to be bolter-free.

Table 1.11 Evaluation of crosses between long day and short day onion during *rabi*

| Crosses | MY (t/ ha) | Heterosis (%) | TY (t/ha) | Heterosis (%) | Bolters (%) | (%) TSS | SL4M (%) |
|----------------------|------------|---------------|------------|---------------|-------------|---------|----------|
| I-9 × E-5 (W) F7 M6 | 25.83 | 26.27 | 29.04 | 32.46 | 0.00 | 12.33 | 100.00 |
| F-6 × J-10 (W) F8 M7 | 21.54 | 5.31 | 25.95 | 18.38 | 7.52 | 13.07 | 80.31 |
| Arka Pitamber | 20.46 | | 21.92 | | 0.00 | 12.67 | 54.27 |

Kharif

Evaluation of white onion germplasm

During *Kharif*2024, sixteen white onion germplasms were replicated and tested using the variety Bhima Shubhra as check. None of the tested germplasm accessions were found superior to the check for marketable and total yield. Marketable yield in the tested lines ranged between 0.64-7.55 t/ha, with the maximum yield noted by the accession W 361. The check recorded the yield of 10.81 t/ha. The TSS in the tested lines ranged from 9.40 (W 143) to 12.05 °Brix (W 418), while the check recorded TSS of 11.60 °Brix. All of the lines were free of bolters and doubles.

Table 1.12 Evaluation of white onion germplasm during *kharif*

| Germplasm accessions evaluated (No.) | Superior accessions for MY (No.) | Marketable Yield (t/ha) Range | TSS range (%) (°Brix) |
|--------------------------------------|----------------------------------|-------------------------------|-----------------------|
| 16 | - | 0.64-10.81 | 9.40-12.05 |

(MY: Marketable Yield; TSS: Total Soluble Solid)

Evaluation of white onion advance/initial breeding lines

During *Kharif*2024, thirty-one white onion germplasms were replicated and tested utilizing the Bhima Shubhra as check. One line W-396 AD-7 was determined to be much better than the check, and it recorded superior marketable (14.18 t/ha) and total yield (14.59 t/ha) than the check Bhima Shubhra (9.78 t/ha). The line W 085 AD-7 had marketable yield (10.03 t/ha) comparable to the check. The check variety noted the maximum TSS (12.50 °Brix). Among the tested accessions, the entries W 355 AD-7 and W 408 EL-11 recorded maximum TSS (12.2 and 12.0 °Brix, respectively). All of the lines were free of bolters and doubles.

Table 1.13 Evaluation of white onion advance/initial breeding lines during *kharif*

| Breeding lines evaluated (No.) | Superior lines for MY (No.) | Marketable Yield (t/ha) Range | TSS range (%) (°Brix) |
|--------------------------------|-----------------------------|--------------------------------|-----------------------|
| 31 | 1 (W 396 AD-7) | 1.50-14.18 | 7.90-12.50 |

(MY: Marketable Yield; TSS: Total Soluble Solid)

Evaluation of white onion high-TSS lines during *kharif*

In *Kharif* 2024, three high TSS *Rabi* lines were tested and compared to the check Bhima Shubhra. The yield in the high-TSS line was low due to the high anthracnose incidence. However, the TSS in these lines ranged from 11.00 to 12.55 °Brix, while the check recorded low TSS (11.00 Brix). All lines were free of bolters and doubles.

1.1.5 Development of new high TSS lines through biparental crossing

A total five crosses were made for obtaining new high TSS lines using selected parental lines (high and low TSS lines). Evaluation of F₂ population for high TSS is under progress.

Table 1.14 Mean performance of F₂ population generated through high and low TSS crosses in white onion

| Code of crosses | Bulb No. obtained in F ₂ population | Parameters | Polar Diameter (mm) | Equatorial diameter (mm) | Neck thickness (mm) | Bulb weight (gm) | Total Soluble Solids (°Brix) (%) | No. of centers to bulb |
|-----------------|--|------------|---------------------|--------------------------|---------------------|------------------|----------------------------------|------------------------|
| HTC-342 | 86 | Range | 62.99-9.47 | 67.56- 36.19 | 20.6-3.08 | 99.5-13.5 | 15.8-10 | 6.0-1.0 |
| | | Max | 47.26 | 50.33 | 7.64 | 56.18 | 12.30 | 2.35 |
| | | Min | 6.11 | 6.61 | 3.45 | 18.91 | 1.36 | 1.01 |
| HTC-321 | 58 | Range | 57.28-32.34 | 98.95-34-41 | 16.9-2.78 | 91.5-13 | 16-10.2 | 4.0-1.0 |
| | | Max | 42.96 | 47.52 | 7.25 | 42.46 | 13.53 | 2.38 |
| | | Min | 4.28 | 9.51 | 2.91 | 16.47 | 1.75 | 0.72 |
| HTC-340 | 190 | Range | 58.04-19.04 | 64.71-24.28 | 14.2-2.35 | 92.5-12.5 | 20-9.8 | 4.0-1 |
| | | Max | 40.54 | 43.49 | 6.36 | 39.07 | 13.42 | 2.27 |
| | | Min | 5.38 | 6.65 | 2.25 | 15.01 | 1.83 | 0.70 |
| HTC-325 | 50 | Range | 52.2-31.25 | 62.01-31.5 | 9.9-2.03 | 95.5-18 | 16-10.2 | 3.0-1.0 |
| | | Max | 42.25 | 44.81 | 4.93 | 43.30 | 13.26 | 1.68 |
| | | Min | 4.24 | 6.92 | 1.90 | 16.51 | 1.58 | 0.68 |
| HTC-332 | 45 | Range | 58.63-32.14 | 60.15-29.01 | 9.5-2.07 | 92-22.05 | 16- 10.02 | 3.0-1.0 |
| | | Max | 47.23 | 45.88 | 5.20 | 47.17 | 13.74 | 2.16 |
| | | Min | 5.97 | 7.03 | 1.73 | 17.92 | 1.68 | 0.77 |

1.1.6 Biochemical diversity studies in High and Low TSS onion lines

A targeted study at the ICAR-Directorate of Onion and Garlic Research evaluated 27 diverse onion genotypes to identify superior lines for the processing industry. By analysing seven key biochemical parameters, we utilized multivariate analysis to successfully categorize the genotypes into three distinct clusters: high TSS (Total Soluble Solids), low TSS white, and red varieties. Principal component analysis (PCA) revealed that over 71% of the genetic variability was explained by key traits like TSS, total sugar, antioxidant capacity (DPPH and ABTS), phenolics, and thiosulfinate content. This analysis also confirmed significant correlations between TSS and DPPH antioxidants, and total sugar with ABTS antioxidants, providing valuable markers for selection.

The most significant outcome is the identification of elite genetic material for direct use in breeding. Genotypes W-103, W-107, and W-123 were singled out for their exceptionally high TSS (>22°Brix), crucial for dehydration. Similarly, W-108, W-111, and W-308 were noted for high sugar content, and W-361 for high thiosulfinate content. These selected lines are being fast-tracked as parental material to develop the next generation of processing-suitable onion varieties.



Table 1.15 Variation in the biochemical traits of the bulbs of the tested lines/varieties of onion

| Biochemical Parameters | High TSS Lines | Low TSS Lines | Varieties |
|--|------------------|------------------|------------------|
| Total Soluble Solids °Brix | 20.69 ± 0.20 a | 14.69 ± 0.13 b | 12.42 ± 0.15 ab |
| Thiosulfinate content µmol/g FW | 21.06 ± 0.18 ab | 21.27 ± 0.43 ab | 20.53 ± 0.23 ab |
| Total phenolic content mg GAE/g FW | 0.33 ± 0.02 bc | 0.28 ± 0.015 ab | 0.40 ± 0.02 abc |
| Total flavonoid content QE mg/100 g FW | 7.48 ± 0.012 bc | 5.88 ± 0.028 abc | 9.06 ± 0.015 bcd |
| Antioxidant capacity ABTS TEAC µmol/g FW | 0.74 ± 0.031 bcd | 0.80 ± 0.022 bcd | 0.58 ± 0.061 bc |
| Antioxidant capacity DPPHAE µmol/g FW | 4.95 ± 0.120 bcd | 4.26 ± 0.125 bcd | 3.75 ± 0.160 ab |
| Total sugar content g/100 g FW | 12.85 ± 0.12 ab | 6.11 ± 0.31 cd | 6.15 ± 0.11 cd |
| Reducing sugar content g/100 g FW | 0.90 ± 0.11 bc | 0.90 ± 0.12 bc | 1.20 ± 0.14 ad |

(Data are reported as the mean ± standard error)

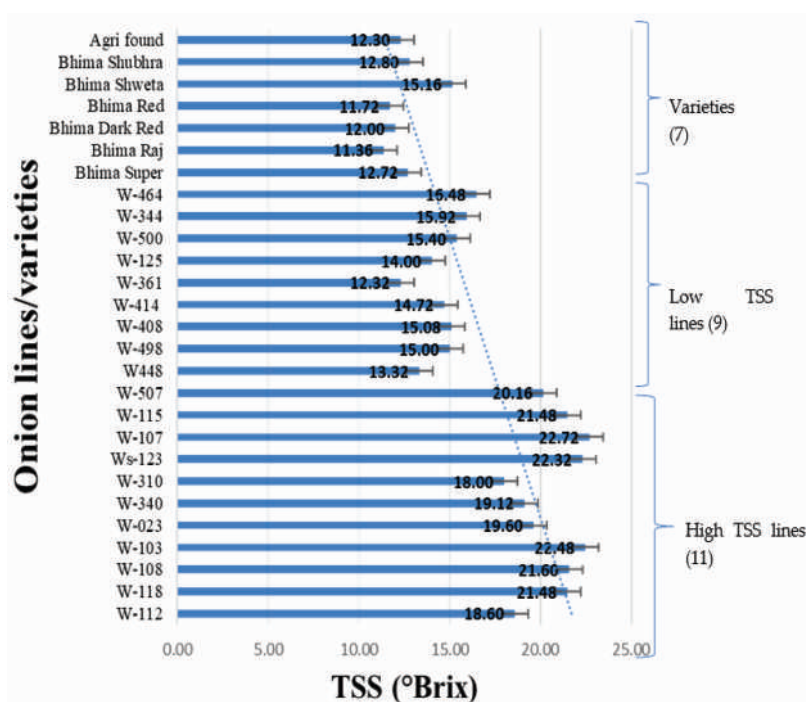


Fig.1.3 Total Soluble Solids (TSS) variability in onion genotypes/varieties

Table 1.16 Principal component analysis for biochemical traits in onion genotypes/varieties

| Traits | PC1 | PC2 | PC3 |
|--------------------------------|----------------|----------------|----------------|
| Total Soluble Solids | 0.48301 | 0.17229 | -0.25215 |
| Thiosulfinate content | 0.15782 | 0.00426 | 0.82728 |
| Total phenolic content | -0.30324 | 0.62220 | 0.08454 |
| Total flavonoid content | -0.26411 | 0.62260 | -0.07996 |
| Antioxidant capacity ABTS TEAC | 0.07765 | 0.23732 | 0.32982 |
| Antioxidant capacity DPPH | 0.46424 | 0.30680 | 0.04090 |
| Total sugar content | 0.49779 | 0.21196 | 0.15292 |
| Reducing sugar content | -0.33277 | 0.01261 | 0.33433 |

(Highlighted values: Significant contribution for variation)

1.1.7 *Allium* species, collection, conservation, maintainance and utilization in breeding

Characterization of the chemical composition and water permeability of the cuticular wax layer in *Allium fistulosum*

Water permeability differed notably between the two accessions of *A. fistulosum*. The variety Pusa Soumya showed the highest permeability to water compared to *A. fistulosum* EC-321643, indicating reduced barrier efficiency. In contrast, *A. fistulosum* contained nearly two-fold more wax than Pusa Soumya, suggesting a stronger protective cuticular layer that may contribute to lower water permeability. In terms of wax composition, C29 ketones were the dominant constituents, while the amount of β -sitosterol was extremely low, highlighting a distinct biochemical profile of the cuticular wax.

Development of pre-breeding lines in Onion: A total of 45 pre breeding lines have been developed in onion using *A. cepa* x *A. fistulosum* EC-321643. Developed F1 hybrids (pre breeding lines) lines were established in field condition for further evaluation as well as generation advancement. Few lines were selected for long pseudo stem length as well as leaf traits (non waxy, dark green colour, texture etc.). The molecular characterization and biochemical characterization of these lines is in progress.

Interspecific hybridization in *Allium*: The new cross combination between *A. cepa* x *A. fistulosum* carried out using standardized embryo rescue protocol by culturing 1023 ovaries. A total of 50 generated plant cultures for elongation and establishment.

1.2 Genetic improvement and development of varieties and hybrids in red onion

Collection, evaluation, conservation and development of red onion germplasm

1.2.1 Evaluation of germplasm

Late *kharif*

Onion germplasm were evaluated during late *kharif* (182 accessions), *rabi* (240 accessions) and *kharif* (165 accessions) along with checks. During late *kharif*, Acc. 1333, 1395, 1481, 1332 and 1284 produced more than 49 t/ha marketable yield and found superior over best check Bhima Shakti (37.23 t/ha). These accessions also recorded >83% marketable yield and were free from doubles and bolters except Acc. 1284 (16.95% doubles). Minimum days to harvesting was recorded in Acc. 1284, 1481 (114 days) and 1332 (116 days) while in check Bhima Shakti (120.33 days). Minimum storage loss after four months of storage was recorded in Acc. 1820 (7.59%) followed by 1616 (13.41%) and 1333 (14.15%) over check Bhima Shakti (46.82%).

Table 1.17 Evaluation of red onion germplasm during late *kharif*

| Entries | MY (t/ha) | Mrk (%) | ABW (g) | TSS (%) | DTH | E:P |
|------------------|-----------|---------|---------|---------|------|------|
| 1333 | 56.27 | 100 | 93.78 | 11.60 | 117 | 1.22 |
| 1395 | 55.33 | 100 | 89.38 | 11.24 | 117 | 1.13 |
| 1481 | 54.40 | 100 | 81.60 | 11.44 | 114 | 1.11 |
| 1332 | 49.60 | 100 | 74.40 | 11.92 | 116 | 1.13 |
| 1284 | 49.00 | 83 | 91.88 | 11.80 | 114 | 1.12 |
| 1214 | 48.00 | 100 | 96.00 | 11.00 | 113 | 1.14 |
| 1713 | 47.83 | 100 | 71.75 | 12.20 | 113 | 1.16 |
| Bhima Shakti (C) | 37.23 | 93 | 67.20 | 11.68 | 120 | 1.07 |
| Bhima Super (C) | 31.77 | 99 | 57.22 | 11.64 | 119 | 1.09 |
| CV (%) | 11.04 | 8.69 | 11.57 | 2.94 | 2.97 | - |
| LSD (P=0.05) | 4.68 | 12.66 | 13.59 | 0.55 | 5.55 | - |

Rabi

During *rabi*, Acc. 1441, 1289, 1208, 1474 and 1284 produced more than 71 t/ha marketable yield and found superior over best check Bhima Shakti (49.42 t/ha). These accessions also recorded 100% marketable yield. All the accessions were free from doubles and bolters except 1616. Minimum days to harvesting was recorded in Acc. 1284, 1616, 1332 (117 days) followed by 1289 (119 days) while in check Bhima Shakti (124 days). Minimum storage loss after four months of storage was recorded in 1284 (13.63%) followed by 1441 (16.54%) and 1211 (22.28%) over check Bhima Shakti (44.36%).

Table 1.18 Evaluation of red onion germplasm during *rabi*

| Entries | MY (t/ha) | Mrk (%) | ABW (g) | TSS (%) | DTH | E:P |
|-----------------|-----------|---------|---------|---------|------|------|
| 1441 | 81.40 | 100 | 152.63 | 12.44 | 122 | 1.09 |
| 1289 | 78.13 | 100 | 117.20 | 11.80 | 119 | 1.14 |
| 1208 | 75.58 | 100 | 120.93 | 12.36 | 122 | 1.16 |
| 1474 | 71.30 | 100 | 106.95 | 12.28 | 122 | 1.13 |
| 1284 | 71.17 | 100 | 112.37 | 11.84 | 117 | 1.10 |
| 1616 | 70.00 | 96 | 121.15 | 11.36 | 117 | 1.14 |
| 1332 | 69.20 | 100 | 103.80 | 12.20 | 117 | 1.10 |
| Bhima Shakti(C) | 49.42 | 97.64 | 82.67 | 11.39 | 124 | 1.15 |
| Bhima Kiran (C) | 43.44 | 98.66 | 68.45 | 11.33 | 124 | 1.14 |
| BLR (C) | 39.68 | 98.40 | 70.58 | 11.52 | 124 | 1.16 |
| CV (%) | 11.17 | 3.10 | 12.06 | 2.10 | 2.97 | - |
| LSD (P=0.05) | 4.77 | 4.88 | 4.48 | 0.39 | 5.68 | - |

Kharif

During *kharif*, more than 16 t/ha marketable yield was recorded in Acc. 1500, 1768, 1243, 1554 and 1818 and found superior over best check Bhima Super (12.21 t/ha). These accessions also recorded >90% marketable yield. All the accessions were free from doubles and bolters. Minimum days to harvesting was recorded in Acc. 1500 (82 days) followed by 1243 (83.33 days) and 1554 (84 days) while in check Bhima Super (97.67 days).

Table 1.19 Evaluation of red onion germplasm during *kharif*

| Entries | MY (t/ha) | Mrk (%) | ABW (g) | TSS (%) | DTH | E:P |
|--------------------|-----------|---------|---------|---------|------|------|
| 1500 | 30.51 | 100 | 62.41 | 9.64 | 82.0 | 1.14 |
| 1768 | 19.72 | 98.78 | 76.05 | 10.1 | 84.6 | 1.19 |
| 1243 | 18.01 | 98.57 | 65.09 | 10.1 | 83.0 | 1.17 |
| 1554 | 16.73 | 90.90 | 72.01 | 10.2 | 84.0 | 1.12 |
| 1818 | 16.49 | 97.74 | 54.12 | 10.2 | 85.0 | 1.22 |
| 1248 | 15.90 | 100 | 59.63 | 10.5 | 84.0 | 1.13 |
| 1242 | 15.86 | 86.12 | 65.86 | 10.0 | 84.6 | 1.18 |
| Bhima Super (C) | 12.21 | 90.39 | 63.11 | 11.2 | 97.6 | 1.20 |
| Bhima Dark Red (C) | 11.97 | 69.15 | 64.96 | 10.8 | 95.6 | 1.25 |
| CV (%) | 10.25 | 9.73 | 11.15 | 3.39 | 2.31 | - |
| LSD (P=0.05) | 2.15 | 6.12 | 4.71 | 0.56 | 3.17 | - |

1.2.2 Breeding improved onion varieties for table purpose

Evaluation of red onion advance breeding lines

Advance breeding lines were evaluated during late *kharif* (40 lines), *rabi* (41 lines) and *kharif* (39 lines) along with checks for 24 important traits. During late *kharif*, more than 40 t/ha marketable yield was recorded in DOGR-1048-Sel, DOGR-1610, DOGR-1773, RGP-3 and DOGR-1745 and found superior over best check Bhima Shakti (32.20 t/ha) with dark red, globe and medium sized bulbs (71-84 g), >93% marketable yield. Lines DOGR-1048-Sel, DOGR-1610, DOGR-1014-GDR and RGP-2 recorded less than 1% double bulbs. Minimum days to harvesting was recorded in RGP-3 (110 days) followed by DOGR-1773 (113.67 days) and DOGR-1610 (117 days) while in check Bhima Shakti (121 days). Minimum storage loss after four months of storage was recorded in DOGR-1172-DR (14.17%) followed by DOGR-1048-Sel (15.87%) and DOGR-1613 (17.19%) whereas, check Bhima Shakti (26.70%).

Table 1.20 Evaluation of red onion advance breeding lines during late *kharif*

| Entries | MY (t/ha) | ABW (g) | Doubles (%) | Bolters (%) | TSS (%) | DTH |
|------------------|-----------|---------|-------------|-------------|---------|------|
| DOGR-1048-Sel | 42.72 | 84.38 | 0.96 | 2.01 | 11.67 | 119 |
| DOGR-1610 | 41.15 | 80.51 | 0.63 | 5.25 | 11.69 | 117 |
| DOGR-1773 | 40.89 | 80.22 | 1.22 | 5.60 | 11.55 | 113 |
| RGP-3 | 40.74 | 71.74 | 1.35 | 2.53 | 11.60 | 110 |
| DOGR-1745 | 40.24 | 73.57 | 3.34 | 2.63 | 11.16 | 121 |
| DOGR-1014-GDR | 40.15 | 76.53 | 0.81 | 7.62 | 11.71 | 121 |
| RGP-2 | 40.04 | 73.51 | 0.93 | 5.30 | 11.41 | 113 |
| Bhima Shakti (C) | 32.20 | 69.83 | 4.40 | 10.77 | 11.83 | 121 |
| Bhima Super (C) | 32.06 | 62.81 | 2.54 | 16.90 | 11.91 | 120 |
| CV (%) | 11.23 | 8.16 | 15.22 | 22.78 | 3.84 | 2.02 |
| LSD (P=0.05) | 3.70 | 9.53 | 3.89 | 9.16 | 0.71 | 3.85 |

During late *kharif*, under bolting free group, DOGR-1168 (LG-107-3) (34.93 t/ha), RGO-53 (LG-107-3) (34.10 t/ha), B-780 (LG-107-3) (33.84 t/ha), DOGR-1133 (LG-107-3) (32.14 t/ha) and Bhima Raj (LG-107-3) (32.10 t/ha) were found superior over best check Bhima Super (26.69 t/ha). These accessions also recorded >81% marketable yield and less than 4.5% double bulbs. Minimum days to harvesting was recorded in RGO-53 (LG-107-3), B-780 (LG-107-3) and DOGR-1133 (LG-107-3) (109 days) while in check Bhima Super (119.67 days). Minimum storage loss after four months of storage was recorded in Bhima Red (LG-107-3) (13.34%) followed by DOGR-1168 (LG-107-3) (18.74%) and B-780 (LG-107-3) (19.49%) whereas, check Bhima Shakti (23.06%).

Table 1.21 Evaluation of red onion bolting tolerant lines

| Entries | MY (t/ha) | ABW (g) | Doubles (%) | Bolters (%) | TSS (%) | DTH |
|---------------------------|-----------|---------|-------------|-------------|---------|-----|
| DOGR-1168 (LG-107-3) | 34.93 | 63.00 | 0.21 | 5.59 | 11.49 | 120 |
| RGO-53 (LG-107-3) | 34.10 | 67.52 | 2.10 | 12.93 | 11.71 | 109 |
| B-780 (5-3-1) (LG-107-3) | 33.84 | 63.93 | 0.52 | 10.96 | 11.63 | 109 |
| DOGR-1133 (LG-107-3) | 32.14 | 64.98 | 4.49 | 7.74 | 11.56 | 109 |
| Bhima Raj (LG-107-3) | 32.10 | 61.25 | 1.31 | 8.94 | 11.49 | 119 |
| DOGR-595 (LG-107-3) | 31.90 | 61.51 | 1.92 | 8.98 | 11.89 | 118 |
| Red Genepool-1 (LG-107-3) | 31.17 | 62.71 | 2.35 | 8.21 | 11.21 | 120 |

| Entries | MY (t/ha) | ABW (g) | Doubles(%) | Bolters(%) | TSS (%) | DTH |
|------------------|-----------|---------|------------|------------|---------|------|
| Bhima Super (C) | 26.69 | 57.57 | 1.29 | 19.10 | 12.01 | 119 |
| Bhima Shakti (C) | 26.65 | 66.43 | 2.57 | 16.30 | 11.53 | 120 |
| CV (%) | 9.06 | 5.57 | 18.47 | 17.37 | 2.77 | 1.50 |
| S.E. | 0.98 | 2.02 | 1.07 | 1.94 | 0.18 | 1.02 |
| LSD (P=0.05) | 2.89 | 5.91 | 3.13 | 5.65 | 0.54 | 2.97 |

During *rabi*, DOGR-1048-Sel (55.23 t/ha), RGP-4 (51.47 t/ha), DOGR-1044-Sel (50.31 t/ha) DOGR-1746 (49.56 t/ha) and DOGR-1773 (49.24 t/ha) were found superior over best check Bhima Light Red (45.19 t/ha) with dark red, globe and big sized bulbs (81-94 g), >94% marketable yield. Line DOGR-1048-Sel was free from doubles. Minimum days to harvesting was recorded in DOGR-1773 (120.33 days) followed by DOGR-1048-Sel (122 days) while in check Bhima Light Red (123.67 days). Minimum storage loss after four months of storage was recorded in DOGR-1744 (25.16%) followed by DOGR-1625 (25.52%) over check Bhima Light Red (27.40%).

Table 1.22 Evaluation of red onion advance breeding lines during *rabi*

| Entries | MY (t/ha) | ABW (g) | Doubles (%) | Bolters (%) | TSS (%) | DTH | E:P |
|---------------------|-----------|---------|-------------|-------------|---------|------|------|
| DOGR-1048-Sel | 55.23 | 94.57 | 0.00 | 1.01 | 11.37 | 122 | 1.12 |
| RGP-4 | 51.47 | 84.74 | 2.63 | 2.67 | 11.41 | 123 | 1.14 |
| DOGR-1044-Sel | 50.31 | 82.59 | 0.46 | 1.20 | 11.45 | 122 | 1.20 |
| DOGR-1746 | 49.56 | 81.08 | 0.35 | 1.45 | 11.40 | 123 | 1.13 |
| DOGR-1773 | 49.24 | 93.99 | 1.26 | 0.73 | 11.44 | 120 | 1.28 |
| DOGR-1610 | 48.81 | 82.79 | 0.61 | 0.60 | 11.31 | 124 | 1.16 |
| DOGR-1639 | 47.98 | 89.75 | 1.94 | 1.17 | 11.05 | 115 | 1.14 |
| Bhima Light Red (C) | 45.19 | 77.35 | 0.27 | 0.47 | 11.29 | 123 | 1.15 |
| Bhima Kiran (C) | 44.53 | 76.35 | 0.38 | 0.38 | 11.39 | 126 | 1.18 |
| CV (%) | 11.02 | 13.23 | 16.84 | 18.94 | 2.30 | 2.59 | - |
| LSD (P=0.05) | 3.64 | 7.21 | 4.21 | 3.08 | 0.42 | 5.05 | - |

During *kharif*, DOGR-1768 (15.44 t/ha) was found superior over best check Bhima Dark Red (12.89 t/ha) with dark red, globe bulbs of medium sized bulbs (65 g) and free from doubles and bolters. Minimum days to harvesting was recorded in DOGR-1774, DOGR-1744, DOGR-1773, DOGR-1744 (83.67 days) followed by DOGR-1768 (84.33 days) while in check Bhima Dark Red (94 days).

Table 1.23 Evaluation of red onion advance breeding lines during *kharif*

| Entries | MY (t/ha) | Mrk (%) | ABW (g) | Doubles (%) | TSS (%) | DTH | E:P |
|-----------|-----------|---------|---------|-------------|---------|-------|------|
| DOGR-1768 | 15.44 | 89.00 | 64.70 | 0.00 | 11.39 | 84.33 | 1.21 |
| DOGR-1774 | 14.75 | 58.00 | 65.76 | 0.00 | 11.48 | 83.67 | 1.14 |
| DOGR-1773 | 9.58 | 64.13 | 58.61 | 0.00 | 11.08 | 83.67 | 1.13 |
| DOGR-1744 | 9.43 | 86.74 | 58.99 | 3.98 | 11.48 | 83.67 | 1.18 |
| DOGR-1772 | 9.25 | 87.71 | 54.25 | 0.00 | 11.52 | 85.00 | 1.19 |

| Entries | MY (t/ha) | Mrk (%) | ABW (g) | Doubles (%) | TSS (%) | DTH | E:P |
|--------------------|-----------|---------|---------|-------------|---------|-------|------|
| DOGR-1762 | 8.29 | 86.61 | 62.33 | 0.00 | 11.72 | 84.33 | 1.15 |
| DOGR-1751 | 6.53 | 60.74 | 61.35 | 0.00 | 11.71 | 85.00 | 1.15 |
| Bhima Dark Red (C) | 12.89 | 80.47 | 68.30 | 0.00 | 10.77 | 94.00 | 1.12 |
| Bhima Super (C) | 7.94 | 80.64 | 74.17 | 0.00 | 10.61 | 97.33 | 1.13 |
| Bhima Raj (C) | 4.40 | 74.81 | 61.49 | 0.00 | 11.24 | 96.33 | 1.14 |
| CV (%) | 11.24 | 8.93 | 7.29 | 19.80 | 3.83 | 1.86 | - |
| LSD (P=0.05) | 2.08 | 6.37 | 6.04 | 1.99 | 0.72 | 2.63 | - |

1.2.3 Evaluation of red onion initial breeding lines

Fifty breeding lines were evaluated during *late kharif*, *rabi* (51 lines) and *kharif* (49 lines) along with checks. During *late kharif*, more than 33 t/ha marketable yield was recorded in DOGR-REC-Sel, LK-07-C2/DR-4, Red Genepool-7, DOGR-1603 and DOGR-1043-GLR and found superior over best check Bhima Super (26.69 t/ha) with medium red, globe and medium sized bulbs (63-77 g), >81% marketable yield. Minimum days to harvesting was recorded in DOGR-REC-Sel (114 days) followed by Red Genepool-7 (117.67 days). Minimum storage loss after four months of storage was recorded in DOGR-654-Sel (14.12%) followed by Red Genepool-7 (16.73%) and R-Rb-M-I (18.21%) whereas, check Bhima Shakti (22.92%).

Table 1.24 Evaluation of red onion initial breeding lines during *late kharif*

| Entries | MY (t/ha) | Mrk (%) | ABW (g) | Doubles (%) | Bolters (%) | TSS (%) | DTH | E:P |
|------------------|-----------|---------|---------|-------------|-------------|---------|------|------|
| DOGR-REC-Sel | 35.98 | 88.89 | 68.55 | 3.05 | 7.67 | 11.99 | 114 | 1.13 |
| LK-07-C2/DR-4 | 35.46 | 87.34 | 76.45 | 2.33 | 10.3 | 11.83 | 119 | 1.11 |
| Red Genepool-7 | 35.30 | 95.94 | 73.74 | 3.03 | 0.66 | 11.60 | 117 | 1.10 |
| DOGR-1603 | 34.09 | 81.52 | 67.86 | 5.79 | 12.31 | 11.45 | 119 | 1.13 |
| DOGR-1043-GLR | 33.97 | 93.94 | 63.00 | 0.32 | 5.13 | 11.95 | 118 | 1.11 |
| DOGR-650-Sel | 33.73 | 100.00 | 77.85 | 0.00 | 0.00 | 11.28 | 114 | 1.21 |
| RGP-1-Kh-Sel | 33.70 | 81.20 | 75.85 | 3.99 | 14.2 | 11.72 | 110 | 1.14 |
| Bhima Super (C) | 26.69 | 78.79 | 57.57 | 1.29 | 19.1 | 12.01 | 119 | 1.09 |
| Bhima Shakti (C) | 26.65 | 79.96 | 66.43 | 2.57 | 16.3 | 11.53 | 120 | 1.18 |
| CV (%) | 11.08 | 9.73 | 10.50 | 25.13 | 29.29 | 2.31 | 2.42 | - |
| LSD (P=0.05) | 2.93 | 12.87 | 10.90 | 9.26 | 11.09 | 0.44 | 4.58 | - |

During *rabi*, LK-07-C2/DR-2 (57.47 t/ha), DOGR-1050-Sel (54.28 t/ha), LK-07-C2/DR-4 (52.47 t/ha), Red Genepool-6 (51.76 t/ha) and LK-07-C2/DR-3 (51.43 t/ha) were found superior over best check Bhima Shakti (46.06 t/ha) with dark red, globe and big sized bulbs (83-110 g), >91% marketable yield. Lines DOGR-1050-Sel and LK-07-C2/DR-4 were free from doubles and bolters. Minimum days to harvesting was recorded in LK-07-C2/DR-4 (118 days) followed by LK-07-C2/DR-3 (120 days), LK-07-C2/DR-2 and DOGR-1050-Sel (122 days) while in check Bhima Shakti (125 days). Minimum storage loss after four months of storage was recorded in LK-07-C2/DR-3 (31.40%) followed by LK-07-C2/LR-2 (33.31%) and Red Genepool-6 (34.95%) over check Bhima Shakti (43.78%).

Table 1.25 Evaluation of red onion initial breeding lines during rabi

| Entries | MY (t/ha) | % Mrk | ABW (g) | Doubles (%) | Bolters (%) | TSS (%) | DTH | E:P |
|------------------|-----------|--------|---------|-------------|-------------|---------|------|------|
| LK-07-C2/DR-2 | 57.47 | 91.58 | 110.60 | 7.15 | 1.27 | 12.01 | 122 | 1.15 |
| DOGR-1050-Sel | 54.28 | 99.72 | 88.67 | 0.00 | 0.00 | 11.91 | 122 | 1.11 |
| LK-07-C2/DR-4 | 52.47 | 100.00 | 84.32 | 0.00 | 0.00 | 11.52 | 118 | 1.17 |
| Red Genepool-6 | 51.76 | 94.03 | 87.65 | 3.91 | 1.70 | 11.60 | 123 | 1.17 |
| LK-07-C2/DR-3 | 51.43 | 95.93 | 83.41 | 3.42 | 0.00 | 11.64 | 120 | 1.15 |
| DOGR-650-Sel | 51.33 | 99.68 | 78.97 | 0.00 | 0.00 | 11.24 | 120 | 1.14 |
| DOGR-654-Sel | 50.30 | 93.95 | 100.60 | 2.16 | 3.89 | 11.52 | 120 | 1.08 |
| Bhima Shakti (C) | 46.06 | 93.83 | 75.29 | 3.85 | 2.18 | 11.85 | 125 | 1.18 |
| BLR (C) | 44.07 | 96.88 | 78.85 | 1.02 | 1.35 | 11.87 | 125 | 1.18 |
| ALR (C) | 38.46 | 98.26 | 68.51 | 0.68 | 0.66 | 11.55 | 115 | 1.14 |
| CV (%) | 11.80 | 4.28 | 13.95 | 14.24 | 18.55 | 3.27 | 3.29 | - |
| LSD (P=0.05) | 3.88 | 6.60 | 6.73 | 5.03 | 3.84 | 0.62 | 6.30 | - |

During *kharif*, DOGR-1768 (15.44 t/ha) was found superior over best check Bhima Dark Red (12.89 t/ha) with dark red, globe bulbs of medium sized bulbs (65 g) and free from doubles and bolters. Minimum days to harvesting was recorded in DOGR-1774, DOGR-1773 (83.67 days) followed by DOGR-1768 (84.33 days) while in check Bhima Dark Red (89.67 days).

Table 1.26 Evaluation of red onion initial breeding lines during *kharif*

| Entries | MY (t/ha) | Mrk (%) | ABW (g) | TSS (%) | DTH | E:P |
|------------------|-----------|---------|---------|---------|------|------|
| DOGR-1768 | 15.44 | 89.00 | 64.70 | 11.39 | 84 | 1.21 |
| DOGR-1774 | 14.75 | 58.00 | 65.76 | 11.48 | 83 | 1.14 |
| DOGR-1773 | 9.58 | 64.13 | 58.61 | 11.08 | 83 | 1.13 |
| DOGR-1744 | 9.43 | 86.74 | 58.99 | 11.48 | 83 | 1.18 |
| DOGR-1772 | 9.25 | 87.71 | 54.25 | 11.52 | 85 | 1.19 |
| DOGR-1762 | 8.29 | 86.61 | 62.33 | 11.72 | 84 | 1.15 |
| DOGR-1751 | 6.53 | 60.74 | 61.35 | 11.71 | 85 | 1.15 |
| Bhima Dark Red © | 13.64 | 74.09 | 66.42 | 11.81 | 89 | 1.14 |
| Bhima Super © | 11.48 | 78.11 | 62.39 | 11.32 | 90 | 1.16 |
| Bhima Red © | 3.58 | 68.90 | 60.68 | 11.73 | 89 | 1.14 |
| CV (%) | 11.24 | 8.93 | 7.29 | 3.83 | 1.86 | - |
| LSD (P=0.05) | 1.58 | 6.37 | 6.04 | 0.72 | 2.63 | - |

1.2.4 Evaluation of onion lines for bulb storability during *kharif* season

During *kharif*, eighteen lines along with two checks were screened for bulb storability. Among these, line DOGR-1768-BS (13.02 t/ha) was found at par with check Bhima Dark Red (12.89 t/ha) but showed good bulb storability with dark red, globe and medium sized bulb (61 g), >90% marketable yield. This line was free from doubles and bolters with 91 days to harvesting after transplanting.

Table 1.27 Evaluation of bulb storability during *kharif*

| Entries | MY (t/ha) | Mrk (%) | ABW (g) | TSS (%) | DTH | E:P | SL |
|--------------------|-----------|---------|---------|---------|-------|------|-------|
| 1768-BS | 13.02 | 90.48 | 60.94 | 10.76 | 91.33 | 1.13 | 21.01 |
| 1774-BS | 9.17 | 89.21 | 64.60 | 10.99 | 98.67 | 1.21 | 66.54 |
| 1739-BS | 6.13 | 58.63 | 55.02 | 10.99 | 90.00 | 1.10 | 36.25 |
| 1603-BS | 3.58 | 59.18 | 52.25 | 10.86 | 91.33 | 1.10 | 23.20 |
| 1747-BS | 1.65 | 46.28 | 46.72 | 10.48 | 90.67 | 1.12 | 48.62 |
| Bhima Dark Red (C) | 12.89 | 80.47 | 68.30 | 10.77 | 94.00 | 1.12 | 68.45 |
| Bhima Super (C) | 7.94 | 80.64 | 74.17 | 10.61 | 97.33 | 1.13 | 46.13 |
| CV (%) | 6.35 | 12.49 | 8.46 | 5.33 | 3.35 | - | - |
| LSD (P=0.05) | 1.03 | 6.27 | 8.52 | 0.97 | 5.25 | - | - |

(SL: % Tl Wt Loss after 2M)

1.2.5 Evaluation of onion lines (Anthracnose *Kharif*) for potential yield traits

During *kharif*, twenty-one lines along with two checks were screened for anthracnose disease. Line DOGR-1664-AN (15.14 t/ha) and DOGR-1768-AN (14.99 t/ha) were found superior over best check Bhima Dark Red (12.89 t/ha) with dark red, globe and medium sized bulb (65 g), >91% marketable yield. These lines were free from doubles and bolters with 90-92 days to harvesting after transplanting.

Table 1.28 Evaluation of anthracnose resistance during *kharif*

| Entries | MY (t/ha) | Mrk (%) | ABW (g) | TSS (%) | DTH | E:P |
|--------------------|-----------|---------|---------|---------|-------|------|
| 1664-AN | 15.14 | 91.48 | 64.72 | 10.84 | 92.00 | 1.17 |
| 1768-AN | 14.99 | 91.30 | 64.83 | 10.97 | 90.67 | 1.21 |
| 1750-AN | 5.25 | 86.93 | 58.25 | 10.88 | 88.67 | 1.20 |
| 1747-AN | 4.37 | 78.60 | 63.67 | 11.00 | 90.00 | 1.21 |
| 1615-AN | 4.29 | 74.53 | 64.03 | 10.93 | 91.33 | 1.19 |
| 1639-AN | 3.81 | 65.39 | 59.50 | 11.02 | 90.67 | 1.18 |
| 1755-AN | 3.06 | 35.56 | 63.63 | 11.17 | 90.67 | 1.22 |
| Bhima Dark Red (C) | 12.89 | 80.47 | 68.30 | 10.77 | 94.00 | 1.12 |
| Bhima Super (C) | 7.94 | 80.64 | 74.17 | 10.61 | 97.33 | 1.13 |
| CV (%) | 10.07 | 11.07 | 17.49 | 3.94 | 1.93 | - |
| LSD (P=0.05) | 1.09 | 7.28 | 6.96 | 0.72 | 2.95 | - |

1.2.6 Evaluation of onion lines for green foliage during *kharif* 2024

During *kharif*, twenty lines along with two checks were screened for green foliage. Line DOGR-1768-GF (14.46 t/ha) was found superior over best check Bhima Dark Red (12.89 t/ha) with dark red, globe and medium sized bulb (80 g), >94% marketable yield. This line was free from doubles and bolters with 91 days to harvesting after transplanting. The leaf trait of selected lines will be studied in coming season

Table 1.29 Evaluation of green foliage lines during *kharif*

| Entries | MY (t/ha) | Mrk (%) | ABW (g) | TSS (%) | DTH | E:P |
|--------------------|-----------|---------|---------|---------|-------|------|
| 1768-GF | 14.46 | 94.66 | 80.02 | 10.56 | 91.33 | 1.20 |
| 1772-GF | 8.86 | 86.09 | 71.02 | 10.51 | 93.33 | 1.15 |
| 1664-GF | 7.28 | 88.13 | 71.51 | 10.61 | 88.67 | 1.15 |
| 1774-GF | 6.42 | 85.59 | 83.87 | 10.69 | 90.67 | 1.21 |
| 1767-GF | 5.95 | 62.23 | 71.03 | 10.58 | 89.33 | 1.16 |
| 1744-GF | 3.44 | 58.82 | 67.84 | 10.44 | 88.00 | 1.23 |
| 1771-GF | 1.23 | 65.46 | 52.60 | 10.19 | 90.67 | 1.29 |
| Bhima Dark Red (C) | 12.89 | 80.47 | 68.30 | 10.77 | 94.00 | 1.12 |
| Bhima Super (C) | 7.94 | 80.64 | 74.17 | 10.61 | 97.33 | 1.13 |
| CV (%) | 9.82 | 11.00 | 11.25 | 3.42 | 2.98 | - |
| LSD (P=0.05) | 1.32 | 6.45 | 5.29 | 0.61 | 4.67 | - |

1.2.7 Onion lines under AINRPOG

Two red onion lines *viz.*; DOGR-1640 and DOGR-1664 have been introduced in AINRPOG trials as IET during 2024-25 whereas, DOGR-1744, DOGR-1745 and DOGR-1746 being evaluated as AVT-I; and DOGR-1654, DOGR-1757, DOGR-1758, DOGR-1773 as AVT-II during 2024-25.

1.2.8 Unique genetic stock in onion

Four unique genetic stocks of common/ multiplier onion are registered with ICAR-NBPGR, New Delhi for their important unique traits. In addition to these, two unique genetic stocks *viz.*; DOGR-1168 for bolting tolerance during late *kharif* and DOGR-1523-Agg multiplier onion, dark red bulb and early maturity with 5-6 bulblets have been identified and registration of these lines with ICAR-NBPGR is in progress.

1.2.9 Development of F₁ hybrids in red onion

Evaluation of red onion F₁ hybrids developed through male sterile lines

Fifty-two F₁ hybrids along with their parents and checks were evaluated during late *kharif* season. Five F₁ hybrids *viz.* MS111A×1604, MS111A×KH-M-2, MS1600A×1657, MS111A×1606 and MS1600A×571-LR recorded more than 20% heterosis for marketable yield over best check Bhima Shakti (30.42 t/ha) with uniform bulbs. All the hybrids were free from doubles and bolters except MS1600A×571-LR (3.29% bolters). Minimum days to harvesting was recorded in MS111A×1604, MS111A×KH-M-2 (115 days) followed by MS1600A×1657 (118 days) while in check Bhima Shakti (122 days). Minimum storage loss after four months of storage was recorded in MS111A×1666 (17.55%) followed by MS1600A×1606 (26.73%) and MS111A×1607 (28.58%) against best check Bhima Shakti (31.41%). The TSS of all crosses ranged between 11-12° Brix.

Table 1.30 Evaluation of red onion F₁ hybrids during late *kharif*

| Entries | MY (t/ha) | Mrk (%) | ABW (g) | DTH | E:P | SH |
|-------------------------------|-----------|---------|---------|--------|------|-------|
| MS111A×1604 F ₁ | 46.71 | 100.00 | 70.07 | 115.00 | 1.10 | 53.57 |
| MS111A×KH-M-2 F ₁ | 39.16 | 100.00 | 58.73 | 115.00 | 1.14 | 28.73 |
| MS1600A×1657 F ₁ | 38.30 | 100.00 | 64.63 | 118.00 | 1.12 | 25.91 |
| MS111A×1606 F ₁ | 37.57 | 99.74 | 62.18 | 119.33 | 1.12 | 23.53 |
| MS1600A×571-LR F ₁ | 36.56 | 96.71 | 65.45 | 122.00 | 1.10 | 20.20 |

| Entries | MY (t/ha) | Mrk (%) | ABW (g) | DTH | E:P | SH |
|----------------------------|-----------|---------|---------|--------|------|-------|
| MS222A×1657 F ₁ | 35.80 | 95.95 | 57.54 | 118.00 | 1.19 | 17.70 |
| MS111A×1657 F ₁ | 35.01 | 95.97 | 64.82 | 117.67 | 1.15 | 15.09 |
| Bhima Shakti (C) | 30.42 | 90.42 | 67.00 | 122.00 | 1.11 | - |
| Arka Lalima (C) | 29.81 | 89.85 | 64.04 | 109.00 | 1.13 | - |
| Bhima Super (C) | 29.01 | 90.50 | 61.01 | 122.00 | 1.11 | - |
| CV (%) | 11.10 | 6.40 | 11.51 | 2.63 | - | - |
| LSD (P=0.05) | 3.51 | 9.62 | 12.41 | 4.97 | - | - |

(SH: Standard heterosis over best check)

During *rabi*, 43 F₁ hybrids were evaluated along with their parental lines and checks. Five F₁ hybrids viz. MS1600A×RGP-5, MS111A×1606, MS111A×1657, MS222A×1672 and MS111A×RGP-4 recorded more than 19% heterosis for marketable yield over best check Bhima Light Red (43.60 t/ha) with uniform bulbs and free from doubles and bolters. Minimum days to harvesting was recorded in MS1600A×RGP-5, MS222A×1672 and MS111A×RGP-4 (109 days) while in check Bhima Light Red (127.67 days). Minimum storage loss after four months of storage was recorded in MS111A×546-DR (19.12%) followed by MS111A×RGP-3 (22.25%) over check Bhima Light Red (34.42%). The percent marketable bulb ranging from 96-100% while TSS is between 11-13° Brix.

Table 1.31 Evaluation of red onion F₁ hybrids during *rabi*

| Entries | MY (t/ha) | ABW (g) | DTH | E:P | SH |
|------------------------------|-----------|---------|--------|------|-------|
| MS1600A×RGP-5 F ₁ | 56.00 | 98.00 | 109.00 | 1.21 | 28.45 |
| MS111A×1606 F ₁ | 52.25 | 104.50 | 122.00 | 1.19 | 19.85 |
| MS111A×1657 F ₁ | 39.54 | 84.57 | 121.00 | 1.11 | - |
| MS222A×1672 F ₁ | 38.67 | 64.44 | 109.00 | 1.20 | - |
| MS111A×RGP-4 F ₁ | 35.93 | 71.87 | 109.00 | 1.22 | - |
| MS111A×1605 F ₁ | 35.71 | 88.79 | 121.00 | 1.16 | - |
| MS222A×1605 F ₁ | 35.33 | 75.71 | 119.00 | 1.09 | - |
| Bhima Light Red (C) | 43.60 | 76.65 | 127.67 | 1.14 | - |
| Bhima Kiran (C) | 41.58 | 78.86 | 126.67 | 1.16 | - |
| Arka Lalima (C) | 41.01 | 90.30 | 123.00 | 1.17 | - |
| CV (%) | 10.55 | 11.92 | 2.17 | - | - |
| LSD (P=0.05) | 4.21 | 10.62 | 4.29 | - | - |

(SH: Standard heterosis over best check)

During *kharif*, 43 F₁ hybrids were evaluated along with their parental lines and checks. Overall crop was damaged due to heavy rainfall and Anthracnose infestation during bulb development stage. Hybrid MS1600A×1608 recorded 17.09% heterosis for marketable yield over best check Bhima Dark Red (15.85 t/ha). All the hybrids were free from doubles and bolters. Minimum days to harvesting was recorded in MS222A×RGP-4 (88.67 days) followed by MS1600A×1608, MS1600A×1657 and MS1600A×1609 (89.33 days) while in check Bhima Dark Red (102.67 days).

Table 1.32 Evaluation of red onion F₁ hybrids during *kharif*

| Entries | MY (t/ha) | Mrk (%) | ABW (g) | TSS (%) | DTH | E:P | SH |
|-------------------------------|-----------|---------|---------|---------|--------|------|-------|
| MS1600A × 1608 F ₁ | 18.56 | 83.33 | 83.50 | 10.22 | 89.33 | 1.12 | 17.09 |
| MS222A × 1608 F ₁ | 15.46 | 80.73 | 40.22 | 10.35 | 90.00 | 1.17 | - |
| MS222A × RGP-3 F ₁ | 13.89 | 65.24 | 57.48 | 10.48 | 90.67 | 1.20 | - |
| MS1600A × 1606 F ₁ | 13.48 | 44.61 | 46.62 | 10.61 | 90.67 | 1.16 | - |
| MS1600A × 1609 F ₁ | 13.46 | 54.20 | 54.28 | 10.72 | 89.33 | 1.18 | - |
| MS222A × RGP-4 F ₁ | 11.58 | 72.52 | 54.95 | 10.68 | 88.67 | 1.17 | - |
| MS1600A × 1657 F ₁ | 11.54 | 45.97 | 68.20 | 10.70 | 89.33 | 1.14 | - |
| Bhima Dark Red (C) | 15.85 | 85.55 | 69.51 | 10.57 | 102.67 | 1.14 | - |
| Bhima Super (C) | 14.20 | 81.94 | 68.66 | 10.57 | 100.00 | 1.18 | - |
| Bhima Raj (C) | 5.09 | 32.14 | 65.75 | 10.15 | 102.00 | 1.13 | - |
| CV (%) | 10.25 | 11.52 | 10.98 | 4.15 | 1.78 | - | - |
| LSD (P=0.05) | 1.40 | 9.88 | 8.68 | 0.71 | 2.65 | - | - |

(SH: Standard heterosis over best check)

Evaluation of Inbreds

Thirty-six inbreds along with the checks were evaluated during *rabi* 2023-24. Among these, I₁-1730, I₁-1633, I₁-RGP-4, I₁-1725 and I₁-1644 were found superior over best check Bhima Shakti (46.06 t/ha). These genotypes were free from doubles and bolters with >91% marketable yield.

F₁ Hybrids under AINRPOG

Two red onion F₁ hybrids *viz.*; DOGR Hy-169 and DOGR Hy-202 have been introduced in AINRPOG trials as IET during 2024-25. However, DOGR Hy-207, DOGR Hy-211 and DOGR Hy-212 being evaluated as AVT-I; and DOGR Hy-56 and DOGR Hy-155 as AVT-II during 2024-25.

Development of male sterile lines and inbreds in red onion

Purification and multiplication of five red onion male sterile lines were continued with the selected bulbs. Six combinations are in BC₁ stage and three combinations in BC₃ stage for transfer of male sterility in different varietal background of DOGR varieties (Bhima Super, Bhima Dark Red, Bhima Kiran, Bhima Shakti and DOGR-1133). Development of inbred lines from single bulb of selected parents (36 inbreds in I₁, 54 inbreds in I₂, 16 inbreds in I₃ stage and 6 inbreds in I₄ stage).

Red onion varieties recommended through AINRPOG

Under improvement of red onion varieties for table purpose, five red onion varieties namely DOGR-1203, DOGR-1625, RGP-3, 1550-Agg and 1546-Agg have been developed and recommended at national level for release under AINRPOG of data during 2016-19, 2017-20, 2018-21, and 2019-22.

The details of nine varieties developed by ICAR-DOGR, Pune which have been recommended for the release are given below:

- 1. 1550-Agg:** Multiplier red onion entry was identified as significantly superior over best check consistently at three locations *viz.*; Junagadh, Rahuri and Rajgurunagar in two years, therefore recommended for Zone V based on marketable yield for *rabi* season.
- 2. 1546-Agg:** Multiplier onion entry was identified as significantly superior over best check consistently at two locations *viz.*; Junagadh and Rahuri in two years (Zone V); Bengaluru and Dharwad in two years (Zone VI), therefore recommended for Zone V and Zone VI based on marketable yield for *rabi* season.

3. **RGP-3:** Red onion entry was identified as significantly superior over best check consistently at two locations viz. Akola and Jabalpur in two years, therefore recommended for Zone IV based on marketable yield for *kharif* season.
4. **DOGR-1625:** Onion entry was identified as significantly superior over best check consistently at two locations viz. Akola and Jabalpur in two years, therefore recommended for Zone IV based on marketable yield for *kharif* season.
5. **DOGR-1203:** Dark red onion entry was identified as significantly superior over best check consistently at four locations viz. Junagadh, Nasik, Rahuri, and Rajgurunagar in two years for early maturity along with 278 q/ha marketable yield therefore, recommended for Zone V based on earliness for *rabi* season.

1.3 Breeding for abiotic stress tolerance in *Allium* species

1.3.1. Cloning and characterization of UV-Resistance 8 (UVR8) gene in onion

This gene has role in abiotic stress tolerance which directly affects the yield of an onion crop. The high doses of UV-B damage plant macromolecules by destroying DNA, causing a build-up of reactive oxygen species, and hindering photosynthesis. To increase UV-B stress tolerance, the UV-B receptor UV RESISTANCE LOCUS 8 (UVR8) is crucial in increasing flavonoid production. In light of the foregoing, it is crucial to characterize UVR8 at the molecular level in order to understand its function in UV-B stress. To better understand the significance of the UVR8 gene in the short-day onion (*Allium cepa* L.) in response to UV-B exposure, it was characterized at the molecular level in the current study. As a result, a fragment of a single copy UVR8 gene of 555 bp was isolated from the cDNA of onion cultivar Bhima Super leaf tissue and cloned into the PJET1.2 sequencing vector, which was then transformed into strain DH5 α of *E. coli* and transformants were then verified by colony, restriction digestion, and sequencing. After sequence confirmation the gene was subsequent cloned into the binary vector pCambia1300 and transformed into *E. coli* and transformants were verified by colony PCR, restriction digestion using BamHI and KpnI. Following a triparental mating technique, recombinant plasmid was mobilized into *Agrobacterium* strain LBA4404 utilizing helper strain pRK2013 and *E. coli* harbouring recombinant plasmid. The *Agrobacterium*-containing recombinant plasmid will be employed for transformation into onion plant for further characterization.

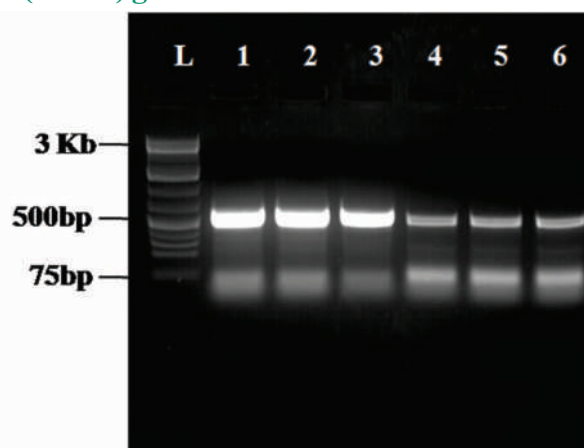


Fig.1.4: 1.5% agarose gel electrophoresis of the cDNA showing PCR amplification of UVR8 gene

1.3.2 Genome wide identification of simple sequence repeats in Onion

The genome sequence of *Allium cepa* was downloaded from GenBank assembly under accession number GCA_905187595. Perl scripts from MISA were used to perform SSR identification with the default parameters (<http://pgrc.ipk-gatersleben.de/misa/>). The identification criteria were as follows: tri-nucleotide repeat motifs with six repeats, tetra-nucleotide, penta- and hexa-nucleotide repeat motifs with five repeats. Compound SSRs were defined as those with a < 100-nt interval between two repeat motifs. A total of 59,481 SSRs were identified from eight chromosomal regions. Analysis of SSR distribution on each chromosome revealed that the largest number of SSRs was present on chromosome 02 (11,510) followed by chromosome 01 (8727). Tri-nucleotide motifs were the most abundant followed by tetra nucleotide motifs. Of the tri nucleotide motifs, AAT/ATT motifs had the highest occurrence followed by AAG/CTT type.

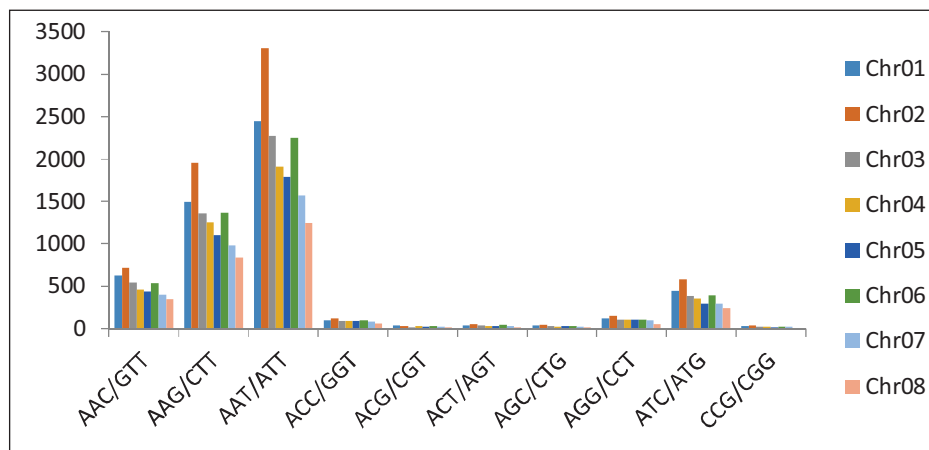


Fig. 1.5 Distribution of tri-nucleotide repeat motif in onion genome

1.3.3 Expression analysis of genes in response to drought and waterlogging stress in onion

The expression analysis revealed distinct patterns among the four genes studied. LFY showed very high expression in flowers but was nearly absent in leaves, indicating its strong association with floral development. In contrast, FT exhibited high expression levels in leaves, suggesting a potential role in initiating the transition from vegetative to reproductive growth. AP1 displayed low expression in both flowers and leaves, implying that its activity may be restricted to specific stages or tissues involved in flower organ formation. Meanwhile, TFL showed moderate expression in leaves but low expression in flowers, which may reflect its function in maintaining vegetative growth and preventing premature flowering. No gene showed relation with drought and water stress response in onion, therefore new primers need to design to see the effect of abiotic stress in onion

1.4 Genetic improvement of garlic through conventional and biotechnological approaches

1.4.1 Collection, conservation and maintenance of Garlic

Collection: In last year, 16 garlic accessions has been added in garlic germplasm collection out of which two accessions could not able to form bulb.

Conservation (*in vivo*/field gene bank): During last season, In field gene bank ICAR-DOGR has conserved nearly 1056 garlic lines which includes varieties/ landraces/elite lines/breeding lines/ germplasm and mutation lines.

Table 1.33 Total garlic accession maintained at ICAR-DOGR

| Group name | No of Accessions |
|--|------------------|
| Elite lines | 39 |
| Core collection | 45 |
| Early maturing lines | 9 |
| <i>Kharif</i> season suitable garlic lines | 12 |
| Local garlic | 18 |
| Garlic Germplasm | 522 |
| Varieties for maintenance | 33 |
| Mutation elite lines | 6 |
| Mutation single line | 298 |
| Elite old group | 66 |

Conservation (*in vitro*): At ICAR-DOGR a total of 32 core collection accessions, 51 trait specific accessions were under *in vitro* conservation at high osmotic concentration of sucrose and mannitol.

