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वार्षिक प्रतिवेदन
Annual Report
2023

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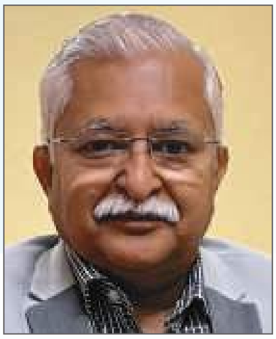
Preface



Vijay Mahajan
Director

I feel privileged to present Annual Report of ICAR-Directorate of Onion and Garlic Research for the year 2023, showcasing our collective achievements, innovations, and continued commitment to the growth and sustainability of onion and garlic research in India. As a premier research institute, ICAR-DOGR has played a pivotal role in advancing scientific understanding, improving crop productivity, and addressing the challenges faced by farmers across the nation on onion and garlic production and storage. In this report, we highlight our major achievements, the impact of our outreach programs, and the collaboration with stakeholders. Our partnerships with farmers, policymakers, and industry leaders have been instrumental in translating our research outcomes into practical solutions for real-world challenges.

In the year 2023, seventeen MoUs were signed with seed companies for commercializing onion varieties, generating ₹17 lakhs in revenue. Seven MoUs were signed for research collaboration and four MoUs for contract research which generated revenue of Rs. 92.48 lakh and 41.47 lakh, respectively. Till December 2023, total 164 licencing MoUs were signed with FPC/FPOs which generated revenue of Rs. 1.62 crore. On transfer of technology front, ICAR-DOGR organized 103 trainings under SCSP, TSP, NEH, MGMG, ATMA, etc., schemes which were attended by 4760 farmers and other stakeholders. A National Symposium cum Industry Meet (NSIM) on "Agri-business in Alliums: Innovation, Promotion & Sustainability" was also organized.

New genetic stocks, *Allium* species were added for breeding, and advances in onion breeding improved yields and stress tolerance. Garlic improvement focused on high-yielding, stress-resistant lines, with DOGR-404 achieving the highest yield. Biotechnological tools, including genome editing and haploid induction, were integrated into onion improvement program. Integrated weed management (pendimethalin + propaquizafop + oxyfluorfen or pendimethalin with polythene mulching) effectively controlled weeds and enhanced garlic yield. Integrated nutrient management (INM) with fertilizers and vermicompost improved soil fertility and bulb yield compared to organic methods. To boost Integrated pest management (IPM), *Trichoderma* spp. was also isolated and identified as *Trichoderma harzianum*. Newer and ecofriendly management options explored for major onion nad garlic diseases. A disease severity map was developed, and infection processes of major pathogens were analyzed. Biopesticides and entomopathogens reduced onion thrips up to 86%, with new-generation pesticides showing over 80% efficacy. *Tetragonula iridipennis* was identified as a key non-*Apis* pollinator, and gut microbiome analysis of *Apis florea* was done and the sequence information is submitted to NCBI genebank. In food innovation, a ready-to-cook snack mix using dehydrated onion was developed to increase Indian market for dehydrated onion besides offering convenience. Studies were also conducted on development of prebiotic drink using onion. In 2023, ICAR-DOGR conducted 817 demonstrations in Maharashtra and Karnataka, showcasing superior onion varieties like Bhima Super, Bhima Raj, Bhima Kiran, and Bhima Shakti. Drone-based spray technology was demonstrated on 187 acres across 50 villages. I am proud of the progress we have made in technology dissemination, farmer education, and fostering collaborations with national and international stakeholders. These efforts are central to our mission of providing practical, science-based solutions that improve onion and garlic farming practices and create lasting value for farmers.

I extend my sincere thanks to the support extended by ICAR and encouragement and guidance by Dr. Himanshu Pathak, Secretary, DARE and Director General, ICAR; Dr. A K Singh, Deputy Director General (Horticulture Science), Dr. Tilak Raj Sharma, Additional charge-Deputy Director General (Horticulture Science), Dr. Sudhakar Pandey, Assistant Director General (Flower, Vegetables, Spices and Medicinal Plants), Dr. V. B. Patel, Assistant Director General (Fruits and Plantation Crops). I extend my appreciation to the scientific, technical, administrative, and supporting staff of the Directorate for their dedicated efforts in achieving these milestones. I trust that the information shared in this report will prove valuable to all stakeholders involved in the onion and garlic sectors.

(Vijay Mahajan)