Maintenance of garlic lines/varieties: ICAR-DOGR is acting as National Active Germplasm site for Onion and Garlic accessions including another *Allium* sp. In case garlic, all the accessions along with garlic varieties developed across the country were under conservation. It is pre requisite to deposit the seed material of developed/identified varieties for obtaining IC number from ICAR-NBPGR. Presently ICAR-DOGR is maintaining such 37 garlic varieties.

1.4.2 Nucleus seed production of garlic varieties developed by ICAR-DOGR: ICAR-DOGR is developed two garlic varieties (Bhima Omkar and Bhima Purple), besides this identified one more Garlic line for release (DOGR-PB-10). Therefore, produced 35-50 kg nucleus seed of each variety.

1.4.3 Evaluation of garlic elite lines for high yield

A total of 14 elite garlic lines were evaluated for high-yield potential and other desirable bulb characteristics. The data from this trial is presented in Table below. Accession 'DOGR-534' recorded the highest yield (119.14 q/ha), followed by 'DOGR-123' (118.16 q/ha) and 'DOGR-571' (115.73 q/ha). Accession 'DOGR-18' was notable for the largest single bulb weight (22.80 gm) and a low clove count (8.00).

Table 1.34 Mean performance of garlic high yielding lines for yield and related traits

| Accession No. | DTH | MY (q/ha) | ABW (gm) | NC/B | W50C (gm) | TSS (°brix) (%) | Bulb colour | Clove colour |
|---------------|-----|-----------|----------|-------|-----------|-----------------|-------------|--------------|
| DOGR-123 | 143 | 118.16 | 17.00 | 16.00 | 50.00 | 41.36 | W | W |
| DOGR-662 | 147 | 111.51 | 13.00 | 23.80 | 31.00 | 43.90 | P | P |
| DOGR-539 | 141 | 108.00 | 13.70 | 14.40 | 47.50 | 43.02 | W | W |
| DOGR-552 | 147 | 110.02 | 16.83 | 17.60 | 46.50 | 43.80 | P | P |
| DOGR-318 | 135 | 116.37 | 18.35 | 16.70 | 47.00 | 41.28 | W | W |
| DOGR-534 | 147 | 119.14 | 21.10 | 18.80 | 47.00 | 43.94 | W | W |
| DOGR-425 | 147 | 114.93 | 13.95 | 21.90 | 31.00 | 43.62 | P | P |
| DOGR-18 | 143 | 109.51 | 22.80 | 8.00 | 35.50 | 43.89 | W | W |
| DOGR-214 | 135 | 105.56 | 14.50 | 13.60 | 54.00 | 41.66 | W | W |
| DOGR-318 | 147 | 112.73 | 14.30 | 14.50 | 47.00 | 43.60 | P | P |
| DOGR-32 | 135 | 113.89 | 15.30 | 17.00 | 49.50 | 41.30 | W | W |
| DOGR-161 | 143 | 115.23 | 12.60 | 17.80 | 44.20 | 44.28 | W | W |
| DOGR-571 | 149 | 115.73 | 19.05 | 17.20 | 53.00 | 41.56 | W | W |
| DOGR-415 | 147 | 113.61 | 15.05 | 15.00 | 48.00 | 43.36 | P | P |

(DTH- Days to Harvest; MY- Marketable Yield; PD-Polar Diameter; ED- Equatorial diameter; ABW- Average Bulb Weight; NC/B- Number of Clove per Bulb; W50C- Weight of 50 Cloves; TSS- Total Soluble Solids)

1.4.4 Evaluation of garlic elite lines for *kharif* garlic

This trial focused on identifying lines suitable for *kharif* season cultivation. Thirteen accessions were assessed for yield and bulb quality, with 'Bhima Purple' and 'Bhima Omkar' as checks. Accessions 'DOGR-100' (52.18 q/ha) and 'DOGR-555' (47.47 q/ha) showed significantly higher yields compared to the checks, demonstrating strong potential for *Kharif* season adaptation. Accession 'DOGR-23' had the highest 10-clove weight (14.00 gm).

Table 1.35 Mean performance of garlic (kharif season): suitable lines for yield and related traits

| Accession No. | DTH | MY (q/ha) | ABW (gm) | NC/B | W10C (gm) | Bulb colour | Clove colour | TSS (°brix) (%) |
|---------------|-----|-----------|----------|-------|-----------|-------------|--------------|-----------------|
| Bhima Purple | 119 | 16.00 | 10.44 | 10.40 | 12.00 | P | P | 37.72 |
| Bhima Omkar | 119 | 10.62 | 4.90 | 7.60 | 5.30 | W | W | 36.12 |
| DOGR-555 | 119 | 47.47 | 8.30 | 10.20 | 7.70 | W | W | 42.16 |
| G-282 | 107 | 38.62 | 10.50 | 7.40 | 8.50 | W | W | 41.52 |
| DOGR-100 | 119 | 52.18 | 10.14 | 7.60 | 12.40 | P | P | 41.44 |
| DOGR-296 | 107 | 23.02 | 6.00 | 6.20 | 7.30 | P | P | 37.36 |
| DOGR-324 | 132 | 10.10 | 3.60 | 5.00 | 4.50 | W | W | 42.36 |
| G-41 | 132 | 16.18 | 9.20 | 8.20 | 9.80 | W | W | 41.64 |
| DOGR-23 | 119 | 23.86 | 10.30 | 6.80 | 14.00 | W | W | 42.36 |
| Gadag Local | 119 | 18.16 | 6.70 | 9.60 | 7.70 | P | P | 41.44 |
| DOGR-282 | 107 | 29.72 | 9.54 | 7.00 | 11.20 | W | W | 41.80 |
| DOGR-26 | 119 | 33.01 | 10.60 | 10.60 | 11.30 | P | P | 43.24 |
| DOGR-27-W | 125 | 30.04 | 11.28 | 10.40 | 8.60 | W | W | 43.20 |

(DTH- Days to Harvest; MY- Marketable Yield; PD-Polar Diameter; ED- Equatorial diameter; ABW- Average Bulb Weight; NC/B- Number of Clove per Bulb; W50C- Weight of 50 Cloves; TSS- Total Soluble Solids)

1.4.5 Evaluation of garlic elite lines for early maturity

Nine selected accessions were evaluated for early maturity, aiming to confirm high-yielding lines with a shorter crop duration (118-119 DTH). Accession 'DOGR-359' was the outstanding performer in this category, with a remarkable yield of 124.93 q/ha and a high 50-clove weight (45.00 gm). Lines 'DOGR-693' (80.65 q/ha) and 'SG-01' (72.11 q/ha) also showed excellent potential.

Table 1.36 Mean performance of garlic early maturing lines for yield and related traits

| Accession No. | DTH | MY (q/ha) | ABW (gm) | NC/B | W10C (gm) | TSS (°brix) (%) | Bulb colour | Clove colour |
|---------------|-----|-----------|----------|-------|-----------|-----------------|-------------|--------------|
| DOGR-671 | 119 | 60.95 | 10.00 | 17.80 | 26.50 | 44.40 | P | P |
| DOGR-527 | 119 | 59.78 | 9.10 | 14.80 | 32.50 | 41.92 | W | P |
| DOGR-693 | 118 | 80.65 | 11.00 | 16.00 | 33.00 | 41.24 | W | W |
| DOGR-791 | 118 | 56.78 | 10.20 | 20.00 | 24.50 | 40.48 | P | P |
| DOGR-430 | 119 | 53.78 | 9.70 | 18.80 | 27.50 | 42.44 | W | M.P |
| DOGR-567 | 119 | 53.56 | 10.00 | 17.00 | 28.50 | 41.24 | W | P |
| DOGR-264 | 118 | 68.15 | 10.40 | 15.40 | 32.50 | 42.20 | MP | MP |
| SG-01 | 119 | 72.11 | 11.40 | 25.20 | 35.50 | 43.92 | W | W |
| DOGR-359 | 119 | 124.93 | 13.20 | 17.40 | 45.00 | 42.92 | P | P |

(DTH- Days to Harvest; MY- Marketable Yield; PD-Polar Diameter; ED- Equatorial diameter; ABW- Average Bulb Weight; NC/B- Number of Clove per Bulb; W50C- Weight of 50 Cloves; TSS- Total Soluble Solids)

1.4.6 Evaluation of garlic elite lines for red clove skin garlic

Seventeen accessions with red or purple bulb colour were evaluated for yield and bulb quality, using 'Phule Baswant' and 'Godavari' as checks. Accession 'DOGR-301' (138.50 q/ha) and 'DOGR-388' (116.39 q/ha) significantly out-yielded the checks. Accessions 'DOGR-34' (64.50 gm) and 'DOGR-534' (61.50 gm) were superior for 50-clove weight, indicating very large clove size.

Table 1.37 Mean performance of garlic red clove skin colour lines for yield and related traits

| Accession No. | DTH | MY (q/ha) | ABW (gm) | NC/B | W50C (gm) | TSS (°brix) (%) |
|---------------|-----|-----------|----------|-------|-----------|-----------------|
| DOGR-63 | 147 | 75.58 | 12.95 | 22.40 | 32.50 | 45.28 |
| DOGR-34 | 132 | 84.16 | 17.55 | 14.80 | 64.50 | 42.04 |
| DOGR-301 | 147 | 138.50 | 14.30 | 22.40 | 28.00 | 42.68 |
| DOGR-534 | 147 | 98.78 | 16.80 | 15.20 | 61.50 | 42.44 |
| DOGR-756 | 147 | 82.96 | 13.80 | 21.10 | 35.00 | 43.71 |
| DOGR-353 | 146 | 107.72 | 15.85 | 18.20 | 48.50 | 41.78 |
| DOGR-388 | 143 | 116.39 | 11.35 | 18.10 | 37.50 | 42.18 |
| Phule Baswant | 147 | 114.50 | 15.00 | 23.80 | 49.50 | 42.66 |
| DOGR-341 | 147 | 73.90 | 14.95 | 18.40 | 50.00 | 42.04 |
| DOGR-224 | 147 | 81.37 | 16.80 | 22.90 | 45.00 | 44.60 |
| DOGR-258 | 147 | 77.98 | 17.65 | 16.10 | 49.50 | 43.86 |
| DOGR-419 | 147 | 67.67 | 14.20 | 16.85 | 15.00 | 41.50 |
| DOGR-266 | 147 | 88.15 | 12.75 | 17.90 | 36.50 | 42.10 |
| DOGR-303 | 147 | 86.11 | 13.90 | 13.10 | 46.00 | 43.02 |
| Godavari | 143 | 81.89 | 15.55 | 19.70 | 39.50 | 42.40 |
| DOGR-444 | 143 | 75.18 | 12.90 | 13.80 | 52.00 | 42.92 |
| DOGR-787 | 143 | 81.74 | 14.85 | 19.10 | 27.50 | 42.32 |

(DTH- Days to Harvest; MY- Marketable Yield; ABW- Average Bulb Weight; NC/B- Number of Clove per Bulb; W50C- Weight of 50 Cloves; TSS- Total Soluble Solids)

1.4.7 Evaluation of garlic elite lines for high TSS

A total of 24 accessions were screened for high Total Soluble Solids (TSS), a key parameter for the dehydration and processing industry. 'Bhima Purple' was used as a check. Multiple lines recorded exceptionally high TSS values. Accession 'DOGR-41' was highest (47.92 °Brix), followed by 'DOGR-493' (46.78 °Brix), 'DOGR-92' (46.96 °Brix), and 'DOGR-48-W' (46.76 °Brix). Several lines combined high TSS with high yield, notably 'DOGR-493' (141.71 q/ha), 'DOGR-48-W' (137.71 q/ha), and 'DOGR-404' (137.36 q/ha), making them excellent candidates for processing.

Table 1.38 Mean performance of garlic high TSS lines for yield and related traits

| Accession No. | DTH | TY (q/ha) | ABW (gm) | NC/B | W50C (gm) | TSS (°brix) (%) |
|---------------|-----|-----------|----------|------|-----------|-----------------|
| DOGR-806 | 137 | 110.57 | 19.70 | 17.2 | 61.0 | 45.42 |
| DOGR-815 | 137 | 126.18 | 19.72 | 17.2 | 77.5 | 44.90 |
| DOGR-48-W | 144 | 137.71 | 21.80 | 26.8 | 40.0 | 46.76 |
| DOGR-404 | 139 | 137.36 | 19.20 | 16.7 | 65.5 | 43.2 |

| Accession No. | DTH | TY (q/ha) | ABW (gm) | NC/B | W50C (gm) | TSS (°brix) (%) |
|---------------|-----|-----------|----------|------|-----------|-----------------|
| DOGR-746 | 137 | 126.47 | 16.65 | 16.4 | 57.0 | 44.64 |
| DOGR-709 | 147 | 126.82 | 15.35 | 22.5 | 52.0 | 45.88 |
| DOGR-493 | 147 | 141.71 | 14.83 | 22.8 | 42.9 | 46.78 |
| DOGR-539- P | 143 | 73.40 | 12.35 | 15.1 | 45.0 | 43.6 |
| DOGR-347 | 147 | 91.01 | 13.45 | 20.5 | 42.5 | 46.0 |
| Bhīma Purple | 135 | 101.36 | 16.10 | 16.4 | 60.5 | 45.8 |
| B.O-5GY-80 | 127 | 72.12 | 15.40 | 16.0 | 45.0 | 45.87 |
| B.O-1GY-9 | 125 | 94.39 | 15.00 | 16.6 | 44 | 45.98 |
| B.O-5GY-1 | 126 | 69.88 | 10.50 | 11.6 | 39.5 | 44.98 |
| DOGR-123 | 141 | 72.66 | 17.3 | 12.6 | 56 | 46.04 |
| DOGR-367 | 141 | 59.57 | 14.2 | 11.4 | 52 | 45.44 |
| DOGR-102 | 141 | 67.4 | 14.9 | 11.2 | 54 | 45.28 |
| DOGR-41 | 141 | 73.78 | 10.2 | 12.2 | 36 | 47.92 |
| DOGR-662 | 141 | 98.83 | 17 | 13.4 | 50 | 45.68 |
| DOGR-92 | 141 | 71.4 | 13 | 8.2 | 40 | 46.96 |
| DOGR-318 | 141 | 58.49 | 14.4 | 10.8 | 48 | 45.16 |
| DOGR-267 | 141 | 62.82 | 9.6 | 17 | 21 | 45.04 |
| DOGR-486 | 141 | 73.61 | 12.2 | 11.2 | 48.5 | 45.52 |
| DOGR-425 | 141 | 78.71 | 12.4 | 18.2 | 30 | 44.92 |
| DOGR-559 | 135 | 68.65 | 12.7 | 8.4 | 42.5 | 45.72 |

(DTH- Days to Harvest; MY- Marketable Yield; PD-Polar Diameter; ED- Equatorial diameter; ABW- Average Bulb Weight; NC/B- Number of Clove per Bulb; W50C- Weight of 50 Cloves; TSS- Total Soluble Solids)

Mutation Breeding

1.4.8 Evaluation of Mutation Garlic lines

Out of 304 garlic mutation lines (M5 generation) developed through gamma radiation in Bhima purple and Bhima Omkar 19 lines were selected on basis of bulb yield performance. Nineteen lines derived from the mutation breeding program (from 'Bhima Omkar' - B.O. and 'Bhima Purple' - B.P.) were evaluated for yield, bulb size, and quality. The mutation breeding program has yielded several promising lines. 'B.P-1GY-2' (114.54 q/ha) and 'B.P-1GY-138' (112.32 q/ha) were the highest yielders. 'B.P-1GY-138' also recorded the largest clove weight (60.50 gm / 50 cloves) and a high TSS (45.52 °Brix). Line 'B.O-1GY-21' showed the highest TSS in this trial at 47.30 °Brix.

Table 1.39 Mean performance of Garlic mutation lines for yield and related traits

| Accession No. | DTH | MY (q/ha) | PD (mm) | ED (mm) | ABW (gm) | NC/B | W50C (gm) | TSS (°brix) (%) | Bulb colour | Clove colour |
|---------------|-----|-----------|---------|---------|----------|-------|-----------|-----------------|-------------|--------------|
| B.O-1GY-15 | 130 | 74.62 | 30.22 | 36.19 | 11.80 | 12.40 | 42.00 | 42.80 | W | W |
| B.O-5GY-92 | 132 | 92.52 | 31.53 | 36.49 | 13.40 | 13.40 | 45.00 | 44.30 | W | W |
| B.O-5GY-83 | 129 | 110.09 | 35.03 | 40.97 | 17.90 | 15.00 | 47.00 | 43.20 | W | P |
| B.O-5GY-80 | 127 | 72.12 | 34.70 | 37.04 | 15.40 | 16.00 | 45.00 | 45.87 | W | W |

| Accession No. | DTH | MY (q/ha) | PD (mm) | ED (mm) | ABW (gm) | NC/B | W50C (gm) | TSS (°brix) (%) | Bulb colour | Clove colour |
|---------------|-----|-----------|---------|---------|----------|-------|-----------|-----------------|-------------|--------------|
| B.O-5GY-52 | 128 | 64.38 | 32.39 | 44.21 | 16.50 | 13.80 | 15.00 | 40.43 | W | P |
| B.O-1GY-9 | 125 | 94.39 | 34.48 | 37.13 | 15.00 | 16.60 | 44.00 | 43.98 | W | W |
| B.O-1GY-21 | 130 | 72.32 | 33.34 | 38.45 | 14.60 | 12.60 | 43.20 | 47.30 | W | W |
| B.O-1GY-4 | 132 | 71.44 | 35.59 | 36.38 | 13.00 | 13.80 | 46.50 | 45.02 | W | W |
| B.O-1GY-23 | 131 | 86.24 | 33.78 | 36.20 | 12.00 | 8.60 | 43.00 | 42.27 | W | W |
| B.O-5GY-1 | 126 | 69.88 | 29.96 | 33.57 | 10.50 | 11.60 | 39.50 | 42.98 | W | W |
| B.P-5GY-7 | 129 | 88.28 | 35.22 | 38.69 | 17.70 | 13.00 | 44.00 | 41.27 | W | W |
| B.P-5GY-9 | 127 | 86.23 | 31.08 | 35.24 | 13.40 | 9.40 | 34.50 | 42.33 | P | P |
| B.P-1GY-146 | 130 | 84.02 | 33.07 | 37.78 | 15.90 | 13.20 | 52.50 | 45.68 | P | P |
| B.P-5GY-6 | 132 | 95.70 | 33.50 | 39.71 | 17.60 | 12.40 | 53.00 | 44.67 | P | P |
| B.P-1GY-2 | 130 | 114.4 | 32.10 | 36.63 | 13.70 | 12.00 | 48.50 | 44.00 | P | P |
| B.P-5GY-38 | 129 | 65.02 | 33.93 | 38.46 | 15.20 | 13.80 | 51.00 | 44.60 | P | P |
| B.P-1GY-46 | 127 | 87.73 | 31.38 | 30.85 | 14.30 | 11.60 | 53.50 | 45.35 | W | W |
| B.P-1GY-138 | 125 | 112.32 | 32.72 | 40.08 | 18.60 | 11.80 | 60.50 | 45.52 | P | P |
| B.P-1GY-125 | 129 | 97.91 | 35.41 | 38.80 | 18.00 | 12.20 | 57.00 | 46.10 | W | P |

(DTH- Days to Harvest; MY- Marketable Yield; PD-Polar Diameter; ED- Equatorial diameter; ABW- Average Bulb Weight; NC/B- Number of Clove per Bulb; W50C- Weight of 50 Cloves; TSS- Total Soluble Solids)

1.4.9 Evaluation of garlic lines for essential oil extraction (EOE): Total 28 garlic lines were screened for EOE through hydro-distillation and further characterized through GCMS technique. Total 10 – 28 compounds were identified in GEO. Promising lines identified for sulfur containing compounds will be evaluated further for re-confirmation of results.

Overall Summary and Promising Lines of Garlic

The 2024 evaluation trials successfully identified several accessions with elite traits across all six programs. These lines represent valuable genetic material for breeding, commercial release, or further specialized testing.

Table 1.40 Summary of promising lines of garlic (Key performers identified across all trial)

| Highest Yield Potential | Top Performers for Processing (High TSS) | Best for Combined Traits | Promising Kharif Adaptation |
|--|--|--|--|
| DOGR-493 (High TSS Trial): 141.71 q/ha DOGR-301 (Red Trial): 138.50 q/ha DOGR-48-W (High TSS Trial): 137.71 q/ha DOGR-404 (High TSS Trial): 137.36 q/ha DOGR-359 (Early Trial): 124.93 q/ha DOGR-534 (Elite Trial): 119.14 q/ha | DOGR-41 : 47.92 °Brix B.O-1GY-21' (Mutation): 47.30 °Brix DOGR-92' : 46.96 °Brix DOGR-493' : 46.78 °Brix DOGR-48-W' : 46.76 °Brix | DOGR-493 : Exceptional yield (141.71 q/ha) combined with elite TSS (46.78 °Brix) DOGR-48-W : Excellent yield (137.71 q/ha) with elite TSS (46.76 °Brix) DOGR-359 : Outstanding early-line yield (124.93 q/ha) with large cloves (45.00 gm / 50 cloves) B.P-1GY-138 : A top mutation line with high yield (112.32 q/ha), the largest cloves in its trial (60.50 gm / 50 cloves), and high TSS (45.52 °Brix) DOGR-34 & DOGR-534 (Red Trial): Demonstrated superior clove size (64.50 gm & 61.50 gm / 50 cloves, respectively) | DOGR-100 (52.18 q/ha) and DOGR-555 (47.47 q/ha) were the clear standouts for monsoon season cultivation, vastly outperforming the checks |

1.4.10 Garlic lines identified through AINRPOG: The Variety Identification Committee (VIC) for onion and garlic under AINRPOG in its meeting held on 21st August 2024 at ICAR KAB-II, PUSA New Delhi, recommended one garlic variety for release. Based on superiority in marketable yield (testing year data: 2019-2022), garlic line **DOGR-PG-10** has been identified for recommendation for Zone II (Durgapura, Karnal, Ludhiana, and Delhi).

1.4.11 Evaluation of garlic lines under AINRPOG: A total of six high yielding entries are presently under evaluation in AINRPOG's different garlic varietal trails namely DOGR-815, DOGR-569 (IET) DOGR-404, DOGR-793(AVT-I) DOGR-48, DOGR-746 (AVT-II) during *rabi* season and DOGR-100 and DOGR-555 during *kharif* season.

1.4.12 Assessment of genetic diversity in garlic genotypes through molecular and biochemical profiling

A total of 32 garlic genotypes were collected and subjected to molecular characterization using 18 SSR markers. DNA was extracted using the CTAB method, and PCR amplification was performed followed by gel electrophoresis. Phylogenetic relationships were analyzed using MEGA X software. Biochemical traits such as pyruvic acid, antioxidant activity, phenolic content, and protein levels were quantified using standard protocols.

Genetic diversity among 32 garlic genotypes was assessed using 18 polymorphic primers, generating 54 distinct bands with amplicon sizes ranging from 120 to 900 bp. The number of bands per primer ranged from 1 to 5, averaging 2.5. PIC values ranged from 0.06 to 0.73, with four primers, including Asa18 (PIC = 0.73), classified as highly informative. The phylogenetic analysis grouped 32 genotypes into four major clusters, indicating significant genetic diversity. Cluster 3 was the largest, containing five distinct subclusters with high similarity indices, while Cluster 1 and Cluster 4 showed the most divergence. These results reflect evolutionary divergence among genotypes and can guide future breeding and conservation strategies. Phylogenetic tree of garlic genotypes is given in figure.

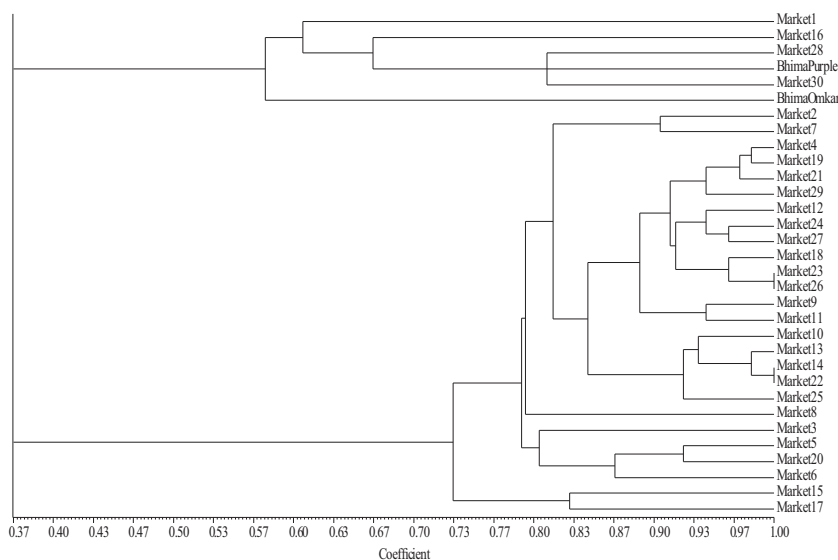


Fig. 1.6 Phylogenetic tree of 32 garlic genotypes constructed based on the selected SSR markers

1.5 Biotechnological approaches for improvement of onion

1.5.1 *In vitro* gynogenesis mediated haploid induction

A total of 18,000 immature flower buds from 10 onion genotypes were cultured, resulting in 842 regenerated shoots, of which 245 successfully developed into rooted plants. The regeneration efficiency varied significantly across genotypes, ranging from 0% to 11.9% of the buds cultured. The highest regeneration rate was observed in the Bhima safed genotype, while Phule suwarna showed no shoot survival. Flow cytometry analysis of the 245 regenerated plants revealed that 193 (78.78%) were haploid, and 52 were diploid. The haploid plants were treated with colchicine to induce chromosome doubling, after which survived shoots were transplanted into the field for further breeding programs.

Table 1.41 Haploid induction through in vitro gynogenesis

| Variety | No. of flower bud initiated | No. of shoots regenerated | No. of shoots survived | No. of shoots died | No. of Haploid | No. of Diploid |
|----------------|-----------------------------|---------------------------|------------------------|--------------------|----------------|----------------|
| Bhima super | 1800 | 130 | 49 | 81 | 36 | 13 |
| Phule samarth | 1800 | 114 | 33 | 81 | 29 | 4 |
| AFW | 1800 | 47 | 13 | 34 | 9 | 4 |
| Phule suwarna | 1800 | 6 | 0 | 0 | 0 | 0 |
| Arka kalyan | 1800 | 82 | 26 | 56 | 20 | 6 |
| NHRDF Red 2 | 1800 | 85 | 17 | 68 | 14 | 3 |
| Bhima safed | 1800 | 215 | 59 | 156 | 44 | 15 |
| Pusa sona | 1800 | 33 | 16 | 17 | 14 | 2 |
| Palampur white | 1800 | 33 | 9 | 24 | 9 | 0 |
| Arka yojith | 1800 | 97 | 23 | 74 | 18 | 5 |
| Total | 18000 | 842 | 245 | 591 | 193 | 52 |

1.5.2 Genome Elimination-Mediated Haploid Induction

CRISPR/Cas9 constructs targeting the *AcCENH3* gene were designed to specifically edit exon 3. The synthesized sgRNA targeting exon 3 was independently cloned into the CRISPR/Cas9 binary vector *pRGEB31*. The resulting plasmid carrying the exon 3-specific sgRNA was designated as *pRGEB31-AcCENH3* exon 3 target. Map of CRISPR/Cas9 construct targeting *AcCenH3* gene is given in fig. 1.7a. Onion calli infected with the construct are shown in fig. 1.7b.

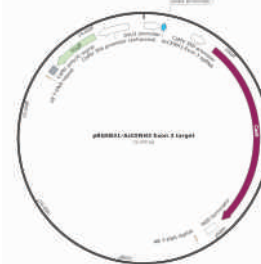
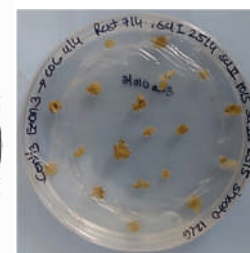

 Fig.1.7a: Vector map of CRISPR/Cas9 construct targeting *AcCenH3* gene


Fig. 1.7b: Onion calli on shooting media

A total of 13 transformation batches were conducted using the construct *pRGEB31-AcCenH3* Exon 3, during which 1,400 calli were co-cultivated. Out of these, 1,200 calli are on selection medium, and 200 calli are in shooting stage.

Table 1.42 Details of transformation of onion with and *AcCenH3* genome editing construct

| Construct | No. of batches | Calli Co-cultivated | Calli on selection | Shooting stage |
|-------------------------------|----------------|---------------------|--------------------|----------------|
| <i>pRGEB31-AcCenH3</i> Exon 3 | 13 | 1400 | 1200 | 200 |

1.6 Molecular responses to combinatorial salinity and pathogen stress in onion

Transcriptome analysis for identification of salt-responsive genes in onion

In this analysis, we sequenced 12 samples of onion, which were subsequently grouped into 4 distinct categories. The *de novo* transcriptome analysis began with a quality assessment of the sequencing data using *FastQC*. The results were aggregated using *MultiQC* to provide an overall quality overview. Adapter trimming was performed, followed by a second round of quality assessment with *FastQC* and *MultiQC*. rRNA contamination was removed using *SortMeRNA*. The cleaned reads for each sample type of *Allium cepa* were then merged, followed by the combination of forward and reverse reads. These merged reads were used as input for *de novo* transcriptome assembly with Trinity.

Assembly quality was evaluated using Trinity Stats and BUSCO. Abundance quantification was performed using RSEM, which aligned the assembled transcripts to the reads and calculated transcript abundance, generating raw counts and TPM-normalized values. Differential gene expression analysis was conducted using edgeR, utilizing the raw counts data, which were merged into a single file using an inbuilt RSEM Perl script. The following parameters are used for measuring Upregulated and Downregulated genes; $FDR < 0.05$ & $\log FC \geq 1$ "For Upregulated genes", $FDR < 0.05$ & $\log FC \leq -1$ "For Downregulated genes". The MA plots and volcano plots of DGE are also presented. Venn diagrams are plotted for Upregulated genes and Downregulated genes across different DGE conditions. Venn diagrams are plotted for upregulated genes and downregulated genes separately to capture differential information of differentially expressed genes among Test 1 vs Control, Test 2 vs Control and Test 3 vs Control samples.

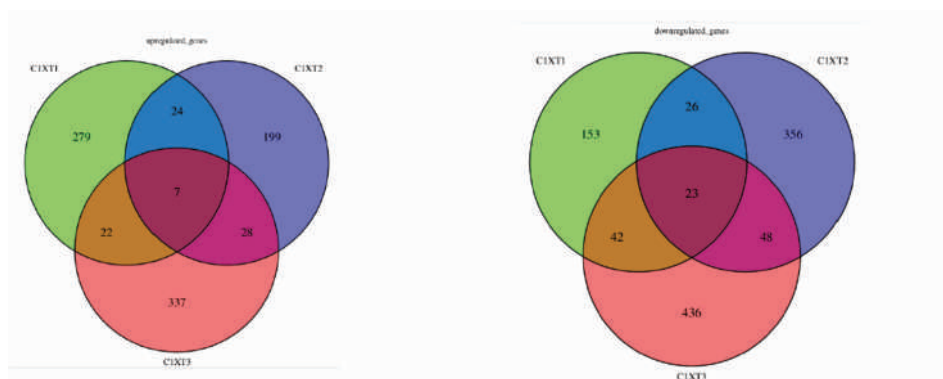


Fig.1.8 Venn diagrams plotted for upregulated genes and downregulated genes

Externally funded projects

1. Development of Hybrids in Onion: A Joint Venture

Under development of F_1 hybrids in red onion, evaluated 43 F_1 hybrids during *kharif*, 52 F_1 hybrids during late *kharif* and 43 F_1 hybrids during *rabi*. Seven F_1 hybrids viz.; DOGR Hy-169, DOGR Hy-202, DOGR Hy-207, DOGR Hy-211, DOGR Hy-212, DOGR Hy-56 and DOGR Hy-155 being evaluated under AINRPOG trials for multi-location evaluation. Further, 69 F_1 hybrids of red onion were developed by crossing between three MS lines (MS 111A, MS 222A and MS 1600A) with selected 23 elite lines as pollinators viz. 546-DR, 571-LR, KH-M-1, KH-M-2, RGP-1, RGP-2, RGP-3, RGP-4, RGP-5, 1604, 1605, 1606, 1607, 1608, 1609, 1612, 1613, 1629, 1630, 1657, 1663, 1666 and 1672 and evaluation of these hybrids are in progress. Six combinations are in BC_1 stage and three combinations in BC_3 stage for transfer of male sterility in different varietal background of DOGR varieties (Bhima Super, BDR, Bhima Kiran, Bhima Shakti and DOGR-1133). Development of inbred lines from single bulb of selected parents (36 inbreds in I_1 , 54 inbreds in I_2 , 16 inbreds in I_3 and 6 inbreds in I_4 stage).

2. CRP on Hybrid Technology in Onion by ICAR

This project was initiated at ICAR-DOGR, ICAR-IARI and ICAR-VPKAS in March 2024 to develop stable, high yielding F_1 hybrids through male sterile lines. Five male sterile lines viz., MS 48 A, MS 65 A, MS 111A, MS222A, MS1600 along with inbred lines are being utilized to develop stable F_1 hybrids. A total of 70 crosses were made using these male sterile lines and inbred/elite lines and will be evaluated in next season. A 26 F_1 hybrids were evaluated including their parents and three standard check varieties. In Addition, several crosses were made between DOGR-1043, 1044, 1606, 1608, 1609 and 1613 as well as between DOGR-1611, 1626, 1672, 1757 1758, 1788, 1647, 1724, 1269, 1746, 1653 and 1636 with DOGR-1203, 1669 and 1168. Nine varieties viz., Bhima Kiran, Bhima Shakti, Bhima Raj, Bhima Super, Bhima Red, BDR, BDR, RGP-3, DOGR-1625 were crossed with DOGR 1203-DR with the goal to transfer earliness traits to the progeny of these crosses, which can be evaluated for early maturity.

3. Development of identification tool to assess varietal purity and bulb storability of onion

The project was initiated in Jan 2024 in collaboration with IIT Bombay and funded by DST through TIH-IoT, aims

to develop an identification tool to assess the varietal purity and storability of onion bulbs. This will facilitate the development of a mobile-based, real-time, cloud-enabled tool for variety identification, addressing the challenges faced by farmers and seed suppliers in the onion industry. Field trials have been conducted during *rabi* and *kharif* seasons, focusing on the identification of varietal purity through defined DUS features such as bulb colour, shape, size, neck thickness, compactness. Data was recorded on foliage, bulb, and storage characteristics. The findings highlight the potential of DenseNet121 for automated onion variety identification and its superiority in addressing the intricate variability within agricultural datasets. This is the first report of ML in onion varietal classification and future work will focus on model development for varietal identification, testing and validation.

4. DBT sponsored project: Hi-edit: One-step induction of genome editing and transgene elimination in onion (*Allium cepa* L.)

1. Transformation of onion with knockout construct

Knockout constructs targeting *AcMYB1* gene and *AcCHS* genes were used for onion transformation. The results of calli transformation experiments for 4 constructs—*AcMYB1* exon 2, *AcMYB1* exon 3, *AcCHS* T1, *AcCHS* T2, and combination of *AcCHS* (T1+T2). The *pRGEB31-AcMYB1* exon 2 construct was used to infect 2300 calli in 22 batches, out of which 1500 calli reached the selection stage and 800 calli progressed to the shooting stage. Calli at shooting stage for the *AcMYB* constructs are shown in figure 6. As a result, three plants were regenerated, of which two were positive for Cas9, HptII, and the target region. The *pRGEB31-AcMYB1* exon 3 construct was used to infect 1200 calli in 10 batches, with 510 calli advancing to the selection stage and 690 calli to the shooting stage. Three plants were regenerated, among which one was positive for Cas9, HptII, and the target region. The *pRGEB31-AcCHS* T1 construct was applied to 710 calli across 7 batches, resulting in 500 calli at the selection stage and 210 calli at the shooting stage. Onion calli transformed with *AcCHS* targets are shown in figure 7. This led to the regeneration of two plants, both of which were positive for Cas9, HptII, and the target region. The *pRGEB31-AcCHS* T2 construct was used in 15 batches to infect 1550 calli, out of which 210 calli reached the selection stage and 1340 calli proceeded to the shooting stage. A total of 15 plants were regenerated, of which four tested positives for Cas9, HptII, and the target region. The *pRGEB31-AcCHS* T1 and T2 combined constructs were used to infect 1350 calli in 12 batches. Out of these, 350 calli were placed on selection media and 1000 calli reached the shooting stage. Eight plants were regenerated; however, none were positive for Cas9, HptII, or the target region.

Table 1.43 Details of transformation of onion with and AcMYB and AcCHS genome editing construct

| Name of construct | No. of batches | No. of calli | No. of calli on selection | No. of calli on shooting | Plants Regenerated | Number of PCR positive |
|----------------------|----------------|--------------|---------------------------|--------------------------|--------------------|------------------------|
| <i>AcMYB1</i> exon 2 | 22 | 2300 | 1500 | 800 | 3 | 2 |
| <i>AcMYB1</i> exon 3 | 10 | 1200 | 510 | 690 | 3 | 1 |
| <i>AcCHS</i> T1 | 7 | 710 | 500 | 210 | 2 | 2 |
| <i>AcCHS</i> T2 | 15 | 1550 | 210 | 1340 | 15 | 4 |
| <i>AcCHS</i> (T1+T2) | 12 | 1350 | 350 | 1000 | 8 | 0 |

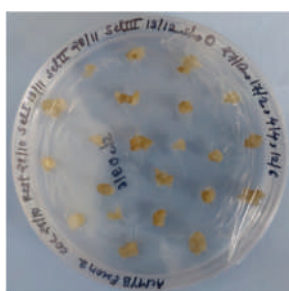


Fig.1.9 Transformed Onion Calli with MYB Target

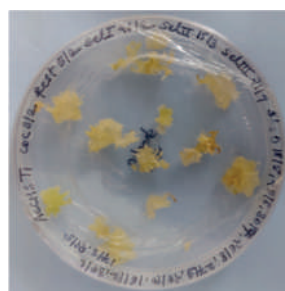
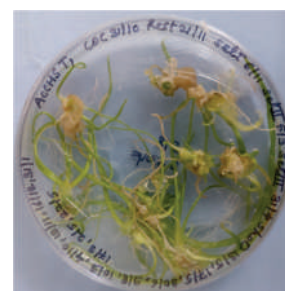


Fig.1.10 Onion calli transformed using pRGEB31-AcCHS target T1 Target at shooting stage



5. Enabling climate resilience and ensuring food & nutritional security through genome editing in horticultural crops

Agrobacterium mediated transformation of *pRGEB-AcMSH1* target construct in onion

Eight-week-old embryogenic calli of onion cv. Bhima super were co-transformed with Agrobacterium strain LBA 4404 harbouring *pRGEB31-AcMSH1* target 1 and *pRGEB31-AcMSH1* target 2 in multiple batches. Transformed calli were sub-cultured on resting medium for two weeks and later transferred to the selection medium containing 50 mg/L hygromycin B. The putatively transformed calli were screened in 3 rounds of selection and survived calli were sub-cultured on the shooting medium containing 50 mg/L hygromycin b for six weeks. The regenerated calli were sub-cultured to the shooting medium containing 30 mg/L hygromycin B and later on shooting medium devoid of hygromycin B for fast regeneration of putatively transformed calli and further transferred in rooting medium for full plant development. The *pRGEB31-AcMSH1* Exon 1 Target construct was used to co-cultivate 1940 calli, resulting in the regeneration of 29 plants, out of which 26 plants survived. Among the survivors, 17 plants were confirmed positive for the target.

The *pRGEB31-AcMSH1* Dual Target construct was used to co-cultivate 1056 calli, leading to the regeneration of 5 plants, of which 4 plants survived. Among these, 3 plants were confirmed positive for the target. Onion calli transformed with *AcMHS1* target are shown in fig. 1.11.

Table 1.44 Details of transformation of onion with genome editing constructs

| Construct | No. of batches | Calli Co-cultivated | Regenerated Plants | Surviving Plants | Positive Plants |
|-------------------------------------|----------------|---------------------|--------------------|------------------|-----------------|
| <i>pRGEB31-AcMSH1</i> Exon 1 Target | 19 | 1940 | 29 | 26 | 17 |
| <i>pRGEB31-AcMSH1</i> Dual Target | 10 | 1056 | 5 | 4 | 3 |

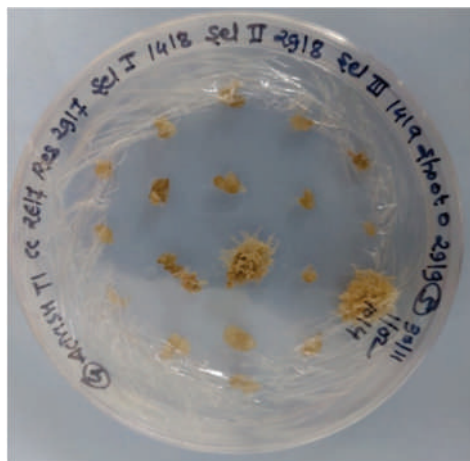


Fig.1.11 Onion calli transformed with *pRGEB31-AcMSH1* Exon 1 Target on shooting media

2. Crop Production

2.1 Abiotic Stress Management in Onion and Garlic

2.1.1 Effect of plant growth regulators on onion crop growth and bulb yield under drought stress

Plant growth regulators (PGRs) has become a promising approach for enhancing crop growth and productivity under drought conditions. A field experiment was conducted to evaluate the effect of different plant growth regulators namely, Salicylic acid (20, 50 ppm), Thiourea (100,250 ppm), BAP (20, 50 ppm), IAA (10, 20 ppm), Kinetin (25, 50,100 ppm), Melatonin (50,100 ppm), Putrescine (100 ppm), Spermidine (100 ppm), KNO₃ (1 and 2%), and Gibberellic acid (100, 200 ppm) in onion cv. Bhima Shakti under drought stress during Rabi season. Foliar application of PGRs was done 10 days before drought stress treatment. Water deficit stress was imposed at the bulb enlargement stage (55-80 days after transplanting) by withholding irrigation for a continuous 25 days. The results revealed that drought stress drastically affected plant growth and yield. Compared to other treatments, the highest photosynthetic rate, stomatal conductance, antioxidant enzyme activities, cellular membrane stability, and low reactive oxygen species accumulation were recorded in kinetin treated plants under drought stress. Foliar spray of Kinetin @ 25 ppm improved plant growth and bulb yield under both control (37 t/ha) and water deficit conditions (33 t/ha) compared to other treatments (Fig.2.1).

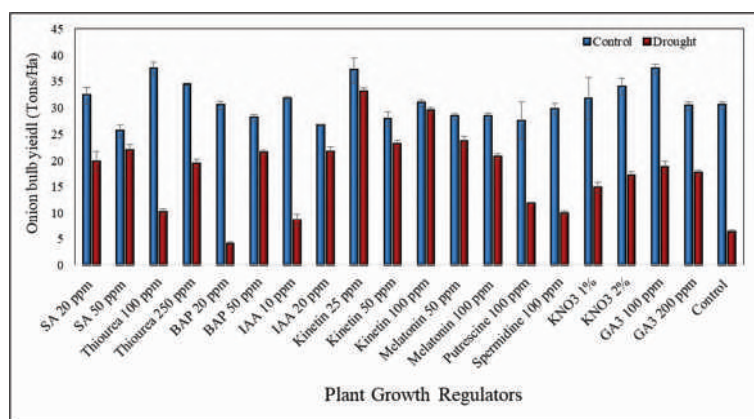


Fig. 2.1 Effect of different plant growth regulators on onion bulb yield under drought stress

2.1.2 To study the impact of plant growth-promoting microbes on onion crop growth and yield subjected to drought stress

Drought stress adversely affects crop growth and yield of onion. Plant growth-promoting microbes (PGPM) has the potential to enhance crop productivity under drought stress. Hence, the present study was conducted to evaluate the effect of PGPM on the plant growth, physiological and biochemical traits, and bulb yield of onion under drought stress. Microbial inoculants: *Azotobacter chroococcum*, *Azospirillum brasilense*, phosphorus solubilizing bacteria, *Serendipita indica*, and potassium mobilizing bacteria were used as microbial treatment in the study, and the plants without microbial treatment were used as a control. In the pot experiment, 50-day-old seedlings were pre-treated with microbial culture before transplantation. Plants were exposed to drought stress 55 days after transplanting, by withholding irrigation for a continuous 25 days; control plants were maintained under a rainout shelter with a routine irrigation schedule. The results showed that microbial treatment significantly enhanced plant growth and bulb yield under drought stress compared to the control. Among the microbial strains, the plants inoculated *Azospirillum* exhibited the highest photosynthetic rate, stomatal conductance, antioxidant enzyme activities, cellular membrane stability, low canopy temperature, lipid peroxidation, and ROS accumulation under drought stress (Fig. 2. 2).

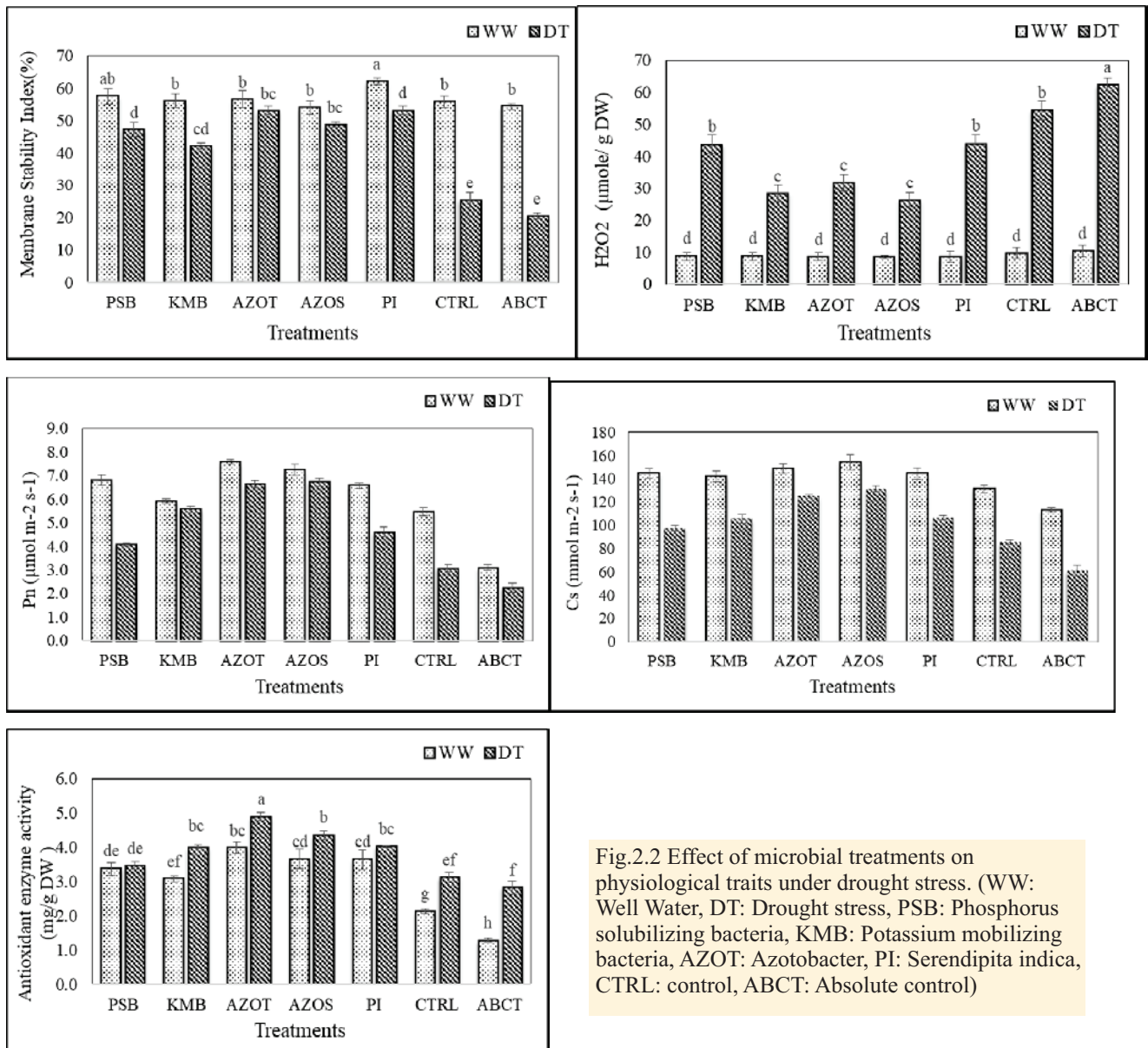
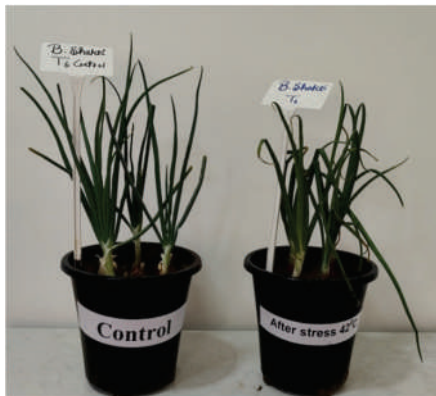


Fig.2.2 Effect of microbial treatments on physiological traits under drought stress. (WW: Well Water, DT: Drought stress, PSB: Phosphorus solubilizing bacteria, KMB: Potassium mobilizing bacteria, AZOT: Azotobacter, PI: Serendipita indica, CTRL: control, ABCT: Absolute control)

2.1.3 Impact of high temperature stress on plant growth and bulb yield of onion

The effect of high temperature stress on plant growth and performance of onion was studied under a controlled growth chamber. This experiment was conducted in pot with two *rabi* onion varieties: Bhima Shakti and Bhima Kiran. Healthy onion seedlings of 45 days old after transplantation were subjected to a different temperature level (26, 30, 35, 38, 40, 42, and 45°C for 24 hours). A set of control plants were maintained under ambient conditions in greenhouse (Fig.2.3). Plants were monitored every 6 hours for their chlorophyll content, membrane stability index, and leaf area. No significant difference was recorded for the morphological traits, such as plant height, leaf area, leaf senescence, and chlorophyll content, when exposed to temperatures of 26, 30, and 35°C compared to control plants. However, increasing the temperature above 35°C significantly reduced chlorophyll, MSI, and leaf area, and antioxidant enzyme activities, whereas it increased reactive oxygen species production compared to the control plants. Additionally, the plants exposed to 42°C showed poor recovery and survival during the post stress period.



High temperature stress of 420C



High temperature stress of 450C

Fig. 2.3 Phenotypic growth of onion plants exposed to heat stress

2.1.4 Evaluation of onion genotypic performance under drought stress

A field experiment was conducted with ten onion varieties namely Bhima Kiran, Bhima Shakti, Bhima Super, Bhīma Red, Bhima Raj, Bhima Dark Red, Bhima Shubhra, Bhima Safed, Bhima Shweta, and Bhima Light Red during the *Rabi* season to demonstrate the effect of water deficit stress on crop growth and yield. The results showed that the drought stress significantly reduced phenotypic traits like plant height, leaf area, and number of leaves compared to the control. It also reduced chlorophyll content and photosynthetic rate in all studied genotypes. Canopy temperature depression (CTD) is an efficient physiological indicator reflecting leaf temperature under stress conditions. Positive CTD values reflect the cooler canopy with efficient transpiration and stomatal conductance, whereas more negative value for CTD shows the effect of drought stress. Genotype, namely, Bhima Shubhra, exhibited higher CTD value (less negative) under stress, reflecting its cooler canopy compared to other genotypes (Figure 2.4). Whereas, B. Red, BLR, and B. Shweta showed more negative CTD values, indicating their low transpiration and stomatal conductance ability under drought stress. Drought stress also reduced bulb yield reduction significantly under drought stress. Genotypes viz., Bhima Raj (30-33%), Bhima Dark Red (28-30%), and Bhima Super (30-35%) showed less reduction in bulb yield (Fig. 2.5). The study further indicated that the genotype with the highest CTD value recorded comparatively higher bulb yield under drought stress.

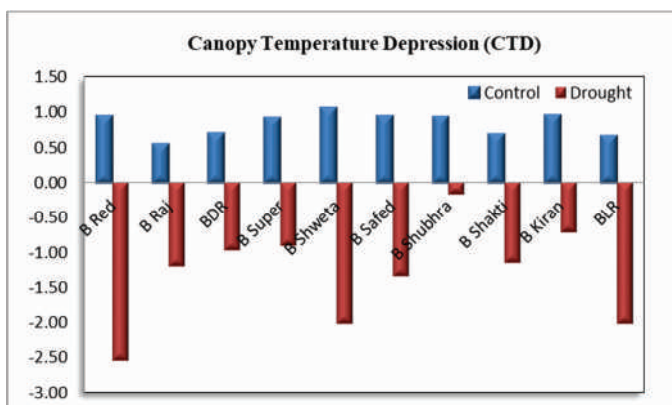


Fig. 2.4 Canopy temperature depression of onion genotypes under drought stress

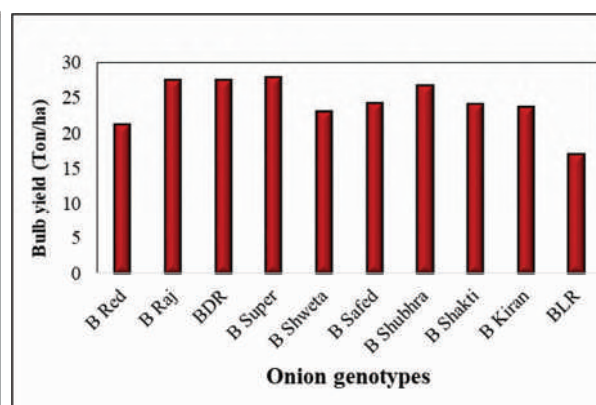


Fig. 2.5 Bulb yield of onion genotypes under drought stress

2.2 Development of improved nutrient management practices for onion and garlic

2.2.1 Effect of continuous use of inorganic fertilizers and manures on onion production and soil fertility status

A long-term experiment was initiated during the *rabi* season of 2013-14 to assess the impact of different fertilizer treatments and cropping systems on onion production and soil fertility. The study included four fertilizer treatments with soybean and maize as preceding crops. In 2015-16, vermicompost (10 t/ha) was introduced as a fifth treatment.

Results revealed that the integration of mineral fertilizers with vermicompost produced onion yields comparable to those achieved with mineral fertilizers alone in both the maize–onion and soybean–onion systems. Among these two cropping systems, the mean onion yield increase under mineral fertilizer and integrated nutrient management treatments in the maize-based onion system was 22.1% higher than in the soybean-based system (Figure 2.6).

Plots treated with vermicompost alone produced significantly lower yields than those receiving mineral fertilizers in both the soybean and maize systems. However, onion yields under organic treatments were statistically similar in the maize–onion and soybean–onion systems. Over the years, onion yield declined more noticeably in the soybean-based system, primarily due to *Stemphylium* incidence and bulb rot.

The highest nutrient uptake (N, P, K, and S) was recorded with the application of 75% recommended mineral fertilizers along with 7.5 t/ha of vermicompost, followed by 100% recommended mineral fertilizers combined with 10 t/ha of vermicompost in the maize–onion system. The uptake of P and K was significantly lower in the soybean–onion system. Additionally, NPKS uptake under organic farming in both cropping systems was considerably lower than INM and mineral fertilizer treatments (Table 2.1).

The combination of mineral fertilizers and vermicompost improved soil organic carbon and nutrient availability, and maintained initial soil fertility levels. The lowest organic carbon content and the highest available soil nitrogen were observed in organic treatments in both the soybean–onion and maize–onion systems (Table 2. 2).

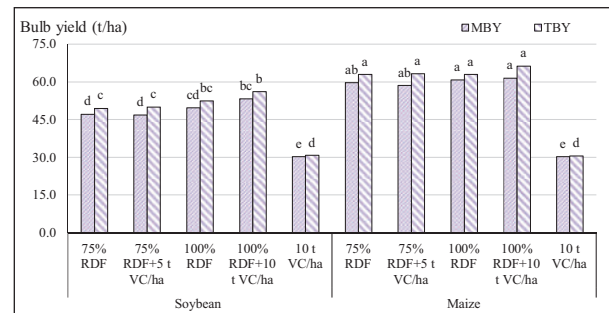


Fig. 2.6 Effect of continuous use of inorganic fertilizers and manures on onion yield

Table 2.1 Effect of continuous use of inorganic fertilizers and manures on total nutrient uptake

| Cropping system | Treatments | Nutrient uptake (kg/ha) | | | |
|-----------------|---------------------|-------------------------|---------|----------|--------|
| | | N | P | K | S |
| Soybean-onion | 75% RDF | 98.2bc | 21.9efg | 114.9bcd | 24.2cd |
| | 75% RDF+5 t VC/ha | 100.2abc | 23.7de | 117.0bcd | 24.6cd |
| | 100% RDF | 90.5c | 22.8def | 106.4d | 25.1cd |
| | 100% RDF+10 t VC/ha | 100.0abc | 26.0bcd | 122.3bc | 30.3b |
| | 10 t VC/ha | 44.4d | 19.0fg | 62.9e | 12.2e |
| Maize-onion | 75% RDF | 97.6bc | 28.9abc | 122.5bc | 22.9d |
| | 75% RDF+5 t VC/ha | 112.7a | 29.9a | 136.6a | 37.2a |
| | 100% RDF | 89.1c | 25.1cde | 111.5cd | 23.6cd |
| | 100% RDF+10 t VC/ha | 103.6ab | 28.9ab | 127.4ab | 27.0bc |
| | 10 t VC/ha | 42.1d | 18.5g | 65.1e | 15.0e |

Table 2.2 Effect of continuous use of inorganic fertilizers and manures on post-harvest soil properties

| Cropping system | Treatments | pH | EC (dS/m) | SOC (%) | Available nutrients (kg/ha) | | | |
|-----------------|---------------------|--------|---------------------|--------------------|-----------------------------|--------------------|---------|--------------------|
| | | | | | N | P | K | S |
| Soybean-onion | 75% RDF | 7.36e | 0.18 ^{cd} | 0.82 ^a | 150.5d | 22.0 ^{bc} | 366.2e | 15.2 ^{ab} |
| | 75% RDF+5 t VC/ha | 7.35e | 0.22 ^{abc} | 0.81 ^{ab} | 166.2bc | 27.9 ^a | 460.6c | 17.5 ^a |
| | 100% RDF | 7.47de | 0.18 ^{cd} | 0.74 ^{cd} | 159.9cd | 20.1 ^{bc} | 407.7d | 14.8 ^{ab} |
| | 100% RDF+10 t VC/ha | 7.54d | 0.14 ^d | 0.73 ^{cd} | 156.8cd | 23.9 ^{ab} | 414.4d | 16.2 ^{ab} |
| | 10 t VC/ha | 7.70c | 0.23 ^{abc} | 0.70 ^{de} | 181.9a | 18.3 ^c | 363.4e | 16.7 ^{ab} |
| Maize-onion | 75% RDF | 7.84b | 0.24 ^{ab} | 0.73 ^{cd} | 166.2bc | 21.7 ^{bc} | 502.9ab | 15.2 ^{ab} |
| | 75% RDF+5 t VC/ha | 8.11a | 0.22 ^{abc} | 0.77 ^{bc} | 169.3abc | 16.9 ^{cd} | 538.2a | 16.6 ^{ab} |
| | 100% RDF | 8.13a | 0.26 ^a | 0.73 ^{cd} | 159.9cd | 13.3 ^{de} | 438.2cd | 14.7 ^b |
| | 100% RDF+10 t VC/ha | 8.15a | 0.26 ^a | 0.77 ^{bc} | 169.3abc | 11.6 ^e | 471.0bc | 14.8 ^{ab} |
| | 10 t VC/ha | 7.87b | 0.21 ^{bc} | 0.67 ^e | 178.8ab | 20.3 ^{bc} | 339.10e | 14.8 ^{ab} |

2.2.2 Effect of organic/natural farming on onion production compared to conventional farming

In 2021-2022, a long-term experiment was initiated to evaluate the effects of organic and natural farming practices on onion production and quality in comparison to conventional methods. The study included six treatments:

1. Organic Module 1: FYM (10 t/ha), vermicompost (2.0 t/ha), neem cake (1.0 t/ha), Azospirillum (3 kg/ha), and PSB (3 kg/ha).
2. Organic Module 2: FYM (7.5 t/ha), vermicompost (1.5 t/ha), neem cake (0.75 t/ha), Azospirillum (3 kg/ha), and PSB (3 kg/ha).
3. Natural Farming Module 1: Organic amendments from Organic Module 1, along with Beejamrit, Jivamrit, Neemastra, Brahmastra, Agniastra, Dashaparni Ark, and a fungicide prepared from cow milk and curd.
4. Natural Farming Module 2: Beejamrit, Jivamrit, Neemastra, Brahmastra, Agniastra, Dashaparni Ark, and a fungicide prepared from cow milk and curd (without organic manures).
5. INM Treatment + Chemical Plant Protection Measures: Mineral fertilizers (110:40:60:30 kg NPKS/ha), FYM (2.5 t/ha), vermicompost (1.0 t/ha), neem cake (0.5 t/ha).
6. Mineral Fertilizers + Chemical Plant Protection Measures: Mineral fertilizers (150:50:80:30 kg NPKS/ha).

The experiment was designed to prevent soil mixing between treatments, with each treatment block consisting of 14 beds. Soybean was grown as the preceding crop in Organic Modules 1 and 2, INM, and mineral fertilizer treatments, whereas Daincha was grown as the preceding crop in natural farming treatments.

The plot under integrated nutrient management produced a significantly higher onion yield than those receiving mineral fertilizers alone or organic/natural farming practices. INM treatment showed a 21.0% and 51.45% increase compared to mineral fertilizer treatments and organic/natural methods, respectively (Fig. 2.7). Among organic and natural farming approaches, natural farming module 1 recorded the highest bulb yield, followed by organic module 1. Conversely, natural farming module 2, which did not include organic manures, yielded only 9.5 t/ha, which was 62.3% lower than the INM treatment. Chemical fertilizer treatments exhibited the lowest storage losses after five months, followed by INM treatments (Fig. 2.8). Storage losses in natural and organic farming treatments ranged from 32.8% to 35.6%, whereas mineral fertilizer treatments exhibited total storage losses of 18%.

Organic and natural farming methods resulted in increased total protein, total phenol, and antioxidant levels. Conversely, INM and mineral fertilizer treatments had higher pyruvic acid concentrations (Table 2.3). Nutrient uptake of N, K, and S was notably higher in conventional and INM plots compared to organically treated plots, while P uptake was greater in organic/natural farming treatments (Fig. 2.9). Soil analysis revealed higher soil organic carbon and available P and K concentrations in organic plots compared to INM and mineral fertilizer treatment, which exhibited the lowest levels (Table 2.4). However, N concentrations were highest in INM and mineral fertilizer treatment.

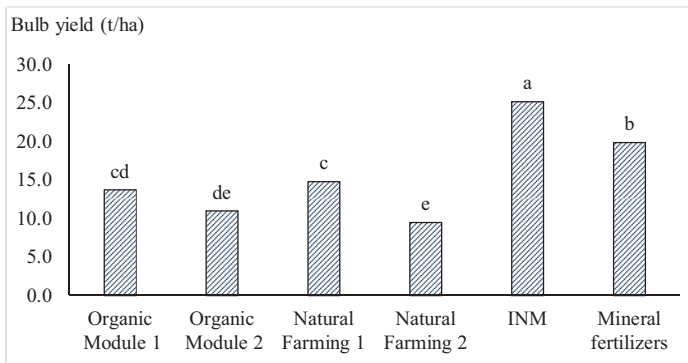


Fig. 2.7 Effect of organic/natural farming on onion yield compared to mineral fertilizers

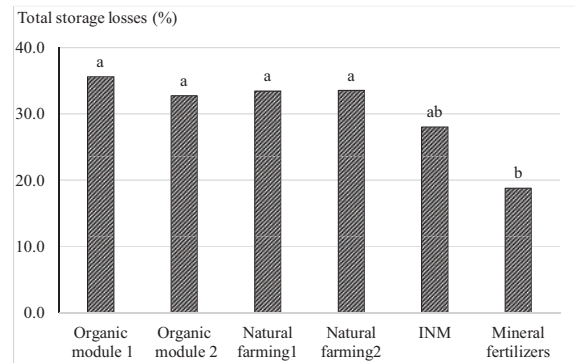


Fig. 2.8 Effect of organic/natural farming on total storage losses compared to mineral fertilizers

Table 2.3 Effect of organic/natural farming on biochemical qualities of onion bulbs compared to mineral fertilizers

| Treatments | Antioxidant activity (mg TE/ g fresh onion) | Total phenol (mg GAE/ g fresh) | Total protein (%) | Pyruvic acid (μ mole/g fresh onion) |
|---------------------|---|--------------------------------|--------------------|-------------------------------------|
| Organic module 1 | 267.1c | 407.5 ^{bc} | 0.42b | 4.38 ^c |
| Organic module 2 | 292.0b | 480.0 ^a | 0.63a | 5.23b |
| Natural farming 1 | 233.5d | 400.0 ^c | 0.40 ^{bc} | 5.29b |
| Natural farming 2 | 305.7a | 457.5 ^a | 0.39 ^{bc} | 4.29c |
| INM | 236.4d | 430.0 ^b | 0.38c | 5.61a |
| Mineral fertilizers | 263.6c | 475.0 ^a | 0.38c | 5.27 ^b |

INM: Integrated nutrient management, TE: Trolox Equivalent, GAE: Gallic acid Equivalent

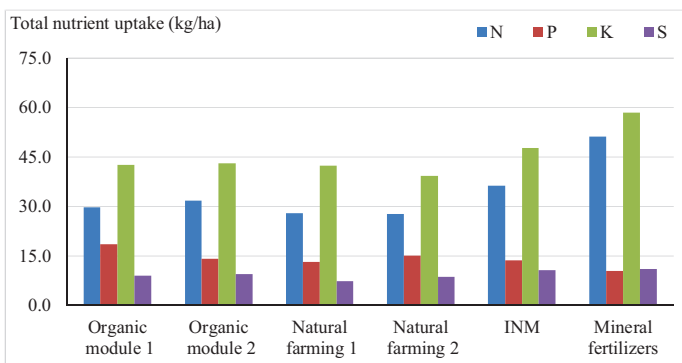


Fig. 2.9 Effect of organic/natural farming on total nutrient uptake compared to mineral fertilizers

Table 2.4 Effect of organic and natural farming practices on soil physico-chemical properties

| Treatments | pH | EC (dS/m) | SOC (mg/kg) | Available N (kg/ha) | Available P (kg/ha) | Available K (kg/ha) |
|---------------------|--------------------|-----------|-------------------|---------------------|---------------------|---------------------|
| Organic module 1 | 8.15 ^c | 0.73a | 8.70 ^a | 112.9 ^b | 28.7a | 600.1a |
| Organic module 2 | 8.26 ^c | 0.50b | 8.90 ^a | 109.8 ^b | 20.6b | 536.2b |
| Natural farming 1 | 8.59 ^{ab} | 0.27c | 8.67 ^a | 112.9 ^b | 13.3d | 451.1cd |
| Natural farming 2 | 8.66 ^a | 0.25c | 7.78 ^b | 119.2 ^{ab} | 15.5c | 427.9cd |
| INM | 8.45 ^b | 0.37bc | 7.72 ^b | 134.8 ^a | 14.2cd | 464.2c |
| Mineral fertilizers | 8.45 ^b | 0.37bc | 7.05 ^c | 134.9 ^a | 10.5e | 417.2d |

2.2.3 Effect of Nitrogen level and irrigation regimes on plant growth, yield and storage quality of onion

A field experiment was conducted to evaluate the effects of nitrogen fertilizers and irrigation methods on onion growth, yield, and storage losses. The study assessed three irrigation methods—drip, sprinkler, and flood irrigation—combined with nitrogen levels at 0%, 50%, 100%, and 150% of the recommended N rate, using a strip plot design with four replications.

Results showed that sprinkler and flood irrigation with 100% and 150% nitrogen levels led to higher chlorophyll concentrations and improved plant growth parameters compared to drip fertigation (Table 2.5). However, drip irrigation with 100% and 150% recommended nitrogen significantly increased onion yield compared to other treatments (Fig.2.10). Additionally, drip fertigation with 100% nitrogen produced a higher proportion of A-grade bulbs with larger equatorial and polar diameters, indicating uniform and bigger bulb sizes.

No significant difference was observed between 100% and 150% nitrogen application across irrigation systems in total nitrogen uptake (Fig. 2.11). However, 100% N applied through drip and sprinkler irrigation resulted in statistically similar total antioxidant activity (Table 2.6). In contrast, applying 150% N through drip and sprinkler irrigation significantly increased total phenol, total protein, and total pyruvic acid concentrations compared to other treatments.

Regarding storage losses, onions grown under 100% nitrogen application via drip irrigation exhibited the lowest losses, followed by those under 100% N with flood irrigation. However, increasing nitrogen application to 150% led to a 10.5% rise in total storage losses compared to the 100% N level (Fig. 2.12). The treatments received 100% and 150% N showed the highest soil available N concentration after harvest (Table 2.7).

Table 2.5 Effect of Nitrogen level and irrigation regimes on chlorophyll concentrations ($\mu\text{g g}^{-1}$)

| Treatments | 30 DAT | | | 60 DAT | | | 90 DAT | | |
|----------------------|--------|-----------|--------|--------|-----------|--------|--------|-----------|--------|
| | Drip | Sprinkler | Flood | Drip | Sprinkler | Flood | Drip | Sprinkler | Flood |
| Chlorophyll A | | | | | | | | | |
| 0% | 3.16 | 4.03 | 3.21 | 2.12 | 2.50 | 3.41 | 3.04 | 2.07 | 2.50 |
| 50% | 4.13 | 4.66 | 4.52 | 2.40 | 2.97 | 3.74 | 3.43 | 3.15 | 3.30 |
| 100% | 4.73 | 4.94 | 4.95 | 4.08 | 4.38 | 4.30 | 3.59 | 4.11 | 3.44 |
| 150% | 5.60 | 5.69 | 5.45 | 3.98 | 4.56 | 4.79 | 4.47 | 4.12 | 4.25 |
| Factors | N | I | N×I | N | I | N×I | N | I | N×I |
| LSD | 0.13 | 0.10 | 0.19 | 0.21 | NS | 0.33 | 0.17 | 0.16 | 0.24 |
| p-value | <0.001 | <0.001 | <0.001 | 0.011 | 0.09 | 0.02 | <0.001 | 0.047 | <0.001 |
| Chlorophyll B | | | | | | | | | |
| 0% | 1.06 | 1.28 | 1.05 | 0.67 | 0.92 | 1.23 | 1.02 | 0.9 | 0.83 |
| 50% | 1.33 | 1.64 | 1.39 | 0.88 | 1.07 | 1.25 | 1.12 | 1.07 | 1.07 |
| 100% | 1.72 | 1.64 | 1.68 | 1.51 | 1.51 | 1.39 | 1.21 | 1.19 | 1.17 |
| 150% | 1.74 | 1.81 | 1.73 | 1.34 | 1.81 | 1.71 | 1.4 | 1.29 | 1.57 |
| Factors | N | I | N×I | N | I | N×I | N | I | N×I |
| LSD | 0.07 | 0.07 | 0.04 | 0.09 | 0.10 | 0.04 | 0.19 | 0.13 | 0.06 |
| p-value | <0.001 | <0.001 | <0.001 | <0.001 | 0.003 | <0.001 | <0.001 | <0.001 | <0.001 |



| Treatments | 30 DAT | | | 60 DAT | | | 90 DAT | | |
|--------------------------|--------|-----------|--------|--------|-----------|--------|--------|-----------|--------|
| | Drip | Sprinkler | Flood | Drip | Sprinkler | Flood | Drip | Sprinkler | Flood |
| Total chlorophyll | | | | | | | | | |
| 0% | 4.22 | 5.3 | 4.26 | 2.79 | 3.42 | 4.63 | 4.06 | 2.97 | 3.33 |
| 50% | 5.46 | 6.3 | 5.92 | 3.29 | 4.05 | 4.99 | 4.56 | 4.22 | 4.37 |
| 100% | 6.45 | 6.57 | 6.63 | 5.59 | 5.89 | 5.69 | 4.8 | 5.31 | 4.61 |
| 150% | 7.33 | 7.5 | 7.18 | 5.33 | 6.37 | 6.5 | 5.88 | 5.41 | 5.83 |
| Factors | N | I | N×I | N | I | N×I | N | I | N×I |
| LSD | 0.07 | 0.13 | 0.07 | 0.06 | 0.18 | 0.07 | 0.09 | 0.30 | 0.14 |
| p-value | <0.001 | <0.001 | <0.001 | <0.001 | 0.02 | <0.001 | <0.001 | <0.001 | <0.001 |

N: Nitrogen level, I: Irrigation method

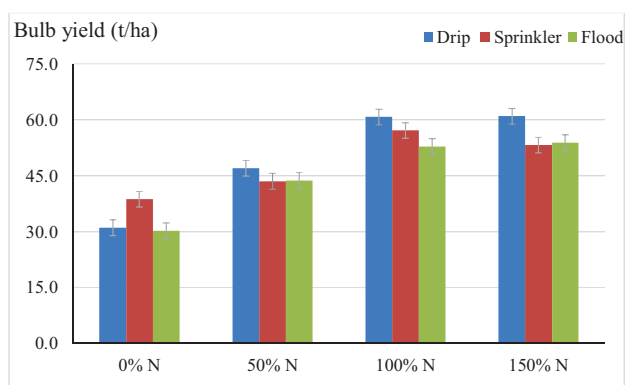


Fig. 2.10 Effect of Nitrogen level and irrigation regimes on onion yield

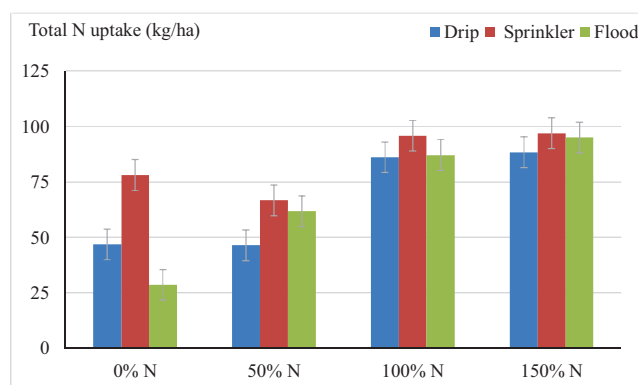


Fig. 2.11 Effect of Nitrogen level and irrigation regimes on total nutrient uptake

Table 2.6 Effect of Nitrogen level and irrigation regimes on biochemical qualities of onion bulbs

| Treatments | Antioxidant activity (mg TE/ g fresh onion) | | | Total phenol (mg GAE/ g fresh onion) | | | Total protein (%) | | | Pyruvic acid (µ mole/g fresh onion) | | |
|------------|---|-----------|---------|--------------------------------------|-----------|---------|-------------------|-----------|---------|-------------------------------------|-----------|-------|
| | Drip | Sprinkler | Flood | Drip | Sprinkler | Flood | Drip | Sprinkler | Flood | Drip | Sprinkler | Flood |
| 0% N | 268.0 | 210.9 | 267.8 | 447.5 | 450.0 | 420.0 | 0.51 | 0.58 | 0.47 | 4.96 | 5.59 | 4.94 |
| 50% N | 280.0 | 299.7 | 267.6 | 500.0 | 572.5 | 475.0 | 0.50 | 0.67 | 0.44 | 4.96 | 5.79 | 4.91 |
| 100% N | 297.7 | 302.6 | 279.4 | 562.5 | 572.5 | 482.5 | 0.61 | 0.67 | 0.50 | 5.24 | 5.90 | 5.54 |
| 150% N | 397.4 | 274.5 | 288.2 | 652.5 | 597.5 | 495.0 | 0.71 | 0.65 | 0.44 | 5.34 | 5.36 | 5.27 |
| Factors | N | I | N×I | N | I | N×I | N | I | N×I | N | I | N×I |
| LSD | 8.6 | 6.4 | 9.9 | 10.2 | 4.8 | 12.9 | 0.01 | 0.01 | 0.01 | 0.22 | 0.26 | 0.28 |
| p-value | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | 0.013 | 0.004 | 0.003 |

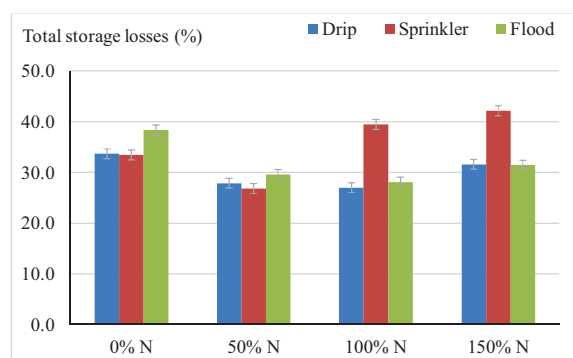


Fig. 2.12 Effect of Nitrogen level and irrigation regimes on total storage losses of onion bulbs

Table 2.7 Effect of Nitrogen level and irrigation regimes on post-harvest soil properties

| Treatments | Soil pH | | | EC (dS/m) | | | SOC (%) | | | Available N (kg/ha) | | |
|------------|---------|-----------|-------|-----------|-----------|-------|---------|-----------|-------|---------------------|-----------|-------|
| | Drip | Sprinkler | Flood | Drip | Sprinkler | Flood | Drip | Sprinkler | Flood | Drip | Sprinkler | Flood |
| 0% N | 7.24 | 7.66 | 7.82 | 0.41 | 0.31 | 0.35 | 0.60 | 0.62 | 0.71 | 108.7 | 108.7 | 117.1 |
| 50% N | 7.31 | 7.50 | 7.93 | 0.51 | 0.43 | 0.27 | 0.60 | 0.61 | 0.69 | 104.5 | 112.9 | 104.5 |
| 100% N | 7.30 | 7.43 | 7.91 | 0.48 | 0.46 | 0.29 | 0.62 | 0.62 | 0.69 | 121.3 | 121.3 | 104.5 |
| 150% N | 7.39 | 7.46 | 7.92 | 0.52 | 0.46 | 0.30 | 0.64 | 0.60 | 0.71 | 117.1 | 121.3 | 108.7 |
| Factors | N | I | N×I | N | I | N×I | N | I | N×I | N | I | N×I |
| LSD | NS | 0.08 | 0.11 | 0.03 | 0.05 | 0.06 | NS | 0.02 | NS | 5.4 | NS | 9.8 |
| p-value | 0.45 | <0.0001 | 0.003 | 0.009 | 0.001 | 0.001 | 0.44 | <0.0001 | 0.62 | 0.03 | 0.39 | 0.020 |

2.2.4 Differential response of onion genotypes to waterlogging stress: Effect on plant growth, physiological and biochemical traits, and bulb yield

Waterlogging significantly affects plant growth, yield, and quality, with onions being highly vulnerable due to their shallow roots. A pot study identified four waterlogging-tolerant onion genotypes, which were further evaluated under field conditions alongside four sensitive genotypes. This field experiment assessed plant growth, physiological and biochemical traits, and bulb yield under waterlogged conditions with three replications. Accession 1666 exhibited minimal growth reduction, while Bhima Dark Red (BDR) showed moderate declines of 17.1%, 10.6%, and 11.7% in plant height, leaf number, and total leaf area, respectively, compared to control plots. Both tolerant genotypes maintained higher membrane stability index (MSI), relative water content (RWC), antioxidant enzyme activities, pyruvic acid, and chlorophyll concentrations under stress. Accession 1666 and BDR exhibited reductions in bulb yield of 29.7% and 28.8%, respectively, compared to the controls (Table 2.3.8). Conversely, sensitive genotypes experienced greater declines in MSI, RWC, and biochemical traits, with total bulb yield reductions ranging from 46.2% (Bhima Raj) to 53.3% (Bhima Shubra). Field performance revealed that Accession 1630 and W-355, previously classified as tolerant, showed higher mortality and lower yields than Accession 1666 and BDR. The findings confirmed the waterlogging tolerance of Accession 1666 and BDR, recommending their use for cultivation in waterlogged areas. Yield could be further improved by adopting raised bed and furrow planting, especially for monsoon onion cultivation.

Table 2.8 Effect of waterlogging on onion yield (t ha⁻¹) during *kharif* season

| Genotypes | Marketable yield (t ha ⁻¹) | | Total yield (t ha ⁻¹) | |
|--------------------------|--|--------------|-----------------------------------|--------------|
| | Control | Waterlogging | Control | Waterlogging |
| Accession 1666 | 13.78 | 9.82 | 14.27 | 10.03 |
| Accession 1630 | 11.13 | 8.19 | 12.08 | 8.47 |
| W 355 | 8.74 | 5.72 | 9.23 | 6.00 |
| Bhima Dark Red | 16.72 | 11.78 | 16.96 | 12.07 |
| Bhima Red | 10.39 | 4.94 | 11.01 | 5.57 |
| Bhima Raj | 10.31 | 5.32 | 11.10 | 5.97 |
| Bhima Shubra | 6.66 | 3.07 | 8.07 | 3.77 |
| Bhima Super | 5.62 | 4.86 | 6.25 | 5.34 |
| Factors | LSD (p=0.05) | | | |
| Waterlogging | 0.71 | | 0.20 | |
| Genotypes | 1.08 | | 1.34 | |
| Waterlogging × Genotypes | 1.54 | | 1.78 | |

LSD: Least significant difference

2.2.5 Salinity Stress Induced Changes in Onion Genotypes: Biochemical and Physiological Traits, Ion Homeostasis, and Bulb Formation

Soil salinity disrupts key physiological, biochemical, and metabolic processes essential for onion growth and development. While the effects of salinity on crop growth are well-documented, the interaction between salinity and heavy-textured soils, which dominate onion-growing regions of India, remains underexplored. A pot experiment was conducted with six salinity levels (Control 0.12, 0.5, 0.85, 1.85, 3.55, and 5.0 dS m⁻¹) to examine the effect of salinity on plant growth, physiological traits, biochemical properties, ionic balance, and bulb formation in four onion genotypes grown in clay loam soils during the winter season at ICAR-DOGR, Pune. At salinity levels of 0.5 and 0.85 dS m⁻¹, Bhima Shakti and Bhima Kiran showed increased plant height, maintained leaf number, leaf area index, and dry matter accumulation, leading to a slight increase in bulb yield (1.3%–1.8%) at 0.5 dS m⁻¹, while a decline in yield (2.1%–2.2%) was observed at 0.85 dS m⁻¹ (Fig. 2.13). In contrast, Bhima Shweta and Bhima Kiran exhibited significant reductions in these parameters, resulting in 11.4% and 19.0% lower bulb yields compared to the control. At salinity levels of 1.85 dS m⁻¹ and higher, plant growth, chlorophyll content, membrane stability index, relative water content, protein levels, and nutrient concentrations significantly declined, with reductions of over 30% at 1.85 dS m⁻¹, which further reduced with higher salinity. Additionally, increased Na⁺ and Cl⁻ accumulation disturbed nutrient balance, raising Na⁺/K⁺, Na⁺/Ca²⁺, Na⁺/Mg²⁺, Cl⁻/N, Cl⁻/P, and Cl⁻/SO₄ ratios. Antioxidant activity, total phenols, and pyruvic acid concentrations increased with salinity up to 5.0 dS m⁻¹ across all genotypes, while protein concentrations decreased at higher salinity levels. The study indicated that Bhima Shakti and Bhima Red showed better growth and yield under mild salinity conditions (0.5–0.85 dS m⁻¹), while Bhima Shweta and Bhima Kiran were highly sensitive to salinity stress in clay loam soils. Overall, identifying genotypes that can tolerate salinity up to 1.85 dS m⁻¹ could help expand onion cultivation in saline regions, boosting agricultural productivity in marginal lands.

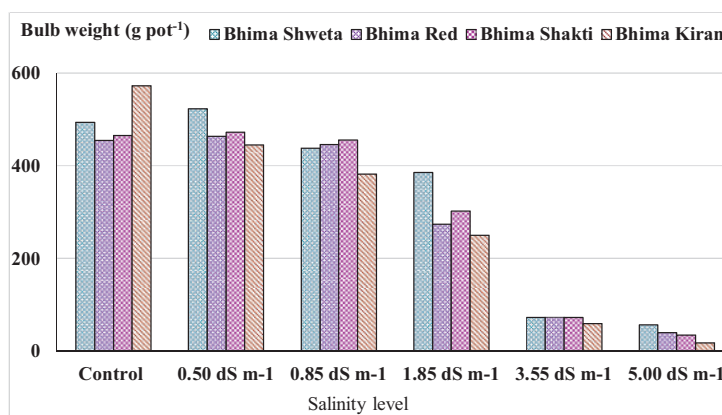


Fig. 2.13 Effect of soil salinity levels on bulb weight (g pot⁻¹) of onion genotypes at different growth stages

2.2.6. Smart-SNWM: Smart soil specific nutrient and water management at different depths using IoT and AI/ML (Smart-SNWM) for onion crop

Precision agriculture has emerged as an important approach to optimize crop management and resource utilization in modern farming practices which can lead to better quality of produce and higher yield. One of the key components in this approach is accurate soil moisture and nutrient monitoring, which allows farmers to make informed decisions about irrigation and fertigation scheduling. To address the need of in-situ, real-field soil and weather parameter monitoring, an indigenous energy-autonomous (solar-powered) agriculture station (SAMBHAVTM) using IoT technology, has been designed. It records and analyzes critical parameters of soil, weather and leaves that can affect the growth of crops, quality and yield. The SAMBHAVTM system gathers data from soil, weather and leaf sensors and sends the data to the cloud server for analysis. However, the quality and reliability of data gathered by sensors are the key attributes of a successful AI-based system. Investigating the variability and benchmarking of commercial soil sensors for real-time monitoring of moisture and nutrient levels (NPK: nitrogen, phosphorus, potassium) is required. Hence, the present study was conducted for sensor-specific calibration due to significant variability observed across different commercial sensors simultaneously at ICAR-DOGR, Pune and Technological Innovation Hub, IIT, Bombay.

The comparative study highlighted the importance of selecting SAMBHAV soil moisture sensors (SAMB_M sensors) with minimal variability ($\pm 0.3\%$) and reasonable accuracy ($\pm 5\%$) compared to gold standard devices. Further, in-field performance of soil moisture exhibited consistent changes with respect to rainfall and irrigation events. Soil specific calibration is required considering the variability across soil from different fields. Additionally, SAMBHAV NPK sensors (SAMB_NPK) displayed $\pm 0.2\%$ nominal variability across multiple sensors in aqua medium. The sensor readings showed R^2 value of 0.76, 0.82, 0.96 for N, P, K, respectively compared to conventional lab-based measurement methods. Further, the consistency observed with respect to applied fertilizers and SAMB_NPK sensors readings demonstrated the usability of these NPK sensors for in-field applications. Future research focusing on long-term in-field sensor behaviour, sensor drift, and data correlation with conventional methods can help standardize IoT technology in digital agriculture. Accurate real-time measurements will enable farmers to apply fertilizers and irrigation more efficiently, reducing costs and improving both the quality and yield of their produce.

2.2.7 Polyhalite as an alternative nutrient source: Effects on onion and garlic growth, yield, quality, and nutrient use efficiency

Polyhalite (POLY4), a naturally occurring multi-nutrient source with a low salt index, has potential as a replacement for muriate of potash (MOP). A field experiment was conducted to assess the effect of POLY4 on the growth, yield, quality, and nutrient use efficiency of onion and garlic, comparing nine fertilizer treatments. The results indicated that applying 100% POLY4 alone significantly enhanced the yield and nutrient uptake of both crops compared to plots treated with 100% K and S from MOP and Bentonite S. Notably, potassium (K) uptake in the POLY4 treatment exceeded the applied quantity, raising concerns about its sustainability for crop productivity and soil health. However, the combination of 100% POLY4 with additional K resulted in a 6.3% onion yield increase in 2022–2023 and a 4.0% increase in 2023–2024 compared to the MOP treatment (Fig. 2.14). This combined treatment yielded statistically similar results to the MOP treatment for garlic in both years (Fig. 2.15). Additionally, it significantly enhanced pyruvic acid and total protein concentrations in both crops and resulted in higher total dry matter yield and N, P, K, and S uptake. Moreover, agronomic efficiency, partial factor productivity, and recovery efficiency were notably higher in plots receiving 100% POLY4 with K. Given the lower cost and reduced chloride contribution of this natural mineral, 100% recommended S through POLY4 with supplementary K from MOP could be recommended for sustainable onion and garlic production and soil health.

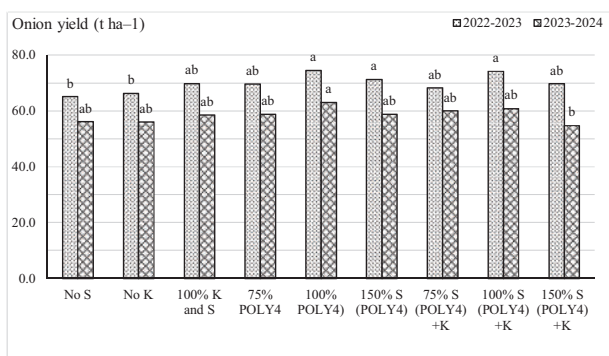


Fig. 2.14 Effect of POLY4 on yield of onion. Different lowercase letters above the bars indicate significant differences ($P < 0.05$) among treatments. 100% K (MOP) and S (BS): 100% recommended potassium applied through muriate of potash and sulphur through bentonite sulphur

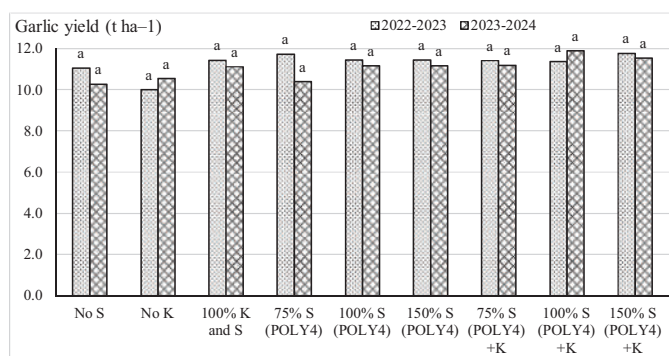


Fig. 2.15 Effect of POLY4 on yield of garlic. Different lowercase letters above the bars indicate significant differences ($P < 0.05$) among treatments. 100% K (MOP) and S (BS): 100% recommended potassium applied through muriate of potash and sulphur through bentonite sulphur.

2.3 Developing improved agronomic practices for onion and garlic production

2.3.1 Integrated weed management approach to improve weed control efficiencies for onion production

The field experiment was conducted to develop integrated weed management modules for onion. The experiment followed a randomized block design with four replications during Late *kharif* 2023 and *rabi* 2023-202 and *kharif* 2024 seasons. Pre-emergence herbicides were sprayed in moist soil one day before transplanting, while post-emergence herbicides were applied 25 and 45 days after transplanting. The results showed that the Weed-Free treatment (T₇) exhibited the highest marketable bulb yield, with a 98.2% increase over the weedy check (T₈). This highlights the significant impact of a weed-free environment on crop productivity. Among the herbicide treatments, Pendimethalin + Propaquizafop + Oxyfluorfen (T₁) showed the second-highest yield increase (73.6%), followed by Pendimethalin + polythene mulching (T₄), which resulted in a 67.2% increase. Other herbicide treatments, such as Pendimethalin + Quizalofop ethyl + Oxyfluorfen (T₆) and Oxyfluorfen + one hand weeding (T₅), demonstrated moderate yield improvements, with 53.0% and 50.6% increases, respectively. While these treatments also provided effective weed control, the level of yield enhancement was lower compared to those that included mulching or a completely weed-free environment. Interestingly, Pendimethalin *fb* Fomesafen + Fluazifop-p-butyl (T₂) resulted in the lowest yield increase (25.8%) due to phytotoxicity. In conclusion, besides weed free treatment, Pendimethalin followed by Propaquizafop + Oxyfluorfen (T₁) and Pendimethalin + Polythene mulching (T₄) resulted in the highest marketable bulb yield compared to the weedy check, demonstrating the effectiveness of integrated weed management strategies. These strategies, combining herbicides with cultural practices such as mulching and hand weeding, can enhance bulb yield and optimize crop production in areas affected by weed competition.

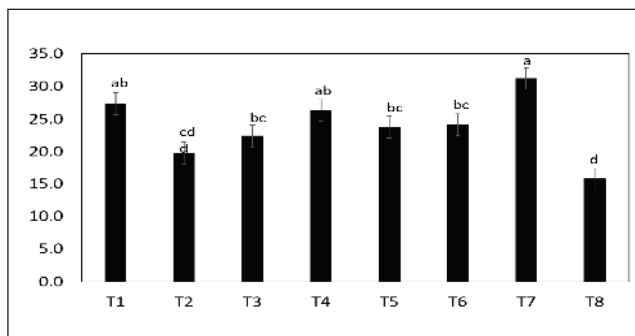


Fig. 2.16 Impact of integrated weed management strategies on bulb yield of onion (pooled analysis)

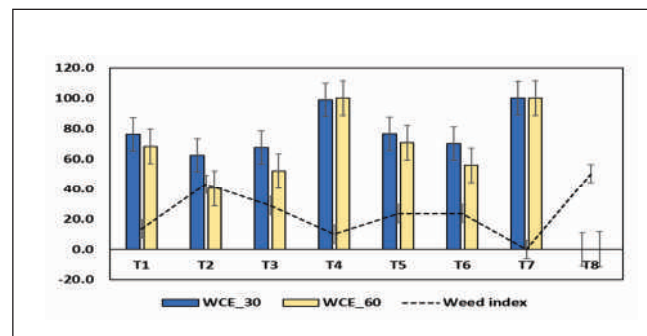


Fig. 2.17 Impact of integrated weed management strategies on weed control efficiency at 30 and 60 DAT and weed index of onion (pooled analysis)

2.3.2 Integrated weed management approach to improve weed control efficiencies for garlic production

A field experiment was conducted to develop weed management strategy for garlic during the *Rabi* 2023-2024 at ICAR-Directorate of Onion and Garlic Research, Pune. The experiment consisted of 10 treatments arranged in a randomized block design (RBD) with three replications. Among the treatment, weed free conditions recorded the highest clove yield (7.33 t ha^{-1}) followed by Pendimethalin 30% EC @ 1 kg a.i./ha (PRE) fb Polythelene mulching (T₁₀). With respect to herbicides, the application of treatment, Pendimethalin 30% EC @ 1 kg a.i./ha fb Propaquizafop 10% EC @ 100 g a.i./ha + Oxyfluorfen 23.5% EC @ 200 g a.i./ha @ 25 DAT and 45 DAT (T₁) recorded the highest yield (6.26 t ha^{-1}). (Table 2.9).

Table 2.9 Effect of different weed management strategies on morphological, yield and yield attributes and biochemical parameters of garlic (*Rabi 2023-24*) (Bhima Purple)

| Treatments | Weed control efficiency (30 DAP)* | Weed control efficiency (60 DAP)* | Weed index* | Phytotoxicity (%) 30 DAP | Clove yield (t ha ⁻¹) |
|-----------------|-----------------------------------|-----------------------------------|--------------------|--------------------------|-----------------------------------|
| T ₁ | 82.75ab (9.08) | 65.39c (8.06) | 26.62cde (4.78) | 10.000b | 5.76cd |
| T ₂ | 78.18ab (8.82) | 74.05b (8.60) | 12.67e (3.56) | 13.333b | 6.76abc |
| T ₃ | 25.53d (5.02) | 18.36f (4.28) | 50.20ab (6.98) | 56.667a | 3.91e |
| T ₄ | 42.48cd (6.09) | 47.11e (6.86) | 73.32a (8.56) | 50.000a | 2.09f |
| T ₅ | 85.20ab (9.21) | 76.66b (8.75) | 26.94cde (4.94) | 10.000b | 5.74cd |
| T ₆ | 57.49bc (7.54) | 64.12c (8.01) | 32.27bcd (5.61) | 0.000c | 5.31cde |
| T ₇ | 74.62ab (8.64) | 55.73d (7.46) | 21.56de (4.37) | 0.000c | 6.16bcd |
| T ₈ | 0.00e (0.00) | 0.00g (0.00) | 40.11bc (6.28) | 0.000c | 4.70de |
| T ₉ | 100.00a (10.00) | 100.00a (10.00) | 0.00f (0.00) | 0.000c | 7.84a |
| T ₁₀ | 100.00a (10.00) | 100.00a (10.00) | 2.59f (1.58) | 0.000c | 7.63ab |
| SEM± | 0.618 | 0.161 | 0.63 | 2.699 | 0.51 |
| CD | 1.835 | 0.48 | 1.87 | 8.019 | 1.51 |
| CV (%) | 14.37 | 3.78 | 23.34 | 33.39 | 15.70 |
| CV (%) | 3.25 | 3.07 | 4.08 | 3.18 | |

*Data transformed with square root method

Note: T₁: Pendimethalin 30% EC @ 1 kg a.i./ha fb Propaquizafop 10% EC 100 g a.i./ha + Oxyfluorfen 23.5% EC 200 a.i./ha; T₂: Pendimethalin 30% EC @ 1 kg a.i./ha fb Propaquizafop 10% EC 100 g a.i./ha + Oxyfluorfen 23.5% EC 200 a.i./ha 200 g a.i./ha (POST 1) fb (POST 2); T₃: Pendimethalin 30% EC @ 1 kg a.i./ha fb Fomesafen 11.1% SL + Fluazifop-p-butyl 11.1% @ 250 g a.i./ha (POST 1); T₄: Pendimethalin 30% EC @ 1 kg a.i./ha fb Fomesafen 11.1% SL + Fluazifop-p-butyl 11.1% @ 250 g a.i./ha (POST 1) fb (POST 2); T₅: Pendimethalin 30% EC @ 1 kg a.i./ha fb Clodinfop propargyl 12.25% + Oxyfluorfen 14.7% EC (POST 1) fb (POST 2); T₆: Herbicide check 1: Oxyfluorfen 23.5% EC 200 a.i./ha (PE) fb 1 HW (40 DAS); T₇: Herbicide check 2: Pendimethalin 30% EC @ 1 kg a.i./ha fb Quizalofop ethyl 4% + Oxyfluorfen 6% EC (POST 1); T₈: Weedy check; T₉: Weed free; T₁₀: Pendimethalin 30% EC @ 1 kg a.i./ha fb Polythelene mulch POST 1:20 DAP and POST 2: 45 DAP

3. Crop Protection

3.1. Development, refinement and validation of management strategies for major fungal diseases pests of onion and garlic

3.1.1 Collection of samples, isolation and identification of diseases

Diseases (*viz.* Anthracnose, purple blotch, *stemphylium* blight, white rot, basal rot, and post-harvest pathogens) samples were collected from the ICAR-DOGR field and adjoining areas of Maharashtra, as well as other states. Pathogens were isolated and their cultures identified as belonging to *Colletotrichum* spp., *Fusarium* spp., *Alternaria* spp., and *Stemphylium* spp. etc., based on morphological characters, and ITS/Tef1 α -based molecular markers. In addition, *Trichoderma* spp. was also isolated, characterized, and sequenced. The cultures are maintained, selective cultures were submitted ICAR-NBIAM, Mau.

NCBI Submissions: Sequenced and submitted *Tef1* α gene of one *Trichoderma* species, five *Fusarium* species (14 isolates), and one *Colletotrichum* species to NCBI. The details are as follow, *Trichoderma asperellum* (KVRDT1-PP390019), *Fusarium acutatum* (OGRDFW5-PP332885, OGRDFW6-PP332886, OGRDFW10-PP332890, OGRDFW11-PP979570, OGRDFW12-PP979571), *Fusarium falciforme* (OGRDFW7-PP332887, OGRDFW8-PP332888, OGRDFW9-PP332889), *Fusarium solani* (OGRDFW13-PP979572, OGRDFW14-PP979573), *Fusarium incarnatum* (OGRDFW15-PP979574, OGRDFW19-PP979577), *Fusarium equiseti* (OGRDFW17-PP979575, OGRDFW18-PP979575), *Colletotrichum gloeosporioides* (OGRDCG1-PP263370). Further, the *RPB2* gene of *Fusarium equiseti* (RPB2_OGRDFW18-PQ619462) has also been submitted to NCBI.

NAIMCC submissions: Total Fourteen isolates were submitted to ICAR-NBAIM, Mau, for inclusion in the National Agriculturally Important Microbial Culture Collection (NAIMCC) and obtained accession numbers *viz.* Six *Trichoderma* isolates *viz.* OGRDT2 (NAIMCC-F-04567), GRDT1 (NAIMCC-F-04557), GRDT3 (NAIMCC-F-04566), OGRDT3 (NAIMCC-F-04558), GRDT6 (NAIMCC-F-04556), KVRDT1 (NAIMCC-F-04555); Six *Fusarium* isolates *viz.* OGRDFW5 (NAIMCC-F-04548), OGRDFW6 (NAIMCC-F-04549), OGRDFW7 (NAIMCC-F-04550), OGRDFW8 (NAIMCC-F-04551), OGRDFW9 (NAIMCC-F-04552), and OGRDFW10 (NAIMCC-F-04553); and Two isolates of *Colletotrichum gloeosporioides* OGRDCG1 (NAIMCC-F-04610) and OGRDCG2 (NAIMCC-F-04611).

3.1.2 Evaluation of *Trichoderma* species/isolates on crop growth of garlic and disease management under field conditions during Rabi 2023-24

Crop growth: Twelve *Trichoderma* spp. /isolates were evaluated, and observations on growth parameters were recorded. *Trichoderma* spp./isolate OGRDT1, enhanced plant height up to 10% during Rabi-2024.



Fig.3.1 Effect of *Trichoderma* spp./isolets

Effect on diseases: Among the twelve *Trichoderma* spp. / isolates evaluated during the *Rabi* 2024 season, all the isolates inhibited *Stemphylium* blight from 9-19% over the control. The maximum (19%) inhibition was recorded with *Trichoderma* isolate GRDT5, at par with GRDT6 (17%). Similarly, purple blotch was also inhibited, with the ranging from 20-49% over control, being maximum in GRDT5 following GRDT4 and GRDT6, 31% each.

Bulb yield: All the 12 *Trichoderma* spp./ isolates enhanced the bulb yield, ranging from 9-30%. The maximum (30%) increase was supported by *Trichoderma* GRDT7 (12t/ha) over the control (9 t/ha) during the *rabi* 2024.

3.1.3 Molecular characterization: Molecular characterization of *Trichoderma* isolates was carried out using PCR and sequencing of translation elongation factor 1 alpha (*tef*) based primers. PCR products were purified, and sequenced. Phylogenetic analyses were performed in the MEGA 11 software program using the Neighbor-Joining distance algorithm method. Sequences submitted to NCBI GenBank (KVRDT1, *Trichoderma asperellum*, PP390019).

3.1.4 Evaluation of modules for efficacy against major fungal diseases of garlic

Effect on diseases: Four modules (M1, M2, M3, M4) with existing practice (EP), farmers' practice (FP), and absolute control (AC) were evaluated during *rabi*-2024. All the modules inhibited the *Stemphylium* disease, ranging from 18-22% over the control. The maximum (22%) inhibition was recorded with M2 (Intensive management) being statistically at par with M3. Similarly, all the modules inhibited purple blotch, also ranging from 47-53%, being maximum with M3 being at par with M1 and M2.

Bulb yield: Among the above four modules (M1, M2, M3, M4), M2 supported 27% higher yield over the control (9 t/ha) during the *Rabi*-2024 season, followed by M1 and M3.



Fig. 3.2 Effect of modules

3.1.5 Evaluation of Amritpani-based organic formulations on garlic diseases and yield

Effect on diseases: During *Rabi*-2024, four *Amritpani*-based organic formulations were evaluated with control. All the formulations inhibited the purple blotch and *Stemphylium* diseases, ranging from 15-24% and 10-27% respectively, over the control. The maximum purple blotch (24%) and *Stemphylium* blight (27%) inhibition was supported by DOGROF3 (*Bajra* flour, *Calotropis* leaves, *Karanj* leaves, *Ginger* powder, *Turmeric* powder, *Hing* powder to Water), followed by DOGROF2 over the control.

Bulb yield: DOGROF3 recorded a 12.5% higher yield (10.4 t/ha) than the control (9.25 t/ha) during *rabi*-2024.



Fig. 3.3 Effect of Amritpani-based organic formulations

Validation of module(s) at AINPROG centres

Three modules, along with modules from NHRDF, Nashik, and UAS, Dharwad, are being validated at eight different locations located in different zones. Among the modules evaluated, our Module 2 has been found superior at most of the locations in the first year's trial. The details are included in AINRPOG report.

3.1.6 Evaluation of onion germplasm for diseases

A total of 103 white germplasm evaluated against anthracnose during *kharif*, 2024, and all germplasm received higher anthracnose disease.



Fig. 3.4 Evaluation of onion germplasm for diseases

Table 3.1 Evaluation of white germplasm against anthracnose during *kharif* 2024

| PDI Range | No. of entries | Name of entries |
|-----------|----------------|--|
| 7-20 | 9 | W-063 GP, W-340 EL-10, W-353 M-4, W-443 M-7, W-418 AD-7, W-385 GP, W-405 GP, W-043 AD-7, W-182 GP |
| 21-30 | 21 | F-6XJ-10(Y) SNG-F7 M6, W-418 GP, W-177 GP, W-141 M-11, W-143 M-8, W-405 M-2, W-455 GP, W-440 M-5, W-203 GP, W-408 EL-11, W-085 GP, W-448 BR-10, W-477 M-5' W-441 M-10' W-286 GP' W-407 AD-7, White GP Comp 7' B. Safed' W-344' W-396 AD-7' W-405 M-3 |
| 31-40 | 14 | W-355, F-6XJ-10(Y) SNG-F7 M6, W-453 M-7, W-500 M-4, W-439 M-10, W-407 AD-7, W-119 GP, W-448, BR-11, WHTB-LT-15 M-12-SC, W-147 M-7, B. Shweta, W-147 M-8, W-419 AD-7, W-453 M-10 |
| 41-50 | 19 | W-310 M-2, W-398 AD-7, F-6XL-12(W) SNG F7 M6, W-394 EL-9, W-337 GP, W-125 M-2, W-504, W-085 AD-8, W-507 GP, W-355 AD-7, W-498 GP, B. Shubhra, AFW, W-453 M-10, W-442 EL-9, W-147-M-8, W-340 EL-11, W-402 AD-7, WHTS-15-18 M-12-SC |
| 51-60 | 28 | W-172 AD-6, W-543 M-4, W-310 WL-9, W-344, W-439 M-10, WHTS-GT-18 M-12-SC, White GP Comp LG-107-8, W-408 GP, W-444 GP, W-085 AD 8, W-340 EL-11, W-396 AD-6, Udaipur-102, W-143 GP, W-208 AD7, White EL Comp LG-209-8, W-045 GP, W-439 M-8, W-364 GP, W-500 GP, W-009 GP, W-448 BR-11, W-085 GP, W-208 AD 6, W-208 GP, W-355, W-355 GP, W-367 AD-6 |
| >60 | 12 | W-344 GP, W-353 M-11, F-6XL-12(W) SNG F7 M6, -440 M-6, W-403 AD-7, W-540 EL-11, B. Shubhra LG-107-8, W-085 AD7, W-361 GP, W-097 GP, W-144 GP, W-210 GP |

3.2. Biotechnological approaches for biotic stress management

3.2.1 Validation of miRNA against purple blotch infection

We identified the 119 miRNA and their target genes from the onion genome (PRJEB29505). Expression of target genes in purple blotch infection was studied using previous RNAseq data. The validation of the expression of candidate miRNA and their corresponding target genes for purple blotch response was performed using qRT-PCR. The information generated in present investigation will be a foundation for elucidating the miRNA mediated gene regulation in onion in response to disease and stress condition.

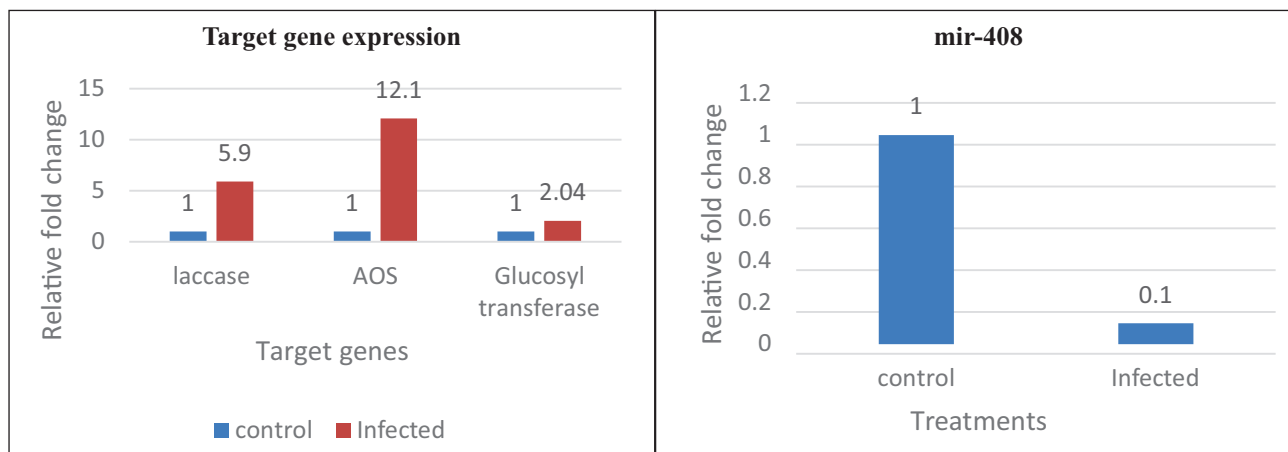


Fig. 3.5 Validation of target and miRNA using qPCR

3.2.2 Isolation and characterization of plant pathogenic fungi

Multiple fungal pathogens associated with foliar and bulb diseases of onion were successfully isolated, including *Colletotrichum* spp. (anthracnose pathogen), *Alternaria*, *Stemphylium*, and *Fusarium* spp. Pure cultures were established on PDA and Water Agar media through repeated sub-culturing, and identification was supported by morphological and microscopic observations. Pathogenicity of isolated fungi was confirmed through artificial inoculation (leaf pricking followed by spore suspension) on onion seedlings. Genomic DNA was extracted from cultured fungal isolates using a modified CTAB protocol, and DNA integrity was confirmed on 0.8–1% agarose gels showing clear high-molecular-weight bands. The extracted DNA was subsequently used for ITS amplification to verify fungal identity and for additional downstream molecular assays.

3.2.3 Rhizosphere microbiome study across wild and cultivated *Allium* species by whole genome metagenomics study

A comprehensive rhizosphere microbiome analysis was performed using soil collected from four wild *Allium* species and one cultivated variety. High-quality metagenomic DNA was extracted from soil DNA extraction protocol. This study aimed to characterize and compare the microbial communities associated with wild and domesticated *Allium* roots, focusing on bacterial and fungal diversity patterns. Whole metagenome sequencing data were processed using OmicsBox workflows, including quality trimming and taxonomic profiling via Kraken2-Bracken. Diversity analysis—richness, evenness, Shannon, and Simpson indices—demonstrated clear differences between wild and cultivated *Allium* rhizospheres, indicating that domestication and agronomic management significantly influence microbial community structure.

3.2.4 Molecular screening of onion germplasm using gene specific markers

Molecular characterization of 30 onion germplasm lines (was carried out using a panel of eleven defense-related gene markers (table 3.2) to assess their genetic potential for disease resistance. High-quality genomic DNA was isolated from each accession and subjected to optimized PCR amplification to detect key genes associated with jasmonic acid signaling, pathogenesis-related responses, and resistance-gene analogues. Additionally, RNA-based assays, including cDNA synthesis, RT-PCR, and qRT-PCR, were performed to evaluate the expression of selected defense genes under pathogen infection. Total RNA was isolated from both healthy and anthracnose-infected onion leaf tissues, and RNA integrity was confirmed on agarose gels showing clean, intact bands. Following DNase treatment, high-quality cDNA was synthesized, and its reliability was validated through successful amplification of the housekeeping Actin gene. Expression profiling of key defense-related genes (MYC A, PR-5, and RGA) was carried out using SYBR-Green-based qRT-PCR, revealing clear differential gene expression between healthy and infected tissues. Melt-curve analysis confirmed specific and accurate amplification for all primers used. The details of presence and absence of defence related genes in 30 genotypes were given in table 3.3.

Table 3.2 Details of the eleven defense-related gene primers used in PCR-based molecular characterisation of onion germplasm

| Sr. No. | Primer | Primer details | Purpose of use |
|---------|---------------|----------------------------------|--|
| 1. | JAR1 A | <i>JASMONATE RESISTANT 1 A</i> | Detect JA-mediated defense activation |
| 2. | JAR1 B | <i>JASMONATE RESISTANT 1 B</i> | Validate JAR1 A & detect allelic variation |
| 3. | CoI1 A | <i>CORONATINE INSENSITIVE 1A</i> | Detect coronatine-insensitive resistance alleles |
| 4. | CoI1 B | <i>CORONATINE INSENSITIVE 1B</i> | Additional CoI1 allele detection |
| 5. | MYC A | Transcription factor MYC A | Detect JA-inducible defense transcription |
| 6. | MYC B | Transcription factor MYC A | Additional MYC allele detection |
| 7. | R1 A | Resistance Gene Analogue 1A | Detect major RGA-associated resistance |
| 8. | R1 B | Resistance Gene Analogue 1B | Confirm RGA-allele variation |
| 9. | PR5 | Pathogenesis-Related Protein 5 | Detect the SA-mediated defense pathway |
| 10. | RGA | Resistance Gene Analogue | Broad-spectrum resistance screening |
| 11. | DMR 1 | Downy Mildew Resistance 1 | General resistance marker |

Table 3.3 Molecular screening results showing presence (+) and absence (-) of PCR-amplified defence gene markers across onion germplasm used in the study

| Sr. No | Onion Germplasm | Primers used | | | | | | | | | | |
|--------|-----------------|--------------|--------|--------|---------|-------|-------|------|------|-----|-----|-------|
| | | JAR1 A | JAR1 B | CoI 1A | CoI 1 B | MYC A | MYC B | R1 A | R1 B | PR5 | RGA | DMR 1 |
| 1 | W-364 | - | - | - | - | + | - | - | - | - | + | - |
| 2 | W-344 | - | - | - | - | - | - | - | - | - | - | - |
| 3 | W-353 | - | - | + | - | + | - | - | + | - | - | - |
| 4 | W-045 | - | - | + | - | - | - | - | + | - | - | - |
| 5 | W-055 | - | - | - | - | + | - | - | - | - | - | - |
| 6 | W-189 | - | - | - | - | + | - | - | - | - | - | - |
| 7 | W-361 | - | - | - | - | - | - | - | - | - | - | - |
| 8 | W-085 | - | + | + | + | + | - | + | + | - | - | + |
| 9 | W-365 | - | - | + | - | + | - | + | + | + | - | + |
| 10 | W-439 | - | - | - | - | + | - | - | - | - | - | - |
| 11 | W-221 | - | + | - | + | + | - | - | - | - | - | - |
| 12 | W-340 | - | - | - | - | + | - | - | - | - | - | - |
| 13 | W-442 | - | + | + | + | + | - | - | + | - | - | + |
| 14 | W-444 | - | - | - | - | + | - | - | - | - | - | - |
| 15 | W-127 | - | - | - | - | + | - | - | - | - | - | - |
| 16 | W -401 | - | - | - | - | - | - | - | - | - | - | - |
| 17 | W-143 | - | - | + | - | + | - | + | + | - | - | - |
| 18 | W-402 | - | - | + | - | + | - | - | + | - | - | + |

| Sr. No | Onion Germplasm | Primers used | | | | | | | | | | |
|--------|-----------------|--------------|--------|--------|---------|-------|-------|------|------|-----|-----|-------|
| | | JAR1 A | JAR1 B | CoI 1A | CoI 1 B | MYC A | MYC B | R1 A | R1 B | PR5 | RGA | DMR 1 |
| 19 | W-459 | - | - | + | - | + | - | - | + | - | - | - |
| 20 | W-418 | - | + | + | + | + | - | - | + | - | - | + |
| 21 | W-448 | - | + | + | + | + | - | + | + | - | + | + |
| 22 | W-498 | + | + | + | + | + | - | + | + | + | + | + |
| 23 | W-453 | - | + | - | + | + | - | - | + | - | + | - |
| 24 | W-147 | - | - | - | - | + | - | - | - | - | - | - |
| 25 | W-174 | - | - | + | - | + | - | - | + | - | + | - |
| 26 | W-208 | - | - | - | - | - | - | - | - | - | - | - |
| 27 | W-009 | - | - | - | - | + | - | - | - | - | - | - |
| 28 | W-355 | - | + | + | + | + | - | + | + | + | + | - |
| 29 | W -087 | - | + | + | + | - | - | + | + | - | - | - |
| 30 | White GP Comp | + | + | + | + | + | - | + | + | - | + | - |

3.3 Epidemiology and bio-management of major fungal diseases of onion and garlic

Fusarium basal rot incidence in Maharashtra

The analysis of reports of data on disease survey of onion growing areas of Maharashtra from 1998 to 2022 was done from available reports of ICAR-DOGR (1998-2020) and AINROPG (2021-2022) with missing years from 2001 to 2006, where Fusarium basal rot (FBR) incidence varied from 11 to 50% (Fig. 3.6). The disease incidence recorded during fresh survey in 2023 of five different districts of Maharashtra viz., Ahilyanagar, Chhatrapati Sambhajanagar, Nashik, Pune and Solapur varied from 17 to 41% (Fig. 3.7).

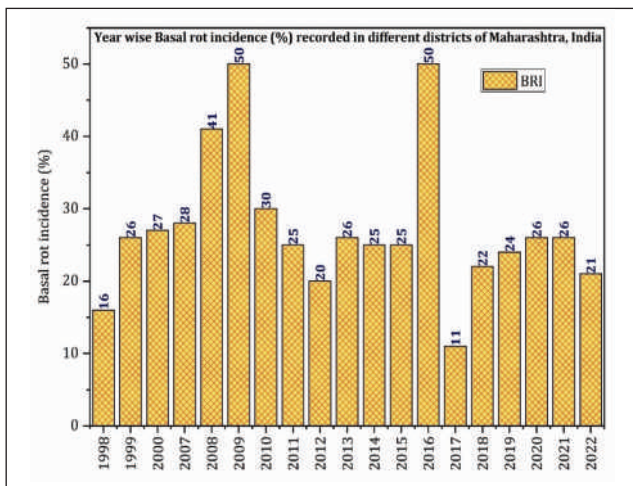


Fig.3.6 Disease incidence of Fusarium basal rot disease in Maharashtra state of India from 1998 to 2022

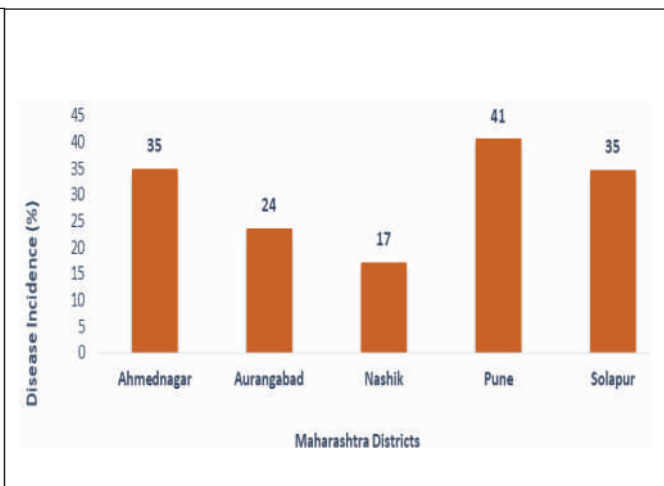


Fig.3.7 Disease incidence of Fusarium basal rot disease in Maharashtra state of India during 2023

3.3.1 Isolation and identification of pathogens causing basal rot

The disease symptoms observed on onion plants and bulb rot spreading from the onion basal plate upwards in the scales were selected and subjected to isolation and morphological identification. The native isolates of *Fusarium* spp. were isolated from respective locations and designated as OGRDFW1 to OGRDFW10 (Fig. 3.8). The isolates were purified and kept for incubation at 25±2 °C. After 7 days of incubation, isolates were preliminarily identified based on morphological characters. The radial growth of all the isolates varied from 64 to 80 mm mycelial growth at 7 days of incubation. Of the ten *Fusarium* isolates collected from selected locations, six species were confirmed as *F. acutatum* (OR102876, OR102877, OR102879, PP332885, PP332886, PP332890) and four as *F. falciforme* (OR102878, PP332887, PP332888, PP332889).

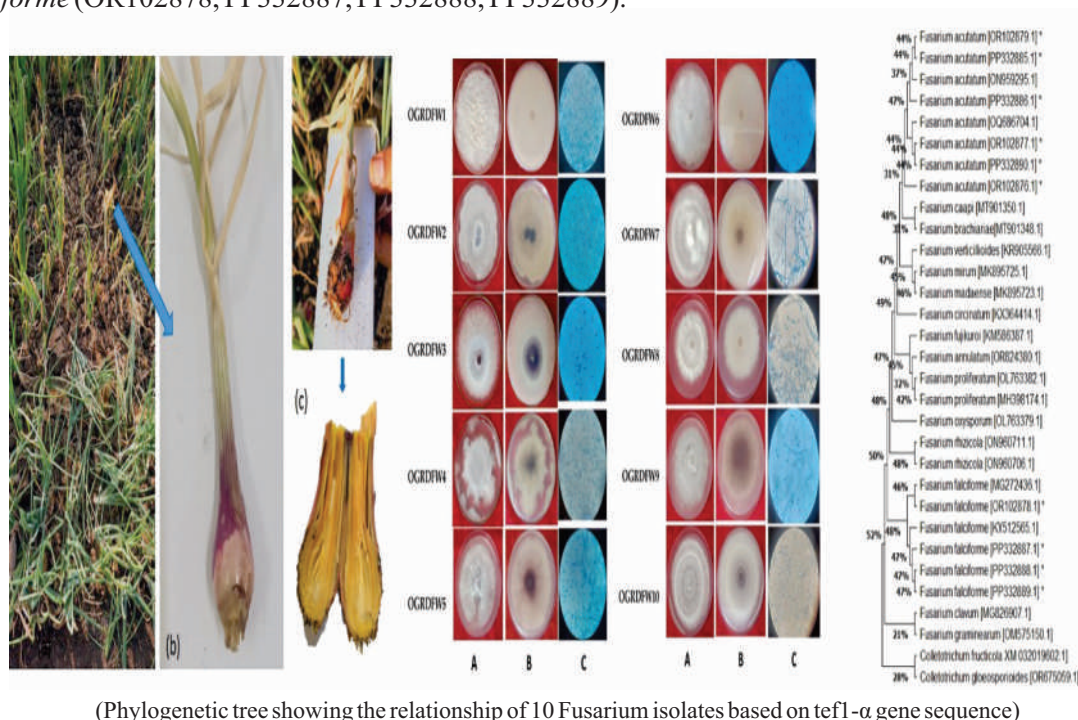


Fig.3.8 Symptoms of *Fusarium* basal rot of onion; colony morphology and microscopic characterization of the *Fusarium* spp./ Isolates

Pathogenicity assay

The pathogenicity of six *F. acutatum* and four *F. falciforme* isolates was tested on seedlings and bulbs of a susceptible variety Bhima Super. All inoculated seedlings received infection and developed typical visible symptoms of FBR viz., yellowing, wilting and were all dead by 20 dpi (days after post inoculation). And inoculated bulbs also developed the soft rotting symptoms of FBR by 15 dpi and development of tissue decay of bulbs accompanied by the outgrowth of white hyphae on the bulb surface exhibited on 20 dpi, while the uninoculated seedlings and bulbs remained healthy. The symptoms that developed in this inoculation assay were similar to those seen in naturally infected onion fields both on seedlings and bulbs. The pathogens *F. falciforme* and *F. acutatum* were reisolated as the original isolate, thus fulfilling Koch's postulates.

3.3.2 First report of *Fusarium equiseti* causing basal rot of onion bulbs from India

In March 2024, onion fields at ICAR-DOGR Pune, India, displayed basal rot symptoms averaging 10-15% disease incidence. The pathogen *Fusarium equiseti* was isolated, identified, and confirmed through sequencing *Tef1-α* gene primers (Genbank accession PP979575, MycoBank database accession 199819, NAIMCC accession NAIMCC-F04603). Pathogenicity was tested fulfilling Koch's postulates and the pathogen was reisolated. To the best of our knowledge, this represents the initial documented occurrence of *F. equiseti* causing basal rot of onion bulbs in India, emphasizing the necessity of developing management strategies for this pathogen.

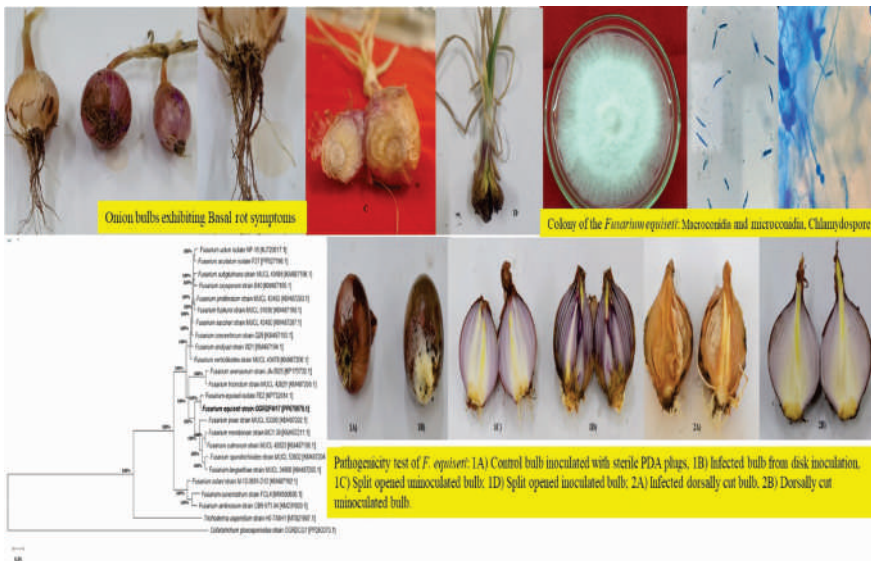


Fig.3.9 *Fusarium equiseti* causing basal rot of onion bulbs

Fusarium dry rot incidence in Maharashtra

The variable incidence of *Fusarium* dry rot was noticed in the survey carried during *rabi* 2024 Pune and Ahilyanagar districts, with a higher disease incidence of 11.50% observed in ICAR-DOGR site of Khed block followed by the village of Gunjalwadi (10.50%) and Wadgaon Sahani (10.30 %) in Junnar block of Pune district. The lowest FDR incidence (2.80%) was observed in the Markal village in Pune district (Fig.3.10)

Fig. 3.10 Map showing the garlic *Fusarium* dry rot incidence in Maharashtra

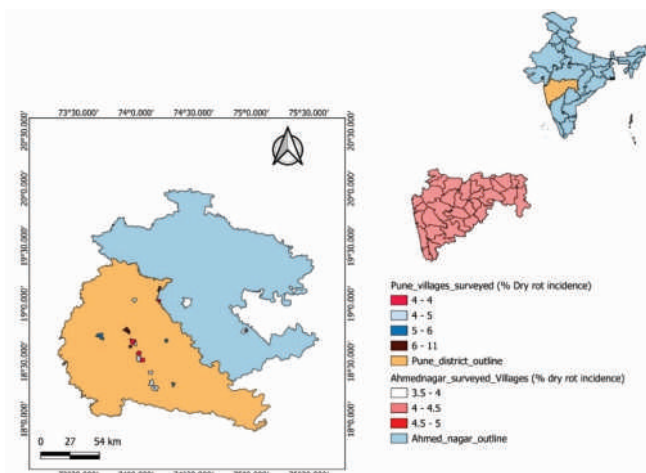


Fig. 3.11 Garlic exhibiting dry rot symptoms (A), Brittle bulb (B) Browning of outer scale and rotting of basal plate and roots (C and D) Brown spots on scales (E) Softening of the bulb (F) Soft, dry and brittle roots with pinkish discoloration (G)

3.3.3 Isolation, morphological and molecular characterization *Fusarium* dry rot pathogens

The infected clove samples from different locations were collected and processed for isolation of fungal strains. The affected garlic plants showed chlorosis and dried leaf tips, brittle bulbs, browning of the outer scale, and rotting of basal plate and roots. Brown spots on scales and softening of the bulb were observed and subjected to isolation and morphological identification of pathogens. The radial growth of all the isolates varied from 59 to 77 mm mycelial growth at 7 days of incubation. We found a significant presence of *Fusarium* spp. in most of the sampled localities and four representative *Fusarium* strains viz. OGRDFW13, OGRDFW15, OGRDFW16, and OGRDFW18 were selected for further characterization. The sequences were deposited in genbank (PP979574, PP979572, PP979578, and PP979576) and obtained accession numbers from NCBI and cultures were deposited at NAIMCC, ICAR-NBAIM, Mau.



3.3.4 Diversity of major fungal pathogens isolated, identified and characterized from onion and garlic

Table 3.4 Fungal and bacterial cultures submission

| Gen bank accession | NAIMCC accession |
|---|---|
| Deposited 25 fungal cultures at National Agriculturally Important Microbial Culture Collection, ICAR, NBAIM Mau, UP | NAIMCC-F-04555 , NAIMCC-F-04492, NAIMCC-F-04493, NAIMCC-F-04495, NAIMCC-F-04494, NAIMCC-F-04548, NAIMCC-F-04549, NAIMCC-F-04550, NAIMCC-F-04551, NAIMCC-F-04552, NAIMCC-F-04553, NAIMCC-F-04601, NAIMCC-F 04605, NAIMCC-F-04604, NAIMCC-F-04606, NAIMCC-F-04595, NAIMCC-F-04603, NAIMCC-F-04602, NAIMCC-F-04567, NAIMCC-F-04557, NAIMCC-F-04513, NAIMCC-F-04566, NAIMCC-F-04558, NAIMCC-F-04556, NAIMCC-F-04555, NAIMCC-F-04610, NAIMCC-F-04611 |
| Submitted 28 fungal culture sequences to NCBI | <i>F. acutatum</i> OR084795(ITS) OR102876 (tef), <i>F. acutatum</i> OR084796 (ITS) OR102877(tef), <i>F. falciforme</i> OR084797 (ITS) OR102878(tef), <i>F. acutatum</i> OR084798 (ITS) OR102879 (tef), <i>F. acutatum</i> PP332885 (tef), <i>F. acutatum</i> PP332886 (tef), <i>F. falciforme</i> PP332887 (tef), <i>F. falciforme</i> , PP332888 (tef), <i>F. falciforme</i> PP332889 (tef), <i>F. acutatum</i> PP332890 (tef), <i>F. acutatum</i> PP979570 (tef), <i>F. acutatum</i> PP979571 (tef), <i>F. solani</i> , PP979572 (tef), <i>F. solani</i> PP979573 (tef), <i>F. incarnatum</i> PP979574 (tef)PQ730143, <i>F. oxysporum</i> PP979578 (tef) <i>F. equiseti</i> , PP979575 (tef)PQ730144 <i>F. equiseti</i> , PP979576 (tef)PQ619462 (rpb2), <i>F. incarnatum</i> PP979577 (tef), <i>F. solani</i> PQ730145 (tef), <i>F. solani</i> PQ730146 (tef), <i>F. falciforme</i> PQ730147 (tef), <i>F. oxysporum</i> PQ827201 (tef), <i>F. falciforme</i> PQ730148 (tef), <i>F. equiseti</i> PQ827202 (rpb2)PV007874 (tef) <i>F. incarnatum</i> , PV173741 (rpb2) <i>F. equiseti</i> , PV173739 (rpb2) <i>F. incarnatum</i> , PV173740 (rpb2) |
| Submitted 20 Bacterial culture sequences to NCBI | <i>Bacillus altitudinis</i> PQ896880, <i>Paenibacillus lautus</i> PQ896881, <i>Pseudomonas chlororaphis</i> PQ896882, <i>Pseudomonas aeruginosa</i> PQ896883, <i>Arthrobacter glacialis</i> PQ896884, <i>Bacillus subtilis</i> PQ896885, <i>Bacillus pumilus</i> PQ896886, <i>Bacillus subtilis</i> PQ896887, <i>Bacillus stercoris</i> PQ896888, <i>Bacillus altitudinis</i> PQ896889, <i>Bacillus tequilensis</i> PQ896890, <i>Bacillus simplex</i> PQ896891, <i>Peribacillus frigiditolerans</i> PQ896892, <i>Bacillus megaterium</i> PQ896893, <i>Staphylococcus warneri</i> PQ896894, <i>Priestia filamentosa</i> PQ896895, <i>Pantoea allii</i> PQ896896, <i>Priestia megaterium</i> PQ89689, <i>Pseudomonas aeruginosa</i> PQ896898, <i>Pseudomonas fluorescens</i> PQ896899 |

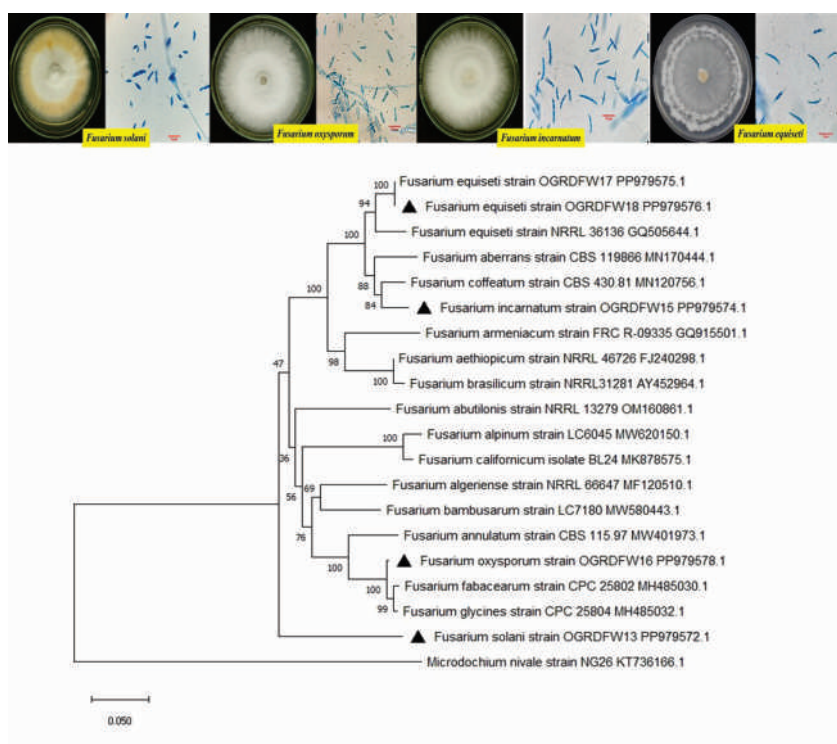


Fig. 3.12 Colony morphology and Phylogenetic analysis

3.3.5 Standardization of challenge inoculation protocol for artificial bulb infection by *Fusarium* and determining magnitude of virulence of basal rot of onion

Challenge inoculation experiments were carried out and pathogenicity and disease progression were assessed up to 15 days post-inoculation by examining the mycelial growth, necrosis of tissues, symptoms development, and assessment of the affected surface area of the bulb, affected volume of the bulb, overall rotting, and disease rating. Five different challenge inoculation methods were standardized, for to induce *Fusarium* basal rot on onion bulb under controlled laboratory conditions and also to determine the magnitude of virulence caused by *F. acutatum* and *F. falciforme*. The five methods used in the current study included 1- Cotton swab impregnated with spore suspension, 2- Pinprick at bulb basal plate and dipping pricked bulb in spore suspension, 3- Combination of pinprick at the basal plate and dipping in spore suspension plus cotton swab, 4- Disk inoculation and 5- Injection of spore suspension. Further, the microscopic examination of root tissue (histopathological) was also performed from the disc inoculation method for induced roots to assess the extent of tissue invasion. Based on our findings, the 'cotton swab method' was found best for creating the artificial infection on the onion bulbs indicated by early mycelial growth, necrosis and rotting of tissues, affected surface area, affected volume, and disease rating by both *F. acutatum* and *F. falciforme* followed by 'Pinprick at the basal plate and dipping in spore suspension method' in comparison to other methods. The affected surface area, the affected volume, rotting over control and disease rating in Cotton swab method was 48 cm², 31 cm³, 56%, 7 for *F. acutatum* and 80 cm², 67 cm³, 92%, 9 for *F. falciforme*, respectively. We have shown for the first time that the *F. acutatum* is capable of causing onion basal rot as early as 3 days of exposure while *F. falciforme* infection was initially slow (The first symptoms appeared on 5th day) but the extent of tissue invasion was highly aggressive. The higher average affected surface area (33%), rotting percent (32%) and volume of the affected area (43%) were noted across methods in *Fusarium falciforme* over *Fusarium acutatum*. Among five inoculation methods, two protocols, i.e., 'The cotton swab' method and 'Pinprick at the basal plate, and dipping in spore suspension' were found best, and these standardized protocols are being recommended to be used by the stakeholder for creating artificial FBR infection. Between two *Fusarium* spp., the FBR magnitude was higher from *F. falciforme* indicating aggressiveness than *F. acutatum*. The protocols suggested in this study would be useful for finding sources of resistance and implementing sustainable management strategies for these pathogens.

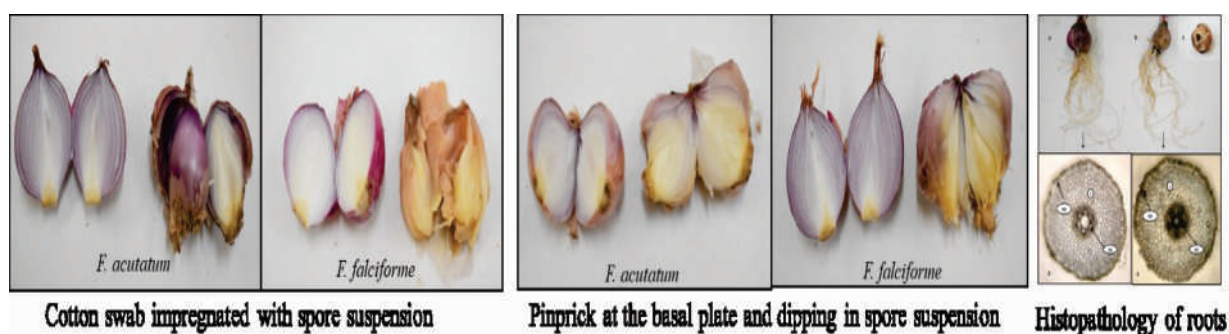


Fig. 3.13 Different methods used in the study

The histopathology of roots induced from the Disc Inoculation Method was studied, as roots induced were more prominent. In this method, we noticed the root induction in the inoculated bulb at 3 DAI. The inoculated bulbs were planted in pots with sterilized soil to observe the germination, and after ten days of seeding the bulbs, it was observed that only *F. acutatum* infected bulbs sprouted after 12 days. While there was no sprouting in the case of bulbs inoculated with *F. falciforme*, rather *F. falciforme* infected bulbs were completely rotten. The above roots from *F. acutatum* inoculated bulbs and control bulbs were subjected to histological studies at 40 DAI, which indicated damages to epidermal, cortex tissues, and xylem tissues of the roots appeared in the form of dark brown colour. However, normal roots from uninoculated bulbs had no damage or browning in the vascular bundles in the xylem and cortical tissues.

3.3.6 Pathogenicity of *Fusarium* species causing dry rot in garlic

The pathogenicity of isolated *Fusarium* species namely *Fusarium solani*, *F. oxysporum*, *F. incarnatum*, *F. equiseti* was confirmed by establishing the infections on garlic cloves using four different inoculation methods

(viz., 1. Pinprick and dipping in spore suspension 2. Wounding and adding spore suspension 3. Wounding and disk inoculation 4. Dipping in spore suspension) as well as by their ability to establish infection in cloves grown in pots under net house conditions and also in laboratory conditions. The *F. solani* have been previously described to cause FDR of garlic in India, however, the *F. oxysporum* have not been reported previously to cause FDR in India. Another two strains *F. incarnatum* and *F. equiseti* are not reported as causative agents of FDR of garlic from any part of the globe and to the best of our knowledge this is the first report of *F. incarnatum* and *F. equiseti* as a causative agent of FDR of garlic.

3.3.7 Pathogenicity *Fusarium* isolates in pots under net house conditions

Clove germination and rooting of garlic were validated for their virulence/ pathogenicity using pot-inoculated cloves with all tested isolates of *F. solani*, *F. oxysporum*, *F. incarnatum*, and *F. equiseti*, under net house conditions. All *Fusarium* spp. reduced clove germination and produced extensive rotting of cloves and white to pinkish mycelium growth on rooted cloves. Among all four species, lowest clove germination (53.33 %) was recorded for *F. oxysporum*, which also recorded maximum disease intensity of 78.67 % after 25 DAS. The *F. equiseti* recorded minimum inhibition of germination (25.33 %) with minimum disease severity of dry rot.

3.3.8 Sensitivity of *Fusarium* spp. to biocontrol agents and fungicides under in vitro conditions

All factors investigated in the study, including fungal strains, fungicides, and biocontrol agents including their interaction, significantly affected fungal growth ($P < 0.01$). The *Fusarium* spp. screened in the study behaved differently for their sensitivity to fungicides and biocontrol agents. The efficacy in decreasing fungal growth was very good, with around 100% inhibition impact detected on Tebuconazole, Carbendazim, Copper oxychloride, and Thiophanate methyl as compared to bio-control agents. All the *Fusarium* spp. showed a mycelial growth inhibition between 74.88 and 31.47 for bacterial bioagents, 60.80 and 53.17% for Trichoderma spp. 100.00 and 68.41 % for fungicides.

BCAs demonstrated varying capabilities to reduce *F. solani*, *F. oxysporum*, *F. incarnatum*, and *F. equiseti* growth. The higher efficacy was recorded with *T. harzianum* and *T. longibrachiatum*, followed by *T. capillare* and *T. asperellum*. However, *B. subtilis* and *P. fluorescens* had the lowest inhibition of *Fusarium* spp. as compared to Trichoderma and fungicides. Overall, the *Fusarium* spp. are more sensitive to the fungicides Tebuconazole and Carbendazim, followed by the biocontrol agents *T. harzianum* and *T. longibrachiatum*.

3.4 Exploring the molecular, biochemical and microbial processes associated with onion spoilage for devising eco-friendly solutions to post-harvest losses

Understanding the microbial dynamics in healthy and rotten onion bulbs is crucial for improving post-harvest quality, disease management, and storage stability. Onions are highly susceptible to post-harvest spoilage caused by complex microbial interactions rather than single pathogens. By employing 16S rRNA (V3-V4 region) and ITS amplicon sequencing, we deciphered both bacterial and fungal communities associated with healthy bulbs (HB), mildly rotten bulbs (MRB), and severely rotten bulb (SRB), allowing the identification of key taxa involved in either bulb spoilage. Such information can help differentiate between beneficial endophytes that suppress pathogens and opportunistic microbes that invade during storage. Moreover, understanding the core microbiome and bulb tissue specific microbiome and its alterations under disease stress can guide the development of microbiome-based bio-interventions and predictive indicators for early spoilage detection. Therefore, a microbiome-based approach was employed to decipher the dynamics of microbial communities associated with bulb spoilage during storage.

3.4.1 Bacterial communities of healthy bulb (HB), mildly rotten bulb (MRB), and severely rotten bulb (SRB)

Healthy bulb tissue harboured the amplicon sequence variants (ASV's) representing four bacterial phyla namely Proteobacteria, Firmicutes, Bacteroidota, Planctomycetota. The higher abundance of Proteobacteria was observed in neck tissue and outer scales of onion bulb whereas Firmicutes were abundant in central tissue of healthy bulb. The ASV's representing bacterial genera *Acinetobacter*, *Carnimonas*, *Carnobacterium*,

Enterobacter, *Luteimonas*, *Muricauda*, *Planctomycetales*, *Prevotella*, *Pseudomonas*, *Staphylococcus*, and *Stappia* were primarily observed in healthy onion bulbs (Fig.3.14). The phylum Proteobacteria was the most abundant phyla in all the three bulb tissues viz. neck, outer scale, and central tissue of the mildly rotten bulb (MRB) followed by the Firmicutes and Bacteroidota. Two bacterial phyla Desulfobacterota and Actinobacteriota were only observed in central bulb tissue of MRB. Phylum Campilobacterota was present in central and neck tissue but not in outer scale tissue. The microbial communities of SRB were dominated by Proteobacteria and Firmicutes in all the tissue including neck region, central bulb and outer scales. The ASV's of Proteobacteria were higher in neck region whereas the ASV's of Firmicutes were higher in central tissues with nearly similar ASV's recorded in outer scale for Proteobacteria and Firmicutes.

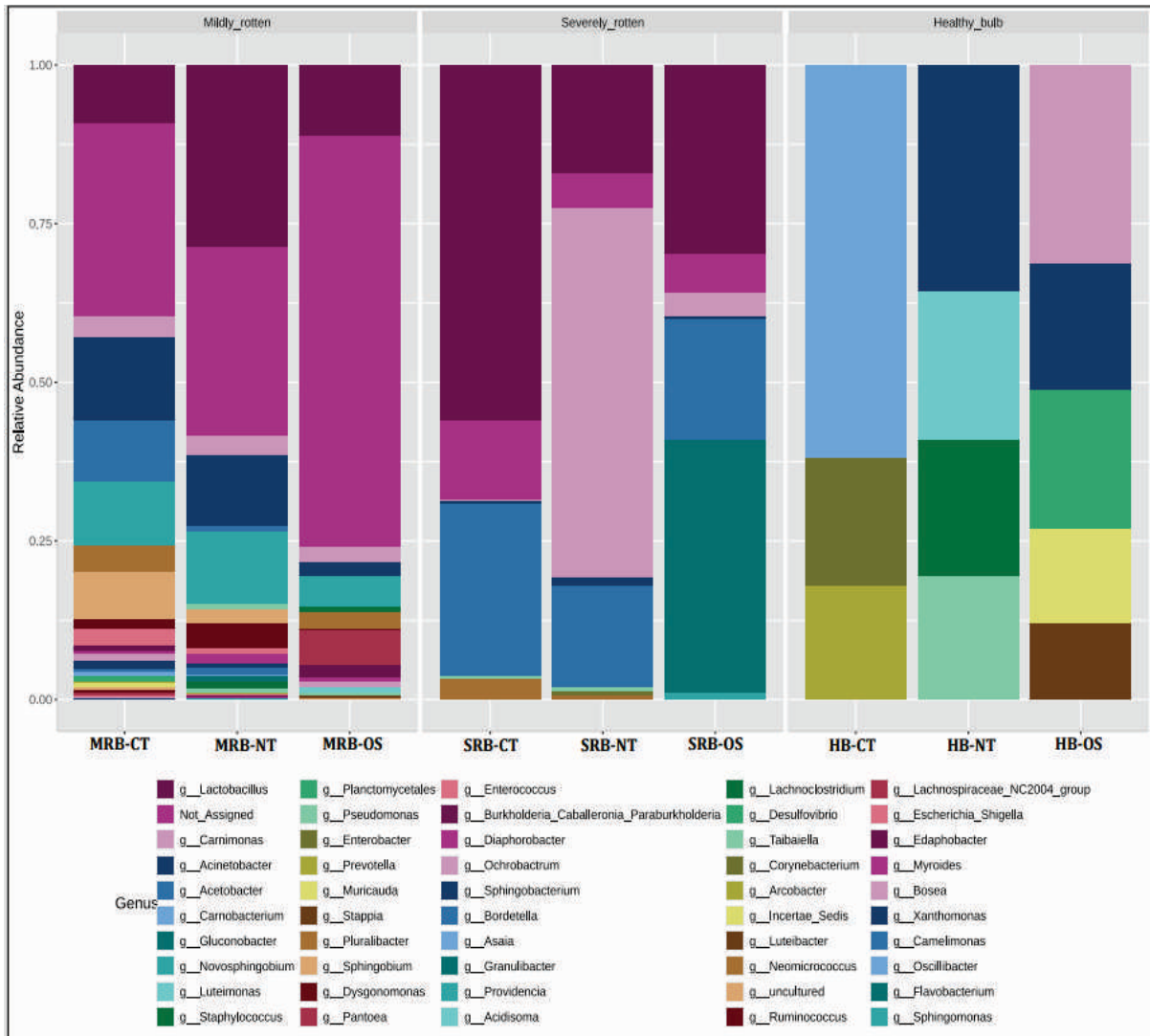


Fig. 3.14 Bacterial community composition of heathy bulb (HB), mildly rotten bulbs (MRB) and severely rotten bulbs (SRB)

3.4.2 Fungal communities of heathy bulb (HB), mildly rotten bulb (MRB), and severely rotten bulb (SRB)

The ASV's of fungal genera Ascomycota were the most abundant in all three bulb tissues viz. neck region, centre tissue and the outer scales followed by Basidiomycota. The abundance of amplicon sequence variants (ASVs) affiliated with the phylum Ascomycota in the neck region of the bulb was approximately 40-fold and 7-fold higher compared to the central tissue and outer scales, respectively. The fungal genera *Aspergillus* was most abundant in neck and outer scales whereas yeast genus *Candida* was abundant in central tissue of the healthy bulb. The relative abundance of *Aspergillus* decreased in neck (22.6%) of MRB along with the increase in genus

Meyerozyma (35.1%) suggesting the major role of *Meyerozyma* in initial bulb rotting. With the gradual rotting of the onion bulb, the genus *Aspergillus* which was a dominant in healthy bulbs reduced in number and the genus *Meyerozyma* dominated the neck region followed by *Aspergillus*, *Blastobotrys*, and *Penicillium* (Fig.3.15). The similar trend of increase in number of *Meyerozyma* with concurrent decrease *Aspergillus* was observed for central tissue of the bulb. However, the decrease in *Aspergillus* was not noted for outer scales of mildly rotten bulb.

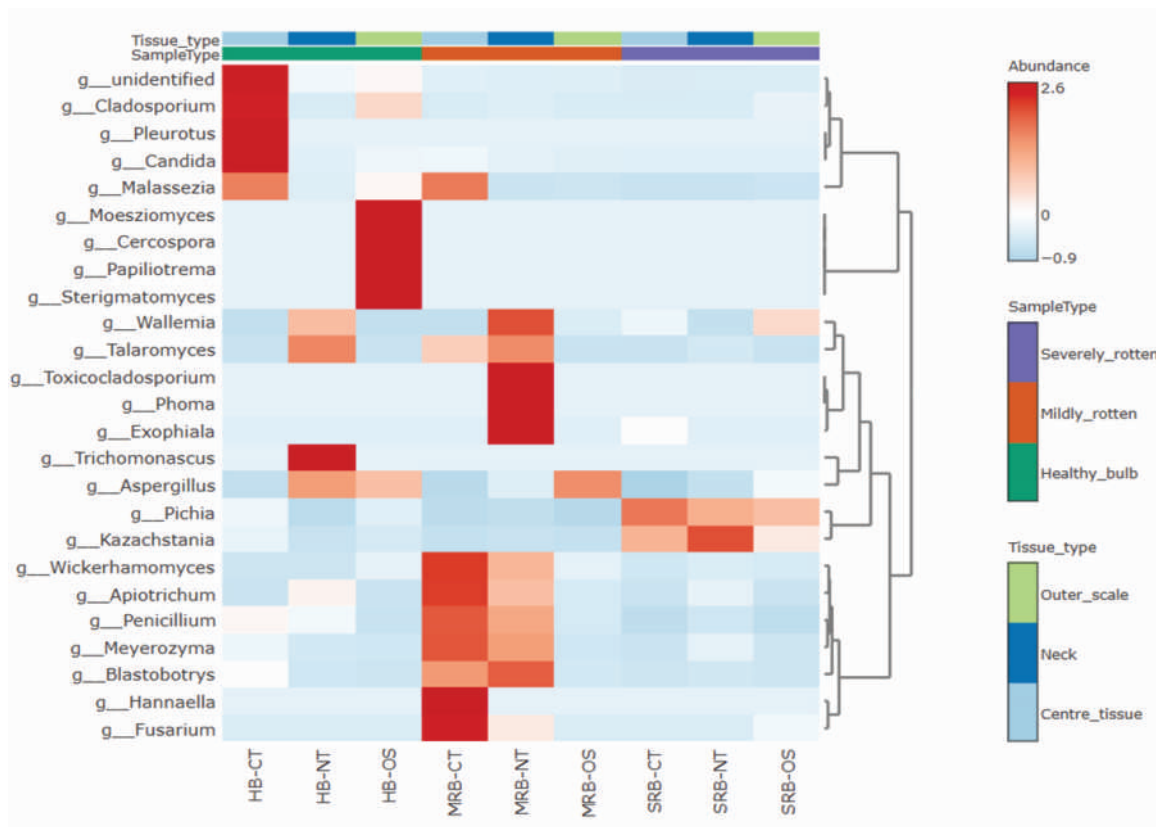


Fig.3.15 Fungal community composition associated with Healthy and Rotten bulbs

3.5. Bio-intensive IPM strategies for insect pests of onion and garlic

3.5.1 Assessment of predatory potential of coccinellids species *Cheilomenes sexmaculata* Fabricius

The six-spotted zigzag coccinellid beetle, *Cheilomenes sexmaculata* (Coccinellidae: Coleoptera), has been identified as a significant predator within the onion and garlic ecosystem, particularly during the *rabi* season. The predator population typically emerges in mid-December, with peak activity observed in January. This beetle is an important natural enemy of both thrips and aphids. The predatory potential of the indigenous coccinellid species

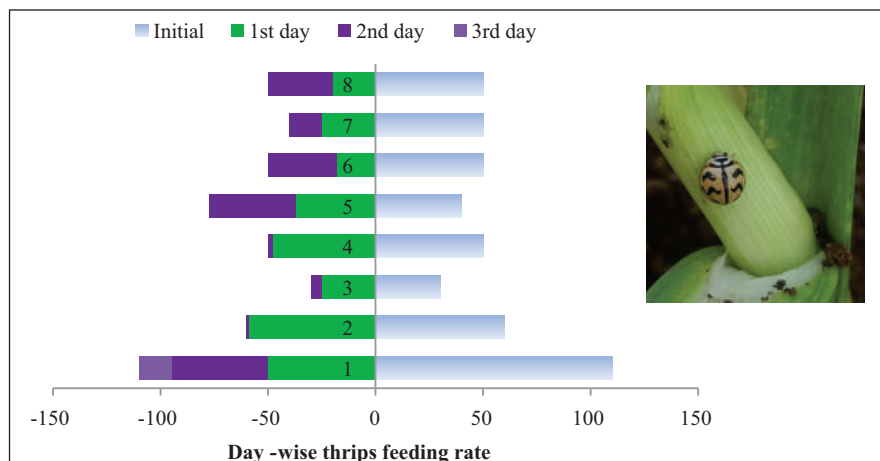


Fig.3.16 Day-wise feeding rate of *C. sexmaculata* on *Thrips tabaci* following release under controlled conditions

C. sexmaculata against onion thrips (*Thrips tabaci* Lindeman) was evaluated under both laboratory and semi-field conditions. In laboratory trials, a known number of field-collected thrips (both nymphs and adults) were offered to adult coccinellids, and the feeding rate of *C. sexmaculata* was recorded at 24-hour intervals. The feeding potential of *C. sexmaculata* ranged from 18 to 50 thrips per day.

Further, under caged (semi-field) conditions, 20 adult *C. sexmaculata* were released into a 45-day-old onion bulb crop. The average number of thrips per plant was recorded before and after the release, using 20 randomly selected onion plants. Results revealed a significant 71% reduction in the thrips population one week after the predator release under caged conditions.

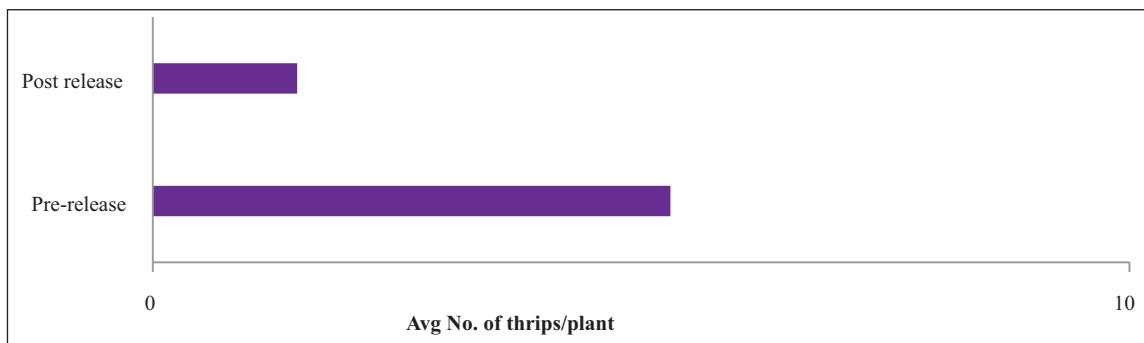


Fig. 3.17 Effect of *C. sexmaculata* release on *T. tabaci* population in onion under caged conditions

3.5.2. Habitat management for enhancing onion thrips predators

An experiment on habitat management aimed at enhancing natural enemies and predators in the onion ecosystem was conducted by intercropping cowpea and coriander with onion in a 6:1 ratio. Pest and natural enemy populations were recorded at regular intervals. The results indicated that intercropping significantly enhanced the activity of the predatory coccinellid *C. sexmaculata* and led to a reduction of approximately 35.3% in the thrips population compared to the sole onion plot.

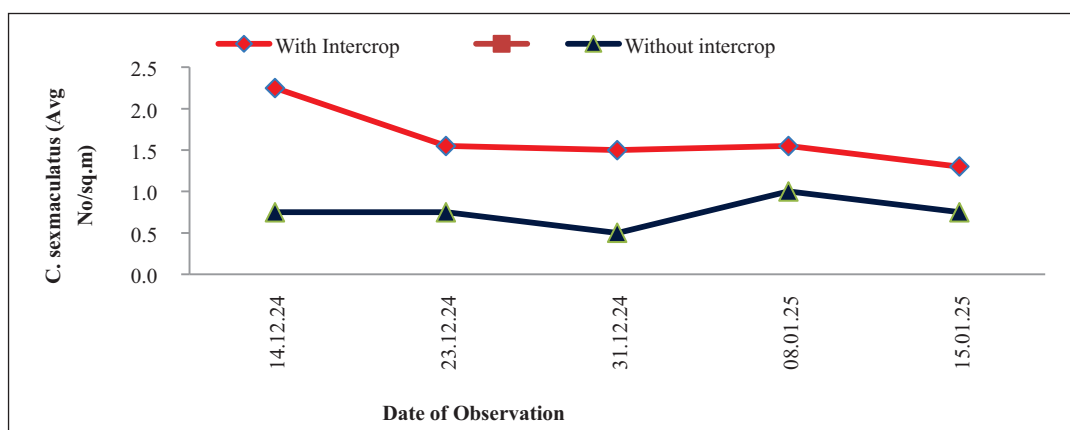


Fig. 3.18 Population of *C. sexmaculata* in onion plots intercropped with cowpea and coriander

Onion intercropped with cowpea and coriander recorded fewer than 10 thrips per plant, whereas the plot without intercrops recorded an average of more than 15 thrips per plant.

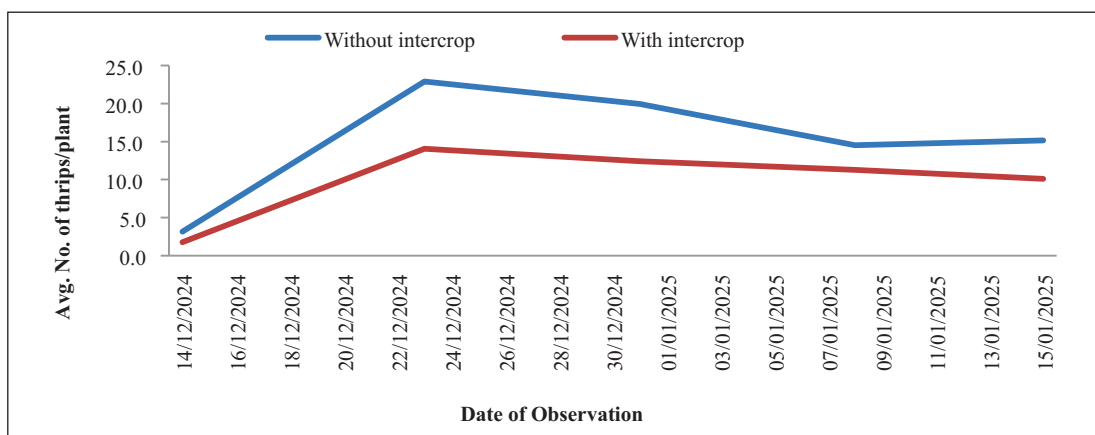


Fig. 3.19 *T. tabaci* population in onion plots intercropped with cowpea and coriander compared to sole onion plots

3.6. Post-harvest management of storage insect pests and diseases in onion and garlic

3.6.1 Isolation and Characterization of the pathogenic fungal isolates from stored onions

The fungal infested bulbs were collected from the naturally ventilated onion storage structure from stored *rabi* harvest. The fungus were isolated on the potato dextrose agar (PDA) and sub-cultured for purification. Morphological characterization identified five isolates as *Aspergillus niger* (SF1, SF3, SF4, SF5, SF6) and one isolate as *Aspergillus ostianus* (SF9). To confirm the identity of these fungal pathogens at the molecular level, genomic DNA was extracted, and PCR amplification was performed using fungal ITS (Internal Transcribed Spacer) primers ITS1 and ITS4. The amplicons were sequenced and analyzed using BLAST against the NCBI database. Sequence analysis confirmed the identity of *A. niger* isolates, while the *A. ostianus* isolate showed distinct phylogenetic placement within the *Aspergillus* genus.

This study provides essential insights into fungal pathogens affecting stored onions and underscores the need for targeted management strategies to mitigate post-harvest losses.

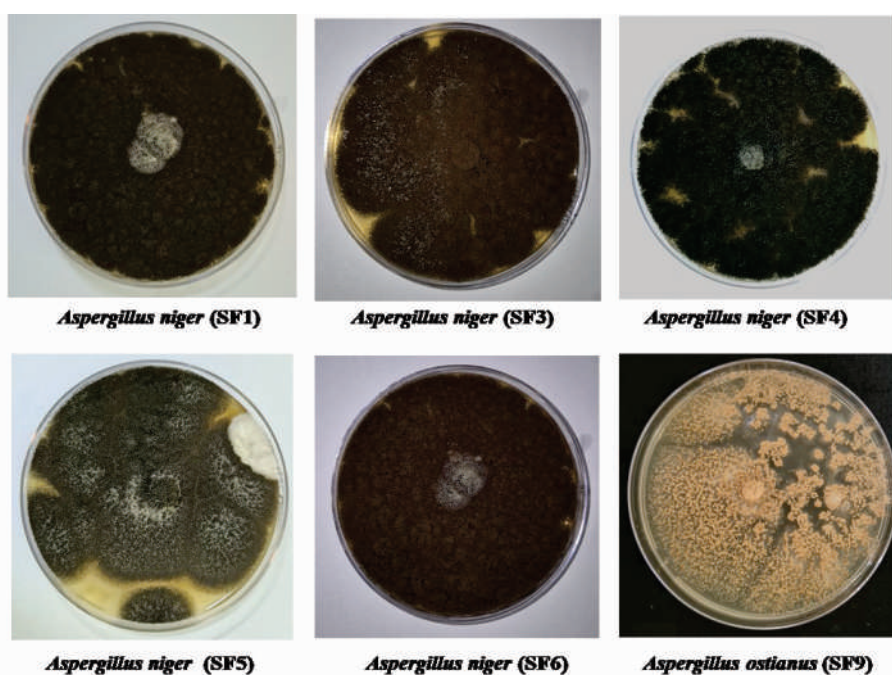


Fig. 3.20 Pathogenic fungal isolates from stored onions

3.6.2 Post-harvest management of storage insect pests and diseases in onion and garlic

An experiment was conducted to evaluate the effect of botanical treatments on storage losses caused by pests and pathogens in onions. The study included nine treatments with four replications, each containing 15 kg of onion bulbs from the *Rabi* 2023-24 harvest, stored in leno mesh bags. For treatment, 30 g of dried leaf powder from Neem, Karanj (Pongamia), Custard Apple, Eucalyptus, *Vitex negundo*, Lemon Grass, Moringa, and Sulphur (chemical control) were applied as a dusting agent. A control set was maintained without any treatment.

Observations on weight loss and rotting were recorded at 30-day intervals over a storage period of 150 days. After five months, the untreated control exhibited the highest storage losses at 50.6%. However, significant reductions in storage losses were observed in onions treated with Neem, Custard Apple, Karanj, Moringa, *Vitex negundo*, and Eucalyptus. Among them, Neem-treated bulbs showed the lowest storage losses (38.39%), followed by Custard Apple (39.29%). On average, storage losses across all treatments were recorded at 44.2%, with weight loss accounting for 77.8% of the total losses, while rotting and sprouting contributed 22.2%.

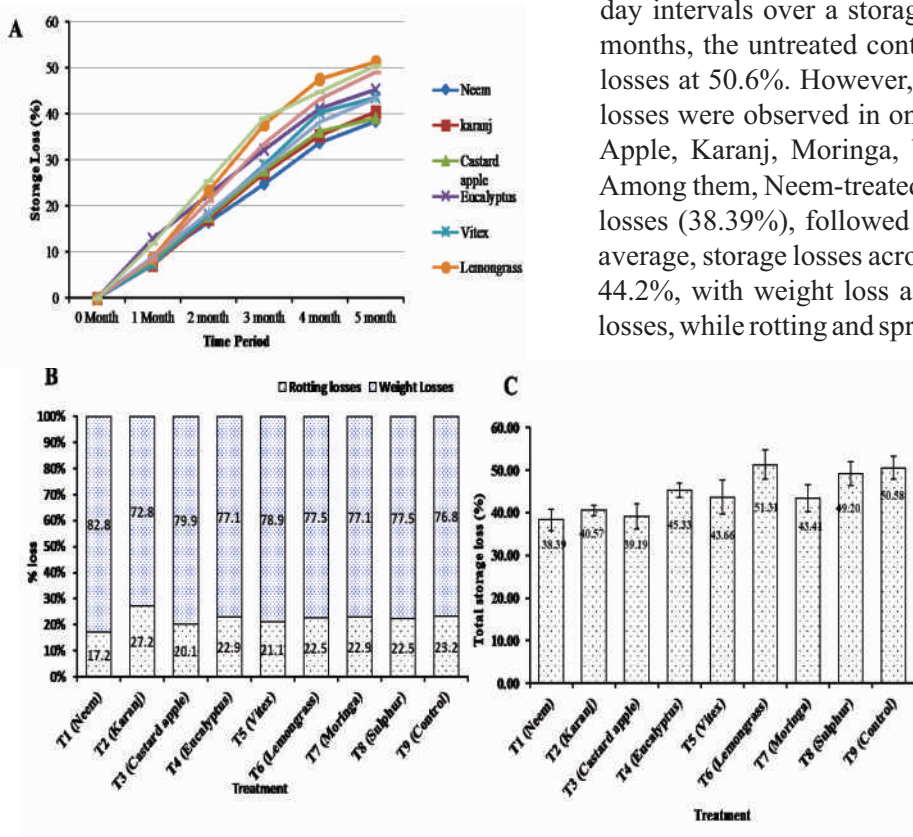


Fig. 3.21 Periodical assessment of post-harvest losses in onions during storage: (A) Periodical assessment of losses; (B) Percent share in total loss and (C) Total storage loss

Externally funded Projects

3.7 Taping the potential of native stingless bee *Tetragonula iridipennis* Smith for pollination enhancement and profitable onion seed production (ANRF, New Delhi)

3.7.1 Survey and sampling of stingless bee's species associated with onion:

Survey and species characterization

A random field survey was conducted in the Pune and Ahilyanagar districts during February and March of 2020-2024, coinciding with the peak onion bloom period. The survey aimed to document stingless bee species associated with onion crops across the districts of Pune, Ahilyanagar, Nashik, Nandurbar, and Satara in Maharashtra. A total of 89 locations were surveyed.

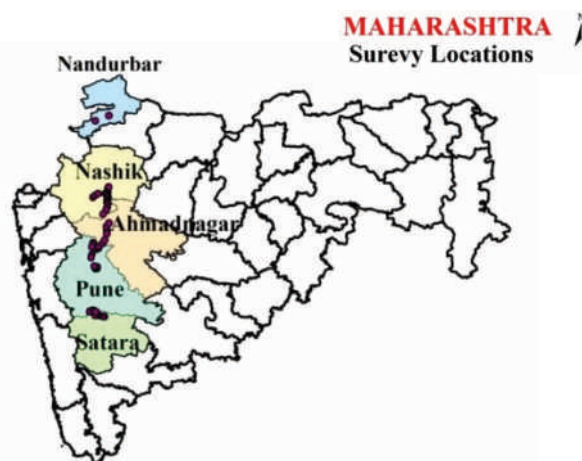


Fig.3.22 Surveyed districts in Maharashtra State

Worker stingless bees visiting onion flowers were recorded (number of bees visiting per unit area per unit time), and species-wise observations were documented. Simultaneously, worker bees were collected and preserved in 70% ethanol for further identification through morphological and molecular methods (DNA barcoding). Species identification was performed using morphometric data, focusing on features such as the head, mouthparts, thorax, wings, abdomen, and legs. Morphometric analysis revealed the presence of *Tetragonula iridipennis* and *Tetragonula travancorica* in the onion ecosystem. DNA barcoding was conducted by isolating total genomic DNA from the legs of individual worker bees using a DNeasy Blood and Tissue Kit (QIAGEN, Germany). The quality and quantity of the extracted DNA were confirmed via 1% agarose gel electrophoresis and spectrophotometric measurements at 260 and 280 nm using a SmartSpec 3000 UV/Visible Spectrophotometer. The primer pair LCO (5'-GTCAACAAATCATAAAGATATTGGGG-3') and HCO (5'-AAACTTCAGGGTGACCAAAAAATCA-3') was used to amplify a 680 bp fragment of the mitochondrial cytochrome c oxidase subunit I (COI) gene, and the resulting amplicons were sequenced. Out of the 89 surveyed locations, stingless bee activity was documented in 27 locations. DNA barcoding confirmed the presence of *Tetragonula iridipennis*, *Tetragonula travancorica*, and members of the genera *Trigona*, *Oxytrigona*, *Scaura*, and *Melipona*. These species were more prevalent in Pune and Ahilyanagar, while activity in Nashik, Satara, and Nandurbar was recorded at fewer locations. Furthermore, the complete mitochondrial genome of *T. iridipennis* was characterized using next-generation sequencing (NGS) to investigate its evolutionary relationship with other stingless bee species and to support comparative studies.

3.7.2 Study of foraging behaviour and pollination potential of stingless bee in onion

Hives of the stingless bee *Tetragonula iridipennis* were obtained from a private beekeeper and relocated to an onion seed production plot (open-field) when flowering reached approximately 25% bloom. Foraging behavior parameters including foraging time, number of visits per unit time, working behavior (top-worker or side-worker), and purpose of visit (pollen or nectar) were studied over three consecutive days, from 9:00 AM to 6:00 PM, at 30-minute intervals. Temperature and relative humidity (RH) during foraging were also recorded. The number of stingless bees foraging on onion flowers per unit area and time was determined. It was found that the peak foraging time occurred between 10:30 AM and 2:30 PM. The majority of bees (72%) exhibited top-working behavior, primarily for pollen collection, while 28% displayed side-working behavior.

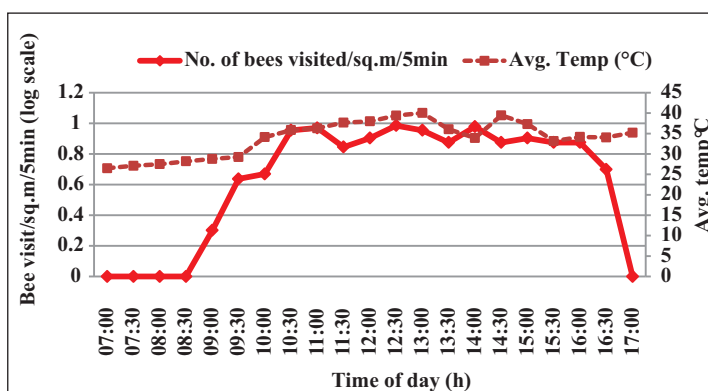


Fig. 3.23 Diurnal foraging activity of stingless bee in onion

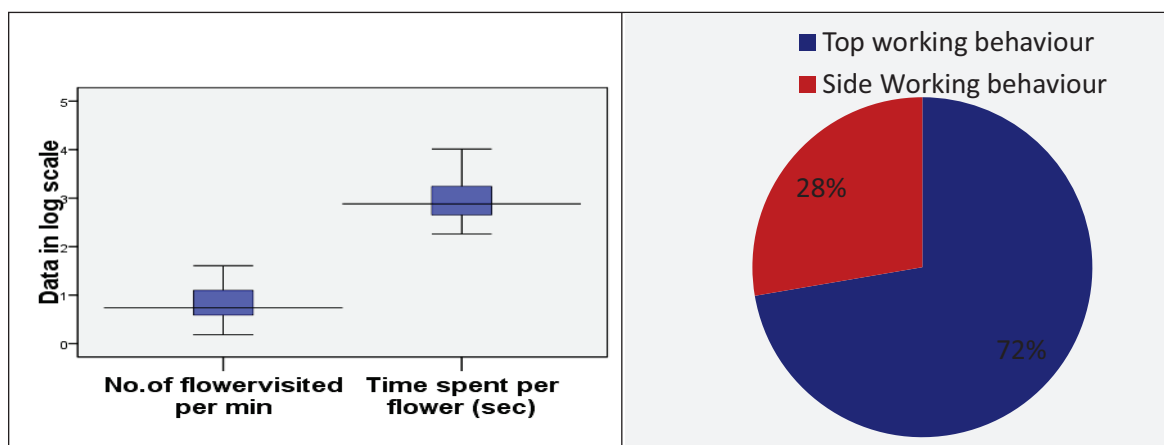


Fig. 3.24 Flower visitation rate and time spent per flower of workers

3.7.3. Standardize the *T. iridipennis* hive requirement for enhancing pollination in onion

The hive requirement of *Tetragonula iridipennis* for a unit area (hives/acre) was studied by relocating stingless bee hives at rates of 8, 6, and 4 hives per acre. Observations on onion bud set and pollination deficit were recorded under stingless bee hive placement regimes and manual cross-pollination regimes. The results revealed a higher number of bud sets in umbels where hives were placed at 8 per acre, followed by 6 hives per acre, and then 4 hives per acre (Fig 8). Pollination deficit analysis across the different regimes showed that the highest deficit occurred in the regime with 4 hives per acre.

$$\text{Co efficient of Pollination deficit (D)} = \frac{1 - (\text{Bud set (umbel) in stingless bee pollination system})}{\text{Bud set in manually cross pollination system}}$$

(0-1): Higher value implies more deficits

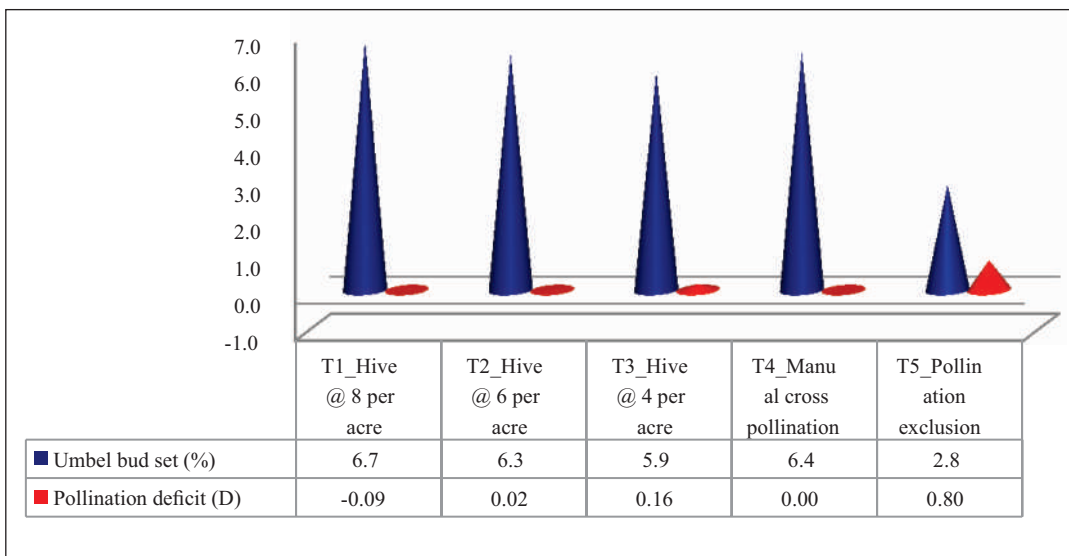


Fig. 3.25 Onion pollination deficits and umbel set under different hive setup

The pollination efficiency index (PEI), estimated based on the total loose pollen grains carried by individual *Apis mellifera* and stingless bee *Tetragonula iridipennis* along with their abundance, revealed significant differences in pollen loads between the two species. The larger-bodied *A. mellifera* carried approximately three times more pollen than the stingless bee *T. iridipennis*. Accordingly, the PEI of the stingless bee was comparatively lower than that of the Italian honey bee, based on the amount of pollen retained on their bodies after foraging.

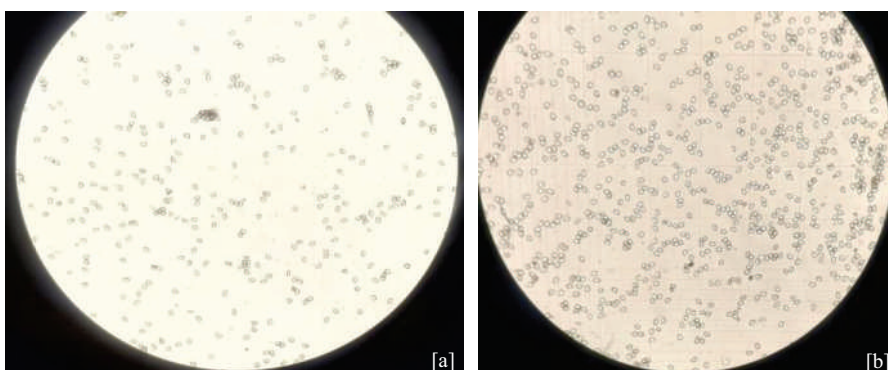


Fig.3.25 The loose pollen gains from the workers of [a] stingless bee body and [b] Italian bee

Table 3.5 Pollination efficiency index (PEI) of *T. iridipennis* and *Apis mellifera* in onion

| Species | Abundance (bees/m ² /5 minutes) | Foraging rate (number of flowers visited/minute) | No. of pollen grain per bee | Pollination index (PEI) (abundance × foraging rate × pollen grains) | Pollination efficiency (Rank) |
|-----------------------|--|--|-----------------------------|---|-------------------------------|
| <i>T. iridipennis</i> | 6.9 | 2.3 | 24800 | 564696 | 2 |
| <i>A. mellifera</i> | 8.7 | 4.9 | 88400 | 3855124 | 1 |

3.7.4 Onion based *T. iridipennis* honey quality analysis

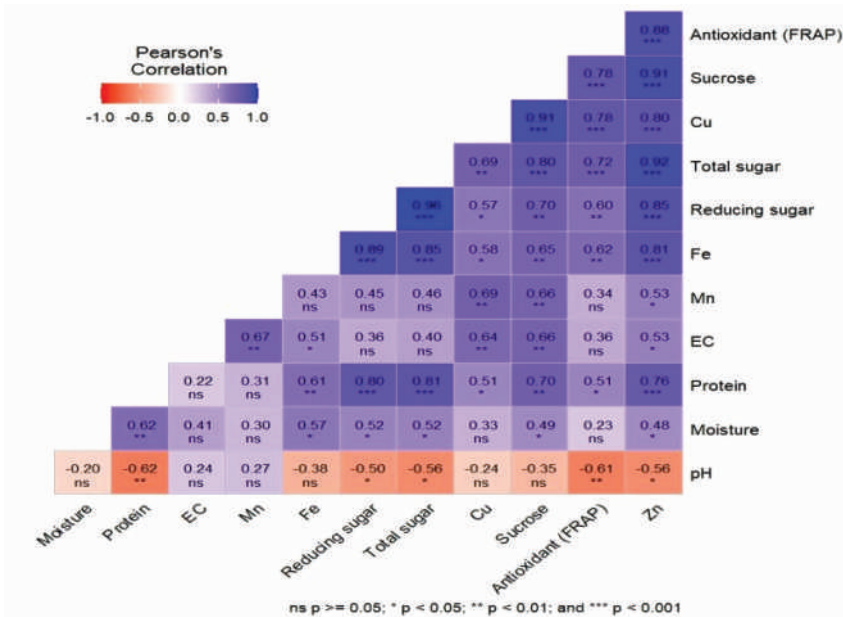
Honey produced in stingless bee hives of *Tetragonula iridipennis* placed in onion seed plots (both caged and open regimes) was collected, extracted, and quantified periodically. The honey samples were then subjected to physiological and biochemical characterization. In each hive, over the two-month period, 15–20 grams of honey were harvested. For the biochemical analyses, honey samples collected from sealed pots of *T. iridipennis* hives placed in the onion seed production plot were carefully preserved in airtight containers and stored in a dark place at room temperature for quality analysis. All samples were analyzed within one month of collection, and none of the samples were kept for more than three months.

This study compares the pH, electrical conductivity (EC), moisture content, total protein, antioxidant activity, sugar content, and mineral composition of four floral honey samples from the stingless bee, *T. iridipennis* and an Italian bee, *A. mellifera*. The pH of *T. iridipennis* honey ranged from 3.36 to 3.46, lower than *A. mellifera* honey (4.48). EC of *T. iridipennis* honey (1.01–1.13 mS/cm) was higher than *A. mellifera* honey (0.58 mS/cm), indicating a greater mineral content. Additionally, *T. iridipennis* honey showed higher moisture content (16.53–19.79%), protein (825–1184.33 µg/g), antioxidant activity (323.05–353.47 mg/100g), and mineral concentrations. This study compares the physicochemical and mineral components of *T. iridipennis* and *A. mellifera* honey. Significant correlations were found between pH and key components, with *T. iridipennis* honey showing superior nutritional and medicinal value due to its higher biochemical and mineral composition.

Table 3.6 Physico-chemical parameters [protein, antioxidant (FRAP), sucrose, reducing sugar and total sugar]

| Parameters | | | Protein (µg/g) | Antioxidant (FRAP) (mg/100g) | Sucrose (%) | Reducing Sugar (%) | Total Sugar (%) |
|-----------------------|--------|-----------|---------------------------|------------------------------|--------------------------|-------------------------|-------------------------|
| <i>T. iridipennis</i> | Hive 1 | Mean ± SD | 1184.3± 64.4 ^a | 323.0 ± 6.8 ^{ab} | 3.73± 0.1 ^{abc} | 78.3± 0.8 ^a | 81.70± 1.4 ^a |
| | Hive 2 | Mean ± SD | 825± 23.0 ^c | 353.4± 29.5 ^a | 3.87± 0.1 ^{ab} | 75.4± 1.2 ^{ab} | 79.20± 1.9 ^a |
| | Hive 3 | Mean ± SD | 1030± 40.7 ^b | 343.2± 10.1 ^a | 4.40± 0.4 ^a | 73.7± 0.9 ^{bc} | 78.40± 1.0 ^a |
| <i>A. mellifera</i> | Hive 4 | Mean ± SD | 709.6± 74.3 ^{cd} | 288.8± 12.4 ^b | 2.17± 0.1 ^c | 70.3± 1.2 ^{cd} | 72.10± 2.4 ^b |
| | Hive 5 | Mean ± SD | 690.3± 1.5 ^d | 287.8± 1.5 ^b | 2.16± 1.0 ^c | 70.1± 1.5 ^d | 73.34± 1.5 ^b |
| | Hive 6 | Mean ± SD | 719.5± 1.5 ^{cd} | 291.3± 1.5 ^b | 2.2± 1.0 ^{bc} | 71.7± 1.5 ^{cd} | 73.6± 1.5 ^b |
| Mean | | | 859.82 | 314.64 | 3.09 | 73.29 | 76.40 |
| CV | | | 22.62 | 9.69 | 35.03 | 4.32 | 5.12 |
| F value | | | 0.64 | 1.55 | 1.94 | 0.13 | 0.28 |
| p. value (p>0.05) | | | 0.72 | 0.37 | 0.02 | 0.15 | 0.54 |
| LSD | | | 79.11 | 27.37 | 1.08 | 2.22 | 3.02 |

The heatmap presents Pearson's correlation coefficients for various parameters of physicochemical and mineral components of *T. iridipennis* and *A. mellifera* honey using a colour gradient. Statistical significance is also represented through p-values. The pH exhibited a significantly negative correlated with Zn (-0.56^{*}), antioxidant (-0.61^{**}), total sugar (-0.56^{*}, ns), reducing sugar (-0.50^{*}, ns), protein (-0.62^{**}). The pH negatively correlated with sucrose (-0.35, ns), Cu (-0.24, ns), Fe (-0.38, ns) and moisture (-0.20, ns). Also, pH positively correlated with EC (0.24, ns) and Mn (0.27, ns). Strong positive correlations were observed between reducing sugar and total sugar



(0.96 ***), sucrose and Zn (0.91 ***), Cu and sucrose (0.91 ***), total sugar and Zn (0.92 ***). Some correlations, such as moisture and antioxidant (0.23, ns), EC and protein (0.22, ns), and Mn and antioxidant (0.34), moisture and Cu (0.33, ns), were found to be weak or statistically insignificant.

Fig.3.27 Pearson correlation heatmap of physic chemical and mineral components of *T. iridipennis* and *A. mellifera* honey

3.8. Deciphering the gut microbiome profile of Apis species in onion to enhance ecosystem services (ANRF, New Delhi)

3.8.1 Screening of the microbial isolates from honeybee guts for the antibiotic susceptibility

The six microbial isolates from the *Apis florea* gut were screened for antibiotic susceptibility against 11 antibiotics: Ampicillin (AMP), Ticarcillin (TI), Tigecycline (TGC), Levofloxacin (LE), Imipenem (IPM), Chloramphenicol (C), Ciprofloxacin (CIP), Meropenem (MRP), Teicoplanin (TEI), Tobramycin (TOB), and Linezolid (LZ). The isolates were cultured on nutrient agar plates, and antibiotic disks were placed on the media. After overnight incubation at 37°C, the zones of inhibition were measured. The results indicated that the gut isolates exhibited tolerance to Tigecycline, Levofloxacin, and Chloramphenicol, suggesting their potential application in bee disease management without adverse effects on bee health.

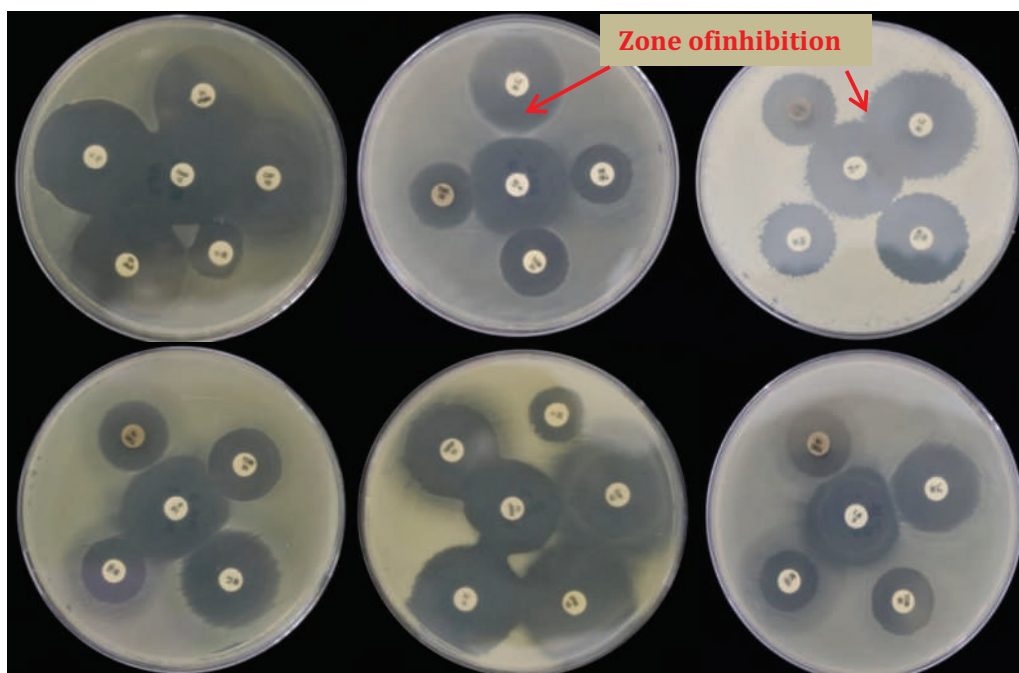


Fig.3.28 Growth Response of Gut Microbes to Antibiotic Susceptibility

Table 3.7 Antibiotic susceptibility of isolates from *A. florea* gut

| Antibiotic | Concentration (µg) | Sensitive | Intermediate | Resistance | AF1 | AF2 | AF3 | AF4 | AF5 | AF6 |
|---------------------|--------------------|-----------|--------------|------------|--------------|--------------|-----------|--------------|-----------|-----------|
| Ampicillin (AMP) | 10 | 17 | 14-16 | 13 | 25 mm | 26 mm | 28 mm | 30 mm | 32 mm | 30 mm |
| | | | | | Sensitive | Sensitive | Sensitive | Sensitive | Sensitive | Sensitive |
| Ticarcillin (TI) | 75 | 20 | 15-19 | 14 | 29 mm | 33 mm | 35 mm | 31 mm | 32 mm | 30 mm |
| | | | | | Sensitive | Sensitive | Sensitive | Sensitive | Sensitive | Sensitive |
| Tigecycline (TGC) | 15 | 18 | - | 18 | 18 mm | 18 mm | 20 mm | 18 mm | 21 mm | 21 mm |
| | | | | | Resistance | Resistance | Sensitive | Resistance | Sensitive | Sensitive |
| Levofloxacin (LE) | 5 | 21 | 17-20 | 16 | 20 mm | 29 mm | 28 mm | 18 mm | 26 mm | 27 mm |
| | | | | | Intermediate | Sensitive | Sensitive | Intermediate | Sensitive | Sensitive |
| Imipenem (IPM) | 10 | 23 | 20-22 | 19 | 30 mm | 30 mm | 32 mm | 32 mm | 36 mm | 40 mm |
| | | | | | Sensitive | Sensitive | Sensitive | Sensitive | Sensitive | Sensitive |
| Chloramphenicol (C) | 30 | 18 | 13-17 | 12 | 15 mm | 14 mm | 18 mm | 15 mm | 30 mm | 27 mm |
| | | | | | Intermediate | Intermediate | Sensitive | Intermediate | Sensitive | Sensitive |
| Ciprofloxacin (CIP) | 10 | 26 | 22-25 | 21 | 35 mm | 35 mm | 34 mm | 36 mm | 32 mm | 34 mm |
| | | | | | Sensitive | Sensitive | Sensitive | Sensitive | Sensitive | Sensitive |
| Meropenem (MRP) | 19 | 23 | 20-22 | 19 | 26 mm | 27 mm | 28 mm | 29 mm | 34 mm | 34 mm |
| | | | | | Sensitive | Sensitive | Sensitive | Sensitive | Sensitive | Sensitive |
| Teicoplanin (TEI) | 30 | 14 | 11-13 | 10 | 14 mm | 16 mm | 18 mm | 16 mm | 20 mm | 21 mm |
| | | | | | Sensitive | Sensitive | Sensitive | Sensitive | Sensitive | Sensitive |
| Tobramycin (TOB) | 10 | 15 | 13-14 | 12 | 17 mm | 20 mm | 19 mm | 18 mm | 25 mm | 20 mm |
| | | | | | Sensitive | Sensitive | Sensitive | Sensitive | Sensitive | Sensitive |
| Linezolid (LZ) | 30 | 20 | - | 20 | 25 mm | 26 mm | 26 mm | 23 mm | 30 mm | 32 mm |
| | | | | | Sensitive | Sensitive | Sensitive | Sensitive | Sensitive | Sensitive |

3.8.2 Screening of the microbial isolates from honeybee guts for the fungicide and insecticide resistance

Six microbial isolates from the *Apis florea* gut were screened for their tolerance to the pesticides Carbendazim and Imidacloprid. Nutrient agar was supplemented with Carbendazim 50% at concentrations of 0, 0.0451, 0.451, and 4.51 ppm, and Imidacloprid 17.8% at 0, 5, 10, and 20 ppb. The microbial isolates were inoculated using the streak plate method and incubated overnight at 37°C. Growth was then monitored. Three isolates exhibited tolerance to both pesticides across all tested concentrations. However, two isolates showed moderate tolerance (faint colony growth) to susceptibility (no growth) at higher concentrations of Carbendazim (0.451 and 4.51 ppm) and Imidacloprid (20 ppb).

Table 3.8 Pesticide susceptibility of the isolates from *A. florea* gut

| Isolates | Carbendazim (ppm) | | | | Imidacloprid (ppb) | | | |
|----------|-------------------|----------|---------------------|---------------------|--------------------|----------|----------|---------------------|
| | 0 | 0.0451 | 0.451 | 4.51 | 0 | 5 | 10 | 20 |
| AF-1 | Tolerant | Tolerant | Moderately tolerant | Susceptible | Tolerant | Tolerant | Tolerant | Moderately tolerant |
| AF-2 | Tolerant | Tolerant | Moderately tolerant | Susceptible | Tolerant | Tolerant | Tolerant | Moderately tolerant |
| AF-3 | Tolerant | Tolerant | Tolerant | Moderately tolerant | Tolerant | Tolerant | Tolerant | Tolerant |
| AF-4 | Tolerant | Tolerant | Tolerant | Tolerant | Tolerant | Tolerant | Tolerant | Tolerant |
| AF-5 | Tolerant | Tolerant | Tolerant | Tolerant | Tolerant | Tolerant | Tolerant | Tolerant |
| AF-6 | Tolerant | Tolerant | Tolerant | Tolerant | Tolerant | Tolerant | Tolerant | Tolerant |

3.9. O-Scan (Onion-Scan): Image-based, Intellectual Diagnosis System for pest, disease and abiotic stress management in Onion Crop

The need to adapt the agricultural sector to the demands and requirements of the population has caused the second green revolution or agriculture 4.0. Onion (*Allium cepa* L.) is an important commercial crop grown all over the world and consumed in various forms. Onion crop can be attacked by multiple diseases and insect pests at different crop growth stages, causing considerable damage/loss in yield. Apart from reduction in onion crop yield, the disease and insect pests also pose harmful effects during harvesting, post harvesting, processing and marketing stages, which lowers the quality and export potential of the crops causing significant economic loss. Accurate detection of diseases and pests in onion crop production is essential to devise efficient strategy for their management which in turn helps in increasing agricultural production in a sustainable way. Currently, the diagnosis of disease and pests is supported by visual inspection of crops by a subject expert, in person or of images, sent by farmers on some electronic device. Such a manual methodology is time-consuming and may not be accessible for an individual farmer. Hence, there is a need for an automated, simplified, cost-effective method for farmers. We propose development of an Artificial Intelligence – machine learning (AI/ML)-based platform specific to onion crop for detection of diseases from images. An image-based mobile application will be developed for the farmers where farmers can click and share the photos of the diseased onion crop. Specially developed image-based AI/ML algorithms will classify the disease and share the scientific advisories.

A smartphone based mobile application that can automatically collect images, send the collected samples to cloud for AI/ML analysis for diagnosis of disease and send back the respective advisories to farmers. In the O-Scan project, our goal is to develop a real-time artificial intelligence-based model using image processing and deep learning methods that can diagnose the onion diseases, and other abiotic stresses, chemical phytotoxicities from real-field images clicked through the mobile application for farmers. Further, the platform will send alert and precautionary measures and scientific advisories on disease.

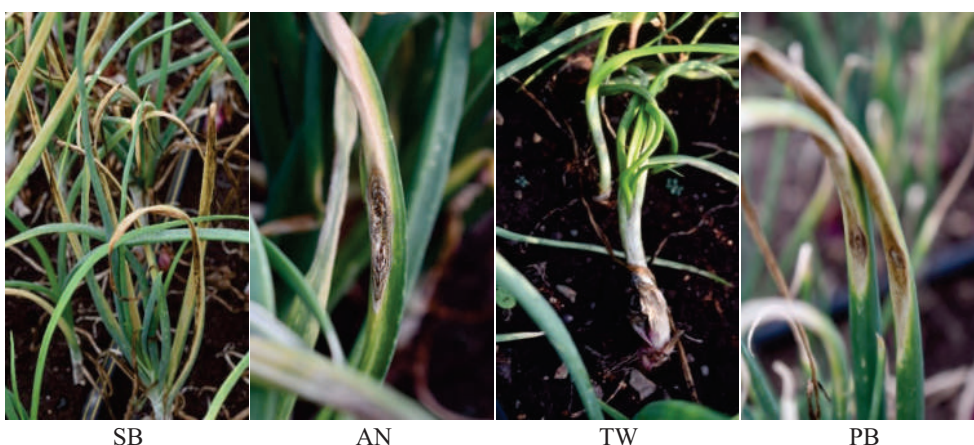


Fig.3.29 Images of various diseased plants

3.9.1 Use of YOLOv8 for real-time disease detection

The detection and identification results for the YOLOv8 approach are validated by prominent statistical metrics like detection precision, recall, mAP value, and F1-score, which resulted in 77.1%, 73.0%, 74%, and 0.76 respectively. Experimental results demonstrate that YOLOv8 for onion disease detection in naturally collected field images helps in classification and understanding the disease severity, thus encouraging us to consider YOLOv8 as a baseline model. This work lays the theoretical groundwork for the application of deep learning to agricultural data by examining a unique method for the quick and precise identification of crop diseases.

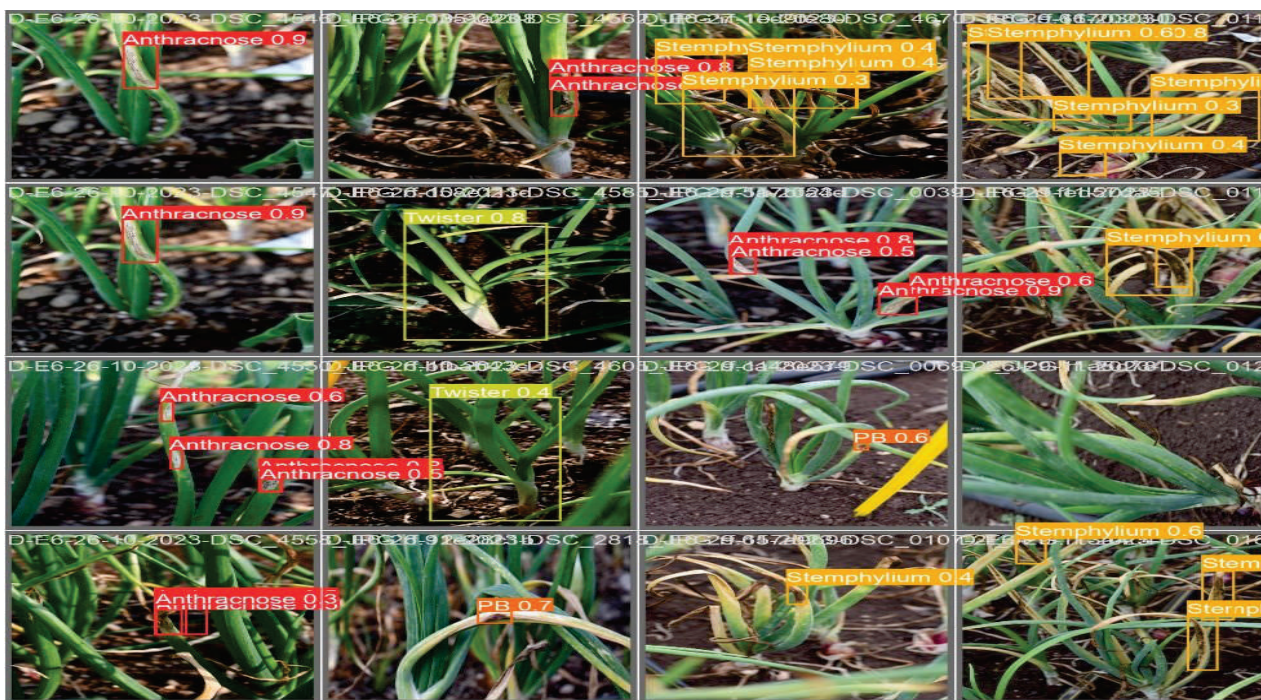


Fig. 3.30 Image database

Practical applications for farmers

During 2024-25, created image database comprised of 5000 images of Stemphylium blight, Iris yellow spot virus, Basal rot, purple blotch, Anthracnose, Twister, Thrips, Bulb rot by capturing images of various stages during crop growth cycle. Model upgrade planned with the collection of 5,000 additional images during the 2025 Kharif and Late Kharif seasons. This platform promises to empower farmers with a real-time, automated, and accessible tool for managing onion crop health efficiently, reducing losses, and improving productivity.

3.9.2 I-DiagnOCe: IoT-based, Intelligent, Detection and Prediction Platform for Diseases and thrips attack in Onion Crops based on real-time Captured data (weather and soil parameters)

India has significantly ramped up onion production in the last half century. The production increase in India can largely be explained by an increase in the area under onion cultivation. The requirement of onion is almost constant throughout the year. Fortunately, onions can be grown in three seasons as Kharif, late Kharif, Rabi. However, kharif/rainy season onion crop is highly vulnerable to fungal disease, such as anthracnose and Stemphylium blight and thrip attack due to conducive weather such as high humidity and continuous rainfall. The fungal diseases and thrips attack have serious and devastating effects of reduction of both seed and bulb quality and quantity. On an average 30% yield decrease is observed due anthracnose twister attack and pests like thrips. Early detection of the disease and control of the spread of disease at early stage can help us in reducing the yield loss of onion. The productivity in rainy season onion crop can be improved by monitoring real-time local climate changes, knowing and understanding abiotic and biotic stress impact on rainy season onion performance. The proposal focuses on developing a mechanism to record and correlate various farm parameters in Realtime (such

as rainfall, ambient temperature, relative humidity, solar radiation, soil moisture, leaf wetness) and finding artificial intelligence/machine learning-based prediction model for early detection of weather-based diseases anthracnose-twister and Stemphylium blight. The predictions related to diseases on-set and scientific advisories for mitigation will be communicated to the farmers through widely adopted platform such as SMS and mobile application in cost-effective, eco-friendly manner. Whenever onion cultivation is undertaken in rainy season, the anthracnose-twister disease complex is widespread across the field due to waterlogging. Besides anthracnose, Stemphylium blight and thrips are major threats for rabi onion crop throughout India. Early prediction of these diseases can effectively control the disease spread. The pre-outbreak mitigation techniques for controlling diseases and pests can be useful not only for reducing the usage of pesticides and associated cost, but also results in increased yield and better quality. Thereby, measuring real-time soil, weather parameters (such as soil moisture, rainfall, temperature, relative humidity, solar radiations) and leaf wetness and establishing their correlations for favourable disease conditions can be used for developing artificial intelligence – machine learning (AI/ML-based) models. Such models are valuable tools for supporting decision-making on whether and when crop management actions are really needed. Though the seasonal factors influencing anthracnose, Stemphylium blight and thrips are identified but modelling based on real-time data for forewarning for these biotic stresses have not been developed.

3.9.2.1 Weather-based thrips model

The Weather-Based Thrips Model leverages Random Forest (RF) regression to predict Thrips population on onion crops using various weather parameters as features. This predictive approach is crucial because climate variability significantly impacts pest outbreaks, and proactive management, enabled by early warnings, is more effective than traditional reactive methods. The model incorporates a comprehensive set of weather data, including Max, Min, and Average Temperature, Humidity, Rainfall accumulation, and Dew Point, utilizing 7-day lagged data across five time periods (Night, Morning, Midday, Evening, Late Night) to capture the complex, delayed influence of weather on the pest.

The performance of the predictive model is quantified by several Model Evaluation Metrics. The Mean Absolute Error (MAE) of 8.065 indicates that, on average, the predicted Thrips population deviates from the actual population by about 8 units (Thrips). The Root Mean Squared Error (RMSE) is 11.79, a value higher than the MAE because the squaring operation within the RMSE formula gives greater weight to larger prediction errors. A crucial metric is the R^2 Score of 0.752 (75.2%), which means that 75.2% of the variability in the Thrips population can be successfully explained by the weather features used in the model. The analysis of the weather parameters revealed significant non-linear effects on the Thrips population. Humidity is a critical factor, as both Relative Humidity (RH) at 8:45 AM and 2:45 PM show complex non-linear relationships, with sharp increases in Thrips populations at higher humidity levels. Similarly, Maximum and Minimum temperatures exhibit non-linear effects, confirming that Thrips thrive within an optimal temperature range. Specifically, the highest populations are observed around 29-31°C (Maximum) and 21°C (Minimum), with populations decreasing in extreme cold or heat. Conversely, increasing rainfall appears to be detrimental to Thrips, causing their populations to decrease, suggesting that wet conditions inhibit their activity or survival.

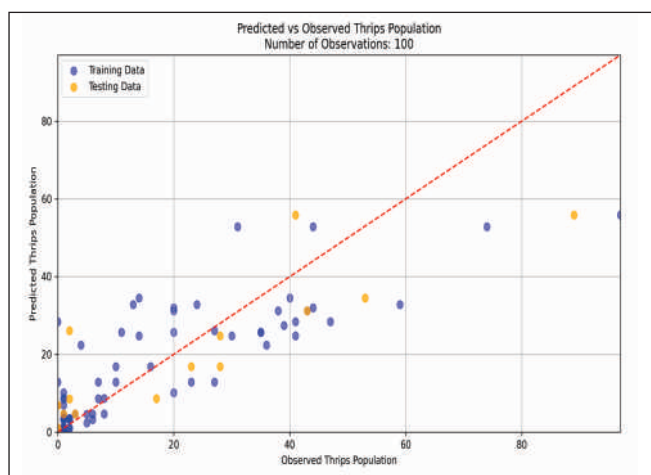


Fig. 3.31 Predicted vs Observed thrips population

3.9.2.2 Disease prediction model overview

The Disease Prediction Model utilizes a hybrid approach: first, a Random Forest (RF) classification model identifies important weather features, and then a Cox Proportional Hazards (CPH) model is applied to determine the significant weather parameters and their seasonal thresholds impacting disease onset.

The model showed good accuracy for the Rabi Season, achieving 0.737 when focusing on *Stemphylium* blight and purple blotch. The key environmental factors driving these diseases were identified as Average Relative Humidity (RH), with critical thresholds observed at 52.81%, 62.01%, and 66.04% and Maximum Temperature (Max Temp), with thresholds at 30.57°C, 32.30°C and 34.06°C. For the Kharif and Late Kharif Season, which targets Anthracnose and Twister diseases, the model performed even better, achieving a higher Accuracy of 0.81. The important parameters in this season include the Average RH (with the same thresholds as *Rabi*), Average Temperature (Avg Temp), which shares the same thresholds as the Rabi Max Temp, and Total Rainfall (Rain). The identification of specific threshold values for these parameters is invaluable for creating timely and targeted early warning systems.

A Weibull Accelerated Failure Time (AFT) Model was specifically employed to predict the time to disease occurrence (or survival time) for the Kharif and Late Kharif diseases, yielding a high statistical significance (p -value < 0.005) and good concordance (0.80).

The Key Findings from the Weibull AFT model highlight the dominant role of specific weather variables in accelerating disease onset: Average Temperature (Avg_Temp_7d) was the most significant accelerator (p -value < 0.005) with a negative coefficient (Coef = -0.20), indicating that higher average temperatures over the week are strongly associated with a significantly faster time until the disease appears. Average Relative Humidity (Avg_RH_7d) was also found to be statistically significant (p -value < 0.005), though its effect size was smaller (Coef = -0.01), suggesting that higher humidity slightly shortens the time to disease onset. Finally, the Trial_name variable was highly significant (Coef = -0.19), strongly suggesting that inherent, non-weather differences between the experimental trials (Date of Transplanting) play a major role in influencing the timing of disease onset.

3.9.2.3 YOLOv8-seg for onion quality classification

YOLOv8-seg for automated onion quality grading

The implementation of YOLOv8-seg (specifically the optimized YOLOv8ghost-seg variant) successfully addresses the challenge of real-time automated quality classification for onion bulbs. The primary objective is to categorize onion bulbs into five distinct quality classes: Acceptable (Healthy), Discard, Double, Rot, and Sprout. The model was trained on a substantial dataset of 5,003 augmented images featuring precise instance segmentation annotations using polygon masks, which enables accurate boundary detection alongside classification.

Model architecture and performance

The chosen architecture—YOLOv8ghost-seg—incorporates an optimized C2f backbone and a PAN-FPN neck for effective multi-scale feature fusion, ensuring robustness in detecting various-sized defects. The overall performance is highly promising, with the model achieving an impressive mean Average Precision (mAP@0.50) of 91.0% across all five classes, confirming its reliability for post-harvest grading.

Analysis of the individual class precision reveals the model's strengths and moderate challenges:

- Exceptional Precision was achieved for identifying Double onions (98.5%) and Rot defects (93.8%), suggesting these visual characteristics are highly distinct and well-segmented by the model.
- High Precision was also noted for Acceptable (Healthy) bulbs (94.0%), making the core sorting task reliable.
- Moderate Precision was observed for Sprout (89.0%) and, notably, the lowest but still moderate precision was for Discard (79.7%). This indicates that while the model is robust, classifying the general 'Discard' category—which may encompass various minor defects not covered by 'Rot' or 'Sprout'—presents the greatest challenge.

Real-time application and key insight

For practical application, the YOLOv8sghost-seg (lightweight) variant is deployed to ensure low-latency inference on edge devices, facilitating integration into existing packing house workflows. The Precision-Recall (PR) analysis confirms consistent detection across all classes, maintaining the average mAP@0.50 of 91.0%. The strong PR curves for Double (0.985) and Acceptable (0.940) further emphasize the model's core grading capability. This robust instance segmentation capability ensures that the automated system can reliably grade and perform defect removal, leading to improved quality monitoring during storage and efficient real-time sorting on conveyor belts.

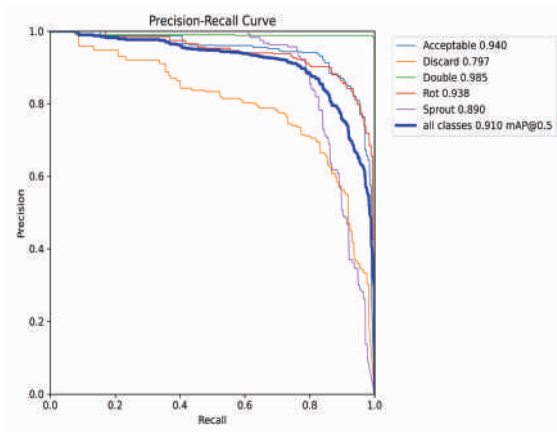


Fig. 3.32 Precision – Recall analysis

3.9.3 Multi-modal image data analysis for aerial phenotyping

The Aerial Phenotyping project utilized multimodal UAV imagery (RGB and multispectral) across a two-year period (2023–2025) to develop predictive models for onion diseases and yield under various biotic (Anthracnose, Stemphylium Blight, Thrips) and abiotic (water) stresses. The experimental design featured staggered planting across 14 dates and a Randomized Block Design (RBD) with five treatments, conducted across five field trials to capture temporal and treatment variations. UAV imagery was captured at three critical crop stages (Vegetative, Bulb Initiation, Bulb Development) and processed into Ortho mosaics and various Vegetation Indices (NDVI, NDRE, SAVI, etc.), alongside manual collection of morphological traits (Plant Height, Leaf Width) and Disease Metrics (Percent Disease Index or PDI, Thrips count).

Analysis of smoothed reflectance curves across five spectral bands (Blue, Green, Red, Red Edge, NIR) was used to distinguish treatment responses. Key observations confirmed expected physiological responses: a dip in the Red Band (due to chlorophyll absorption) and a sharp rise in Red Edge and NIR for healthy, vigorous treatments.

3.9.3.1 Spectral Indices (Captured via Multispectral Imagery)

- _ NDVI (Normalized Difference Vegetation Index): Indicates plant Vigor and biomass
- _ NDRE (Red Edge NDVI): Sensitive to chlorophyll content and early stress
- _ SAVI (Soil Adjusted Vegetation Index): Reduces soil brightness influence
- _ LAI (Leaf Area Index): Estimates canopy density
- _ NORM2 & SR (Simple Ratio), GNDVI: Indicate greenness and growth stage

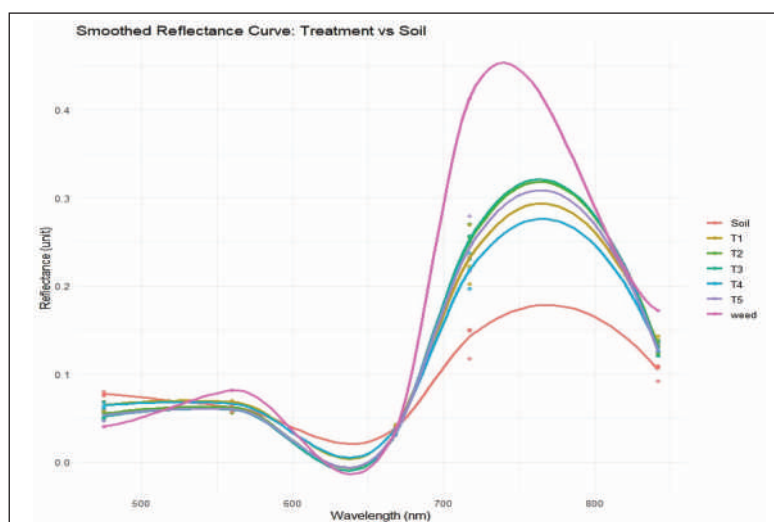


Fig. 3.34 Spectral indices captured via multispectral imagery

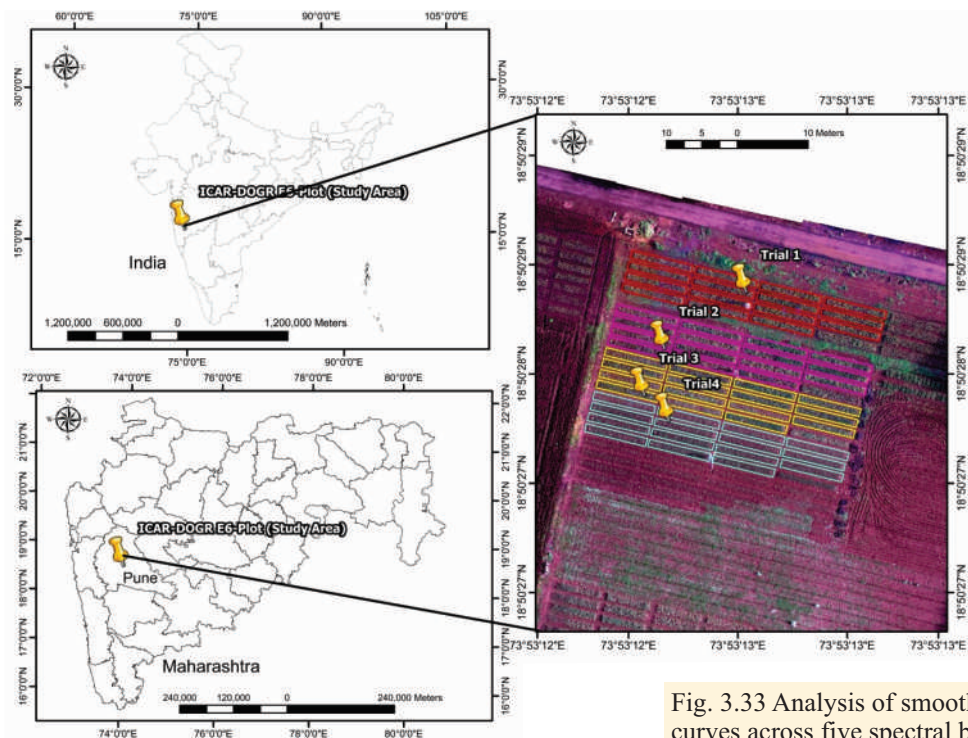


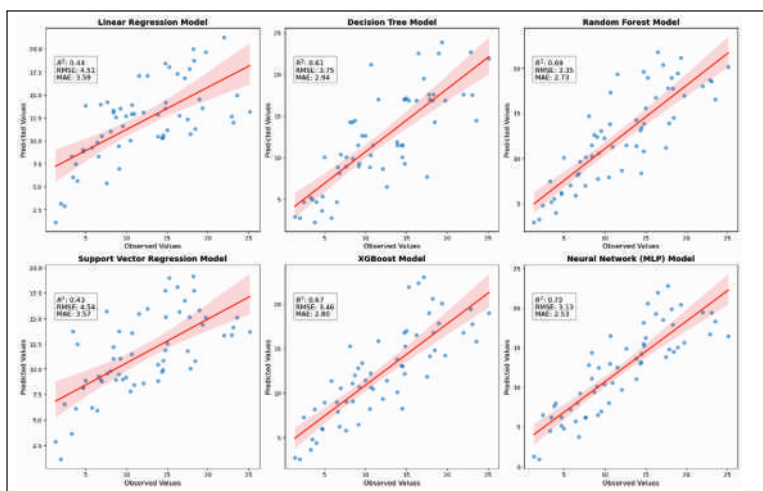
Fig. 3.33 Analysis of smoothed reflectance curves across five spectral bands

3.9.3.2 Yield prediction using machine learning

Avoiding Fixed Train-Test Splits, instead of using a fixed train-test split, employ 6-Fold Cross-Validation (K=6). Ensures all data contributes to both training and validation. (Breiman (2001): "Random Forests"; explains why cross-validation improves model reliability.) Merging Trials is Scientifically Valid, Reduces overfitting risks from small datasets. Aligns with best practices in multi-season and multi-trial yield prediction. Use proper validation via K-Fold Cross-Validation.

The table provides key evaluation metrics based on cross-validation results (mean ± standard deviation) across different models.

R^2 (R-squared): Measures how well the model explains the variance in the target variable (Higher values (closer to 1) indicate better performance.), RMSE (Root Mean Squared Error): Measures the error magnitude in the same unit as the target variable (Lower values indicate better performance.) and MAE (Mean Absolute Error): Measures the average absolute difference between predictions and actual values (Lower values indicate better performance).



We evaluate the model multiple times on different subsets of data (e.g., 6-fold). Each fold gives a slightly different result due to data variability. Standard deviation shows model stability: A high standard deviation (e.g., Decision Tree: $R^2 = 0.55 \pm 0.28$) means the model's performance varies a lot across different test sets → less reliable model. A low standard deviation (e.g., Neural Network: $R^2 = 0.72 \pm 0.08$) means the model is more consistent across different test sets → more reliable model

Fig. 3.35 Yield prediction using machine learning

4. Post-Harvest Technology

4.1 Extraction and encapsulation of bioactive compounds in *Allium* species

4.1.1 Optimization of plant stage (*Allium tuberosum*) of harvest for high level of bioactive compounds

Allium tuberosum species was grown from June to August with sample analysis at one week interval. The species were completely cut and then allowed to grown gain. After two weeks growth period, the data collection started and the data was recorded every week to check the changes in bioactive compounds with growth period and optimize the best stage for cutting. Total phenol content and antioxidant content was maximum in 4 week grown plants (6.8 mg GAE/g, 9.36 TEAC μ mol/g respectively). Flavonoid content started decreasing from 4 weeks to six weeks and then increased at seven weeks grown plants ranging from 184.64 to 353.50 mg QE/g. Total chlorophyll content increased up to three weeks and then started decreasing till seven weeks.

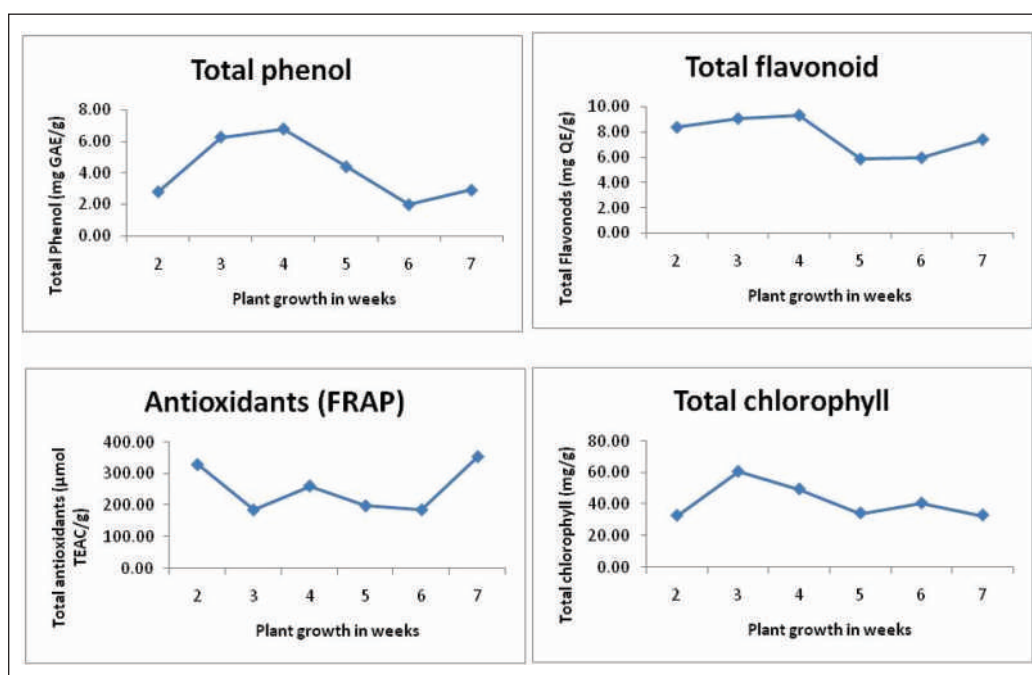


Fig 4.1 Biochemical changes during growth period of *Allium tuberosum*

4.1.2 Storage study of harvested wild *Allium* species

Allium tuberosum leaves were harvested, cleaned and then tied in bunches. The tied bunches were wrapped with or without cling film. The packed bunches were stored at ambient conditions and refrigerated conditions of 12°C and 4°C. The physical and biochemical parameters of the fresh leaves before storage and after storage of 2,3,4,5 days were analysed. *Allium tuberosum* samples were completely spoiled after five days at ambient conditions while they retained their freshness even after five days of storage at 4°C. Maximum weight loss was observed at ambient conditions (23.76%) after four days. Weight loss at 12°C and 4°C was 10.73% and 9.69% respectively after 5 days. Wrapping showed weight loss reductions of 54.95%, 37.56%, and 22.73% at ambient, 12°C and 4°C respectively compared to unwrapped samples.



Fig. 4.2 Fresh and cling film wrapped *Allium tuberosum* samples

4.1.3 Ultrasonic extraction of bioactive compounds from Chinese chives (*Allium tuberosum*)

Study was conducted to know the effect of solvent type, solvent-to-solid ratio and soaking time on the total phenolic content, total flavonoid content, antioxidant activity, and chlorophyll content of Ultrasonic Extraction of *Allium tuberosum*. Freshly cut Chinese chive (*Allium tuberosum*) leaves were obtained from the field, cut into small, roughly equal-sized pieces. They were then spread evenly on the plates of the food dryer and dried at 65°C. Three factor design was used for the experiment. The independent variables were solvent (methanol or ethanol), solvent-to-solid ratio (3% or 6% or 9%), and soaking time (0 minutes or 15 minutes or 30 minutes). Meanwhile, the constant parameters set on Probe Sonicator (Model: VCX500) were time (13 minutes), and power/amplitude (370W/75%). Pulse ON was set to be 10 seconds and pulse OFF was set at 5 seconds. Solvent has no significant difference on phenol content. Solvent to solid ratio and soaking time had significant effect on phenol content. Solvent, solvent-to-solid ratio, and soaking time had significant effect on flavonoid and Antioxidant (FRAP) content.

4.1.4 Microwave-assisted extraction of bioactive compounds from Chinese chives (*Allium tuberosum*)

Study was conducted to know the effect of solvent type, solvent-to-solid ratio and soaking time on the total phenolic content, total flavonoid content, antioxidant activity, and chlorophyll content of microwave-assisted extraction of *Allium tuberosum*. Freshly cut Chinese chive (*Allium tuberosum*) leaves were obtained from the field, cut into small, roughly equal-sized pieces. They were then spread evenly on the plates of the food dryer and dried at 65°C. The independent variables were solvent (methanol or ethanol), solvent-to-solid ratio (3% or 6% or 9%), and soaking time (0 minutes or 15 minutes or 30 minutes). Microwave extraction was done at constant power level of 240 W with regular intervals of 5 minutes. All the three factors solvent, solvent to solid ratio and soaking time and their interaction had significant effect of phenol, flavonoid and antioxidant (FRAP) content. Methanol at 30 minutes soaking time was effective in extraction of bioactive compounds.

5. Extension

5.1 Transfer of improved onion and garlic technologies and impact assessment

5.1.1 Transfer of improved onion and garlic technologies

Extension activities not only help to disseminate the technology but also evaluate its impact on socio-economic aspects of the farmers for further refinement. This project aims at improving knowledge and skill of the farmers, extension workers and all others concerned with onion and garlic production through dissemination of improved technologies developed by the Directorate and conduction of various skill development activities. Total 320 onion crop demonstrations were conducted in Maharashtra state during *kharif* (110), late *kharif* (30) and *rabi* (180) seasons through institute project (30), SCSP (230), and MGMG (60) for the study. For demonstration purpose, about 2 kg onion seed was provided for each demonstration by the Directorate. Farmers arranged the onion seed of local variety to compare the performance with the varieties of the Directorate. Recommendations made by the Directorate were followed in all demonstrations.

Demonstrations in *kharif* season: Onion varieties; Bhima Super and Bhima Dark Red were selected for *kharif* in 2 districts viz., Pune and Ahilyanagar of Maharashtra state. Total 110 *kharif* demonstrations (10 from institute project, 80 from SCSP and 20 from MGMG) were carried out in these districts.

Demonstrations in late *kharif* season: Onion varieties; Bhima Red and Bhima Raj were selected for late *kharif* demonstrations in Pune district of Maharashtra state. Total 30 late *kharif* demonstrations (10 from institute project and 20 from MGMG) were carried out in Pune district.

Demonstrations in *rabi* season: Onion varieties; Bhima Red and Bhima Shweta were selected for *rabi* demonstrations in Pune and Ahilyanagar districts of Maharashtra state. Total 180 *rabi* demonstrations (10 from institute project, 150 from SCSP and 20 from MGMG) were carried out in these districts.

Demonstrations in garlic crop: Garlic variety Bhima Purple was selected for garlic crop demonstration. Total 4 demonstrations were carried out in farmers' fields in Ahilyanagar district. For demonstration purpose, 100 kg garlic seed was provided by the Directorate for each demonstration. Farmers arranged the garlic seed of local variety to compare the performance with the variety of the Directorate. Recommendations made by the Directorate were followed in all demonstrations.

The cultural practices which were common to all onion trials are described below.

Nursery raising: The debris of previous crops, weeds and stones were removed before bed preparation. Raised beds (size: 1.5 m width x 4 m length x 15 cm height) were prepared. Seeds were treated with thiram @ 2 g/kg seed before sowing to avoid damage from damping off disease. At the time of bed preparation, 50 kg of FYM and 10 kg vermicompost were added. Before sowing, the beds were moistened and then sprayed with weedicide pendimethalin @ 2ml/L. Seeds were treated with carbendazim @ 3 g/kg of seeds. The seeds (35 g/bed) were mixed with sand and vermicompost, and sown in line on bed. Distance between two lines was 8 cm and depth of sowing was 1-1.5 cm. Seeds were covered with fine soil followed by light watering.

Land preparation and transplanting: Prior to transplanting, field was ploughed and disked properly to eliminate debris and soil clods. At the time of land preparation, 15 t FYM/ha was added. Seedlings were transplanted on broad bed furrows of 1.2 m width, 15 cm height and 60 m length with drip irrigation. Transplanting of seedlings has been done after 45 days of sowing in *kharif*, after 50 days of sowing in late *kharif* and after 55 days of sowing in *rabi* season. Before transplanting, the bed was wetted by drip irrigation and weedicide pendimethalin (3.5-4 ml/L) was sprayed. After uprooting of seedlings, 1/3rd part of leaves was cut and the roots were washed by clean water and then seedlings were kept for an hour in 10 L water having 15 g carbendazim.

Pest and disease management: Foliar sprays of carbosulfan (2 ml/L) and profenophos (1 ml/L) with hexaconazole (1 g/L) were given 30 and 45 DAT respectively, to control diseases and pests.

Irrigation: Inline dripper of 16 mm lateral with 40 cm distance between two drippers was used and discharge of 4 L/hour was released. Drip irrigation was given for half an hour twice a day on daily basis. Irrigation was stopped before 20 days of harvesting.

Harvesting: It was done at 50-60% neck fall stage.

The cultural practices which were common to all garlic trials are described below.

Field preparation and planting: Field was ploughed using mould board plough and tilled using cultivar 3-4 times to eliminate debris and soil clods. FYM compost 5 t/ha was incorporated at the time of last ploughing. Flat beds of 1.5-2.0 m width and 4-6 m length were formed. Big cloves (1.2-1.5g) were selected for planting. Cloves were dipped in carbendazim solution (0.1%) just before planting. Selected cloves were planted vertically 2 cm below soil surface with plant to plant spacing of 10 cm and row to row spacing of 15 cm. Pendamethalin (3.5-4 ml/L) was sprayed before or at the time of planting.

Pest and disease management: Foliar sprays of carbosulfan (2 ml/L) and profenophos (1 ml/L) with hexaconazole (1 g/L) were given 30 and 45 DAT respectively, to control diseases and pests.

Irrigation: Garlic crop irrigated immediately after planting and subsequently at 7-10 days interval depending upon the soil moisture. Irrigation was stopped when the crop attained maturity (10-15 days before harvest).

Harvesting: It was done after 50% drying of leaves.

Performance of frontline demonstrations

The onion crop demonstrations in *kharif* season revealed that the germination percentage (98), average bulb weight (80g) and yield (25.8 t/ha) of Bhima Super was the highest. Bhima Dark Red (25.2 t/ha) also yielded more than local variety (18.4 t/ha). The germination percentage (96), average bulb weight (85 g) and the yield (47.0 t/ha) of Bhima Raj were the highest in late *kharif* onion crop demonstrations. Bhima Red (45.5 t/ha also yielded more than local variety (25.0 t/ha) in late *kharif* demonstrations. The onion crop demonstrations conducted in *rabi* in Maharashtra revealed that the germination percentage (95), average bulb weight (85 g) and marketable yield (42.5 t/ha) of Bhima Red were the highest and Bhima Shweta (40.0 t/ha) also yielded more than local variety (27.0 t/ha). The garlic crop demonstrations revealed that the germination percentage (94), average bulb weight (16 g) and yield (8 t/ha) of Bhima Purple was the highest. The germination percentage (82), average bulb weight (10 g) and yield (6.5 g) of local garlic variety was lower than of Bhima Purple. The varieties developed by ICAR-DOGR were found superior over the local cultivars in all the demonstrations.

Table 5.1 Performance of frontline demonstration trials

| Crop | Variety | Germination Percentage | Av. Bulb weight (g) | Marketable yield (t/ha) |
|--------------------------|----------------|------------------------|---------------------|-------------------------|
| <i>Kharif</i> Onion | Bhima Super | 98 | 80 | 25.8 |
| | Bhima Dark Red | 95 | 75 | 25.2 |
| | Local | 80 | 60 | 18.4 |
| Late <i>Kharif</i> Onion | Bhima Raj | 96 | 85 | 47.0 |
| | Bhima Red | 90 | 80 | 45.5 |
| | Local | 75 | 72 | 25.0 |
| <i>Rabi</i> Onion | Bhima Red | 95 | 85 | 42.5 |
| | Bhima Shweta | 90 | 82 | 40.0 |
| | Local | 78 | 75 | 27.0 |
| Garlic | Bhima Purple | 94 | 16 | 08.0 |
| | Local | 82 | 10 | 06.5 |

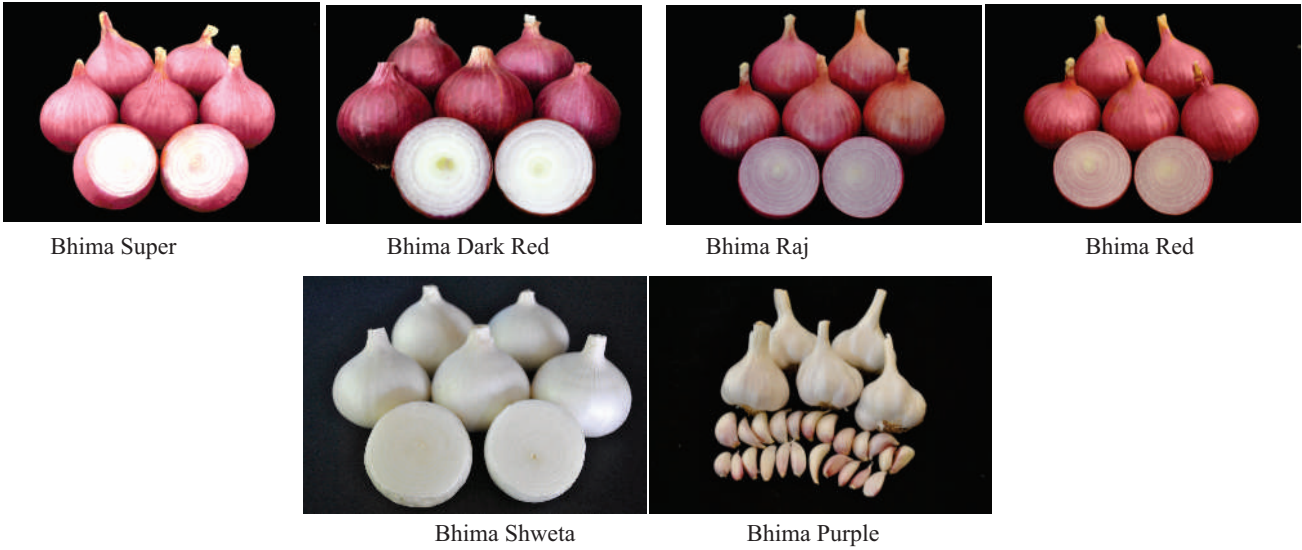


Fig. 5.1 ICAR-DOGR varieties performing better than local varieties in different seasons

Impact Assessment

The impact assessment of ICAR-DOGR varieties and technologies (package of practices, BBF with drip irrigation and modified storage structures) has been carried out in traditional (Western Maharashtra) and non-traditional (Vidarbha) regions of Maharashtra.

Impact analysis of adoption of ICAR-DOGR technologies in traditional area

Western Maharashtra is known as traditional area for onion and garlic cultivation. The data were collected using structured questionnaire from randomly selected 150 farmers of 15 villages namely Vetale, Thorandale, Kurwandi, Nirvi and Chincholi from Pune; Koundhane, Mulewadi, Pimpri Gurav, Panoli and Ralegan from Ahilyanagar; and Bilwadi, Devlane, Sangvi, Kalewadi and Ningavhan from Nashik district.

ICAR-DOGR varieties, package of practices, BBF with micro irrigation and modified storage structures were adopted by 84%, 68%, 58% and 48% farmers, respectively. In onion cultivation, 78% area was covered by ICAR-DOGR varieties. While in garlic, 24.5% area was covered by ICAR-DOGR varieties.

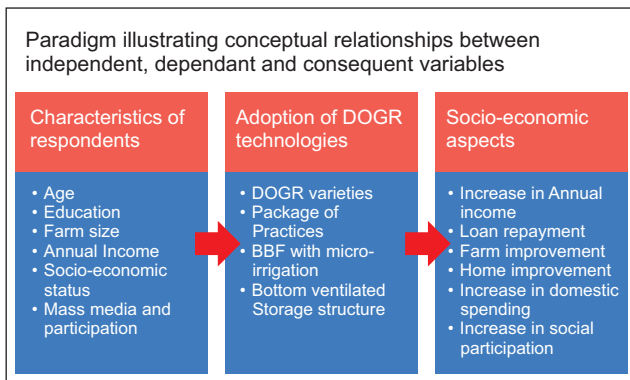


Fig.5.3: Adoption of ICAR-DOGR technologies in Western Maharashtra

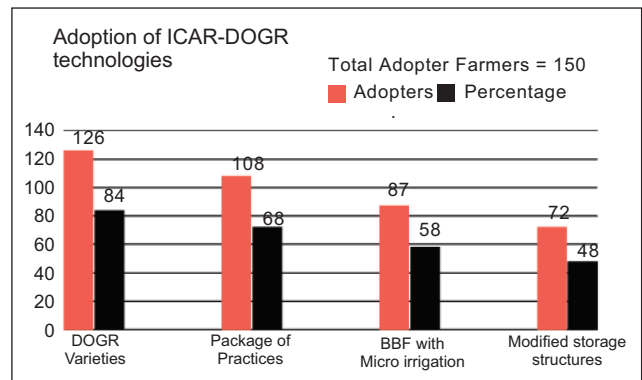


Fig. 5.2: Paradigm illustrating conceptual relationship between independent, dependent and consequent

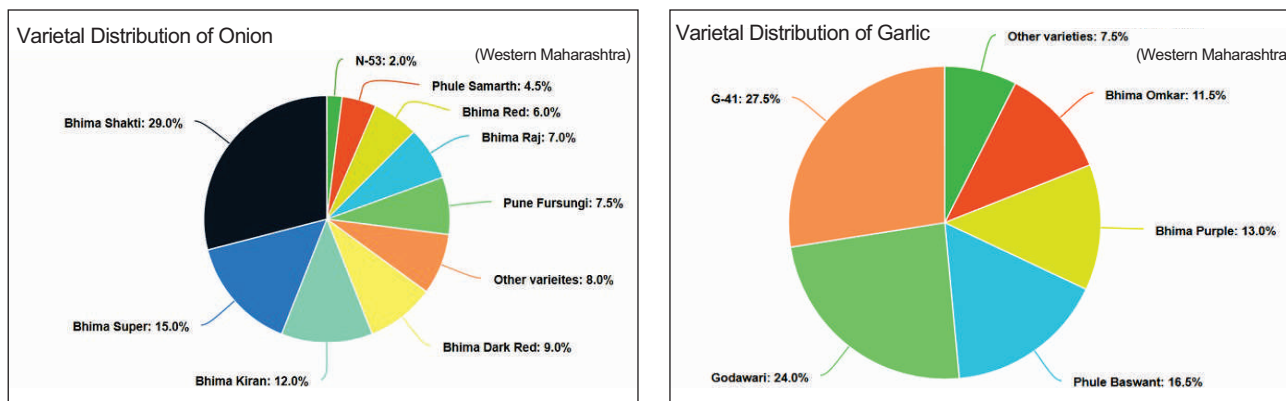


Fig.5.4 Varietal distribution of onion and garlic in Western Maharashtra

Findings indicated a significant association between the level of adoption among the farmers and level of overall change in socio-economic aspects. Among the farmers who adopted medium to high degree of adoption, majority of them reported a positive change in socio-economic aspects. There was significant impact of ICAR-DOGR technologies (varieties, package of practices, BBF with drip irrigation and modified storage structures) on socio-economic aspects (increase in annual income, loan repayment, farm improvement, home improvement, increase in domestic spending and increase in social participation of onion and garlic farmers).

Table 5.2 Relationship between characteristics of respondents and adoption of ICAR-DOGR technologies

| Characteristics of respondents | 'r' values |
|--------------------------------|------------|
| Age | -0.3221* |
| Education | 0.3458* |
| Farm size | 0.3713* |
| Annual Income | 0.4212* |
| Socio economic status | 0.7328* |
| Economic motivation | 0.4274* |
| Extension contract | 0.3322* |
| Social participation | 0.6143* |
| Mass media participation | 0.6732* |

*Significant at 1% level of probability

Table 5.3 Association between adoption level and socio-economic aspects

| Socio-economic aspects | X2 values | Degree of Freedom |
|----------------------------------|-----------|-------------------|
| Increase in Annual Income | 12.24* | 4 |
| Loan repayment | 23.56* | 6 |
| Farm Improvement | 18.12* | 6 |
| Home Improvement | 13.00** | 6 |
| Increase in Domestic spending | 14.67* | 4 |
| Increase in Social participation | 22.12* | 6 |

*Significant at 1% level of probability

**Significant at 5% level of probability

5.1.2 Impact analysis of adoption of ICAR-DOGR technologies in non-traditional area

Vidarbha region of Maharashtra State is known as non-traditional area for onion and garlic cultivation. The data were collected using structured questionnaire from randomly selected 150 farmers of 15 villages namely Deulgaon, Ambhora, Sangola, Sawargaon and Nimbha from Akola; Manoli, Gogri, Poha, Rajura and Jogaldari from Washim; and Giroli, Pardi, Borgaon, Deoli and Bhidi from Wardha district.

ICAR-DOGR varieties, package of practices, BBF with micro irrigation and modified storage structures were adopted by 77%, 74%, 60% and 45% farmers, respectively. Total 82.5% area where onion crop cultivated, was covered by ICAR-DOGR onion varieties. The area under garlic crop is negligible in Vidarbha region.

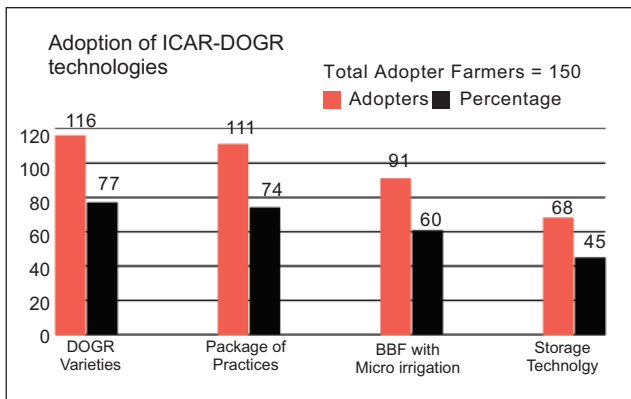


Fig.5.5 Adoption of ICAR-DOGR technologies in Vidarbha

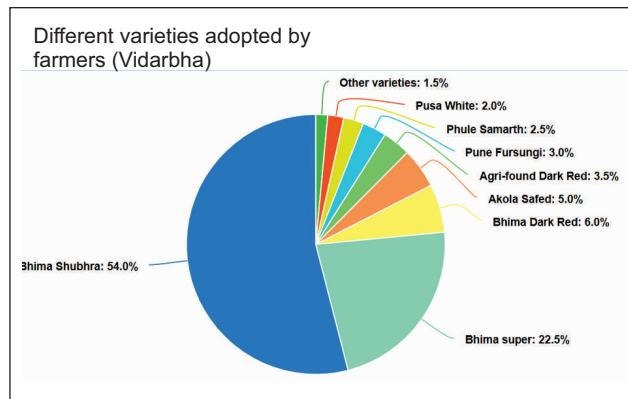


Fig.5.6 Varietal distribution of onion and garlic in Vidarbha

Findings indicated a significant association between the level of adoption among the farmers and level of overall change in socio-economic aspects. Among the farmers who adopted medium to high degree of adoption, majority of them reported a positive change in socio-economic aspects. There was significant impact of ICAR-DOGR technologies (varieties, package of practices, BBF with drip irrigation and modified storage structures) on socio-economic aspects (increase in annual income, loan repayment, farm improvement, home improvement, increase in domestic spending and increase in social participation of onion and garlic farmers).

Table 5.4 Relationship between characteristics of respondents and adoption of ICAR-DOGR technologies

| Characteristics of respondents | 'r' values |
|--------------------------------|------------|
| Age | 0.6482* |
| Farm size | 0.0651* |
| Annual Income | 0.0037 |
| Education | 0.7238* |
| Socio economic status | 0.6219* |
| Scientific orientation | 0.7264* |
| Economic motivation | 0.7183* |
| Extension contact | 0.7232* |

*Significant at 1% level of probability

Table 5.5: Association between adoption level and socio-economic aspects

| Socio-economic aspects | X2 values | Degree of Freedom |
|----------------------------------|-----------|-------------------|
| Increase in Annual Income | 22.90* | 4 |
| Loan repayment | 23.27* | 4 |
| Farm Improvement | 23.68* | 6 |
| Home Improvement | 19.81** | 6 |
| Increase in Domestic spending | 18.45* | 4 |
| Increase in Social participation | 13.51* | 4 |

*Significant at 1% level of probability

**Significant at 5% level of probability

The significant impact of adoption of ICAR-DOGR technologies (varieties, package of practices, BBF with drip irrigation and modified storage structures) was found on socio-economic aspects viz., increase in annual income, loan repayment, farm improvement, home improvement, increase in domestic spending and increase in social participation of farmers.

Determinants of entrepreneurial behavior (EB) of participants of Entrepreneurship Development Programme (EDP)

Entrepreneurship Development Programme (EDP) on “Commercial Onion Seed Production” organized from 7th to 9th October, 2024 for Farmer Producer Companies, Seed Companies, Entrepreneurs and Farmers. This study explores the behavioral determinants and configurational pathways that influence entrepreneurial intention (EI) and entrepreneurial behavior (EB) of onion seed entrepreneurs who participated in a three-day Entrepreneurship Development Programme (EDP). Using the Theory of Planned Behavior (TPB) and the Entrepreneurial Event

Model (EEM), the study incorporates psychological dimensions such as attitude, perceived behavioral control, subjective norm, perceived desirability, feasibility, tendency to act, and self-efficacy. A mixed-method approach incorporating Partial Least Squares Structural Equation Modeling (PLS-SEM), NCA (Necessary Condition Analysis), and fuzzy-set Qualitative Comparative Analysis (fsQCA) was used to examine 175 participants' post-training responses. The SEM results show that perceived desirability and feasibility have a considerable influence on EI, which is the strongest predictor of EB. In contrast, digital entrepreneurial education, innovativeness, and subjective norms had minimal direct benefits. FsQCA identifies many equifinal configurations of determinants that lead to high EI and EB, emphasizing the nonlinear and asymmetric nature of entrepreneurial decision-making in rural environments. The necessary condition analysis highlights perceived desirability, feasibility, and entrepreneurial self-efficacy as crucial thresholds.

5.2 Novel Approaches for Transfer of Onion and Garlic Technologies

5.2.1 Decision Support Systems for Garlic Cultivation

'Garlic Nutri Planner': A decision support system for balanced nutrition management in garlic

Efficient nutrient management plays a critical role in achieving high yields and maintaining soil health. Recognizing the widespread problem of indiscriminate fertilizer use in garlic cultivation, a digital advisory tool Garlic Nutri Planner has been developed to support farmers with precise, science-based nutrition guidance. The system integrates two key data inputs to generate accurate recommendations: Soil test information provided by the farmer, and Standard nutrient requirements of garlic derived from established crop uptake patterns. Based on these inputs, Garlic Nutri Planner determines the optimal nutrient dose needed for the crop. A built-in fertilizer dose calculator further refines these recommendations by adjusting the suggested quantities according to the type of fertilizer used, the method of application, and the size of the cultivated area. This ensures that farmers apply the right amount of nutrients in a cost-effective and environmentally responsible manner. Beyond recommending nutrient doses, Garlic Nutri Planner also includes a diagnostic module for identifying nutrient deficiencies. Farmers can match visible symptoms in the field with the tool's database to pinpoint possible deficiencies and access corrective measures. By combining scientific nutrient recommendations, real-time decision support, and practical field-level diagnostics, Garlic Nutri Planner serves as a valuable instrument for improving garlic productivity and promoting sustainable nutrient management practices.

'Garlic Doctor': data-driven approach to manage and mitigate pest and disease pressures on Garlic

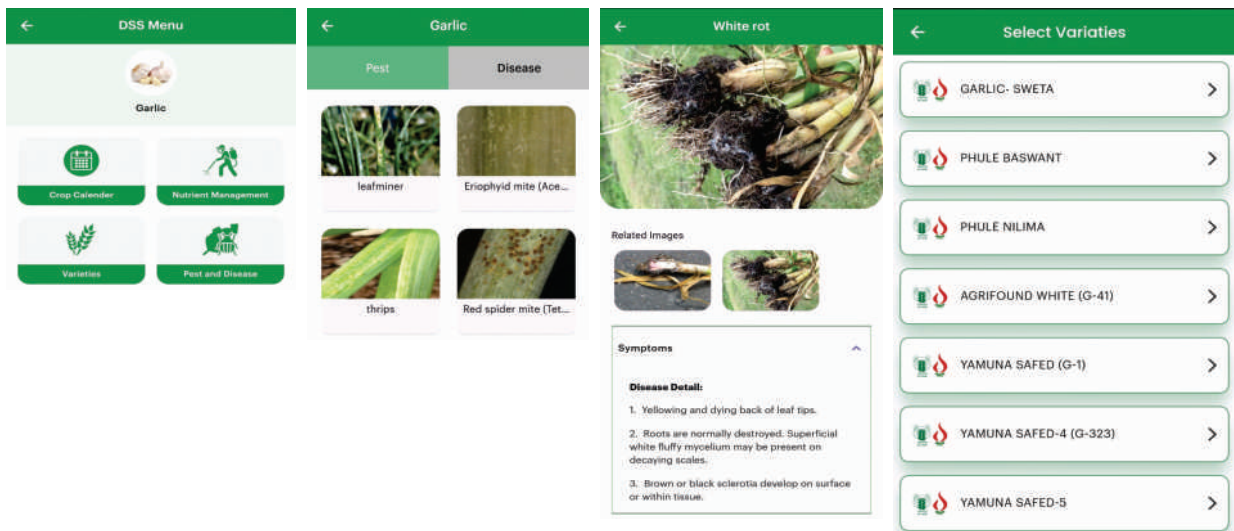
Pest and disease outbreaks are among the major factors limiting garlic productivity, often causing substantial yield and quality losses. To support farmers in making timely and accurate plant protection decisions, a specialized decision support system 'Garlic Doctor' has been developed for garlic pest and disease management. Garlic Doctor adopts a systematic, data-driven approach to help farmers quickly diagnose field problems. The system includes a well-curated library of symptom photographs that enables users to visually compare and correctly identify the pests, pathogens, or disorders affecting their garlic crop. This visual diagnostic support empowers farmers to pinpoint issues even at early stages. Once the problem is identified, Garlic Doctor provides science-backed recommendations for effective management. The advisory includes suitable cultural practices, biological options, and need-based chemical control measures aligned with recommended plant protection protocols for garlic. These targeted suggestions help farmers adopt the most appropriate and sustainable solutions. By combining accurate diagnosis with practical field-level guidance, Garlic Doctor enhances farmers' ability to respond promptly to pest and disease threats. The system ultimately contributes to reducing crop losses, improving garlic health, and ensuring better yields under diverse production conditions.

'Garlic Variety Guide': ICT based decision support system for variety selection in garlic cultivation

Farmers often face difficulty in choosing the right garlic variety due to limited access to reliable information and the continued use of traditional local types. To bridge this gap, the Garlic Variety Guide has been developed as an ICT-based decision support system that helps farmers select the most suitable garlic variety for their region and cropping season. The system analyses key inputs provided by the farmer such as location, sowing window, and preferred bulb characteristics and recommends varieties best aligned with local growing conditions and yield potential. In addition to variety selection, the tool also offers guidance on essential crop management operations to support timely and efficient cultivation which ultimately may contribute to higher productivity and better-quality garlic.

'Garlic Crop Advisor': A mobile application

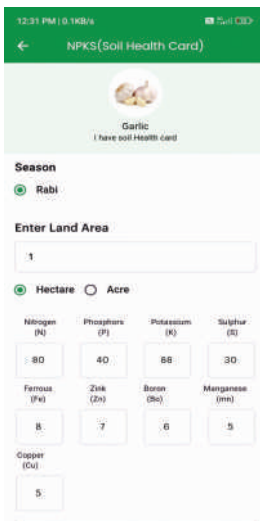
Garlic Crop Advisor is a user-friendly mobile application developed to provide farmers with quick, reliable, and practical guidance for garlic cultivation. The app offers concise text and video advisories covering all major crop stages, including planting, nutrient scheduling, irrigation, pest and disease management, and post-harvest handling. To keep farmers updated, the app features a crop calendar, notifications, and short information posts on new technologies and training programs. Integrated decision-support tools (Garlic Doctor, Garlic Nutri planner and Garlic variety Guide) help users diagnose field problems and receive science-based recommendations tailored to garlic production. Acting as a single-window digital resource, Garlic Crop Advisor empowers farmers with timely information and actionable insights, supporting better decision-making and improved garlic productivity.



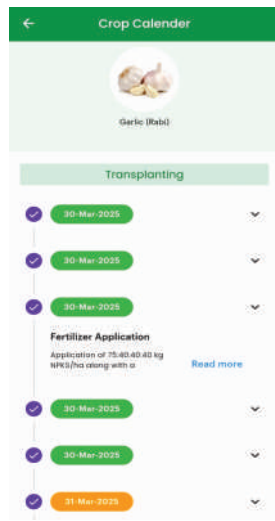
Decision Support Systems(DSS)

'Garlic Doctor': A Decision Support System for Disease and Pest Management in Garlic

'Garlic Variety Guide': Decision support system for variety selection in Garlic



'Garlic Nutri Planner': A Decision Support System for Balanced Nutrient Management in Garlic



Garlic Crop Calendar



'Garlic Crop advisor' Mobile application for farmers

Fig. 5.7 Decision Support Systems for Garlic Cultivation

5.2.2 Multimedia based Onion and Garlic Samachar: Onion and Garlic Samachar, a multimedia-based news bulletin has been published in Marathi (Kanda va Lasun Samachar) and hindi (Piyaz evm Lahsun Samachar). 11 issues of this bilingual Samachar have web casted on YouTube, featuring onion and garlic production advisories, expert talks, and Q and A sessions contemporary to the monthly crop conditions.

5.2.3 Agritoons - Animation-based advisory: An animation video on *Krushik Kshetratil Udyojakta va Startup-sathi Sandhi* was developed and disseminated to enhance awareness on entrepreneurship and startup opportunities in the agriculture sector. The video received an encouraging response, garnering 14,638 views across digital platforms.

5.2.4 WhatsApp based advisories: Socially integrated messaging platforms were found effective in connecting 12350 farmers' members nationwide through 116 farmer groups over WhatsApp application. These groups were further clustered block-wise for key producing districts and were used to impart time and location specific crop production advisories and addressing the farmer's queries. A total of 43 timely advisories were sent to farmers of different pockets of the country including text (21) Video (22) advisories.

5.2.5 Decision support systems for onion: A mobile application enabled with decision support systems for prompt management decisions in nutrient management, pest and diseases, variety selection and day to day operations is being used by over 2000 farmers and stakeholders.

Externally Funded Project

5.3 Agricultural Drone Project



Fig.5.8 Drone based spray in farmers' fields

Demonstrations were conducted on drone-based spray technology at farmers' fields under Agri-drone project. A total of 223 demonstrations were conducted on 314 acres of land under onion cultivation in 58 villages of Pune and Ahilyanagar districts of Maharashtra. Around 2532 farmers were participated in the demonstrations. The project focused on six key tahsils: Shirur, Khed, Junnar, and Ambegaon in Pune district, and Parner and Sangamaner in Ahilyanagardistrict. Farmers reported with increased willingness to adopt drone spraying technology primarily due to the significant reduction in labour and time, as well as the observed improvement in onion yields. This initiative will promote drone technology for spraying of insecticide, pesticide, water soluble fertilizers and weedicide in onion and garlic crops in particular and agricultural crops in general. The feedback suggests potential for scaling up its adoption among farmers.

Table 5.6 Demonstrations of drone based chemical sprays

| Types of chemical spray | No. of demonstrations | Area covered (Acres) |
|-------------------------|-----------------------|----------------------|
| Fungicide | 107 | 151 |
| Pesticide/Weedicide | 07 | 08 |
| Insecticide | 109 | 155 |
| Total | 223 | 314 |

Survey Research findings under Agri Drone Project

A comprehensive survey was conducted across two districts of Maharashtra Pune and Ahilyanagar covering a total of 450 farmers. The study assessed farmers' experiences with different crop-spraying methods by examining costs, labour requirements, time efficiency, and overall satisfaction levels. The Spraying Difficulty Index (SDI) was calculated to categorize spraying challenges across different crops based on factors viz. crop height, crop damage risk due to spraying movement, difficulty due to density or canopy spread, physical injury risk, and frequency of required spraying. Crops such as soybean (65.46), sugarcane (63.95), and mango (63.76) were categorized as high-difficulty crops, primarily due to their height, dense canopies. In contrast, low-difficulty crops included onion (34.31), garlic (33.88), and coriander (38.18). Farmers were also asked to indicate their maximum willingness to pay (WTP) for drone-based spraying services and to share the reasons influencing their decision to adopt or reject such technologies. The WTP analysis shows that farmers are willing to pay higher premium for drone services when it comes to high-value, labor-intensive crops like banana, soybean, and wheat. Furthermore, the survey captured farmers' perceptions of different service providers, where they rated and ranked private, cooperative, and government agencies based on key criteria such as cost, accessibility, trust, and the quality of technical support.

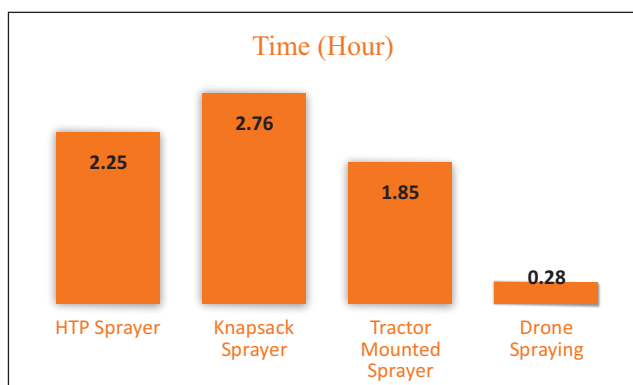


Fig. 5.9 Time requirement for different sprays

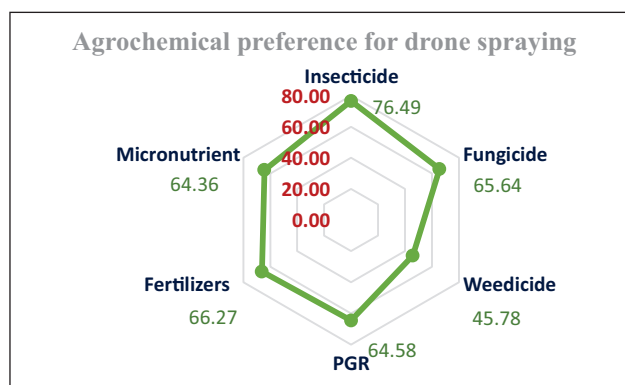


Fig. 5.10 Agrochemical preference for drone spraying

A comprehensive study was conducted following field demonstrations of the Agricultural Spray Drone (ASD) technology by ICAR-DOGR. The sample for this study consisted of farmers who actively participated in these Agricultural Spray Drone (ASD) demonstrations; a total of 450 responses were collected from Pune and Ahilyanagar districts of Maharashtra. The study utilized Partial Least Squares Structural Equation Modeling (PLS-SEM), Necessary Condition Analysis (NCA), and Importance–Performance Map Analysis (IPMA) to investigate the key factors influencing farmers' behavioral intention and actual usage of this emerging agricultural technology. Among the various constructs examined, Performance Expectancy, the belief that adopting the technology will lead to improved yields and productivity, emerged as a necessary condition for high behavioral intention. The NCA results revealed that enhancing Performance Expectancy by at least 21.78% is essential to maximize users' willingness to adopt the ASD technology.

Further, study conducted to measure the entrepreneurial intentions and behaviors of individuals involved in agricultural drone spraying services in India, encompassing those who own drones, rent them, or work under drone service provider agencies. A total of 152 responses were collected from drone service providers across India. The study employed PLS-SEM to identify significant predictors of entrepreneurial intention and behavior, followed by Artificial Neural Network (ANN) analysis. A market potential scoring framework was also developed using Python 3.10, with essential data science libraries such as pandas, scikit-learn, matplotlib, and seaborn to segment respondents into high, moderate, and low market readiness groups. The findings revealed considerable entrepreneurial intent among youth, though many remain in the aspirational stage due to operational and structural constraints.



All India Network Research Project on Onion and Garlic

1. Red onion germplasm at different locations

a. *Kharif* red onion germplasm

Twenty-six accessions along with two checks were evaluated at different locations during *kharif*. More than 230 q/ha marketable yield was recorded in RO-1772 at Delhi, Karnal, Junagadh, Pune and Bengaluru; RO-1787 at Delhi, Junagadh, Pune and Bengaluru and RO-1771 at Karnal, Junagadh and Pune; whereas, more than 290 q/ha total yield was recorded by RO-1772 at Delhi, Karnal and Pune while RO-1787 at Delhi, Pune and Bengaluru. Acc. POS22K and POS27K produced more than 75 g average bulb weight at Karnal, Bengaluru and Coimbatore. Less than 100 days to maturity was recorded in RO-1741 at Pune and Bengaluru.

b. *Rabi* red onion germplasm

Twenty-three accessions along with two checks were evaluated at different locations during *rabi*. More than 250 q/ha marketable yield was recorded in RO-1672 at Karnal, Jabalpur, Junagadh, Pune and Bengaluru; RO-1625, RO-1657, RO-1747 and RO-1770 at Delhi, Junagadh, Pune and Bengaluru and RO-1773 at Karnal, Junagadh and Pune; whereas, more than 310 q/ha total yield was recorded by RO-1625, RO-1657, RO-1747, RO-1769 and RO-1770 at Delhi, Pune and Bengaluru. Acc. RO-1654, RO-1769 and RO-1770 produced more than 70 g average bulb weight at Delhi, Junagadh, Pune and Bengaluru. Less than 112 days to maturity was recorded in RO-1620 and RO-1622 at Karnal, Jabalpur and Pune.

2. White onion germplasm at different locations

a. *Kharif* white onion germplasm

Nine accessions along with three checks were evaluated at different locations during *kharif*. More than 200 q/ha marketable yield was recorded in Acc. W-355 and W-448 at Delhi and Junagadh whereas, more than 220 q/ha total yield was recorded by W-125 at Delhi and Bengaluru. Acc. W-210 produced more than 60 g average bulb weight at Bengaluru and Coimbatore. Less than 100 days to maturity was recorded in W-125 at Pune and Bengaluru.

b. *Rabi* white onion germplasm

Fourteen accessions along with two checks were evaluated at different locations during *rabi*. More than 270 q/ha marketable yield was recorded in Acc. W-210 at Karnal, Junagadh, Pune and Bengaluru; Acc. W-125 at Karnal, Junagadh and Pune; and Acc. W-448 at Delhi, Junagadh and Pune whereas more than 280 q/ha total yield was recorded by Acc. W-125 and W-210 at Karnal, Pune and Bengaluru while W-448 at Delhi and Pune. Acc. W-085 produced more than 70 g average bulb weight at Junagadh, Pune, Bengaluru and W-344 Pune, Bengaluru and Coimbatore. Less than 110 days to maturity was recorded in W-141 and W-355 at Jabalpur and Bengaluru.

3. Onion Varietal Trial

Red onion varieties

In short day red onion varietal trial during *kharif*, 2 entries in IET and 4 entries in AVT-I at 22 centres were evaluated. In short day red onion varietal of sets trial during *kharif*, 4 entries in IET at 3 centres were evaluated. In short day red onion varietal trial during late *kharif*, 4 entries at 22 centres were evaluated in AVT-I. In Short

day red onion varietal trial during *Rabi*, 2 entries at 22 centres in IET, 7 entries at 22 centres in AVT-I, 5 entries at 22 centres in AVT-II were evaluated. In Hill region, red onion varietal trial during *Rabi*, 2 entries at 4 centres in IET, in AVT-I, 6 entries at 4 centres and in AVT-II 5 entries at 4 centres, respectively were evaluated.

Red onion hybrid

In short day red onion hybrid trial during *Kharif*, 2 entries in IET at 22 centres were evaluated. In Short day red onion hybrid trial during *Rabi*, 2 entries each at 22 centres in IET and AVT-I and 2 entries in AVT-II at 22 centres were evaluated. In Hill region, red onion hybrid trial during *Rabi*, 2 entries each at 4 centres in IET and AVT-I, 3 entries at 4 centres in AVT-II were evaluated.

White onion varieties

In short day white onion varietal trial during *kharif*, 2 entries in IET at 22 centres were evaluated. In short day white onion varietal trial during Late *Kharif*, 5 entries at 22 centres were evaluated in IET. In short day white onion varietal trial during *Rabi*, 2 entries at 22 centres were evaluated in IET. In hill region during *Rabi*, 2 entries at 4 centres in IET were evaluated.

4. Garlic Varietal Trial

In garlic, varietal trial was conducted at total 19 centers. The trials viz. IET, AVT-I & AVT-II were conducted in short day condition, In IET, 5 entries at 19 centres, 7 entries at 19 centres in AVT-I and 4 entries at 20 centres in AVT-II were evaluated, respectively. In hill region during *Rabi*, 5 entries at 4 centres in IET, 9 entries at 4 centres in AVT-I and 4 entries at 4 centres in AVT-II were evaluated.

Recommendation of Varieties (Onion and Garlic)

Onion (8):

DOGR-361: White onion entry was identified as significantly superior over best check consistently at two locations viz.; Junagadh and Rahuri in two years, therefore recommended for **Zone V** based on marketable yield for *rabi* season.

1550-Agg: Multiplier red onion entry was identified as significantly superior over best check consistently at three locations viz.; Junagadh, Rahuri and Rajgurunagar in two years, therefore recommended for **Zone V** based on marketable yield for *rabi* season.

1546-Agg: Multiplier onion entry was identified as significantly superior over best check consistently at two locations viz.; Junagadh and Rahuri in two years (Zone V); Bengaluru and Dharwad in two years (Zone VI), therefore recommended for **Zone V** and **Zone VI** based on marketable yield for *rabi* season.

RGP-3: Red onion entry was identified as significantly superior over best check consistently at two locations viz.; Akola and Jabalpur in two years, therefore recommended for **Zone IV** based on marketable yield for *kharif* season.

DOGR-1625: Onion entry was identified as significantly superior over best check consistently at two locations viz.; Akola and Jabalpur in two years, therefore recommended for **Zone IV** based on marketable yield for *kharif* season.

DOGR-1203: Dark red onion entry was identified as significantly superior over best check consistently at four locations viz. Junagadh, Nasik, Rahuri, and Rajgurunagar in two years for early maturity along with 278 q/ha marketable yield therefore, recommended for **Zone V** based on earliness for *rabi* season.

DOGR-HT-3 and DOGR-HT-4: High TSS onion entries were identified as significantly superior over best check consistently at two or more locations Nashik, Rahuri, and Rajgurunagar in two years (Zone V) and Bengaluru and Dharwad in two years in (Zone VI) for high-TSS along with marketable yield (>22 t/ha) during *rabi*, therefore both the entries recommended for **Zone V** and **VI** for high TSS.

Garlic (1):

DOGR-PB-10: Short-day garlic entry was identified as significantly superior at two locations viz.; Ludhiana and Karnal in two years over the best check, therefore recommended for **Zone-II** based on marketable yield for *rabi* season.

Crop Production

In crop production, total of five experiments conducted viz., i) Weed management studies in onion seed crop ii) Effect of nano-urea on growth, yield and quality of onion (All main centers, Rahuri, Nasik of this two experiments conducted), iii) Fertilizer scheduling through drip fertigation for long day onion at Srinagar experiments conducted iv) Evaluation of bulbils as planting material of long day garlic (VL Lahsun 2) (at Almora, Srinagar, Muktesh war, Palampur, Gangtok & Ooty experiments conducted) v) Evaluation of organic farming practices with natural farming practices for plant growth, yield and quality of onion (at Pune, Dharwad, Nasik, Jabalpur experiments conducted).

Crop Protection

Pest Management

Four experiments including (i) Management of pest and diseases in garlic (All mains centre) ii) Survey and monitoring of major insect pests of onion and garlic iii) Evaluation insecticide/miticide against sucking pests and mites of garlic (All main centers, of these three experiments conducted) iv) Screening of Onion and garlic varieties/lines for thrips resistance (All main centers and voluntary centers for varietal trials)

Survey on insect pests of onion and garlic was conducted at eight locations. Onion thrips *Thrips tabaci* was the major pest recorded in all the locations. Occurrence of cutworm (*Spodoptera* sp) recorded at Rajgurunagar and Ludhiana centre. Eriophyid mite's incidence recorded at Junagadh and Rajgurunagar. Green looper, *Chrysodeixis* sp incidence recorded at Rajgurunagar and Tripura centers. Besides *Helicoverpa armigera* was reported at Tripura and Sikkim center. Hairy caterpillar incidence recorded at Ludhiana centers. Coccinellids population recorded at Rajgurunagar and Ludhiana.

Recommandation

It is recommended that four foliar sprays of spinetoram 11.7% SC (0.8 ml/lit) or spinosad 45% SC (0.4 ml/lit) at 40, 55, 70 and 85 days after dibbling for effective and economical management of thrips in garlic and also improve the marketable bulb yield of garlic.

Disease Management in Onion and Garlic

Total four pathological trials were conducted at the entire main and some voluntary centres. All allotted centers conducted the disease survey. Among the centers that conducted the survey major diseases found were Stemphylium blight, Purple Blotch and Anthracnose. The other fungal diseases recorded at various centers include Fusarium Basal rot, Black mould, Downy mildew and Iris yellow spot virus were recorded at some centers.

Four pesticides, including Fenpyroximate 5% EC, Propargite 57% EC, Spinetoram 11.7 SC, and Spinosad 45% SC, were tested against garlic pests in seven locations. All of the treatments were effective in reducing thrips and mite numbers in garlic. Spinetoram and Spinosad were effective against thrips, whereas Fenpyroximate and Propargite were effective against mites in most cases.

AINRPOG Seed Production (Onion and Garlic)

Onion:

Palampur-Palam Lohit (0.1q), **Him Palam Shweta** (0.02 q) = **0.12 q**

Srinagar-Brown Spanish (0.23 q), **Yellow Globe** (0.05 q) = **0.28 q**



Ludhiana- Punjab Naroya (0.69 q), PRO-6 (1.32 q), PRO-7 (4.95 q), PWO-2 (0.04 q), PYO-1 (0.17 q), POH-1 (F1) (0.50 q) = **7.67 q**

Kanpur- Bhima Shakti (0.061 q) = **0.061 q**

Akola- Akola Safed (36.8 q) = **36.8 q**

Jabalpur- Bhima Shakti (0.10 q) = **0.10 q**

Junagadh- GJWO-3 (0.65 q), GJRO-11 (2.10 q) = **2.75 q**

Nashik- Agrifound Dark Red (200.23 q), Agrifound Light Red (154.29 q), NHRDF Red (20.69 q), NHRDF Red-2 (1.25 q), NHRDF Red-4 (72.3 q), NHRDF Fursungi (19.4 q) = **468.16 q**

Rajgurunagar- Bhima Super (24.88 q), Bhima Raj (6.45 q), Bhima Red (10.84 q), Bhima Dark Red (10.75 q), Bhima Shakti (9.28 q), Bhima Kiran (2.70 q), Bhima Shubhra (1.98 q), Bhima Shweta (4.10 q), and Bhima Safed (2.43 q) = **73.41 q**

TNAU- CO(On)5 (2.52 q), CO 6 (1.95 q) = **4.47 q**

Dharwad- Bhima Super (32.40 q), Bhima Shakti (3.40 q), Bhima Red (3.50 q) = **39.3 q**

Overall total onion seeds production= 633.12 q (Onion), 4.47 q (Multiplier Onion)

Garlic:

Palampur- GHC-1 (0.30 q) = **0.30 q**

Srinagar- CITH-G-1 (0.27 q), CITH-G-3 (0.47 q) = **0.74 q**

Ludhiana- PG-18 (44.5 q) = **44.5 q**

Sikkim- SG-01 (1.15 q), SG-02 (0.45 q), SG-03 (0.42 q) = **2.02 q**

Akola- PDKV-Purna (7.00 q) = **7.00 q**

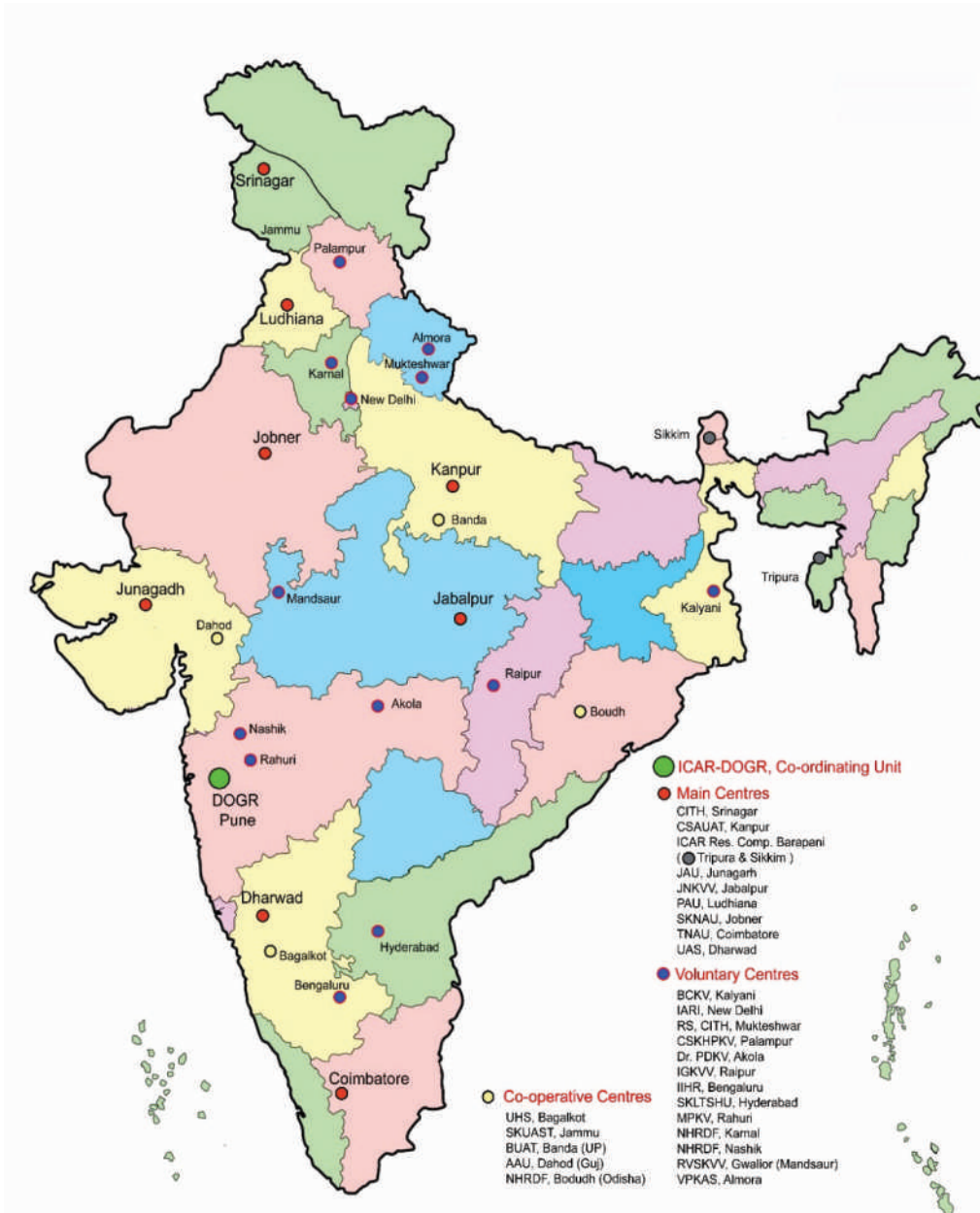
Junagadh- GJG-5 (19.8 q), GG-8 (0.95 q) = **20.75 q**

Nashik- Agrifound White (G-41) (1.65 q), Yamuna Safed (G-1) (1.62 q), Yamuna Safed-2 (G-50) (215.79 q), Yamuna Safed-3 (G-282) (1624.50 q), Yamuna Safed-4 (G-323) (15.13 q), Yamuna Safed-5 (G-189) (25.67 q), Yamuna Safed-8 (G-384) (4.05 q), Yamuna Safed-9 (G-386) (6.96 q), Yamuna Purple-10 (G-404) (207.52 q), Agrifound Parvati (G-313) (1.08 q), Agrifound Parvati-2 (G-408) (0.74 q) = **2104.71 q**

Rajgurunagar- Bhima Omkar (13.16 q), Bhima Purple (60.76 q) = **73.92 q**

Dharwad- DWDG – 1 (15.77 q), DWDG – 2 (7.30 q) = **23.07 q**

Overall total garlic production= 2277.0 q



Map showing All India Onion and Garlic Research Network Centre

D. Scheduled Caste Sub-Plan for Onion and Garlic

The main objective of Scheduled Caste Sub-Plan (SCSP) is economic development of scheduled caste farmers by providing resources for filling up the critical gaps and providing missing vital inputs. During *kharif* season, total 216 kg onion seed of Bhima Super and Bhima Dark Red was distributed among 108 scheduled caste farmers of Ahilyanagar and Pune districts of Maharashtra. During late *kharif* season, total 110 kg onion seed of Bhima Red, Bhima Super, Bhima Dark Red and Bhima Shakti was distributed among 55 scheduled caste farmers of Ahilyanagar, Sambhajnagar and Pune districts of Maharashtra. During *rabi* season, total 800 kg onion seed of Bhima Red and Bhima Shweta and 400 kg garlic of Bhima Purple were distributed among 300 scheduled caste farmers of Ahilyanagar and Pune district of Maharashtra. The fertilizers (289.44 q), micronutrients (108 litre) and pesticides (216 litre) in *kharif*, fertilizers (127.40 q), micronutrients (55 litre) and pesticides (40 kg and 55 litre) in late *kharif* and fertilizers (494.05 q), micronutrients (400 litre) and pesticides (750 litre) in *rabi* seasons were also distributed to scheduled caste farmers.



Garlic seed distribution



Input distribution

Training programmes under SCSP

ICAR-DOGR regularly organize training programmes for the dissemination of onion and garlic technologies to the targeted clientele and upgradation of their skills. Total 11 training programmes were also organized for scheduled caste farmers, in which total 636 farmers were participated from different districts of Maharashtra.

The following training programmes were organized under SCSP.

1. Training programme on “*Rabi* onion harvesting and post-harvest management” attended by 130 farmers from District Ahilyanagar on 18 February 2024 at Karjat, District Ahilyanagar.
2. Training programme on “*Rabi* onion harvesting and post-harvest management” attended by 70 farmers from District Wardha on 23 February 2024 at Deoli, District Wardha.
3. Training programme on “Onion crop production” attended by 8 farmers from District Pune on 19 June 2024 at ICAR-DOGR, Pune.
4. Training programme on “Onion crop production” attended by 70 farmers from District Ahilyanagar on 21 June 2024 at Mirajgaon (Karjat), District Ahilyanagar.



5. Training programme on “Onion crop production” attended by 30 farmers from District Ahilyanagar on 22 June 2024 at Wagha (Jamkhed), District Ahilyanagar.
6. Training programme on “Late *kharif* onion production technology” attended by 23 farmers from District Ahilyanagar on 10 July 2024 at Parner, District Ahilyanagar.
7. Training programme on “Late *kharif* onion production technology” attended by 32 farmers from District Pune on 13 July 2024 at ICAR-DOGR, Pune.
8. Training programme on “Late *kharif* onion production technology” attended by 32 farmers from District Pune, Ahilyanagar and Chhatrapati Sambhajanagar on 23 July 2024 at ICAR-DOGR, Pune.
9. Training programme on “*Rabi* onion production technology” attended by 113 farmers from District Ahilyanagar on 8 October 2024 at Karjat, District Ahilyanagar.
10. Training programme on “Scientific Cultivation in Onion and Garlic” attended by 18 farmers from District Ahilyanagar on 9 October 2024 at ICAR-DOGR, Pune.
11. Training programme on “Garlic production technology” attended by 110 farmers from District Ahilyanagar on 10 October 2024 at Jamkhed, District Ahilyanagar.



Training programmes organized under SCSP



Visit to demonstration plots under SCSP

E. Tribal Sub-Plan for Onion and Garlic

TSP activities by ICAR-DOGR plays a vital role in food and nutritional security of tribal farmers. The systematic efforts were undertaken to improve the area and production of onion and garlic by careful application of improved technologies. Thus, focus was given in conduct of field demonstrations of improved technologies at farmer's fields through improved seed/bulb distribution, knowledge dissemination, capacity building and entrepreneurship building. About 1510 tribal farmers selected in 151 groups in Nandurbar (Navapur, Akalkua and Dhadgoan Talukas) and 760 tribal farmers selected in 76 groups in Pune (Khed and Ambegaon talukas) in Maharashtra whereas, 200 tribal farmers selected in 20 groups in Sonbhadra (UP) under TSP Scheme.

Field Demonstrations

A total of 40 demonstrations in *kharif* and 112 demonstrations in *rabi* were conducted under TSP during 2023-24. The kits of fertilizers, fungicides, insecticides, weedicides, spray pump, tarpaulins etc. were distributed for each selected group of tribal farmers. Each demonstration is being conducted on one-acre common land of selected farmers group and each group consist about ten tribal farmers.

Trainings

A total of seven trainings/ field days were organized under TSP in Maharashtra and Uttar Pradesh in which 505 tribal farmers participated.

Table 1. Trainings organized under TSP

| Topic of Training | Sponsored Agency | Date and Venue | No. of Participants |
|--|--|---|---------------------|
| Commercial cultivation of onion and garlic | ICAR-DOGR under TSP | 31 January 2024 Ambegaon, Pune (MS) | 44 |
| Onion production technology | ICAR-DOGR under TSP | 3 March 2024 Ambegaon, Pune (MS) | 40 |
| Commercial cultivation of onion in tribal belts of Nandurbar | ICAR-DOGR and KVK, Nandurbar under TSP | 20 March 2024 Khandwara, Navapur, Nandurbar | 60 |
| Scientific cultivation of onion and garlic | ICAR-DOGR under TSP | 27 March 2024 ICAR-DOGR, Pune (MS) | 31 |
| Commercial cultivation of onion in eastern parts of UP | ICAR-DOGR under TSP | 4-5 November 2024 IIVR, Varanasi (UP) | 60 |
| Improved cultivation and seed production of onion and garlic | ICAR-DOGR under TSP | 16-17 December 2024 at Navapur, Nandurbar (MS) | 210 |
| Kisan Diwas on Improved cultivation of onion | ICAR-DOGR under TSP | 23 December 2024 ICAR-DOGR, Pune (MS) | 60 |



F. Mera Gaon Mera Gaurav

The objective of “*Mera Gaon Mera Gaurav*” (My Village My Pride), Village Adoption Programme is to provide farmers with required information, knowledge and advisories on regular basis by adopting villages. Under this scheme, ICAR-DOGR has adopted 20 villages viz., Gadakhwadi, Varude, Gulani, Wafgaon, Jawulke, Khadakwadi, Loni, Pondewadi, Dhamni, Ranmala, Gosasi, Mitgudwadi, Kanhur Mesai, Khairewadi, Khairenagar, Kahu Koyali, Sakurdi, Vetale, Saigaon and Saburdi. The various activities were carried out in these twenty villages by four teams of scientists. The linkages were developed with three agencies viz., NGO “TVS” Srinivasan Services Trust, State Department of Agriculture and KVK, Narayangaon. These organizations help ICAR-DOGR in organizing training programmes, conducting demonstrations, etc. activities. The scientists (20) of ICAR-DOGR provided scientific information to the farmers about improved technology of onion and garlic time to time. The activities to be undertaken in *Mera Gaon Mera Gaurav* programme have been discussed with village officials and Sarpanch of the respective villages.

The scientists of ICAR-DOGR are in constant touch with the villagers and visit identified villages to address various technical issues in cultivation of various crops by the farmers. ICAR-DOGR publications were provided to farmers of the selected villages under the scheme. Soil samples from these villages were collected, analysed and Soil Health Cards provided to the farmers. Advisories for onion and garlic farmers were uploaded on Directorate's website, ICAR-DOGR MobileApp and also published in *Agrowon* Newspaper on regular basis. In total, 1594 farmers of 20 villages were benefitted due to 63 activities (awareness creation, interface meetings, etc.) under MGMG scheme. A total of 60 demonstrations on *kharif*, late *kharif* and *rabi* onion crop of ICAR-DOGR varieties viz., Bhima Dark Red (*kharif*), Bhima Shakti (late *kharif*) and Bhima Kiran (*rabi*) were conducted in the villages adopted in this scheme.

Total 39 training programmes on different topics such as; pest and disease management, *rabi* onion harvesting and storage, post-harvest management, *kharif* onion cultivation, nursery preparation, etc. were organized in the adopted villages in which total 1014 farmers were participated.

Awareness was imparted about cleanliness among the people of these adopted villages and cleanliness activities were also conducted in these villages by involving the villagers under Swachh Bharat Abhiyan. Dr. S. S. Gadge, Principal Scientist (Agricultural Extension) planned and monitored the activities as Nodal Officer of MGMG scheme.





Distinctness, Uniformity and Stability

ICAR-DOGR is working as Nodal Centre for conducting DUS test of onion and garlic and maintaining 56 onion and 34 garlic varieties under this project. These varieties of onion and garlic are treated as extant varieties. In case of onion, 46 *rabi* season varieties and 10 *kharif* season varieties and 34 varieties of garlic are being maintained at ICAR-DOGR, Pune. Long day onion and garlic varieties are being maintained at ICAR-CITH, Srinagar and multiplier onion varieties at TNAU, Coimbatore. All the data recorded as per DUS test guidelines in all the maintained varieties of onion and garlic under DUS project.

Evaluation of DUS *Rabi* Onion Varieties (2023-24)

Forty-six *rabi* onion varieties *viz.*, Agrifound White, Agrifound Light Red, Arka Bheem, Arka Niketan, Arka Pitamber, Arka Pragati, Bhima Kiran, Bhima Raj, Bhima Red, Bhima Shakti, Bhima Shweta, Bhima Light Red, GWO-1, GWO-2, GWO-3, GJRO-11, N-2-4-1, NHRDF Red (L-28), NHRDF Red-2 (L-355), NHRDF Red-3 (L-625), NHRDF Fursungi (L-819), NHRDF Red-4 (L-744), PKV White, Phule Safed, Phule Samarth, Pilipatti Junagadh, Punjab Naroya, Pusa Red, Pusa Sona, Pusa Riddhi, Pusa White Round, PRO-6, PRO-7, PWO-2, PYO-1, Phursungi Local, RO-01, RO-59, RO-252, Sanjivani Kala, Sukhsagar, Sukhsagar Ballia, Talaja Red, Telagi Local, Early Grano and Udaipur-102 were sown on 8 November 2023 and transplanted on 3 January 2024 in 3 replications with the plot size of 3×2 m. Crops were harvested in the month of April-May 2024 and all the observations were recorded as per DUS test guidelines.

Evaluation of DUS *Kharif* Onion Varieties (2024)

Ten *kharif* onion varieties *viz.*, Agrifound Dark Red, B-780, Bhima Raj, Bhima Red, Bhima Shubhra, Bhima Shweta, Bhima Super, Bhima Dark Red and Bhima Safed along with five farmers varieties *viz.* EWR-401 (Reg/2019/10), NOO-74 (Reg/2022/0122) with three reference varieties (23ONBHER05, 23ONBHED04 and 23ONBHTI02) were sown on 19 June 2024 and transplanted on 11 August 2024 in 3 replications with the plot size of 1×6 m on raised beds. Crops were harvested in the month of November 2024 and all the observations were recorded as per DUS test guidelines.

Evaluation of DUS Garlic Varieties (2023-24)

Thirty-four garlic varieties *viz.*, Bhima Omkar, Bhima Purple, Chunar Local-1, Chunar Local-2, DWDG-2, G-1, G-41, G-50, G-282, G-323, G-386, G-404 (YP-10), GJG-5, GJG-6, GJG-7, GG-2, GG-3, GG-4, G-384 (YS-8), Godawari, Navapur Local, Ooty Local, Phule Baswant, Phule Nilima, PG-17, PG-18, Rani Bennur Local, Sikkim Local, Silkuei Local, Faizpur MP Local, Faizpur DP Local, JG-17-04, Sabour Garlic-2 and Anta Lahsun and were planted on 27 October 2023 in 3 replications with the plot size of 3×2 m. Crops were harvested in the month of March 2024 and all the observations were recorded as per DUS test guidelines.

ICAR-DOGR Varieties Registered with PPV&FRA

DUS testing of two varieties along with reference varieties were conducted during *kharif*. Nine onion varieties as well as one garlic variety have been registered with PPV&FRA. One onion variety Bhima Shweta and one garlic variety Bhima Purple are under registration with PPV&FRA.



Garlic varieties



Onion varieties



Maintenance of onion and garlic varieties under DUS Project

H. > Agri-Business Incubation

During the period from January to December 2024, the Agribusiness Incubation (ABI) Centre at ICAR-Directorate of Onion and Garlic Research continued to play a pivotal role in fostering entrepreneurship, innovation, and capacity building in the onion and garlic sector. Several key programmes and initiatives were undertaken to strengthen the ecosystem for agri-based startups and farmer-led enterprises. The year began with the *Agri Startups Conclave – 2024* held on 16 January 2024, which served as a platform for networking, knowledge sharing, and collaboration among entrepreneurs, researchers, and agribusiness stakeholders. This was followed by *Sankalp – Start-Up Cohort 2024* organized during 8-23 March 2024, designed to mentor and support early-stage startups with technical and business incubation support.

In the latter part of the year, the ABI Centre conducted a *Three-day Online Entrepreneurship Development Programme (EDP) on Commercial Onion Seed Production* during 7-9 October 2024, aimed at building entrepreneurial capacity in seed production. A *Scientist–Farmer/FPO–Exporter Interface Programme on Improved Onion Production Technology and Export Supply Chain* was organized on 7 October 2024 to promote interaction between different stakeholders. On 5 November 2024, a one-day EDP on *Improved Technologies for Commercial Onion Seed Production* was held to train Farmer Producer Companies and seed companies on advanced technologies. To encourage value addition and product diversification, a *Hands-on Training Programme on Transforming Onion and Garlic into Profitable Products* was conducted on 24 November 2024 in collaboration with National Institute of Food Technology Entrepreneurship and Management, Kundli, Sonapat, Haryana.

| | | |
|----|---|--------------------|
| 1. | Agri Startups Conclave- 2024 | 16 January 2024 |
| 2. | Sankalp-Start-Up Cohort- 2024 | 8 - 23 March 2024 |
| 3. | EDP on "Commercial Onion Seed Production" (Online) | 7 - 9 October 2024 |
| 4. | Scientist-Farmer/FPO-Exporter Interface Programme on "Improved Onion Production technology and Export Supply Chain" | 7 October 2024 |
| 5. | EDP on "Improved Technologies for Commercial Onion Seed Production" | 5 November 2024 |
| 6. | Hands on training program on "Transforming Onion and Garlic into Profitable Products" | 24 November 2024 |

Programmes conducted

A total of 19 promising startups were enrolled during the year, working across multiple segments of the onion and garlic value chain. The list and details of these start-ups are given below:

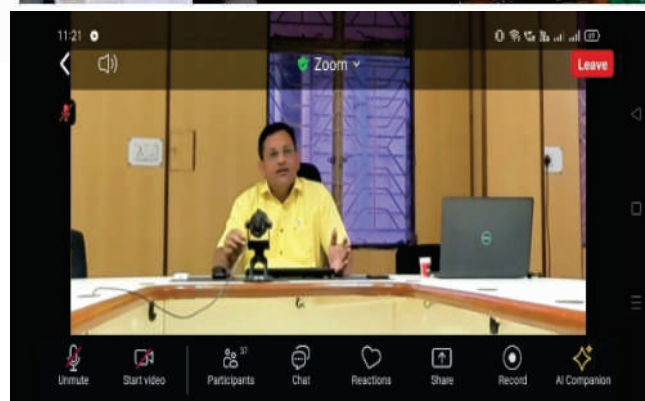
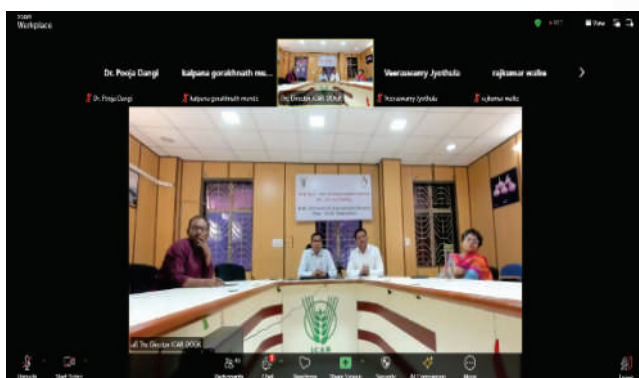
List of Incubatees / start-ups enrolled

| Sl. No. | Name of the Startup enrolled | Product details |
|---------|---|--|
| 1. | Pragun Agro Foods | Dehydrated Onion and Garlic products |
| 2. | Omdatt Agrotech Services & Counseling Pvt. Ltd. | IoT-based Hydroponic System |
| 3. | Shreya Trading Company | Dehydrated vegetables |
| 4. | Temperate Technologies Private Limited | Controlled environment storage technology for onions |

| Sl. No. | Name of the Startup enrolled | Product details |
|---------|--|---|
| 5. | Keshavraj Agro Producer Company Ltd. | Honey bee rearing for onion seed production |
| 6. | SP Agro Innovations | Onion Transplanter |
| 7. | IndiDroneSpray | Drone technology for pest and disease management |
| 8. | Thinkpure Organic Produce Org. Pvt. Ltd. | Seed processing and Quality seed production |
| 9. | Farmers Smile Farmer Producer Com Ltd. Pune | Onion seed production |
| 10. | Palanduh FPC | Dehydrated onion flakes and onion and garlic powder |
| 11. | Vanastha | Processing and Preserving of Forest Agro Foods Mahua Ladoo and Karvand Pickle, Black Rice |
| 12. | Satpro Food Processing (OPC) Pvt. Ltd. | Crunchy Fried Onion, Dehydrated Fried Onion, Coated Fried Onion |
| 13. | Pragun Agro Foods | Dehydrated Onion and Garlic Products |
| 14. | Dronagiri Farmer Producer Company | Flavoured Banana Chips |
| 15. | Baravkar Agro and Foods Private Ltd | Dehydration of Fruits and Vegetables |
| 16. | Parashara Krishi Farmer Producer Company Ltd | Processing and Preserving Fruits and Vegetables |
| 17. | Pikpani (OPC) Private Limited | Dehydration of Fruits and Vegetables |
| 18. | Pritesh Food Products | Processing and Preserving of Fruit and Vegetables |
| 19. | Ghode and Jadhav Agritech Equipments Industries Pvt. Ltd | Mechanizing Agriculture |

Through these programmes and initiatives, the ABI Centre has continued to strengthen its support to agri-entrepreneurs by providing capacity building, market visibility, and technology linkages. Its efforts have significantly contributed to enhancing the competitiveness of onion and garlic-based agribusinesses, thereby supporting rural entrepreneurship and sustainable agri-value chains.

During this year, a total revenue of Rs. 95,000/-is Generated through ABI activities and start-up registrations.



Training programmes



Signing of MoU



Sankalp-Cohort programme



Visit to Industries

I. > North East Hill Plan

ICAR-DOGR, Pune began carrying out several initiatives were implemented to support tribal populations and improve the production of onion and garlic in the NEH region viz., Arunachal Pradesh, Nagaland, Manipur, Tripura, and Sikkim were chosen as the five states to promote onion and garlic growing in the NEH region.

Demonstrations and Trainings

- In total, 124 field demonstrations were conducted in five NEH states viz., Arunachal Pradesh, Manipur, Nagaland, Tripura, and Sikkim, with 1375 male and female farmers directly benefiting.
- The villages viz., Namsing, Kongkul, Mebo, Rani, East Siang, Regi, Leparada, Basar, and Ledum are all villages in Arunachal Pradesh. Maowa, Beisumpuikam, Molvom, Samziuram, Suchunoma, New Suchunoma, Renthan, Lotsu, Phek, and Medziphema are all in Nagaland. The villages of Sikkim State include Barfok, Dzongu. North Sikkim, Passi, South Sikkim, KVK East Sikkim, Gangtok, West Sikkim, Namthang. Tripura's villages include Kakraban, Rajnagar Lankamura, Belbari, Lembucherra, Poangbari, South Tripura, Shilghati, Gomati, Kushamara, Uttar Tulamura, Melagarh, Rangamati, and Lankamura. And Manipur villages viz., Imphal East District (Moirankampu Sajeb, Porompat, Itham Mayai Leikai Keirao, Kongba, Kontha Ahallup Awang Leikai, Urup Khunou Makha Leikai, Lamlai Mayai Leikai, Unambol Leikai and Machengpat- Andro, Pungdongbam Awang Leikai Ukhrul Road, Imphal West District (Ningombam, Waheng Leikai, Sanakeithel, Irom Meijrao, Meitram, Lamshang, Kangchup Kharang, Achanbigai, Maklang Maning Leikai, Khurkhul, Yarou Bandiar Mayai Leikai Nambol, Wangoi Thounaojam and Longjam Leikai, Konthoujam Awang Leikai, Langjing Achouba, Pishumthong Oinam Leikai), and Imphal West District (Lamshang) were selected for carrying out the demonstrations.
- KVKs in these locations were contacted and participated in demonstrations to improve onion bulb growth.
- ICAR-DOGR provided farmers with onion seeds (Bhima Super and Bhima Dark Red in the *kharif* season and Bhima Shakti and Bhima Kiran in the *rabi* season. Farmers also received demonstration kits including organic inputs.
- A total of 2685 farmers, both male and female, participated in 47 training sessions organised in these states to provide farmers with information on the *kharif* and *rabi* onion producing technology developed by ICAR-DOGR.



Farmers – Scientist meet and input distribution at Zhuikhu, District Chumoukedima, Nagaland



Farmers' training cum input distribution programme at CoH, Bermiok, Sikkim



Demonstration, training and kits distribution at Dhupakhura, Meghalaya



Training cum input distribution and commercial production of onion at Thenzwal, Mizoram



Demonstration of nursery raising techniques and training programme at Arunachal Pradesh



J. > Transfer of Technology

Training programmes organized

| Topic of Training | Sponsoring Agency | Date and Venue | Participants |
|--|--|--|---|
| Onion Production, Post-Harvest and Processing Technology | Head (SMART-DIU) cum Project Director (ATMA), Nashik | 8-10 January 2024 ICAR-DOGR, Pune | 60 Farmers from District Nashik |
| Training cum exposure visit for college students to Principal Investigator institute ICAR-DOGR under SERB-DST project: Scientific Social Responsibility (SSR) activity | SERB-DST, New Delhi | 10 January 2024 ICAR-DOGR, Pune | 25 Under Graduate students from District Pune |
| PRAYAS-Pune Agri Start up Conclave | ICAR-NRC Grapes and ICAR-DOGR, Pune | 16 January 2024 NRC Grapes, Pune | 93 members of start ups from Maharashtra |
| Onion Production, Post-Harvest and Processing Technology | Head (SMART-DIU) cum Project Director (ATMA), Nashik | 17-19 January 2024 ICAR-DOGR, Pune | 60 Farmers from District Nashik |
| <i>Rabi</i> onion crop management | MGMG, ICAR-DOGR, Pune | 23 January 2024 Saburdi, Pune | 23 Farmers from District Pune |
| <i>Rabi</i> onion crop management | MGMG, ICAR-DOGR, Pune | 29 January 2024 Mitgudwadi, District Pune | 30 Farmers from District Pune |
| Commercial cultivation of onion and garlic | TSP, ICAR-DOGR, Pune | 31 January 2024 Ambegaon, District Pune | 44 Farmers from District Pune |
| Improved cultivation practices of onion | Action for Agricultural Renewal in Maharashtra (AFARM), Pune | 6 February 2024 ICAR-DOGR, Pune | 70 Farmers from District Ahilyanagar and Pune |
| Improved cultivation practices of onion | Action for Agricultural Renewal in Maharashtra (AFARM), Pune | 7 February 2024 ICAR-DOGR, Pune | 73 Farmers from District Ahilyanagar and Pune |
| Technology Day Training Programme on Advances in Onion Production Practices | ICAR-DOGR, Pune and TIH, Mumbai | 12 February 2024 Karjat, Ahilyanagar | 250 Farmers from District Ahilyanagar |
| <i>Rabi</i> onion harvesting and post-harvest management | SCSP, ICAR-DOGR, Pune | 18 February 2024 Karjat, District Ahilyanagar | 130 Farmers from District Ahilyanagar |
| <i>Rabi</i> onion harvesting and post-harvest management | SCSP, ICAR-DOGR, Pune | 23 February 2024 Deoli, District Wardha | 70 Farmers from District Wardha |
| <i>Rabi</i> onion crop management | MGMG, ICAR-DOGR, Pune | 23 February 2024 Khadakwadi, District Pune | 28 Farmers from District Pune |
| <i>Rabi</i> onion crop management | MGMG, ICAR-DOGR, Pune | 26 February 2024 Sakurdi, District Pune | 25 Farmers from District Pune |
| Onion production technology | TSP, ICAR-DOGR, Pune | 3 March 2024 Ambegaon, District Pune | 40 Farmers from District Pune |

| Topic of Training | Sponsoring Agency | Date and Venue | Participants |
|---|---|--|---|
| 21 Days Summer School on Sankalp-Startup Cohort, Networking and Capacity Building Incubation cum Training Programme on “Fostering networking opportunities and enhancing the capacities of potential startups in agricultural sector” | ABI and ITMU, ICAR-DOGR, Pune | 8-28 March 2024 ICAR-DOGR, Pune | 18 members of start-ups from Maharashtra |
| <i>Rabi</i> onion crop management | MGMG, ICAR-DOGR, Pune | 11 March 2024 Wafgaon, District Pune | 27 Farmers from District Pune |
| <i>Rabi</i> onion crop management | MGMG, ICAR-DOGR, Pune | 15 March 2024 Saigaon, District Pune | 28 Farmers from District Pune |
| Commercial cultivation of onion in tribal belt of Nandurbar | TSP, ICAR-DOGR, Pune and KVK, Nandurbar | 20 March 2024 Khandwara, Tal. Navapur, District Nandurbar | 60 Farmers from District Nandurbar |
| Training-cum-awareness programme on Scientific cultivation of onion and garlic | TSP, ICAR-DOGR, Pune | 27 March 2024 ICAR-DOGR, Pune | 31 Farmers from District Pune |
| <i>Rabi</i> onion harvesting and post-harvest management | MGMG, ICAR-DOGR, Pune | 1 April 2024 Mitgudwadi, District Pune | 27 Farmers from District Pune |
| <i>Rabi</i> onion harvesting and post-harvest management | MGMG, ICAR-DOGR, Pune | 2 April 2024 Varude, District Pune | 24 Farmers from District Pune |
| <i>Rabi</i> onion harvesting and post-harvest management | MGMG, ICAR-DOGR, Pune | 4 April 2024 Gulani, District Pune | 26 Farmers from District Pune |
| <i>Rabi</i> onion harvesting and post-harvest management | MGMG, ICAR-DOGR, Pune | 17 April 2024 Wafgaon, District Pune | 23 Farmers from District Pune |
| <i>Rabi</i> onion harvesting and post-harvest management | MGMG, ICAR-DOGR, Pune | 19 April 2024 Khairewadi, District Pune | 28 Farmers from District Pune |
| <i>Rabi</i> onion harvesting and post-harvest management | MGMG, ICAR-DOGR, Pune | 22 April 2024 Vetale, District Pune | 25 Farmers from District Pune |
| <i>Rabi</i> onion harvesting and post-harvest management | MGMG, ICAR-DOGR, Pune | 24 April 2024 Loni, District Pune | 27 Farmers from District Pune |
| IP management in agriculture research | ITMU, ICAR-DOGR, Pune | 25 April 2024 ICAR-DOGR, Pune | 52 Scientific staff, YPs, students from District Pune |
| <i>Rabi</i> onion harvesting and post-harvest management | MGMG, ICAR-DOGR, Pune | 26 April 2024 Pondewadi, District Pune | 26 Farmers from District Pune |
| <i>Kharif</i> onion production technology | MGMG, ICAR-DOGR, Pune | 14 May 2024 Kanhur Messai, District Pune | 24 Farmers from District Pune |
| <i>Kharif</i> onion production technology | MGMG, ICAR-DOGR, Pune | 15 May 2024 Gadakhwadi, District Pune | 26 Farmers from District Pune |
| Nursery preparation of <i>kharif</i> onion | MGMG, ICAR-DOGR, Pune | 31 May 2024 Dhamni, District Pune | 30 Farmers from District Pune |
| Agribusiness Incubation for promoting Agri-preneureship through startups (online) | ABI, ICAR-DOGR, Pune | 4-8 June 2024 ICAR-DOGR, Pune | 42 Incubatees from District Pune |
| Nursery management in <i>kharif</i> onion production | MGMG, ICAR-DOGR, Pune | 10 June 2024 Sakurdi, District Pune | 26 Farmers from District Pune |



| Topic of Training | Sponsoring Agency | Date and Venue | Participants |
|---|-----------------------|---|---|
| Nursery management in <i>kharif</i> onion production | MGMG, ICAR-DOGR, Pune | 11 June 2024 Khairenagar, District Pune | 27 Farmers from District Pune |
| Nursery management in <i>kharif</i> onion production | MGMG, ICAR-DOGR, Pune | 13 June 2024 Ranmala, District Pune | 25 Farmers from District Pune |
| Nursery management in <i>kharif</i> onion production | MGMG, ICAR-DOGR, Pune | 14 June 2024 Kahu Koyali, District Pune | 28 Farmers from District Pune |
| Onion crop production | SCSP, ICAR-DOGR, Pune | 19 June 2024 | 8 Farmers from District Pune |
| Onion nursery management | MGMG, ICAR-DOGR, Pune | 19 June 2024 Gosasi, District Pune | 23 Farmers from District Pune |
| Onion crop production | SCSP, ICAR-DOGR, Pune | 21 June 2024 Mirajgaon (Karjat), District Ahilyanagar | 70 Farmers from District Ahilyanagar |
| Onion crop production | SCSP, ICAR-DOGR, Pune | 22 June 2024 Wagha (Jamkhed), District Ahilyanagar | 30 Farmers from District Ahilyanagar |
| Onion nursery management | MGMG, ICAR-DOGR, Pune | 26 June 2024 Saigaon, District Pune | 25 Farmers from District Pune |
| Onion nursery management | MGMG, ICAR-DOGR, Pune | 27 June 2024 Jawulke, District Pune | 32 Farmers from District Pune |
| Onion nursery management | MGMG, ICAR-DOGR, Pune | 28 June 2024 Saburdi, District Pune | 27 Farmers from District Pune |
| Late <i>kharif</i> onion production technology | SCSP, ICAR-DOGR, Pune | 10 July 2024 Parner, District Ahilyanagar | 23 Farmers from District Ahilyanagar |
| Late <i>kharif</i> onion production technology | SCSP, ICAR-DOGR, Pune | 13 July 2024 ICAR-DOGR, Pune | 32 Farmers from District Pune |
| Onion nursery management | MGMG, ICAR-DOGR, Pune | 16 July 2024 Khairewadi, District Pune | 30 Farmers from District Pune |
| Onion nursery management | MGMG, ICAR-DOGR, Pune | 19 July 2024 Saigaon, District Pune | 26 Farmers from District Pune |
| Onion nursery management | MGMG, ICAR-DOGR, Pune | 22 July 2024 Ranmala, District Pune | 25 Farmers from District Pune |
| Late <i>kharif</i> onion production technology | SCSP, ICAR-DOGR, Pune | 23 July 2024 ICAR-DOGR, Pune | 32 Farmers from District Pune, Ahilyanagar and Aurangabad |
| Late <i>kharif</i> onion nursery management | MGMG, ICAR-DOGR, Pune | 6 August 2024 Khairenagar, District Pune | 23 Farmers from District Pune |
| Late <i>kharif</i> onion nursery management | MGMG, ICAR-DOGR, Pune | 8 August 2024 Saburdi, District Pune | 27 Farmers from District Pune |
| Late <i>kharif</i> onion nursery management | MGMG, ICAR-DOGR, Pune | 13 August 2024 Gadakhwadi, District Pune | 22 Farmers from District Pune |
| Improved Technologies of Onion and Garlic Cultivation | ICAR-DOGR, Pune | 21 August 2024 ICAR-DOGR, Pune | 80 students from District Pune |
| Late <i>kharif</i> onion nursery management | MGMG, ICAR-DOGR, Pune | 27 August 2024 Gosasi, District Pune | 26 Farmers from District Pune |

| Topic of Training | Sponsoring Agency | Date and Venue | Participants |
|---|---|--|--|
| Late <i>kharif</i> onion production technology | MGMG, ICAR-DOGR, Pune | 6 September 2024 Kahu Koyali, District Pune | 28 Farmers from District Pune |
| Onion and Garlic Cultivation and Value Addition | Project Director, ATMA, East Champaran | 16-18 September 2024 ICAR-DOGR, Pune | 26 Farmers from East Champaran (Bihar) |
| Onion and garlic crop management | MGMG, ICAR-DOGR, Pune | 25 September 2024 Kanhur Mesai, District Pune | 24 Farmers from District Pune |
| <i>Rabi</i> onion production technology | MGMG, ICAR-DOGR, Pune | 1 October 2024 Varude, District Pune | 26 Farmers from District Pune |
| <i>Rabi</i> onion production technology | MGMG, ICAR-DOGR, Pune | 4 October 2024 Saigaon, District Pune | 22 Farmers from District Pune |
| Scientists-Farmers/FPOs-Exporters Interface Programme on Improved Onion Production Technology and Export Supply Chain | ABI, ICAR-DOGR, Pune | 7 October 2024 ICAR-DOGR, Pune | 46 scientists from ICAR-DOGR, farmers from FPOs and exporters |
| Enteprenueral Development Programme (EDP) on “Commercial Onion Seed Production” (Online) | ABI & ITMU, ICAR-DOGR, Pune | 7-10 October 2024 ICAR-DOGR, Pune | 110 Representatives from Licensee Seed companies, breeders, seed scientists, SMS |
| <i>Rabi</i> onion production technology | SCSP, ICAR-DOGR, Pune | 8 October 2024 Karjat, District Ahilyanagar | 113 Farmers from District Ahilyanagar |
| Scientific Cultivation in Onion and Garlic | SCSP, ICAR-DOGR, Pune | 9 October 2024 ICAR-DOGR, Pune | 18 Farmers from District Ahilyanagar |
| Garlic production technology | SCSP, ICAR-DOGR, Pune | 10 October 2024 Jamkhed, District Ahilyanagar | 110 Farmers from District Ahilyanagar |
| <i>Rabi</i> onion production technology | MGMG, ICAR-DOGR, Pune | 11 October 2024 Pondewadi, District Pune | 27 Farmers from District Pune |
| <i>Rabi</i> onion crop management | MGMG, ICAR-DOGR, Pune | 1 November 2024 Khadakwadi | 25 Farmers from District Pune |
| Commercial cultivation of onion in eastern parts of UP | TSP, ICAR-DOGR, Pune | 4-5 November 2024 IIVR, Varanasi (UP) | 60 Farmers from Districts Varanasi and Mirzapur |
| Training on “Improved Onion Seed Production” (Online) | ABI & ITMU, ICAR-DOGR, Pune | 5 November 2024 ICAR-DOGR, Pune | 40 Members of FPOs from Maharashtra |
| <i>Kharif</i> onion harvesting technology | MGMG, ICAR-DOGR, Pune | 18 November 2024 Gulani | 23 Farmers from District Pune |
| Hands-on Training for srartups on Transforming Onion and Garlic into Profitable Products | ICAR-DOGR, Pune and NIFTEM, Kundli, Sonipat | 24 November 2024 ICAR-DOGR, Pune | 38 members of startups from District Sonipat (Haryana) |
| Improved cultivation and seed production of onion and garlic | TSP, ICAR-DOGR, Pune | 16-17 December 2024 Navapur, District Nandurbar (MS) | 210 Farmers from District Nandurbar |
| Onion Cultivation, Seed Production and Processing | Marathwada Navnirman Lokayat, Ambajogai | 18-20 December 2024 ICAR-DOGR, Pune | 20 farmers from Hortimix Farmers Producer Company, District Solapur |
| Improved cultivation of onion on the occasion of Kisan Diwas | TSP, ICAR-DOGR, Pune | 23 December 2024 ICAR-DOGR, Pune | 60 Farmers from District Pune |

Beside these, 47 trainings were organized under NEH Plan by ICAR-DOGR in NEH Region for 2685 farmers.

Participation in Exhibition

| Date | Exhibition | Organizers | Venue |
|---------------------|---|--|--|
| 17-21 January 2024 | Krushik 2024 | KVK, Baramati | KVK, ADT, Baramati |
| 8-11 February 2024 | Global Krishi Mahotsav 2024 | KVK, Narayangaon | KVK, Gramonnati, Narayangaon |
| 12 February 2024 | Technology Day: IoT Based Technologies in Onion | ICAR-DOGR, TIH and KVK, Baramati | Mirajgaon, Karjat, Ahilyanagar |
| 21-23 February 2024 | Western Regional Agriculture Fair (WRAF) 2023-24 on farmers Prosperity through Climate friendly Sustainable Agriculture | VNMKV Parbhani | VNMKV Parbhani |
| 28-29 February 2024 | GMRT Science Exhibition 2024 | Giant Metrewave Radio Telescope (GMRT), Khodad | Tata Institute of Fundamental Research (TIFR), Narayangaon |
| 11-15 December 2024 | Kisan Agri Show 2024 | Pune International Exhibition and Convention Centre (PIECC), Moshi, Pune | Kisan Forum Pvt Ltd, Pune |
| 23 December 2024 | Agricultural Exhibition | ICAR-ATARI, Pune | ICAR-ATARI, Pune |

Lectures delivered

| Topic | Event and Organizer | Date and Venue |
|--|--|---|
| A. J. Gupta | | |
| TSP activities and improved varieties of onion and garlic | Training program on “Commercial cultivation of onion and garlic” under TSP | 31 January 2024 Ambegaon, Pune |
| Onion and Garlic: Improved varieties and production techniques | Three days “National Agricultural Fair” (NAF-2024) on 3-5 Feb, 2024 organized by ICAR-IIVR, Varanasi | 5 February 2024 ICAR-IIVR, Varanasi |
| Commercial cultivation of onion | Training program on “Onion production technology” under TSP | 3 March 2024 Ambegaon, Pune |
| Impact of TSP activities and improved varieties of onion | Training program on “Commercial cultivation of onion in tribal belts of Nandurbar” under TSP | 20 March 2024 Khandwara, Nandurbar |
| TSP activities and improved varieties of onion and garlic | Training program on “Scientific cultivation of onion and garlic” | 27 March 2024 ICAR-DOGR, Pune |
| Onion and garlic production | Three days training program on “Onion and garlic cultivation and value addition” under ATMA | 16-18 September 2024 ICAR-DOGR, Pune |
| Improved varieties and production technology of onion and garlic | Training program on “Commercial cultivation of onion in eastern Uttar Pradesh” under TSP in collaboration with ICAR-IIVR, Varanasi and Agrimitra FPC, Mirzapur | 4 November 2024 Sonbhadra |
| Improved production technology of onion and garlic | “Improved cultivation and seed production of onion and garlic” under TSP | 16-17 December 2024 Navapur, Nandurbar |
| TSP activities and improved varieties of onion and garlic | Kisan Diwas on “Improved cultivation of onion” under TSP | 23 December 2024 ICAR-DOGR, Pune |

| Topic | Event and Organizer | Date and Venue |
|---|--|---------------------------------------|
| Ram Dutta | | |
| Management of fungal diseases in onion and garlic | Three-day training programme on “Onion and garlic cultivation and value addition” under ATMA scheme for farmers from East Champaran, Bihar | 17 September 2024 ICAR-DOGR, Pune |
| Integrated disease management in onion | Scientist-farmers/FPO – Exporter interface on “Improved onion production technology and export supply chain” | 07 October 2024 ICAR-DOGR, Pune |
| Management of fungal diseases in onion | Three-day training programme on “Onion cultivation, seed production and processing” for farmers from the district Solapur | 19 December 2024 ICAR-DOGR, Pune |
| Disease management for residue-free onion production | One day training programme on “Residue free onion production technology” for farmers from the district of Pune | 21 January 2025 ICAR-DOGR, Pune |
| | One-day training programme on “Residue-free onion production technology” for farmers from the district Pune | 24 January 2025 ICAR-DOGR, Pune |
| Integrated pest and disease management in onion | One day training programme on “Advance production technology for onion crop” | 25 March 2025 ICAR-DOGR, Pune |
| S. S. Gadge | | |
| Role of field demonstrations and self-help groups in improving socio-economic status of onion producing farmers | Training on onion “Production, post-harvest and processing technology” organized by ATMA Nashik and ICAR-DOGR, Pune | 8-10 January 2024 ICAR-DOGR, Pune |
| | | 17-19 January 2024 ICAR-DOGR, Pune |
| <i>Rabi</i> onion crop management | Training on “ <i>Rabi</i> onion crop management” organized under MGMG scheme by ICAR-DOGR, Pune | 23 January 2024 Saburdi, Pune |
| | | 29 January 2024 Mitgudwadi, Pune |
| | | 23 February 2024 Khadakwadi, Pune |
| | | 26 February 2024 Sakurdi, Pune |
| | | 11 March 2024 Wafgaon, Pune |
| | | 15 March 2024 Saigaon, Pune |
| Role of SHGs in improving socio-economic status of onion producing farmers | Training-cum-awareness programme on “Scientific cultivation of onion and garlic” under TSP by ICAR-DOGR, Pune | 27 March 2024 ICAR-DOGR, Pune |
| <i>Rabi</i> onion harvesting and post-harvest management | Training on” <i>Rabi</i> onion harvesting and post-harvest management” organized under MGMG scheme by ICAR-DOGR, Pune | 1 April 2024 Mitgudwadi, Pune |
| | | 2 April 2024 Varude, Pune |
| | | 18 April 2024 Gulani, Pune |
| | | 17 April 2024 Wafgaon, Pune |



| Topic | Event and Organizer | Date and Venue |
|--|--|--|
| | | 19 April 2024 Khairewadi, Pune |
| | | 22 April 2024 Vetale, Pune |
| | | 24 April 2024 Loni, Pune |
| | | 26 April 2024 Pondewadi, Pune |
| Kharif onion production technology | Training on “Kharif onion production technology” organized under MGMG scheme by ICAR-DOGR, Pune | 14 May 2024 Kanhur Messai, Pune |
| | | 15 May 2024 Gadakhwadi, Pune |
| Nursery preparation of kharif onion production | Training on “Nursery preparation of kharif onion” organized under MGMG scheme by ICAR-DOGR, Pune | 31 May 2024 Dhamni, Pune |
| | | 10 June 2024 Sakurdi, Pune |
| | | 11 June 2024 Khairnagar, Pune |
| | | 13 June 2024 Ranmala, Pune |
| | | 14 June 2024 Kahu Koyali, Pune |
| Onion nursery management | Training on “Onion nursery management” organized under MGMG scheme by ICAR-DOGR, Pune | 19 June 2024 Gosasi, Pune |
| Kharif and late kharif onion production technology | Training on “Onion crop production” organized under SCSP by ICAR-DOGR, Pune | 21 June 2024 Mirajgaon (Karjat), Ahilyanagar |
| Onion nursery management | Training on “Onion nursery management” organized under MGMG scheme by ICAR-DOGR, Pune | 26 June 2024 Saigaon, Pune |
| | | 27 June 2024 Jawulke, Pune |
| | | 28 June 2024 Saburdi, Pune |
| | | 16 July 2024 Khairewadi, Pune |
| | | 19 July 2024 Saigaon, Pune |
| | | 22 July 2024 Ranmala, Pune |
| Late kharif onion production technology | Training on “Late kharif onion production technology” organized under SCSP by ICAR-DOGR, Pune | 23 July 2024 ICAR-DOGR, Pune |
| Late kharif onion nursery management | Training on “Late kharif onion nursery management” organized under MGMG by ICAR-DOGR, Pune | 18 August 2024 Khairnagar, Pune |
| | | 8 August 2024 Saburdi, Pune |
| | | 13 August 2024 Gadakhwadi, Pune |
| | | 27 August 2024 Gosasi, Pune |
| Late kharif onion production technology | Training on “Late kharif onion nursery management” organized under MGMG by ICAR-DOGR, Pune | 18 September 2024 Kahu Koyali, Pune |
| Onion and garlic crop management | Training on “Onion and garlic crop management” organized under MGMG by ICAR-DOGR, Pune | 25 September 2024 Kanhur Mesai, Pune |

| Topic | Event and Organizer | Date and Venue |
|---|--|---|
| <i>Rabi</i> onion production technology | Training on “ <i>Rabi</i> onion production technology” organized under MGMG by ICAR-DOGR, Pune | 1 October 2024 Varude, Pune |
| <i>Rabi</i> onion production technology | Training on “ <i>Rabi</i> onion production technology” organized under MGMG by ICAR-DOGR, Pune | 18 October 2024 Saigaon, Pune |
| Interaction on onion seed production | Online training on “Commercial Onion Seed Production” organized by ABI & ITMU, ICAR-DOGR, Pune | 7-10 October 2024 ICAR-DOGR, Pune |
| Onion and garlic cultivation technologies | Training on “Scientific cultivation in onion and garlic” organized under SCSP by ICAR-DOGR, Pune | 9 October 2024 ICAR-DOGR, Pune |
| <i>Rabi</i> onion production technology | Training on “ <i>Rabi</i> onion production technology” organized under MGMG by ICAR-DOGR, Pune | 11 October 2024 Pondewadi, Pune |
| <i>Rabi</i> onion crop management | Training on “ <i>Rabi</i> onion crop management” organized under MGMG by ICAR-DOGR, Pune | 1 November 2024 ICAR-DOGR, Pune |
| Onion bulb production technology | Online training on “Improved Onion Seed Production” organized by ABI & ITMU, ICAR-DOGR, Pune | 5 November 2024 ICAR-DOGR, Pune |
| <i>Kharif</i> onion harvesting technology | Training on “ <i>Kharif</i> onion harvesting technology” organized under MGMG by ICAR-DOGR, Pune | 18 November 2024 ICAR-DOGR, Pune |
| Improving socio-economic status of onion producing farmers through self help groups | Training on “Onion cultivation, seed production and processing” organized by Marathwada Navnirman Lokayat, Ambajogai and ICAR-DOGR | 18-20 December 2024 ICAR-DOGR, Pune |
| Kalyani Gorrepati | | |
| Post-harvest management of onion and garlic | Training programme on “Onion and garlic cultivation and value addition” under ATMA scheme for farmers from East Champaran, Bihar | 16-18 September 2024 ICAR-DOGR, Pune |
| Post-harvest management of onion and field visit | Three days training programme on “Onion cultivation, seed production and processing” for farmers from district Solapur | 18-20 December 2024 ICAR-DOGR, Pune |
| Processing and value addition of garlic | Webinar on “Garlic processing and value addition” organized by NIFTEM, Thanjavur | 17 October 2024 Online |
| Rajiv B. Kale | | |
| Production of export-quality onions | Organized by MSAMB under SMART project | 01 July 2024 Maharashtra State Agriculture Marketing Board, Pune |
| Production of export-quality onions | Organized by MSAMB under SMART project | 12 August 2024 Maharashtra State Agriculture Marketing Board, Pune |
| Pre- and post-harvest practices in onion cultivation | Organized by MSAMB under SMART project | 12 August 2024 Maharashtra State Agriculture Marketing Board, Pune |
| Onion production technology | 91 st Farmer–Scientist Programme Organized by KVK, Chhatrapati Sambhajinagar | 1 November 2024 KVK, Chhatrapati Sambhajinagar |

| Topic | Event and Organizer | Date and Venue |
|--|--|---|
| Seed production in onion | Organized by DSC, Narayangaon | 10 February 2024 Gunjalwadi, Belhe, Taluka Junnar, Pune |
| Pranjali A. Gedam | | |
| Nutrient and Water management in onion | Three days training program on “Onion production, post-harvest and processing technology” for farmers of District Nashik | 17-19 January 2024 ICAR-DOGR, Pune |
| Abiotic stress management in onion and garlic | Three days training program on “Onion and garlic cultivation and value addition” for farmers from East Champaran, Bihar | 16-18 September 2024 ICAR-DOGR, Pune |
| Abiotic stress management in onion | Three days training program on “Onion cultivation, seed production and processing” for farmers from Solapur, Maharashtra | 18-20 December 2024 ICAR-DOGR, Pune |
| Soumia P.S. | | |
| Insecticide safety management | Three days training programme on “Onion and garlic cultivation and value addition” under ATMA scheme for farmers from East Champaran, Bihar | 16-18 September 2024 ICAR-DOGR, Pune |
| Bhushan Bibwe | | |
| Post-harvest management and processing in onion | Training Programme on “Onion production, post-harvest and processing technology” | 08-10 January 2024 ICAR-DOGR, Pune |
| Post-harvest management in onion | Training program on “Improved cultivation practices of onion” | 18 February 2024 ICAR-DOGR, Pune |
| Processing of onion and garlic | Training program on “ <i>Onion and garlic cultivation and value addition</i> ” under ATMA scheme for farmers from East Champaran, Bihar. | 16–18 September 2024 ICAR-DOGR, Pune |
| Mechanization and post-harvest management | Collaborative training organized by ICAR-DOGR and RAMETI, Pune. | 19 September 2024 ICAR-DOGR, Pune |
| Processing of onion | Training program on “ <i>Onion cultivation, seed production and processing</i> ” for farmers from Solapur district | 18–20 December 2024 ICAR-DOGR, Pune |
| Onion processing and value addition | Webinar organized by State level technical institute –PMFME, Krishi Vigyan Kendra, Baramati | 12 December 2024 ICAR-DOGR, Pune |
| Jayalakshmi, K. | | |
| Integrated disease management in onion | Training programme on “Improved cultivation practice of onion” organized by ICAR-DOGR, | 7 February 2024 ICAR-DOGR, Pune |
| Pest and disease diagnosis and their management in onion | Training programme rganized by Bayer Crop Science | 7 March 2024 ICAR-DOGR, Pune |
| Management of fungal diseases in onion and garlic | Three days training programme on “Onion and garlic cultivation and value addition” under ATMA scheme for farmers from East Champaran, Bihar, | 16-18 September 2024 ICAR-DOGR, Pune |
| Integrated disease management in onion | Scientist-farmers/FPO – Exporter interface on “Improved onion production technology and export supply chain” | 7 October 2024 ICAR-DOGR, Pune |
| Management of fungal diseases in onion | Three days training programme on “Onion cultivation, seed production and processing” for farmers from district Solapur during | 18-20 December 2024 ICAR-DOGR, Pune |

K. > Success Story

Onion Seed Villages: Empowering marginalized SC farmers' community

Ahilyanagar district of Maharashtra is second largest producer of onion in Maharashtra. However, the productivity of onion is low. Scheduled cast farmers were doing the traditional farming without adoption of improved technologies which led to low productivity in Onion. In the year 2021, Gurav Pimpri, Rajapur, Halgaon villages of Karjat Tahsil in Ahilyanagar District of Maharashtra were selected under SCSP project. The majority of the farmers in the region were from the Scheduled Caste (SC) community, who were doing traditional farming.

Intervention by ICAR-DOGR

ICAR-DOGR, in collaboration with KVK, Agricultural Development Trust, Baramati initiated a SCSP project to promote high-yielding, disease-resistant onion varieties suitable for the local climate and soil conditions. The project involved the following interventions:

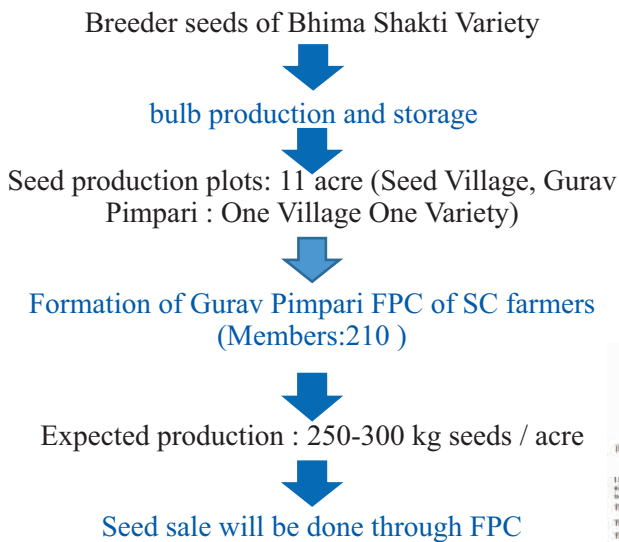
- 1. Demonstration of improved variety and cultivation practices:** ICAR-DOGR demonstrated two new onion varieties, Bhima Super, and Bhima Shakti which were specifically developed for *Kharif* and *Rabi* season. These varieties were found to have higher yields, better disease resistance, and improved bulb quality compared to traditional varieties.
- 2. Training and Capacity Building:** ICAR-DOGR provided training to farmers on the new varieties, seed production, and marketing techniques. This capacity building helped farmers to improve their skills and knowledge in onion seed production and marketing.
- 3. Establishment of Farmers' Collective:** Gurav Pimpri Farmers Producer Company in the year 2022 with the objective of empowering SC farmers in the region.
- 4. Development of Seed villages:** Onion is highly cross-pollinated crop Onion which is hurdle for quality seed production. Seed Village concept was implemented with theme of 'One variety One village' for high quality seed production. The company used the new varieties developed by ICAR-DOGR and implemented good agricultural practices (GAPs) to ensure consistent seed quality. The produced seeds are sold to the member of FPC and local farmers with low price.

These interventions by ICAR-DOGR had a significant impact on the local onion seed production and onion productivity:

- 1. Increased Yield:** The new onion varieties developed by ICAR-DOGR resulted in higher yields for farmers, with an average increase of 20% compared to traditional varieties. The farmers before intervention producing 25 to 30 tonnes of yield per ha started producing the 40 to 42 tonnes of yield per ha.
- 2. Improved Disease Resistance:** The disease-resistant varieties developed by ICAR-DOGR reduced the incidence of diseases in onion crops, resulting in lower crop losses and improved overall crop health.
- 3. High shelf life during storage:** Bhima Shakti variety have good storage life up to six month which reduces the storage losses and fetch good prices for onion.
- 4. Seed Sufficiency:** The village achieved self-sufficiency in onion seed production. Farmers are now able to cultivate their own high-quality seeds, ensuring consistent and reliable planting material. During 2022-23, about 2200 kg seeds of Bhima Shakti variety were produced and during 2023-24, about 4000 kg seeds were produced. This FPC is distributing this seed among the farmers with no profit no loss basis.

5. Enhanced Market Access: With consistent production of quality onions, farmers gained better access to markets and were able to command higher prices for their produce resulting in improved profitability and livelihoods.
6. Empowered Farmers: The FPC empowered farmers, particularly those belonging to the Scheduled Caste community, by providing them with a collective voice, bargaining power, and access to essential resources.
7. Increased Farmer Participation: The training and capacity building by ICAR-DOGR encouraged more farmers to participate in onion seed production and quality onion production, leading to increased economic activity and employment opportunities in the region.

Development of seed village and seed supply chain through farmer producer company under SCSP at Karjat, Ahilyanagar



Visit to onion seed production plots under SCSP



Onion seed produced by the farmers under SCSP

Conclusion

The success story of the Onion Seed Village demonstrates the potential of collaborative efforts between farmers, and research institutions, to improve agricultural productivity and livelihoods. The intervention by ICAR-DOGR and the Onion Seed Village has created a model for sustainable onion seed production, dissemination of improved varieties of onion, thereby enhancing onion productivity, which can be replicated in other regions to promote agricultural development and improve the lives of small-scale farmers.

S. S. Gadge, R. B. Kale and V. Mahajan



L. > Research Projects

Institute Projects

IXX16154: Genetic improvement of red onion

PI: Dr. A.J. Gupta and **Co-PIs:** Dr. V. Mahajan, Dr. S.J. Gawande, Dr. Anandhan, S, Dr. V. Karuppaiah, Dr. Kalyani Gorrepati, Mrs. Ashwini P. Benke, Dr. Pranjali Gedam., Dr. Y.P. Khade and Dr. Rajkumar Dagadkhair

IXX16120: Genetic improvement of white, yellow onion and other *Allium* species

PI: Dr. Hem Raj Bhandari and **Co-PIs:** Dr. A.J. Gupta, Dr. Ram Dutta Dr. SJ Gawande, Dr. Karuppaiah, V, Mrs. Ashwini P. Benke, Dr. Pranjali Gedam., Dr. Soumia P.S., Dr. Y.P. Khade, Dr. Shabeer Ahmed (NRCCG, Pune) and Dr. Geetika Shameer (CITH, Srinagar)

IXX16060: Development of onion hybrids for quality and yielding traits

PI: Dr. A.J. Gupta, and **Co-PIs:** Dr. V. Mahajan, and Dr. Ashwini P. Benke

IXX16059: Genetic improvement of garlic through conventional and biotechnological approaches

PI: Mrs. Ashwini P. Benke and **Co-PIs:** Dr. Hem Raj Bhandari, Dr. A.J. Gupta, Dr. S.J. Gawande, Dr. Pranjali Gedam., and Dr. Geetika Shameer (CITH, Srinagar)

IXX16093: Biotechnological approaches for improvement of onion

PI: Dr. Anandhan S. and **Co-PIs:** Dr. Soumia P.S. and Dr. Y.P. Khade

IXX16107: Breeding for abiotic stress tolerance in *Allium* species

PI: Dr. Y.P. Khade and **Co-PIs:** Dr. Hem Raj Bhandari, Dr. A.J. Gupta, Dr. Pranjali Gedam and Mr. Radhakrishna A.

IXX16221: Abiotic stress management in onion and garlic

PI: Dr. Pranjali Gedam and **Co-PIs:** Dr. V. Mahajan, Dr. A. J. Gupta, Dr. S.J. Gawande, Dr. A. Thangasamy, Dr. Y.P. Khade, Dr. Satish Kumar., Dr. Sanket More., Dr. Kiran Bhagat (ICAR-DFR, Pune), Dr. Shabeer Ahmed (NRCCG, Pune) and Dr. Rajkumar Dagadkhair

IXX16403: Development of improved nutrient management practices for onion and garlic

PI: Dr. A. Thangasamy and **Co-PIs:** Dr. V. Karuppaiah, Dr. Soumia P.S., Dr. Pranjali Gedam, Dr. Bhushan Bibwe and Dr. Shabeer Ahmed (NRCCG, Pune)

IXX16077: Bio-intensive IPM strategies for insect pests of Onion and Garlic

PI: Dr. V. Karuppaiah **Co-PIs:** Dr. Ram Dutta, Dr. A. Thangasamy and Dr. Soumia P.S.

IXX16111: Post-harvest management of storage insect pests and diseases in onion and garlic

PI: Dr. Soumia PS and **Co-PIs:** Dr. Ram Dutta, Dr. S.J. Gawande, Dr. A. Thangasamy, Dr. V. Karuppaiah and Dr. Kalyani Gorrepati

IXX16074: Development, refinement and validation of management strategies for major fungal diseases of onion and garlic

PI: Dr. Ram Dutta and **Co-PIs:** Dr. V. Mahajan, Dr. S.J. Gawande, V. Karuppaiah, Mrs. Ashwini P. Benke, Dr. Soumia P.S., Dr. Y.P. Khade, Dr. Kiran Bhagat (DFR, Pune), Dr. Satish Kumar, Mr. Radhakrishna A. and Dr. Jayalakshmi K

IXX16061: Biotechnological approaches for biotic stress management

PI: Dr. S.J. Gawande and **Co-PIs:** Dr. Ram Dutta, Dr. S. Anandhan, Dr. V. Karuppaiah, Dr. Pranjali Gedam, Dr. Soumia P.S. and Dr. Y.P. Khade, Dr. Jayalakshmi K

IXX16540: Epidemiology and Bio-management of major fungal diseases of Onion and Garlic

PI: Dr. Jayalakshmi K. and **Co-PIs:** Dr. Ram Dutta, Dr. Suresh J. Gawande and Mrs. Ashwini P. Benke

IXX19658: Exploring the molecular, biochemical and microbial processes associated with onion spoilage for devising eco-friendly solutions to post-harvest losses

PI: Dr. Satish Kumar, **Co-PIs:** Dr Ram Dutta, Dr. Suresh Gawande, Dr. Vijay Mahajan, Dr. Amarjeet Gupta, Dr. Radhakrishna A, Dr. Kalyani Gorrepati, Dr. Rajiv Kale, Dr. Bhushan Bibwe, Dr. Pranjali Gedam and Dr. Rajkumar Dagadkhair

IXX16210: Refinement of storage technologies in onion and garlic

PI: Dr. Kalyani Gorrepati, **Co-PIs:** Dr. Bhushan Bibwe, Dr. Rajkumar Dagadkhair, Dr. S.S. Gadge and Dr. R.B. Kale

IXX16113: Processing and value addition in onion and garlic

PI: Dr. Bhushan Bibwe and **Co-PIs:** Dr. Kalyani Gorrepati and Dr. Rajkumar Dagadkhair

IXX16114: Mechanization in onion and garlic

PI: Dr. Bhushan Bibwe and **Co-PIs:** Dr. S.S. Gadge, Dr. Kalyani Gorrepati and Dr. R.B. Kale

IXX19349: Enhancing the nutraceutical delivery potential of onion through probiotication

PI: Dr. Rajkumar Dagadkhair, **Co-PIs:** Kalyani Gorrepati, Dr. Bhushan Bibwe, Dr. Ram Dutta, Dr. S. Gawande, Dr. Satish Kumar, Dr. Rajiv Kale and Pranjali Gedam

IXX16214: Transfer of improved onion and garlic technologies and impact assessment

PI: Dr. S.S. Gadge and **Co-PIs:** Dr. R.B. Kale

IXX16155: Novel approaches for transfer of Onion and Garlic Technologies

PI: Rajiv B Kale and **Co-PIs:** Dr. S.S. Gadge

Externally Funded/Other projects

Project 1: All India Network Research Project on Onion and Garlic (AINRPOG)

Dr. V. Mahajan, Nodal Officer, Funding: ICAR

Project 2: DUS testing through ICAR-SAU's system

Dr. A.J. Gupta, Nodal Officer, Funding: PPV&FRA



Project 3: Intellectual Property Management and Transfer/ Commercialization of Agricultural Technology Scheme (IPMTCATS)

Dr. Rajiv B. Kale, PI & Member Secretary, Funding: ICAR

Project 4: Agri Business Incubation Project

PI: Dr. Rajiv B.Kale, **Co-PI:** Dr. Kalyani Gorrepati, Funding: ICAR

Project 5: Tribal Sub-Plan (TSP) for onion and garlic

Dr. A.J. Gupta, Nodal Officer, Co-PI: Dr. S. S. Gadge, Dr. R. B. Kale, Mrs. Ashwini P. Benke, Mr. A. R. Wakhare, Mr. H. S. Gawali

Project 6: North East Hill Plan

Dr. V. Mahajan, Nodal Officer, Dr. S.S. Gadge, Funding: ICAR

Project 7: Scheduled Caste Sub-Plan (SCSP) for onion and garlic

Dr. S. S. Gadge, Nodal Officer, Dr. R.B. Kale and Dr. A. Thangasamy, Funding: ICAR

Project 8: Haploid induction in onion (*Allium cepa* L.) through genome elimination

PI: Dr. S. Anandhan, Funding: ICAR-National Fellow

Project 9: Development of cytoplasmic male sterile lines in onion (*Allium cepa* L.) through targeted mutagenesis of *AcMSH1* gene

PI: Dr. S. Anandhan, **Co-PIs:** Ashok Kumar, Funding: Department of Science and Technology, New Delhi

Project 10: Tapping the potential of stingless bee *Tetragonulairidipennis* Smith for pollination enhancement and profitable onion seed production

PI: Karuppaiah V., Funding: SERB-Department of Science and Technology, New Delhi

Project 11: Deciphering the gut microbiome profile of Apis species in Onion (*Allium cepa*) to enhance ecosystem

PI: Dr. Soumia P.S., Funding: SERB-Department of Science and Technology, New Delhi

Project 12: Development of hybrids in onion: A joint venture with Beej Sheetal

PI: Dr. A.J. Gupta, Funding: Beej Sheetal Seeds Pvt. Ltd. and ICAR-DOGR

Project 13: Efficacy evaluation of ICAR-CIRCOT Nano-Sulphur as fertilizer formulation for different field crops (Collaborative Project ICAR-DOGR and ICAR-CIRCOT)

PI: Dr. A. Thangasamy, **Co-PI:** Dr. Bhushan Bibwe

Project 14: POLY4 Rate Response Trial on Onion and Garlic

PI: Dr. A. Thangasamy, Funding: AngloAmerican, New Delhi

Project 15: Evaluation of bio-efficacy of GPH 1821 for controlling weeds in onion

PI: Dr. A. Thangasamy, Funding: UPL India Ltd. Mumbai

Project 16: Bio-efficacy Evaluation of Bensulf SUPERFAST on Onion

PI: Dr. A. Thangasamy, Funding: Smartchem Technologies Limited, Pune

Project 17: Evaluation of RCF's Nano-Urea in onion

PI: Dr. A. Thangasamy, Funding: Rashtriya Chemicals and Fertilizers Limited, Mumbai

Project 18: Evaluation of Foliar Application of Coromandel Nano-Urea in Onion Crop

PI: Dr. A. Thangasamy, Funding: Coromandel International Limited, Hyderabad

Project 19: Smart-SNWM: Smart Soil specific Nutrient and Water Management at different depths using IoT and AI/ML (Smart-SNWM) for onion crop

PI: Dr. A. Thangasamy, Funding: TIH-IIT, Mumbai

Project 20: Design and development of an ergonomic onion compartment and performance evaluation of environment control-based onion storage system.

PI: Dr. Bhushan Bibwe, **Co-PIs:** Vijay Mahajan, Kalyani Gorrepati Rajkumar Dagadkhair, and Rajiv Kale and Funding: Tata Steel Pvt Ltd

Project 21: Capacity Building and Demonstration of improved technologies to enhance water use efficiency in onion

PI: Dr. Rajiv B. Kale and **Co-PIs:** Dr. S.S. Gadge and Dr. A. Thangasamy

Funding: Development Support Centre, Narayangaon, Pune

Project 22: Multi-parameter, Remote-controlled Energy-Autonomous Smart Agristation (EAgriS) and Data Analytics

PI: Dr. S.J. Gawande

Funding: TIH-IIT, Mumbai

Project 23: Image-based, Intellectual Diagnosis System for pests, disease and abiotic stress management in Onion Crop (Onion-Scan) for onion crop

PI: Dr. S.J. Gawande, **Co-PI:** Dr. Rajiv Kale

Funding: TIH-IIT, Mumbai

Project 24: I-DiagnOCe: IoT-based, Intelligent, Detection and Prediction Platform for Diseases and trips attack in Onion Crops based on real-time Captured data

PI: Dr. S.J. Gawande, **Co-PI:** Dr. Karuppaiah V.

Funding: TIH-IIT, Mumbai

Project 25: Comprehensive Muti-modal image data acquisition for aerial phenotyping

PI: Dr. S.J. Gawande, **Co-PIs:** Dr. Pranjali Gedam, Dr. Bhushan Bibwe

Funding: TIH-IIT, Mumbai

M. Awards, Honours and Recognitions

| Name of Scientist | Award / Recognition / Responsibility | Event / Authority / Details |
|-------------------|---|---|
| Dr. Gupta A. J. | Nominated as Member, Judging Committee for selection of Best Poster Presentation (Session IV: Post-Harvest Management of Vegetable Crops) | Organized by ISVS in collaboration with ICAR–Indian Institute of Vegetable Research and ANDUAT during 24–26 February 2024 at Kumarganj, Ayodhya |
| | Guest of Honour | 18th Agriculture Technology Mahotsava organized by KVK, Nandurbar during 16–21 December 2024 |
| | In-charge, Breeder Seed Production (w.e.f. 05.07.2023 – till date) | ICAR–Directorate of Onion and Garlic Research, Pune and SATHI Portal |
| | Member, Variety Identification Committee (Onion & Garlic) | Committee constituted by Hon'ble DDG (Horticultural Sciences), ICAR vide File No. Hort.10(86)/2023-HS-II (E-270712), dated 24.07.2024 |
| | Councillor (Scientific Member), Executive Body | Indian Society of Alliums; as per proceedings of the 15th Executive Body Meeting held on 09.09.2023 (continuing) |
| | Joint Editor, Journal of Alliums | Published by the Indian Society of Alliums; approved in the 15th Executive Body Meeting held on 09.09.2023 (continuing) |
| | Member Secretary, Task Force Committee for Monitoring DUS Trials (Onion & Garlic) | Committee constituted by PPV&FR Authority, New Delhi for Rabi 2024; coordinated through ICAR-DOGR, Pune |
| Dr. P. S. Soumia | Best Poster Presentation Award (Joint) | International Conference on Plant Protection in Horticulture (ICPPH-2024), ICAR–Indian Institute of Horticultural Research, Bengaluru |
| Dr. V. Karuppaiah | Best Poster Presentation Award (Joint) | ICPPH-2024, ICAR-IIHR, Bengaluru |
| Dr. Ram Dutta | Subject Matter Expert (Onion & Garlic) | Laghu Udyog Bharati, Rajasthan |
| | Deputed for Nursery Accreditation | National Horticulture Board (NHB) |
| | Recognized as Research Guide / Faculty | ICAR–Indian Agricultural Research Institute, New Delhi |

| Name of Scientist | Award / Recognition / Responsibility | Event / Authority / Details |
|--------------------|--|---|
| Dr. Bhushan Bibawe | Resource Person (International Delegation) – ERASMUS Project | Delivered expert talk on “ <i>Digital Agriculture: Transforming Onion Post-Harvest Management (Production, Mechanization, Storage & PHM)</i> ” during International Workshop on Agriculture Technology, organized by COEP Technological University, Pune (3–4 October 2024) |
| | Expert Talk (Guest Lecture) – RAWE Programme | Delivered lecture on <i>Post-Harvest Management of Onion</i> during RAWE Programme at Akharwadi Village, organized by Dr. D. Y. Patil College of Agricultural Business Management, Pune on 09 August 2024 |
| | Resource Person – MAHA-KISAN Chaupal (Farmer Meet) | Delivered expert talk on <i>Post-Harvest Management in Onion and Modern Agriculture</i> ; organized by Green TV in association with Madhya Pradesh Agriculture Department at Barnagar, Ujjain on 20 December 2024 |
| | Expert Speaker – Webinar | Delivered talk on <i>Onion Processing and Value Addition</i> in a webinar organized by State Level Technical Institute – PMFME |
| | Reviewer (International Journal) | Reviewed manuscript (ID: TIFS-D-24-00646) titled “ <i>From Agroindustrial Waste to Nutraceuticals: Potential of Mango Seed for Sustainable Product Development</i> ” for Trends in Food Science & Technology (Impact Factor: 15.1) |

N. > Publications

Publication in referred journals

1. Benke, A. P., Mahajan, V., and Mokate, D. N., 2024. *Morphological and molecular diversity of some locally grown, underutilized and cultivated Allium species from India*. Genetic Resources and Crop Evolution, 1–20.
2. Bhushan, B., Bharat, S., Satish Kumar, C. K., Veena Devi, D. P. C., Alla Singh, Manesh Chander Dagla, 2024. Beyond colors: Health benefits of maize anthocyanins. *Applied Food Research*, 4(1), Article 100399.
3. Champaneri, D. D., Desai, K. D., Sharma, V., Madane, D. A., and More, S. J., 2024. A synoptic review of deficit irrigation methods: Sustainable water-saving strategies in vegetable cultivation. *Water Supply*. <https://doi.org/10.2166/ws.2024.195>.
4. Dutta, R., Jayalakshmi, K., Radhakrishna, A., Kumar, S., and Mahajan, V., 2024. Active prevalence of *Fusarium falciforme* and *F. acutatum* causing basal rot of onion in Maharashtra, India. *Journal of Fungi*, 10, Article 413. <https://doi.org/10.3390/jof10060413>
5. Dutta, R., Jayalakshmi, K., Radhakrishna, A., Kumar, S., and Mahajan, V., 2024. Prevalence of *Fusarium* species causing basal rot in onion in Maharashtra. *Journal of Fungi*, 10, 413. <https://doi.org/10.3390/jof10060413>
6. Dutta, R., Jayalakshmi, K., Satish Kumar, A. Radhakrishna, Manjunathagowda, D. C., Sharath, M. N., Gurav, V. S., and Mahajan, V., 2024. Insights into cumulative effect of *Colletotrichum* & *Fusarium* causing anthracnose–twister in onion. *Scientific Reports*, 14(1), 9374. <https://doi.org/10.1038/s41598-024-59822-w>.
7. Dutta, R., Jayalakshmi, K., Satish Kumar, Radhakrishna, A., Manjunathagowda, D. C., Nadig, S. M., Gurav, V. S., and Mahajan, V., 2024. Insights into the cumulative effect of *Colletotrichum gloeosporioides* and *Fusarium acutatum* causing anthracnose-twister disease complex of onion. *Scientific Reports*, 14, 9374. <https://doi.org/10.1038/s41598-024-59822-w>
8. Dutta, R., Kumar, S., Jayalakshmi, K., Radhakrishna, A., Bhagat, K., Manjunatha Gowda, D. C., Karuppaiah, V., Bhandari, H. R., Bomble, R., Gurav, V., Mahajan, V., and Singh, M., 2024. Potential of *Trichoderma* strains to positively modulate plant growth processes and bulb yield in Rabi onion. *Frontiers in Sustainable Food Systems*, 8, Article 1427303. <https://doi.org/10.3389/fsufs.2024.1427303>
9. Dutta, R., Kumar, S., Jayalakshmi, K., Radhakrishna, A., Bhagat, K., Manjunatha Gowda, D. C., Karuppaiah, V., 2024. *Trichoderma* strains modulate growth & bulb yield in onion. *Frontiers in Sustainable Food Systems*, 8, 1427303. <https://doi.org/10.3389/fsufs.2024.1427303>
10. Gadge, A. S., Karuppaiah, V., Soumia, P. S., Dutta, R., Kumar, S., Mahajan, V., and Ramesh, S. V., 2024. Physiochemical, biological, and therapeutic uses of stingless bee honey. *Frontiers in Sustainable Food Systems*, 7, Article 1324385. <https://doi.org/10.3389/fsufs.2023.1324385>
11. Gadge, A. S., Shirsat, D. V., Singh, M., Thangasamy, A., Karuppaiah, V., Maruthadurai, R., Das, B., Soumia, P. S., Ramesh, S. V., and Mahajan, V., 2023. Predicting the potential geographical distribution of onion thrips (*Thrips tabaci*) in India based on climate change projections using MaxEnt. *Scientific Reports*, 13, 7934. <https://doi.org/10.1038/s41598-023-35012-y>
12. Gavhane, A. D., Kale, R. B., Khade, Y., Bhandari, H. R., Gaikwad, S. Y., Singh, S., Shabeer, T. P. A., Garde, Y. A., Khandagale, K., and Mahajan, V., 2024. Cultivation viability of *Allium tuberosum* L. in the Western Ghats: Insights into crop dynamics, yield and quality. *Frontiers in Plant Science*, 15, Article 1480510. <https://doi.org/10.3389/fpls.2024.1480510>

13. Gavhane, A. D., Thorat, V. S., Gaikwad, S. Y., Wayal, S. M., Singh, S., Khandagale, K., Bhat, R., Kale, R. B., Gadge, S. S., and Mahajan, V., 2023. Efficiency dynamics among onion growers in Maharashtra: A comparative analysis of drip-irrigation adopters and non-adopters. *BMC Plant Biology*, 24, 237. <https://doi.org/10.1186/s12870-024-04875-2>
14. Gawai, T., Sadawarte, S., Khandagale, K., Raj, A., Kulkarni, A., Jaiswal, D. K. and Gawande, S., 2024. Phylogenetic and population genetic analyses of *Thrips tabaci* Lindeman (Thysanoptera: Thripidae) on *Allium* host in India. *PeerJ*, 12, e17679. <https://doi.org/10.7717/peerj.17679>
15. Gorrepati, K., Krishna, R., Singh, S., Shirsat, D. V., Soumia, P. S., and Mahajan, V., 2024. Harnessing the nutraceutical and therapeutic potential of *Allium* spp.: Current insights and future directions. *Frontiers in Nutrition*, 11, Article 1497953.
16. Gorrepati, K., Kumar, A., Ahammed Shabeer, T. P., Khan, Z., Satpute, P., Anandhan, S., Arunachalam, T., Yalamalle, V. R., Mahajan, V., and Singh, M., 2024. Characterization and evaluation of antioxidant potential of onion peel extract of eight differentially pigmented short-day onion (*Allium cepa* L.) varieties. *Frontiers in Sustainable Food Systems*, 8, Article 1469635.
17. Gowd, T. Y. M., Deo, C., Manjunatha Gowda, D. C., Mahajan, V., Dutta, R., Bhutia, N. D., Singh, B., and Mounika, V., 2024. Deciphering genetic diversity, phylogeny and assembly of *Allium* species using microsatellite markers on nuclear DNA. *Heliyon*, 10(11).
18. Gupta, A. J., and Mahajan, V., 2023. Onion: Breeding and genomics. *Vegetable Science*, 50, 244–260. <https://doi.org/10.61180/vegsci.2023.v50.spl.10>
19. Gupta, A. J., Benke, A. P., Mahajan, V., Chauhan, H., and Singh, M., 2024. Assessment of genetic diversity and stability performance of 38 genotypes of onion (*Allium cepa* L.). *The Journal of Horticultural Science and Biotechnology*, 99(5), 560–569. <https://doi.org/10.1080/14620316.2024.2315941>.
20. Gupta, A. J., Benke, A., Gorrepati, K., Mahajan, V., and Singh, M., 2024. Trait association and variability study for biochemical and yield related traits in onion (*Allium cepa* L.). *Vegetable Science*, 51(1), 49–55.
21. Gupta, A. J., Khade, Y. P., Benke, A. P., Gedam, P. H., and Mahajan, V., 2024. Assessing onion genotype stability and potential in diverse Indian environments. *Cogent Food & Agriculture*, 10(1), Article 2360606. <https://doi.org/10.1080/23311932.2024.2360606>
22. Gupta, A. J., Khade, Y. P., Benke, A. P., Mainkar, P., Gedam, P. A., Mahajan, V., and Singh, M., 2024. Assessing onion genotypes' stability and potential in diverse Indian environments. *Cogent Food & Agriculture*, 10(1). <https://doi.org/10.1080/23311932.2024.2360606>.
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2. Gadge S. S. 2024. Extension Activities by ICAR-DOGR. *Shreshth Sansthan Programme*. TV Show. 28 April 2024. DD Kisan.
3. Bibwe, B.R. 2024. Post harvest management in Onion. *Farmers Meeting in association with MP Agriculture Department and private organization in Barnagar, Ujjain*. TV Show. 20 December 2024. Green TV.
4. Kale R. B. 2024. *Rabi kanda lagavadeetun adhunik utpadanachi panchsutri* (Five-Point Formula for Higher Production through Rabi Onion Cultivation). TV Show. 12 February 2024. DD Sanhyadri.
5. Kale R.B. 2024. *Lasun Lagvadiche Tantradnyan* (Garlic Cultivation Technology). TV Show. 17 October 2024. DD Sahyadri.
6. Kale R.B. 2024. *Shreshth Sansthan ICAR-DOGR* (Part-1), 21 April 2024. DD Kisan.
7. Kale R.B. 2024. *Shreshth Sansthan ICAR-DOGR* (Part-2), 28 April 2024. DD Kisan.

Radio Talks

1. Kale R.B. 2024. *Aadhunik kanda shetisathi mahiti tantradnyan* (Information technology for modern onion farming). *Majh Ghar Majh Shet Programme*. 3 October 2024. All India Radio, Pune.
2. Bibwe B.R. 2024. *Lasun prakriya* (Garlic Processing), *Majh Ghar Majh Shet Programme*. 1 April 2024. All India Radio, Pune.

O. Institutional Activities

ICAR-DOGR organizes training programmes for farmers of District Nashik

Two training programmes on “Onion Production, Post-harvest and Processing Technology” under the SMART-ATMA scheme were organized by ICAR-Directorate of Onion and Garlic Research for farmers of District Nashik (Maharashtra) during 8-10 January 2024 and 17-19 January 2024 at ICAR-DOGR, Pune. A total of 60 members from different Farmers Producer Companies of Nashik district participated in each training programme organized at ICAR-DOGR, Pune. In the inaugural function, Dr. Vijay Mahajan, Director, ICAR-DOGR, motivated the participants to adopt advanced onion cultivation technologies developed by the Directorate. Different topics related to onion production, post-harvest, and processing were covered in the training programme. Lectures were delivered by the scientists of ICAR-DOGR on improved varieties, nursery management, cultivation practices, fertilizer management, micro-irrigation, pest and disease management, harvesting, post-harvest management and processing, onion seed production, improving the socio-economic status of farmers through SHGs, etc. topics. The various agro-practices were demonstrated to the farmers at the ICAR-DOGR farm. Farmers were exposed to different agro-innovative techniques. The queries of the farmers were answered by the scientists of ICAR-DOGR in an interactive session. The farmers also expressed their views on the occasion. The exposure visit of participants to the “Controlled Storage Structure” developed by ICAR-DOGR and Kala Biotics at Peth was also organized during the training programme. The training programmes were coordinated by Dr. S. S. Gadge, Principal Scientist (Agricultural Extension), Dr. R.B. Kale, Senior Scientist (Agricultural Extension), and Dr. B.R. Bibwe, Scientist (AS&PE).



ICAR-DOGR participates in Krushik 2024 and Global Krishi Mahotsav 2024

ICAR-Directorate of Onion and Garlic Research participated in the Agricultural Exhibition “Krushik 2024” organized by KVK Baramati, at KVK Baramati during 18-22 January 2024. The onion and garlic technologies developed by ICAR-DOGR were showcased in live demonstration plot. Dr. A. Thangasamy, Dr. R. B. Kale, and Dr. Sanket More



participated in the exhibition. ICAR-DOGR also participated in the Agricultural Exhibition “Global Krishi Mahotsav 2024” organized by KVK Gramonnati, Narayangaon at KVK Gramonnati, Narayangaon during 8-11 February 2024. The onion and garlic technologies developed by ICAR-DOGR were showcased at the ICAR-DOGR stall. Dr. S. S. Gadge, Dr. R. B. Kale, Dr. Y. P. Khade, and Dr. Sanket More, with technical and supporting staff, participated in Global Krishi Mahotsav with the ICAR-DOGR stall. Each exhibition was visited by about one lakh farmers.



Celebration of the 75th Republic Day

ICAR-DOGR celebrated 75th Republic Day on 26 January 2024 with immense enthusiasm and patriotism. Dr. Vijay Mahajan, Director of ICAR-DOGR, unfurled the national flag. The campus was beautifully decorated in tri colors, fostering a deep sense of national pride. Staff and students gathered to honour this significant occasion. Dr. Vijay Mahajan highlighted the importance of Republic Day and reaffirmed ICAR-DOGR's commitment to advancing agricultural progress. The celebration also featured cultural programme. The sports competitions for the children of the ICAR-DOGR staff were organized by the Employee Welfare Committee. As the festivities drew to a close, the spirit of patriotism and unity continued to inspire all those who participated in the programme.

ICAR-DOGR participates in Science Exhibition

ICAR-Directorate of Onion and Garlic Research participated in “Science Exhibition” organized on the occasion of National Science Day by TIFR, Narayangaon, during 28-29 February 2024 at GMRT, Khodad. The onion and garlic technologies developed by ICAR-DOGR were showcased at the ICAR-DOGR stall. Dr. S. S. Gadge and Dr. H.R. Bhandari, with technical and supporting staff, participated in the exhibition with the ICAR-DOGR stall.



IP day celebration at ICAR-DOGR

World Intellectual Property Day 2024, was celebrated at ICAR-DOGR, Pune, on 25 April 2024. The theme of IP Day was “IP and the SDGs: Building our common future with innovation and creativity”. Dr. Rajiv Kale (PI-ITMU) welcomed the guest speaker, audience, and briefed about the World IP Day, its relevance. Dr. Vijay Mahajan, Director, ICAR-DOGR, emphasized the importance of protection of intellectual property as well as its commercialization. On this occasion, Mr. Abhijit K. Bhand Co-founder & CEO, Kanadlab, Institute of Intellectual Property & Research, Nashik delivered a lecture on 'IP Management in Agriculture Research'. The programme was attended by all the scientists, technical staff, YP, JRF, SRF, RA and research students.



Celebration of 78th Independence Day

ICAR-DOGR celebrated India's 78th Independence Day on 15 August 2024 with great enthusiasm. As part of the *Azadi Ka Amrit Mahotsav* celebrations, the '*Har Ghar Tiranga*' campaign was actively celebrated by the ICAR-DOGR employees. The ICAR-DOGR campus was illuminated with lightning and decorated with tricolor flags and balloons. The beautification and decoration with a tricolor theme were done right from the main gate to the office. Dr. Ram Dutta, Director In-charge, ICAR-DOGR hoisted the flag, symbolizing our freedom. He in his address,



highlighted the importance of Independence Day in upholding democratic values and fostering progress. He emphasized ICAR-DOGR's commitment to agricultural advancements for the betterment of the nation. Meritorious children of the staff who got top success in SSC and HSC were also felicitated by the Director. A flag march past, also known as a parade or procession, was planned in the ICAR-DOGR campus and residential areas. The ceremony ended with a renewed sense of patriotism and a collective commitment to a stronger India. The event served as a reminder of our shared history, achievements, and the path towards a brighter future together.

Global Campaign “एक पेड़ मां के नाम ” Plant 4 Mother

As a part of the Global Campaign “एक पेड़ मां के नाम ” Plant4Mother, “Ek Ped Maa Ke Naam” plantation event was organized at ICAR-DOGR, Pune, on 5 June 2024 and 29 August 2024 to create momentum for the Global Campaign “एक पेड़ मां के नाम ” Plant4Mother.

On 5 June 2024, Dr. Ram Dutta, Principal Scientist, ICAR-DOGR, briefed about the programme, outlining its objectives and significance in promoting environmental sustainability. He emphasized the need for active participation in tree conservation efforts to enhance ecosystem services and agricultural resilience. Dr. Vijay

Mahajan, Director, ICAR-DOGR, in his address, emphasized on the importance of tree planting as trees act as natural air purifiers, absorbing carbon dioxide and releasing oxygen while also filtering pollutants to improve air quality. He highlighted their role in soil conservation, groundwater recharge, and climate regulation, which contribute to sustainable agriculture and environmental stability. Dr. Mahajan also elaborated on the ecosystem services provided by trees, such as maintaining biodiversity by offering habitat and food for various species, regulating temperature through transpiration, and mitigating climate change by acting as carbon sinks. He further discussed their economic and social benefits, including providing timber, fruits, and medicinal resources, supporting livelihoods, and enhancing human health and well-being. He concluded his address by emphasizing the collective responsibility to plant and protect trees for a greener and healthier future. After his address, all the staff members actively participated in the plantation drive and planted around 100 saplings in and around the directorate premises. Additionally, approximately 200 saplings were distributed to staff members to encourage further tree planting. The programme concluded with a vote of thanks by Dr. Thangasamy, Senior Scientist and Nodal Officer for Tree Plantation.



On 29 August 2024, Dr S. S. Gadge, Director In-Charge, ICAR-DOGR encouraged ICAR-DOGR staff to plant a tree as a tribute to their mothers. He urged the staff to actively participate in the plantation programme. ICAR-DOGR staff planted 25 saplings in and around the Directorate's premises to promote sustainable practices to ensure long-term ecological balance.



हिंदी पखवाड़ा का आयोजन

भाकृअनुप- प्याज एवं लहसुन अनुसंधान निदेशालय, पुणे में 13 से 25 सितंबर 2024 तक हिंदी पखवाड़ा बड़े उत्साह और उमंग के साथ मनाया गया। इस आयोजन का मुख्य उद्देश्य कर्मचारियों में हिंदी भाषा के प्रति जागरूकता बढ़ाना तथा इसे राजभाषा के रूप में अधिक से अधिक प्रयोग में लाना था। पखवाड़े के दौरान संस्थान में विभिन्न प्रतियोगिताओं का आयोजन किया गया, जिनमें सभी श्रेणियों के कर्मचारियों, विद्यार्थियों एवं संविदा कर्मियों ने बढ़-चढ़कर भाग लिया। आयोजित प्रतियोगिताओं में आशु भाषण, निबंध लेखन, प्रश्नोत्तरी, हिन्दी भाषण (केवल सहायक एवं फार्म स्टाफ के लिए), तथा वाद-विवाद प्रतियोगिता प्रमुख रूप से सम्मिलित थीं।

इन प्रतियोगिताओं ने न केवल हिंदी भाषा के प्रयोग को प्रोत्साहित किया बल्कि प्रतिभागियों को अपनी अभिव्यक्ति, सृजनशीलता और तर्कशक्ति प्रदर्शित करने का अवसर भी प्रदान किया। हिंदी पखवाड़े का समापन समारोह 26 सितंबर 2024 को संस्थान के सभागार में आयोजित किया गया। इस अवसर पर मुख्य अतिथि डॉ. डी. आर. परिहार, पूर्व अधिकारी, भारतीय वन सेवा एवं डॉ. विजय महाजन, निदेशक द्वारा विजेताओं को प्रमाणपत्र एवं पुरस्कार प्रदान किए गए। इसके अतिरिक्त 26 सितंबर 2024 को एक दिवसीय हिंदी कार्यशाला का भी आयोजन किया गया, जिसका संचालन डॉ. डी. आर. परिहार ने किया। इस आयोजन ने हिंदी को राजभाषा के रूप में मजबूत करने तथा संस्थान में उसके उपयोग को बढ़ावा देने में महत्वपूर्ण भूमिका निभाई।



ICAR-DOGR organizes Swachchhata Pakhwara

Swachchhata Pakhwara with the theme 'स्वभाव स्वच्छता – संस्कार स्वच्छता' was organized by ICAR-DOGR during 15 September - 2 October 2024 including Swachchh Bharat Diwas on 2 October 2024. A series of activities was organized which included display of banner at prominent places, pledge taking, cleanliness awareness, cleanliness dialogue, cleanliness walk, cleanliness drive, plantation drive, preventive health check-up, debate and rangoli competition at ICAR-DOGR and outside the campus. A Special Sanitation Campaign 4.0 was organized during 2-31 October 2024. Swachchta Pakshwara was also celebrated during 16-31 December 2024.



Brainstorming Session on Efficiency of Nano Fertilizers in Sustaining the Yield of Onion and Garlic

The Indian Society of Alliums, in collaboration with the ICAR-Directorate of Onion and Garlic Research, Pune, organized a one-day brainstorming session on 9 October, 2024, at ICAR-DOGR, Pune, in hybrid mode. Dr. Vijay Mahajan, Director, ICAR-DOGR, and Vice President of ISA, welcomed the participants and highlighted the contributions of ICAR-DOGR, partner institutions, and SAUs in developing technologies and varieties to boost onion and garlic production in India. He also outlined the objectives of the brainstorming session on nano-fertilizers. Dr. K. E. Lawande, President, the Indian Society of Alliums, former Director, ICAR-DOGR, Pune, and former Vice Chancellor, Dr. BSSKV, Dapoli, graced the event as the Chief Guest. Dr. Lawande discussed the evolution of chemical fertilizers from the pre-Green Revolution era to advanced nano-formulations, emphasizing their influence on crop productivity, quality, and soil health. While recognizing their benefits, he expressed concerns about their long-term impact on soil, sustainability, and human health. He encouraged researchers and stakeholders to investigate their application in onion and garlic cultivation, considering both scientific and policy perspectives. Dr. K.V. Prasad, Director, ICAR-DFR, Pune, graced the occasion as the Guest of Honour, and He emphasized the need for in-depth discussions on nano-formulations, their pros and cons, prospects, and the use of drones for precise application. Other esteemed participants included Dr. S.P. Datta, Director, ICAR-IISS, Bhopal; Dr. Irene Vedamani, Dean, HC&RI, Coimbatore; Dr. Anil Khar, Head, ICAR-IARI, Pune; Dr. B.T. Patil, Senior Vegetable Breeder and Head, Department of Vegetable Sciences, MPKV, Rahuri; Dr. Archana Kale, Chief Manager, RCFL, Mumbai; Dr. Ajay Kumar Upadhyay, Principal Scientist, ICAR-NRCG, Pune; Dr. S.S. Kushwaha, Professor, College of Horticulture, Mandasour; along with several other dignitaries contributed to the deliberations and supported in bringing out proceedings. A total of 75 delegates, including researchers, students, farmers, representatives from the fertilizer industry, agribusiness entrepreneurs, and development departments, participated in the discussions on the potential use of nano-fertilizers and the challenges being faced in onion and garlic cultivation. Dr. K. E. Lawande chaired the technical session, with Dr. Vijay Mahajan and Dr. K. V. Prasad as co-chairs. The session featured seven technical presentations on nano-fertilizers from various institutes and universities. Following in-depth discussions, ten key recommendations emerged. The meeting concluded with a vote of thanks by the organizing secretary, Dr. Thangasamy A., ICAR-DOGR, Pune.



Observance of Vigilance Awareness Week

ICAR-Directorate of Onion and Garlic Research, Pune has observed the Vigilance Awareness Week-2024 from 28 October 2024 to 3 November 2024 with the theme "Culture of Integrity for Nation's Prosperity". The observance of Vigilance Awareness Week was commenced with pledge taking ceremony on 28 October 2024 by all the staff members of the Directorate to promote ethical practices, foster a culture of honesty, integrity and transparency without corruption in the Institution. All the staffs of the Directorate also took 'Online Integrity Pledge' (e-pledge) by visiting the CVC's website (<https://www.cvc.gov.in>). During Vigilance Awareness Week, various activities were organized such as the display of banners and posters, integrity pledge by staff, sensitization programme on importance of vigilance in office and daily life, vigilance awareness programme for villagers, workshop on vigilance awareness and competitions such as debate and rangoli for staff, and a drawing

competition for staff's children to create awareness among the employees and school children against corruption. The certificate and prizes were distributed to the winners of various competitions organized during Vigilance Awareness Week. The prizes were distributed to the winners of various competitions organized during Vigilance Awareness Week. Dr. V. Mahajan, Director, ICAR-DOGR, addressed the staff on preventive vigilance measures. To conclude the VAW observance, the Director of the Institute substantiated his remark on the policies and procedures of the organization. Dr. Shailendra Gadge, Principal Scientist & Vigilance Officer, ICAR-DOGR, expressed a vote of thanks. The Vigilance Awareness Week was concluded on 3 November 2024. The programme was coordinated by Dr. Rajiv Kale, Senior Scientist, ICAR-DOGR.



ABI Centre organizes specialized EDPs to promote entrepreneurship in commercial onion seed production

The Agri-Business Incubation (ABI) Centre organized two specialized Entrepreneurship Development Programmes (EDPs) on *Commercial Onion Seed Production* and *Improved Technologies for Commercial Onion Seed Production*, specifically designed for potential seed companies, entrepreneurs, Farmer-Producer Organizations (FPOs), and progressive farmers. The programmes were conducted from 7 to 9 October 2024 and 5 November 2024, with the objective of strengthening entrepreneurial capacities in the onion seed sector. These EDPs comprehensively covered critical aspects ranging from improved and advanced technologies in onion seed production to quality standards, seed certification procedures, and legal compliances required for establishing and operating a commercial seed enterprise.



ABI Centre in collaboration with NIFTEM organizes Hands-on training on Value Addition of Onion and Garlic

The Agri-Business Incubation (ABI) Centre, in collaboration with the National Institute of Food Technology Entrepreneurship and Management (NIFTEM), Kundli, Sonipat, Haryana, organized a one-day hands-on training programme titled “*Transforming Onion and Garlic into Profitable Products*” on 24 November 2024. The programme was conducted for enrolled incubatees, potential entrepreneurs, and farmers to promote value addition and entrepreneurship in onion and garlic-based enterprises. During the training, participants were provided practical, hands-on exposure to the preparation of value-added products such as onion flakes, onion and garlic paste, and onion powder, enabling them to gain technical skills for product development and commercialization.



ICAR-DOGR participates in Kisan Agri Expo 2024

ICAR-Directorate of Onion and Garlic Research participated in Agricultural Exhibition “Kisan Agri Expo 2024” organized by Kisan Forum Pvt. Ltd., Pune at Pune International Exhibition and Convention Centre (PIECC) during 11-15 December 2024. The onion and garlic technologies developed by ICAR-DOGR were showcased at ICAR-DOGR stall. Dr. S. S. Gadge, Dr. Kalyani Gorrepati, Dr. V. Karuppaiah, Dr. H. R. Bhandari, Mrs. Ashwini P. Benke, Dr. R. B. Kale, Dr. Pranjali Gedam, Dr. B. R. Bibwe, Dr. Y. P. Khade and Dr. Sanket More with technical and supporting staff participated in exhibition with ICAR-DOGR stall. It invoked a great response from the farmers and large number of publications were sold out.



ICAR-DOGR organizes a training for farmers of District Solapur

A training programme on “Onion Cultivation, Seed Production and Processing” was organized by ICAR-Directorate of Onion and Garlic Research for farmers of District Solapur (Maharashtra) during 18-20 December 2024. A total of 20 members from Hortimix Farmers Producer Company of Solapur district participated in the training programme organized at ICAR-DOGR, Pune. In inaugural function, Dr. Ram Dutta, Director In charge,

ICAR-DOGR expressed views on onion seed production. Different topics related to onion production, post-harvest and processing were covered in the training programme. Lectures were delivered by the scientists of ICAR-DOGR on improved varieties, nursery management, cultivation practices, fertilizer management, micro-irrigation, pest and disease management, harvesting, post-harvest management, processing, improving socio-economic status of farmers through SHGs, onion seed production etc. topics. The various agro-practices were demonstrated to the farmers at ICAR-DOGR farm. Farmers were exposed to different agro-innovative techniques. The queries of the farmers were answered by the scientists of ICAR-DOGR in interactive session. The farmers also expressed their views on the occasion. The exposure visit of participants to the controlled storage structure developed by ICAR-DOGR and Kala Biotics at Peth was also organized during training programme. The training programme was coordinated by Dr. S. S. Gadge, Principal Scientist (Agricultural Extension), Dr. R.B. Kale, Senior Scientist (Agricultural Extension) and Dr. Pranjali Gedam, Senior Scientist (Plant Physiology).



P. Technology Licensing, Commercialization, Collaborations

Institute Technology Management Unit

The Institute Technology Management Unit (ITMU) primarily aims to manage, protect, and commercialize the intellectual property (IP) and technologies developed within the institute. Throughout the year, ITMU conducted various activities to fulfil this mandate.

Technology licensing

During the year 2025, 12 MoUs were signed with eight seed companies for licensing of five onion varieties including Bhima Shakti, Bhima Super, Bhima, Bhima Red, Bhima Shubhra, Bhima Shweta and one garlic variety Bhima Omkar. Among these 8 companies 3 are the Farmer's Producer Companies. The total revenue generated for variety licensing was Rs. 12 lakh only. A total 10 ITMC meetings were conducted to discuss the technology licensing and MoUs with various public and private parties.

| Sr. No. | Company | State | Fees (Rs) | Variety | Date |
|---------|--|----------------|-----------|---------------|------------|
| 1. | Mahhore seeds company, Jalna | Maharashtra | 100000 | Bhima Shubhra | 24-07-2024 |
| 2. | Om Gayatri FPC, Nashik | Maharashtra | 100000 | Bhima Shubhra | 26-07-2024 |
| 3. | Raj Seed Traders, Bhopal | Madhya Pradesh | 100000 | Bhima Shakti | 26-07-2024 |
| 4. | Bapna seeds pvt ltd, Khargone | Madhya Pradesh | 100000 | Bhima Shakti | 12-08-2024 |
| 5. | Bapna seeds pvt ltd, Khargone | Madhya Pradesh | 100000 | Bhima Super | 12-08-2024 |
| 6. | Raj Seed Traders, Bhopal | Madhya Pradesh | 100000 | Bhima Omkar | 19-08-2024 |
| 7. | Krushnaganga FPC, Jalna | Maharashtra | 100000 | Bhima Shakti | 13-09-2024 |
| 8. | JSC Seeds Company Pvt. Ltd., Jalna | Maharashtra | 100000 | Bhima Red | 30-09-2024 |
| 9. | JSC Seeds Company Pvt. Ltd., Jalna | Maharashtra | 100000 | Bhima Shweta | 30-09-2024 |
| 10. | Agrimint Crop Care, Dhule | Maharashtra | 100000 | Bhima Shakti | 11-10-2024 |
| 11. | Agrimint Crop Care, Dhule | Maharashtra | 100000 | Bhima Super | 11-10-2024 |
| 12. | Jayagro Farmers Producer Company Ltd, Nashik | Maharashtra | 100000 | Bhima Shakti | 18-10-2024 |

Professional service

Two MoUs were signed for the collaborative projects with TIH Foundation for IoT and IoE, Mumbai and TATA Steel ltd. Which led to revenue generation of Rs.33,05,602/-.

| Party | Purpose | Revenue | Date |
|--|---|--|-----------|
| TIH Foundation for IoT and IoE, IIT Bombay | Development of identification tool to asses varietal purity and bulb storability of onion | Rs. 30,10,602/- | 4-1-2024 |
| TATA Steel Ltd. | Design & development of an ergonomic onion compartment and performance evaluation of environment control-based onion storage system | Collaborative research project with total project outlay - Rs. 44, 45, 000/- (including Infrastructure and developmental cost owned by TSL Rs. 41,50,000/- and Rs. 2,50,000 + GST provided to DOGR for operational expenses) | 25-4-2024 |

MoUs signed for academic purpose

Three MoUs were signed with various institutes for academic purposes as mentioned in table below.

| Sr. No. | Organization | Date | Purpose |
|---------|--|-----------|------------------------------------|
| 1 | Nya. Tatyasaheb Athalye Arts, Ved. S. R. Sapre Commerce and Vid. Dadasaheb Pitre Science College, Devrukh (Autonomous) | 3-7-2024 | MSc/PhD Students Training/Research |
| 2 | Sangamaner Nagarpalika Arts, D.J. Malpani Commerce & B.N. Sarda Science College (Autonomous), Sangamner | 26-6-2024 | MSc/PhD Students Training/Research |
| 3 | ITM University, Gwalior | 26-9-2024 | MSc/PhD Students Training/Research |

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Five copyright applications were filed of which two were registered (14267/2024-CO/SW; ODP advisor, 29829/2024-CO/CF प्याज एवं लहसुन समाचार: अंक 1).

| Sr. No | Application/Registration No. | Name of Innovation/Technology/ Product/ Variety | Date of Filing/Registration |
|--------|------------------------------|---|-----------------------------|
| 1 | 14267/2024-CO/SW | ODP advisor: decision support system for disease and pest management in onion | 3-5-2024 |
| 2 | 14264/2024-CO/SW | ONDSS: decision support system for balanced nutrient management in onion | 3-5-2024 |
| 3 | 14259/2024-CO/SW | Onion Crop Advisor: mobile application for farmers | 3-5-2024 |
| 4 | 14216/2024-CO/SW | SMART ONION: decision support system for onion variety selection | 3-5-2024 |
| 5 | 29829/2024-CO/CF | प्याज एवं लहसुन समाचार: अंक 1 | 24-9-2024 |

Seminar/trainings organized

World Intellectual Property Day 2024, was celebrated at ICAR-DOGR, Pune on 25 April 2024. The theme of this year's IP Day was "IP and the SDGs: Building our common future with innovation and creativity". On this occasion, Mr. Abhijit K. Bhand Co-founder & CEO, Kanadlab, Institute of Intellectual Property and Research, Nashik delivered a lecture on 'IP Management in Agriculture Research'. The programme was attended by all the scientists, technical staff, YP, JRF, SRF, RA and research students. Two trainings for seed companies and FPCs were conducted on Commercial Onion Seed Production.

| S No | Name of Programme | Date | Participants | Type of Participants |
|------|---|-----------|--------------|---|
| 1 | IP Management in Agriculture Research | 25-4-2024 | 52 | Scientists, technical staff, YP, JRF, SRF, RA and research students |
| 2 | Training for licensee seed companies for Commercial Onion Seed Production | 7-10-2024 | 110 | Seed companies, breeders, seed scientist, SMS |
| 3 | Training for FPOs on 'improved onion seed production | 5-11-2024 | 40 | Directors of FPOs, Employees of FPOs |

Q. Human Resource Development

Training Programmes Attended

| Title | Date and Venue |
|--|--|
| Amar Jeet Gupta | |
| Training programme on 5 Batch of Pedagogy Development Programme on "Enhancing Pedagogical Competencies for Agricultural Education" organized by National Academy of Agricultural Sciences (NAAS) | 4-8 March 2024, New Delhi |
| V. Karuppaiah | |
| Training Programme on use of SATHI Portal (N2B Module) for Nucleus to Breeder Seed Modules | 21 May 2024, Seed Division, Ministry of Agriculture and Farmer Welfare, New Delhi |
| Hem Raj Bhandari | |
| Training on Data Visualization using 'R' | 20-24 January 2024, ICAR-NAARM, Hyderabad |
| Pranjali A. Gedam | |
| Training Programme on "Metagenomics Data analysis" Online mode | 22-24 July 2024, ICAR-IASRI, New Delhi (Virtual Mode) |
| Dr. Jayalakshmi, K. | |
| Brainstorming session entitled "Efficacy of Nano Fertilizers in Sustaining yield of Onion and Garlic" | 9 October 2024, ICAR-DOGR, Pune |

Conferences/Symposiums/Seminars/Workshops/Group Meetings

| Title | Date and Venue |
|---|--|
| Vijay Mahajan | |
| Workshop on Plant Protection of Major Crops in Maharashtra | 29 July 2024, ICAR-ATARI, Pune |
| Brainstorming Session on "Efficiency of Nano Fertilizers in Sustaining Yield of Onion and Garlic" | 9 October 2024, ICAR-DOGR, Pune |
| IP Management in Agriculture Research | 25 April 2024, ICAR-DOGR, Pune |
| National Seminar on "Technological Innovations in Vegetable Production under Changing Climate Regime" | 24-26 February 2024, ANDUAT, Kumarganj, Ayodhya, Uttar Pradesh |



| Title | Date and Venue |
|--|---|
| National Seminar on “Medicinal & Aromatic Plants in perspective of Health & Wealth” | 22-23 October 2024, ICAR-DMAPR, Anand, Gujarat |
| 15 th AINRPOG Annual Group Meeting | 29-31 July 2024, ICAR-CITH, Srinagar |
| 177 th Meeting of Managing Committee of NHRDF | 23-24 September 2024, NHRDF, New Delhi |
| Monitoring AINRPOG trails | 6-7 November 2024, Mandsaur (MP) |
| Monitoring of Breeder Seed Plots of ICAR-DOGR onion varieties plot | 10 April 2024, Karjat, Maharashtra |
| Monitoring AINRPOG trial | 29-30 May 2024, JAU Junaghad |
| Monitoring of AINRPOG trails of IGKV Raipur | 16-17 February 2024, Ambikapur at College of Agriculture/ KVK Ambikapur (Surguja) Chhattisgarh |
| Technology Day cum farmer-scientist interface | 12 February 2024, Mirajgaon, Karjat, Ahilyanagar Maharashtra) |
| International Conference on Recent Trends in Smart and Sustainable Agriculture for Food and Nutritional Security (SSAFNS-2024) | 27-28 September 2024, LAU, Jalandhar |
| Chairing Technical Session in 3rd Indian Horticulture Summit-cum-international Conference-2024 | 1-3 February 2024, Rajasthan Agricultural Research Institute, Jaipur, Rajasthan |
| Director Conference 2024 | 26-27 February 2024, New Delhi |
| Indian Seed Congress -2024 | 29 February-1 March 2024, Pune |
| ABI Meeting | 5 December 2024, ICAR- DOGR, Pune |
| Interaction meeting with Mrs. Alka Arora, AS&FA, DARE | 26 April 2024, ICAR-DOGR, Pune |
| ISS General Body Meeting | 15 May 2024, IISP, Kozhikode (Online) |
| XIV th Group meeting of AINRP on Onion and Garlic | 11-12 January 2024, JNKVV, Jabalpur |
| Evaluation Committee Meeting for evaluation of Scientist (Genetics & Plant Breeding) | 17 May 2024, ICAR-NRCCS, Ajmer |
| Chief Guest for "Allium Day 2024" | 22 May 2024, ICAR-Central Institute of Temperate Horticulture, Srinagar, Jammu & Kashmir |
| 87 th meeting of Scientific Advisory Committee of NHRDF | 24 June 2024, NHRDF, New Delhi |

| Title | Date and Venue |
|---|---|
| Meeting with Tata Group Chairman Mr. N Chandrasekaran | 29 June 2024, ICAR-DOGR, Pune |
| 96 th ICAR Foundation and Technology Day Ceremony | 15-16 June 2024, Pusa, New Delhi |
| Online Meeting with Mr. S. Gokul IAS, Sub Collector, Perambalur, on Onion Value Chain | 24 July 2024, Online mode |
| Meeting of Selection Board for Finalizing Promotion Proposals for Maharashtra Agricultural Universities Recruitment Board, Pune | 29-30 July 2024, Pune |
| Varietal Identification Committee meeting | 21 August 2024, Krushi Anusandhan Bhavan, Pusa, New Delhi |
| 15 th AINRPOG Annual Group Meeting | 29-31 August 2024, ICAR-CITH, Srinagar |
| Shivar Pheri programme | 20 September 2024, Dr. PDKV Akola |
| 177 th Meeting of Managing Committee of NHRDF | 23 September 2024, NHRDF, Head Office, New Delhi |
| Meeting with Dr. Sanjay Kumar Singh, DDG, Horticulture on Review of Genome Editing Projects | 9 October 2024, (Online mode) |
| Chief Guest for the Inaugural Function of One District One Product (ODOP) Webinar on "Garlic Processing and Value Addition" | 17 October 2024, NIFTEM, Thanjavur |
| 88 th Meeting of Scientific Advisory Committee of NHRDF | 25 October 2024, NHRDF Head Office, New Delhi |
| Research Advisory Meeting | 14-16 November 2024, SAGE University, Indore |
| Visit to IIT Bombay and meeting with the scientist related to Onion and Garlic to discuss about Collaboration work | 3 December 2024, IIT Bombay |
| Organized One-day Scientific Social Responsibility (SSR) activity as a component of the research project "Tapping the potential of native stingless bee <i>Tetragonula iridipennis</i> Smith for pollination enhancement and profitable onion seed production," funded by SERB-DST, New Delhi | 10 January 2024, ICAR-DOGR, Pune |
| Monitoring of AINRPOG trails | 16 February 2024, IGKV Raipur |
| Explored the possibilities of onion and garlic in non-traditional area of tribal belt of Ambikapur at College of Agriculture/ KVK Ambikapur (Surguja) Chhattisgarh | 17 February 2024, Chhattisgarh |
| ITMC meeting for discussion on signing of MoU with TATA Steel Ltd. for collaborative research | 22 April 2024, ICAR-DOGR, Pune |
| ITMC meeting for discussion on signing of MoU with seed companies at the committee hall, ICAR- DOGR, Pune | 26 June 2024, ICAR-DOGR, Pune |
| ITMC meeting for discussion on technology licensing with Agrinnovate, New Delhi | 19 July 2024, ICAR-DOGR, Pune |
| ITMC meeting for discussion on technology licensing and MoU drafts | 23 July 2024, ICAR-DOGR, Pune |



| Title | Date and Venue |
|--|---|
| ITMC meeting for discussion on signing of MoU with seed companies, student research collaborations universities, research collaboration with private parties | 9 September 2024, ICAR-DOGR, Pune |
| ITMC meeting for discussion on annexure MoU with TIH Mumbai for research collaboration | 11 September 2024, ICAR-DOGR, Pune |
| ITMC meeting for discussion on signing of MoU with seed companies, research collaboration with TIH Mumbai and ESDS | 3 October 2024, ICAR-DOGR, Pune |
| ITMC meeting to discuss collaborative research proposal and onion licensing of onion varieties to the seed companies | 12 November 2024, ICAR-DOGR, Pune |
| ITMC meeting for discussion on signing of MoU with ASP college, Ratnagiri and a consultancy project | 30 January 2024, ICAR-DOGR, Pune |
| ITMC meeting for discussion on signing of MoUs with THE FARM and SPPU-RESEARCH PARK FOUNDATION | 22 February 2024, ICAR-DOGR, Pune |
| ITMC meeting for discussion on signing of MoU with TATA steel and also for the copy right application and commercialization of Onion Decision Support System | 6 March 2024, ICAR-DOGR, Pune |
| Ram Dutta | |
| IPS National conference on plant health for food security: Threats and promises | 1-3 February 2024, IISR-Lucknow |
| 23 rd IMC Meeting | 6 December 2024, ICAR-DOGR, Pune |
| Meeting for Departmental Promotion Committee | 05 August 2024, ICAR-DOGR, Pune |
| Amar Jeet Gupta | |
| XIV th AINRPOG Annual Group Meeting | 11-13 January 2024, JNKVV, Jabalpur (MP) |
| National Agricultural Fair (NAF-2024) | 3-5 February 2024, ICAR-IIVR, Varanasi (UP) |
| ISVS Golden Jubilee National Seminar on “Technological Innovations in Vegetable Production under Changing Climate Regime organized by ISVS in collaboration with ICAR-IIVR, Varanasi and ANDUAT, Kumarganj | 24-26 February 2024, ICAR-IIVR, Varanasi |
| Monitoring of onion breeder seed production plots at five locations under TSP | 20-23 March 2024, Nandurbar, KVK, Jalna and KVK, Pal (MS) |
| Variety Identification Committee meeting for onion and garlic | 21 August 2024, SMD, KAB-II, Pusa, New Delhi |
| XV th Annual Group Meeting of AINRPOG | 29-30 August 2024, CITH, Srinagar |
| S. J. Gawande | |
| National Conference on Digital Agriculture on Empowering Indian Farming | 17-18 December 2024, NASC Complex, New Delhi |
| S. S. Gadge | |
| Viksit Bharat Meeting with DG, ICAR, New Delhi | 16 April 2024, ICAR-DOGR, Pune (Virtual Mode) |

| Title | Date and Venue |
|---|--|
| 2nd Review meeting with DG, ICAR | 20 June 2024, ICAR-DOGR, Pune |
| Workshop on “Empowering Agriculture: Integrating Advanced Technologies for Farmer Prosperity” | 29 July 2024, ICAR-ATARI, Pune |
| Panel Discussion on “IPRs in Horticulture Sciences” organized by IP&TM, ICAR, New Delhi | 13 September 2024, ICAR-DOGR, Pune |
| Webinar on “Dynamic Digital Presence” organized by ICAR-NAARM, Hyderabad | 7 October 2024, ICAR-DOGR, Pune |
| Brainstorming Session on “Efficiency of Nano Fertilizers in Sustaining Yield of Onion and Garlic” | 9 October 2024, ICAR-DOGR, Pune |
| Workshop on Vigilance Awareness with the theme “Culture of Integrity for Nation's Prosperity” | 11 November 2024, ICAR-DOGR, Pune |
| Conference on Onion Crop at Mirajgaon (Karjat) and Wagha (Jamkhed) | 21 June 2024, Karjat and Jamkhed |
| Presentation of DG, ICAR on Best practices for project formulation | 16 December 2024, ICAR- DOGR, Pune (Virtual Mode) |
| A. Thangasamy | |
| Global Soils Conference 2024 Caring Soils Beyond Food Security: Climate Change Mitigation & Ecosystem Services | 19-22 November 2024, NASC Complex, New Delhi |
| National Seminar on “Soil Ecosystem Services for Sustainable Agriculture (SESSA-2024) | 21-23 February 2024, NBSS & LUP, Nagpur, India |
| Brain storming on Efficiency of Nano fertilizers | 9 October 2024, ICAR-DOGR, Pune |
| Annual Group meeting of All India Network Research Project on onion and Garlic | 11-13 January 2024, JNKVV, Jabalpur |
| Annual Group meeting of All India Network Research Project on onion and Garlic | 29-31 August 2024, CITH, Srinagar |
| World Soil Day Celebration | 5 December 2024, KVK, Narayangaon |
| Hem Raj Bhandari | |
| International Conference on 'Global Research Initiatives for Sustainable Agriculture & Allied Sciences (GRISAAS 2024) | 10-12 December 2024, ICAR-DOGR, Pune (Virtual Mode) |
| Karuppaiah V. | |
| International Conference on Plant Protection in Horticulture (ICPPH-2024) | 25–27 September 2024, ICAR-Indian Institute of Horticulture Research, Bengaluru |
| Annual Group meeting of AINRPOG | 29-31 August 2024, ICAR-CITH, Srinagar |
| Brain storming on Efficiency of Nano fertilizers | 9 October 2024, ICAR-DOGR, Pune |



| Title | Date and Venue |
|--|--|
| National Workshop on SATHI portal | 21 October 2024, NASC, New Delhi |
| Meeting for Finalization of Breeder Seed Indents of Agriculture, Vegetables, Seed Species, Bulb and Tuber Crops for <i>Rabi</i> 2025-26 | 11 September 2024, NASC, New Delhi |
| Kalyani Gorrepati | |
| National seminar on Medicinal and aromatic plants in perspective of health and wealth | 22-23 October 2024, Anand, Gujarat |
| Seminar on Intellectual Property Rights (IPR) awareness titled: Lab to Market - Leveraging IP | 9 September 2024, ICAR - National Research Centre for Grapes, Pune (Virtual Mode) |
| Rajiv Kale | |
| Workshop on 'Research methodologies in veterinary extension' and Brainstorming session on 'Dairy Farmer First (DFF)' | 13 June 2024, KNP College of Veterinary Science, Shirwal, Satara |
| Workshop on “Validation of functional review of Department of agriculture” | 16 February 2024, YASHADA, Pune |
| SAMIKSA: Quarterly Review Meetings (QRMs) of NAIF (Innovation Fund) | 11 January 2024, ICAR-DOGR, Pune (Virtual Mode) |
| SHRIJAN programme to sensitize the ITMU/ZTMU of ICAR | 13-15 February 2024, NASC Complex, Pusa, New Delhi |
| Meeting of Selection Committee for filling up one vacant post of Programme Assistant (Computer)/T-4 and 2 posts of Driver/T-1 | 21 March 2024, KVK, Jalna |
| Seed monitoring under seed village SCSP inspection | 10 April 2024, Baramati and Karjat |
| Research planning meeting of Dept. of Extension | 14 March 2024, MPKV Rahuri |
| Monitoring KVK activities | 20-24 August 2024, Beed, Nanded, Latur, Jalgaon, Chhatrapati Sambhajinagar |
| Workshop under public-private partnership for KVKs of Maharashtra on Empowering Agriculture: Integrating advanced Technologies for farmers | 29 July 2024, ICAR-ATARI, Pune |
| XVth Annual Group Meeting of All India Network Research Project on Onion and Garlic | 29-31 August 2024, ICAR-CITH Srinagar, J&K. |
| 96 th ICAR foundation day and technology day | 15-16 July 2024, NASC complex ICAR, New Delhi |
| ICAR-IIHR, Industry Meet 2024 | 24 October 2024, ICAR-IIHR, Bengaluru |
| National Conference on Digital Agriculture Empowering Indian Farming | 17-18 December 2024, NASC Complex, ICAR, New Delhi |
| Workshop on IP Management in Agricultural Research for scientists, technical staff, YP, JRF, SRF, RA, and research students on the occasion of World IP Day under ABI and ITMU | 25 April 2024, ICAR-DOGR, Pune |

| Title | Date and Venue |
|--|---|
| XIVth Annual Workshop of the All-India Network Research Project on Onion and Garlic | 11-13 January 2024, JNKVV, Jabalpur |
| ABI Advisory Committee Meeting | 2 February 2024, ABI-NRC Grapes, Pune |
| Scientist–Farmer/FPO–Exporter Interface Programme on “Improved Onion Production Technology and Export Supply Chain” to connect FPOs and farmers with exporters | 7 October 2024, ICAR-DOGR, Pune |
| Ashwini P. Benke | |
| IX International Conference on “Global Research Initiative for Sustainable Agriculture and Allied Sciences” | 10-12 December 2024, SKNAU, RARI, Durgapura, Jaipur, Rajasthan India (Virtual Mode) |
| XIV th Annual Group meeting of AINRPOG | 11-13 January 2024, JNKVV, Jabalpur |
| Varietal identification meeting of onion and garlic under AINRPOG | 21 August 2024, New Delhi |
| Varietal identification meeting of onion and garlic under AINRPOG | 29 August 2024, New Delhi |
| XVth Annual Group meeting of AINRPOG | 29-31 August 2024, CITH, Srinagar |
| Pranjali A. Gedam | |
| International Conference on Plant Protection in Horticulture (ICPPH-2024) | 25-27 September 2024, ICAR-Indian Institute of Horticulture Research, Bengaluru |
| 10 th International Conference on <i>Bacillus anthracis</i> , <i>Bacillus cereus</i> and <i>Bacillus thuringiensis</i> (Bacillus ACT 2024) | 13-17 October 2024, New Delhi |
| XVth Annual Group meeting of AINRPOG | 29-31 August 2024, ICAR-CITH, Srinagar |
| Brainstorming session on the Efficiency of Nano fertilizers in Sustaining yield of onion and Garlic | 09 October 2024, ICAR-DOGR, Pune |
| Soumia P.S. | |
| International Conference on Plant Protection in Horticulture (ICPPH-2024) | 25-27 September 2024, ICAR-IIHR, Bengaluru |
| 10 th International Conference on <i>Bacillus anthracis</i> , <i>Bacillus cereus</i> and <i>Bacillus thuringiensis</i> (Bacillus ACT 2024) | 13-17 October 2024, New Delhi. |
| Annual Group Meeting of AINRPOG | 29-31 August 2024, ICAR-CITH, Srinagar |
| Brainstorming session on the Efficiency of Nano fertilizers in Sustaining yield of onion and Garlic | 09 October 2024, ICAR-DOGR, Pune |
| Bhushan Bibwe | |
| PRAYAS: Pune Agri Startup Conclave 2024 | 16 January 2024, ICAR-NRCG, Pune |
| International Workshop on Agriculture Technology Transformation (ERASMUS Program) | 03-04 October 2024, COEP Technological University, Pune |



| Title | Date and Venue |
|---|---|
| National Conference on Digital Technologies for Transforming the Horticulture Sector | 28–30 January 2025, ICAR-IARI, New Delhi |
| Meeting to include Onion processing under PMFME scheme | 30 January 2024, ICAR-DOGR, Pune (Virtual Mode) |
| Meeting on Role and Importance of Secondary Agriculture organized by DDG (Hort.), ICAR, New Delhi | 08 April 2024, ICAR-DOGR, Pune (Virtual Mode) |
| Meeting with Maharashtra State Government officials on Onion Storage and Processing | 12 June 2024, ICAR-DOGR, Pune (Virtual Mode) |
| Meeting with Ministry of Consumer Affairs, DOCA, Government of India and other stakeholders on Advancements and Strategies Related to Onion Storage Technology | 13 June 2024, ICAR-DOGR, Pune (Virtual Mode) |
| Meeting on Post-Harvest Engineering and Technology for Horticulture Plan C Project with ICAR-DOGR, CIAE, CIPHET and other stakeholders. Organized by SMD–Engineering, ICAR HQ | 31 July 2024, ICAR-DOGR, Pune (Virtual Mode) |
| Meeting on TOP Crops Strategy for preparation of Strategies and Action Plan for Enhancing Production and Storage Capacity of Tomato, Onion, and Potato (TOP) Crops organized by Deputy Director (Hort-Tech), Krishi Bhavan, New Delhi | 1 August 2024, ICAR-DOGR, Pune (Virtual Mode) |
| Yogesh Khade | |
| 10 th International Conference on <i>Bacillus anthracis</i> , <i>Bacillus cereus</i> and <i>Bacillus thuringiensis</i> (Bacillus ACT 2024) | 13-17 October 2024, New Delhi |
| Sanket More | |
| Conference on achieving sustainable development goals in challenged Agro-ecosystems | 3-5 March 2024, ICAR–Central Arid Zone Research Institute, Jodhpur, India |
| Jayalakshmi K. | |
| Brainstorming session entitled “Efficacy of Nano Fertilizers in Sustaining yield of Onion and Garlic” | 9 October 2024, ICAR-DOGR, Pune |
| IPS National conference on plant health for food security: Threats and Promises | 1-3 February 2024, IISR-Lucknow |

R. Personnel

New Joining, Retirement/Superannuation, Transfer, Promotion (January-December 2024)

A. New joining

| Sr. No. | Name | Designation | Date of Birth | Date of Joining (ICAR-DOGR) |
|-----------|-----------------------------|----------------------------|---------------|-----------------------------|
| A. | Administrative Staff | | | |
| 1 | Sh. Anand Maitreya | Administrative Officer | 01.05.1989 | 22.04.2024 |
| 2. | Sh. Rahul Yadav | Finance & Accounts Officer | 16.09.1991 | 24.04.2024 |
| 3. | Sh. Dheeraj Kumar | Assistant | 23.01.2000 | 13.09.2024 |
| 4. | Sh. Shivaji Suresh Gopale | Lower Division Clerk | 02.05.1984 | 21.08.2024 |

B. Retirement/Superannuation

| Sr. No. | Name | Designation | Date of Birth | Date of Superannuation |
|-----------|------------------------------|-----------------------|---------------|------------------------|
| A. | Skilled Support Staff | | | |
| 1 | Shri Kale Mahadu Sukhdeo | Skilled Support Staff | 02.06.1964 | 30.06.2024 |

C. Transfer

| Sr. No. | Name | Designation | Date of Joining at ICAR-DOGR | Date of Joining at ICAR-DOGR | Remarks |
|-----------|-------------------------------|-------------|------------------------------|------------------------------|---|
| A. | Scientific Staff | | | | |
| 1 | Dr. Rajkumar Arjun Dagadkhair | Scientist | 07.03.2022 | 13.09.2024 | Deputation for the period of two years at FSSAI as Joint Director |
| B. | Administrative Staff | | | | |
| 1. | Sh. Nilesh S. Warkar | Assistant | 21.05.2010 | 21.08.2024 | Promotion to the post of Asstt. Fin. & Accounts Officer. Transfer to ICAR-ATARI, Pune |

D. Promotion / Assessment

| Sr. No. | Name and Designation | Pay Level/ Research Pay Level | Promoted Post | Promoted post-Pay Matrix level/ Research Pay Level | Date of Promotion |
|----------------------------|---|----------------------------------|-------------------------------|--|-------------------|
| A. Scientific Staff | | | | | |
| 1 | Dr. Gadge Shailendra Shankarrao, Senior Scientist | Research Pay Level- 13 A | Principal Scientist | Research Pay Level- 14 | 10.07.2015 |
| 2 | Dr. Hem Raj Bhandari, Sr. Scientist (Plant Breeding) | Research Pay Level- 12 | Senior Scientist | Research Pay Level- 13 A | 16.12.2022 |
| 3 | Dr. Karuppaiah V., Sr. Scientist (Agricultural Entomology) | Research Pay Level- 12 | Senior Scientist | Research Pay Level- 13 A | 07.01.2023 |
| 4 | Dr. Kalyani Gorrepati, Sr. Scientist (AS&PE) | Research Pay Level- 12 | Senior Scientist | Research Pay Level- 13 A | 27.04.2023 |
| 5 | Dr. Pranjali Atul Gedam, Scientist (Plant Physiology) | Research Pay Level- 11 | Senior Scientist | Research Pay Level- 12 | 01.01.2023 |
| 6 | Dr. Khade Yogesh Popat, Scientist (Vegetable Science) | Research Pay Level- 10 | Scientist | Research Pay Level- 11 | 18.11.2019 |
| B. Technical Staff | | | | | |
| 1 | Mr. Shaikh Hasan Shaikh Chand, Asstt. Chief Technical Officer (T-7/8) | Pay Matrix Level- 11 | Chief Technical Officer (T-9) | Pay Matrix Level- 12 | 08.05.2023 |
| 2 | Shri. Ram Yashwant Bomble, Sr. Technician | Pay Matrix Level- 04 | Technical Assistant (T-3) | Pay Matrix Level- 05 | 18.02.2023 |
| 3 | Mrs. Poonam Vinayak Shekle, Sr. Technician | Pay Matrix Level- 04 | Technical Assistant (T-3) | Pay Matrix Level- 05 | 01.03.2023 |

Staff strength (As on 31.12.2024)

| Category | Sanctioned Strength | In Position | Vacant |
|-----------------------|---------------------|--------------------|--------|
| Scientific | 22+1 [#] | 19 +1 [#] | 3* |
| Technical | 10 | 10 | 0 |
| Administration | 15 | 7 | 8 |
| Skilled Support Staff | 11 | 6 | 5 |
| Total: | 58+1 | 42+1 | 16 |

One post of RMP

* One Scientist is on deputation for the period of two years w.e.f. 13.09.2024

Scientific staff strength (As on 31.12.2024)

| Sr. No. | Name of Discipline | Revised Cadre Strength | | | | | | | |
|---------|--|------------------------|-----------|---------------|----------|---------------|----------|-----------|-----------|
| | | Scientist | | Sr. Scientist | | Pr. Scientist | | Total | |
| | | SS | IP | SS | IP | SS | IP | S.S | IP |
| 1. | Agricultural Biotechnology | 1 | 1 | 1 | 1 | 0 | 0 | 2 | 2 |
| 2. | Agricultural Entomology | 2 | 2 | 0 | 0 | 0 | 0 | 2 | 2 |
| 3. | Agricultural Extension | 1 | 1 | 1 | 1 | 0 | 0 | 2 | 2 |
| 4. | Agricultural Structure and Process Engineering | 2 | 2 | 0 | 0 | 0 | 0 | 2 | 2 |
| 5. | Agronomy | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| 6. | Genetics and Plant Breeding | 2 | 2 | 0 | 0 | 0 | 0 | 2 | 2 |
| 7. | Plant Biochemistry | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 1 |
| 8. | Plant Pathology | 1 | 1 | 1 | 1 | 1 | 1 | 3 | 3 |
| 9. | Plant Physiology | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 1 |
| 10. | Seed Science and Technology | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| 11. | Soil Science | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 1 |
| 12. | Vegetable Science | 2 | 2 | 1 | 1 | 1 | 0 | 4 | 3 |
| | Total | 16 | 14 | 4 | 4 | 2 | 1 | 22 | 19 |

List of Staff (As on 31.12.2024)

Scientific Staff

| Sr. No. | Name | Designation |
|---------|-------------------------|---|
| 1 | Dr. V. Mahajan | Director |
| 2 | Dr. Ram Dutta | Principal Scientist (Plant Pathology) |
| 3 | Dr. A. J. Gupta | Principal Scientist (Vegetable Science) |
| 4 | Dr. S. S. Gadge | Principal Scientist (Agricultural Extension) |
| 5 | Dr. S. J. Gawande | Principal Scientist (Plant Pathology) |
| 6 | Dr. S. Anandhan | Principal Scientist (Biotechnology) |
| 7 | Dr. A. Thangasamy | Principal Scientist (Soil Science) |
| 8 | Dr. Hem Raj Bhandari | Senior Scientist (Plant Breeding) |
| 9 | Dr. V. Karuppaiah | Senior Scientist (Agricultural Entomology) |
| 10 | Dr. Kalyani Gorrepati | Senior Scientist (Agricultural Structure and Process Engineering) |
| 11 | Dr. Satish Kumar | Senior Scientist (Biotechnology) |
| 12 | Dr. R. B. Kale | Senior Scientist (Agricultural Extension) |
| 13 | Dr. Pranjali Gedam | Senior Scientist (Plant Pathology) |
| 14 | Mr. A. Radha Krishna | Scientist (Biotechnology) |
| 15 | Mrs. Ashwini Benke | Scientist (Genetics) |
| 16 | Dr. Soumia P. S. | Scientist (Agricultural Entomology) |
| 17 | Dr. Bhushan Bibwe | Scientist (Agricultural Structure and Process Engineering) |
| 18 | Dr. Yogesh Khade | Scientist (Vegetable Science) |
| 19. | Dr. Sanket Jijabao More | Scientist (Vegetable Science) |
| 20 | Dr. Jayalakshmi, K. | Scientist (Plant Pathology) |



Administrative Staff

| Sr. No. | Name | Designation |
|---------|-----------------------|----------------------------------|
| 1 | Mr. Anand Maitreya | Administrative Officer |
| 2 | Mr. Rahul Yadav | Finance & Accounts Officer |
| 3 | Mrs. Mangala S. Salve | Assistant Administrative Officer |
| 4 | Mrs. Neha R. Gaikwad | Assistant |
| 5 | Mr. Rajan K. Dedage | Assistant |
| 6 | Mr. Dheeraj Kumar | Assistant |
| 7 | Mr. Shivaji S. Gopale | Lower Division Clerk |

Technical Staff

| Sr. No. | Name | Designation |
|---------|----------------------|----------------------------|
| 1 | Mr. H.S.C. Shaikh | Chief Technical Officer |
| 2 | Mr. R.B. Baria | Technical Officer |
| 3 | Mr. S.P. Yeole | Technical Officer (Driver) |
| 4 | Dr. A.R. Wakhare | Senior Technical Officer |
| 5 | Mr. D.M. Panchal | Technical Officer |
| 6 | Mr. B. A. Dahale | Technical Officer (Driver) |
| 7 | Mr. Vishal S. Gurav | Senior Technical Assistant |
| 8 | Mr. H.S. Gavali | Senior Technical Assistant |
| 9 | Mr. Ram Y. Bombale | Technical Assistant |
| 10 | Mrs. Punam V. Shelke | Technical Assistant |

Skilled Supporting Staff

| Sr. No. | Name | Designation |
|---------|------------------------------|--------------------------|
| 1 | Mr. Rajendra S. Kulkarni | Skilled Supporting Staff |
| 2 | Mr. Pandharinath R. Sonawane | Skilled Supporting Staff |
| 3 | Mr. Popat E. Tadge | Skilled Supporting Staff |
| 4 | Mr. Sanjay D. Waghmare | Skilled Supporting Staff |
| 5 | Mr. Nayeem H. Shaikh | Skilled Supporting Staff |
| 6 | Mr. Satish B. Tapkir | Skilled Supporting Staff |

S. > Financial Statement

| Budget Head | Budget Allocation (Rs. in Lakhs) | Expenditure (Rs. in Lakhs) |
|--------------------------|----------------------------------|----------------------------|
| Salary | 1019.95 | 999.96 |
| Pension | 24.50 | 17.28 |
| Total (A) | 1044.45 | 1017.24 |
| Capital | 150.00 | 149.99 |
| General | 524.25 | 524.25 |
| Network Project | 150.75 | 150.75 |
| NEH-General | 100.00 | 99.99 |
| TSP-General | 40 | 40.00 |
| SCSP-Capital | 0.00 | 0.00 |
| SCSP-General | 80.00 | 79.99 |
| Total (B) | 1045.00 | ₹ 1044.97 |
| Grand Total (A+B) | 2089.45 | ₹ 2062.21 |

| Revenue Generation | Rupees (in lakhs) |
|-------------------------|-------------------|
| Sale of Farm Produce | 5.89 |
| Sale of Publication | 0.31 |
| Licensing Fees | 0.00 |
| Analytical Testing Fees | 0.00 |
| Interest from STD/TDR | 10.59 |
| Other Income | 15.49 |
| Total | ₹ 32.28 |



T. > Meteorological Data

| Month | Avg. Temperature (°C) | | Avg. Relative Humidity (%) | | Wind velocity (km/hr) | Av. Sunshine (hrs. /day) | Total Rainfall (mm) | Avg. Evaporation (mm) |
|-----------|-----------------------|-------|----------------------------|-------|-----------------------|--------------------------|---------------------|-----------------------|
| | Max | Min | Max | Min | | | | |
| January | 29.68 | 13.39 | 80.13 | 60.32 | 2.55 | 8.12 | 6.20 | 2.80 |
| February | 32.84 | 14.37 | 73.17 | 51.41 | 3.04 | 9.35 | 0.00 | 3.67 |
| March | 35.97 | 16.96 | 65.26 | 43.71 | 3.84 | 9.02 | 0.00 | 4.83 |
| April | 39.26 | 22.73 | 65.37 | 42.07 | 4.60 | 8.98 | 0.00 | 6.70 |
| May | 38.09 | 22.94 | 71.23 | 49.65 | 7.20 | 8.95 | 0.00 | 5.60 |
| June | 32.97 | 23.07 | 83.45 | 68.23 | 7.61 | 6.81 | 17.63 | 4.55 |
| July | 28.15 | 22.78 | 90.45 | 81.42 | 7.73 | 0.89 | 9.90 | 1.30 |
| August | 28.72 | 22.43 | 90.10 | 79.68 | 9.33 | 3.13 | 9.85 | 1.45 |
| September | 29.75 | 21.55 | 86.57 | 72.00 | 5.00 | 4.67 | 2.24 | 2.19 |
| October | 32.50 | 21.36 | 85.65 | 65.68 | 3.34 | 7.10 | 2.50 | 2.84 |
| November | 31.24 | 15.30 | 75.67 | 62.20 | 2.45 | 8.83 | 0.00 | 4.18 |
| December | 30.33 | 15.91 | 75.87 | 62.23 | 2.62 | 6.76 | 0.00 | 3.99 |



हर कदम, हर डगर
किसानों का हमसफर
भारतीय कृषि अनुसंधान परिषद

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भाकृअनुप-प्याज एवं लहसुन अनुसंधान निदेशालय
पुणे-410 505, महाराष्ट्र, भारत

ICAR-Directorate of Onion and Garlic Research
Pune-410 505, Maharashtra, India

Phone: (02135) 222026, Fax: (02135) 224056
Email: director.dogr@icar.gov.in