कार्यकारी सारांश

भाकृअनुप-प्याज एवं लहसुन अनुसंधान निदेशालय का अनुसंधान, विस्तार और विकास कार्य वर्ष 2023 के दौरान संस्थागत अनुसंधान परियोजनाओं और तदर्थ/बाह्य वित्त पोषित परियोजनाओं के माध्यम से किया गया। विवरणीय अवधि के दौरान, निदेशालय ने अनुसूचित जाती उप-योजना, जनजातीय उप-योजना, पूर्वोत्तर पर्वतीय योजना, मेरा गांव मेरा गौरव, आत्मा, आदि योजनाओं के तहत 103 प्रशिक्षण कार्यक्रम आयोजित किए, जिनमें कुल 4760 किसानों और अन्य हितधारकों ने भाग लिया। साथ ही निदेशालय ने प्याज और लहसुन की प्रौद्योगिकियों को प्रदर्शित करने के लिए 5 प्रदर्शनियों में भी भाग लिया। प्याज की चार किस्मों (भीमा किरण, भीमा सुपर, भीमा शक्ति, भीमा डार्क रेड) के व्यावसायीकरण के लिए 13 बीज कंपनियों के साथ सत्रह अनुज्ञप्ति समझौता ज्ञापन (एमओयू) पर हस्ताक्षर किए गए। इन कंपनियों में दो किसान उत्पादक कंपनियां (एफपीसी) हैं। प्रौद्योगिकी अनुज्ञप्ति गतिविधियों से वर्ष 2023 में ₹17 लाख का राजस्व प्राप्त हुआ। अनुसंधान सहयोग के लिए सात समझौता ज्ञापनों पर हस्ताक्षर किए गए और अनुबंध अनुसंधान के लिए चार समझौता ज्ञापनों पर हस्ताक्षर किए गए, जिनसे क्रमशः 92.48 लाख और 41.47 लाख रुपये का राजस्व प्राप्त हुआ। दिसंबर 2023 तक, किसान उत्पादन कंपनियों/संगठनों के साथ कुल 164 अनुज्ञप्ति समझौता ज्ञापन (एमओयू) पर हस्ताक्षर किए गए, जिससे 1.62 करोड़ रुपये का राजस्व प्राप्त हुआ। उपर्युक्त परियोजनाओं के अलावा, शैक्षणिक उद्देश्यों के लिए विभिन्न संस्थानों के साथ छह समझौता ज्ञापनों पर हस्ताक्षर किए गए। वर्ष के दौरान, आईसीएआर-डीओजीआर को ''प्याज कंदों के भंडारण के लिए एक भंडारण संरचना और उसकी एक विधि'' (पेटेंट संख्या 469459) के लिए अपना पहला पेटेंट प्रदान किया गया। ''प्याज की फसल के कीट और रोग प्रबंधन के तरीके और प्रणाली'' (आवेदन संख्या 202321081043) के लिए एक पेटेंट आवेदन भी दर्ज किया गया। इसके अलावा, निदेशालय में कृषि व्यवसाय उद्भवन (एबीआई) के लोगो के लिए एक ट्रेडमार्क आवेदन दर्ज किया गया था। भाकृअनुप-प्याज एवं लहसुन अनुसंधान निदेशालय (डीओजीआर) में कृषि-व्यवसाय उद्भवन (एबीआई) केंद्र प्याज, लहसुन और कृषि क्षेत्रों में उद्यमियों को स्थायी व्यवसाय बनाने के लिए तकनीकी सहायता, परामर्श, बुनियादी ढांचे और प्रशिक्षण की पेशकश करके आवश्यक सहायता प्रदान करता है। वर्ष 2023 के दौरान, कुल पांच सलाहकार समिति की बैठकें आयोजित की गईं, जिसमें निदेशालय में कृषि-व्यवसाय उद्भवन (एबीआई) केंद्र के तहत पंजीकृत पांच उद्भावकों ने प्याज और लहसुन प्रसंस्करण में स्टार्टअप शुरू किए। प्याज और लहसुन में कटाई के बाद प्रसंस्करण और मूल्य संवर्धन पर दो दिवसीय उद्यमिता विकास कार्यक्रम (ईडीपी) एवं प्रशिक्षण कार्यक्रम भी आयोजित किया गया। इसके अतिरिक्त, दिनांक 20-22 दिसंबर 2023 के दौरान ''एलियम्स में कृषि-व्यवसाय: नवाचार, संवर्धन और स्थिरता'' पर एक राष्ट्रीय संगोष्ठी एवं उद्योग बैठक (एनएसआईएम) आयोजित की गई। वर्ष 2023 में किए गए अनुसंधान, विस्तार और विकास गतिविधियों का संक्षिप्त सारांश नीचे प्रस्तुत किया गया है।

फसल सुधार

भाकृअनुप-प्याज एवं लहसुन अनुसंधान निदेशालय (आईसीएआर-डीओजीआर) एक राष्ट्रीय सक्रिय जननद्रव्य स्थल (एनएजीएस) के रूप में कार्य करता है, जिसके तहत वन्य और कम उपयोग वाली प्रजातियों सहित प्याज और लहसुन जननद्रव्यों के 2,200 प्राप्तियों को संरक्षित किया गया। निदेशालय वांछित लक्षणों के लिए 17 विभिन्न प्रजातियों की 89 वन्य और कम उपयोग वाली *एलियम* वंशक्रमों का रखरखाव कर रहा है। वर्ष 2023 में, *एलियम रोयली*, *ए. कैरोलिनियनम*, और *ए. रामोसम* सहित आठ नई प्रजातियों को मूल्यांकन और अंतर्मुखीकरण (इन्ट्रोग्रेशन) प्रजनन कार्यक्रमों के लिए अधिग्रहित किया गया। *एलियम* प्रजाति (17) को उपजातियों में समूहीकृत किया गया, जिससे प्रजातियों की पहचान करने और वंशावली संबंधों को समझने में मदद मिली, जिनकी 50 आईएलपी मार्करों का उपयोग करके जांच की गई। निदेशालय *ए. ट्यूबरोसम* के उत्पादन, उपभोक्ता प्रतिक्रिया और विपणन क्षमता के आधार पर एक प्रणालीगत मूल्य श्रृंखला विकसित कर रहा है। भ्रूण बचाव (एम्ब्रीयो रेस्क्यू) तकनीकों का उपयोग करके 45 अंतरविशिष्ट (इन्टरस्पेसिफिक) संकर (एफ1) (*ए. सेपा* और *ए. फिस्टुलोसम* के बीच संकरण) विकसित किए गए, जिनमें कई वंशक्रम कंद निर्माण और बारहमासी लक्षणों

की क्षमता दिखाते हैं और इनका उद्देश्य जैविक और अजैविक तनाव-प्रतिरोधी वंशक्रमों को विकसित करना है। सफेद प्याज में सुधार, प्याज के प्रजनन में महत्वपूर्ण प्रगति, उच्च पैदावार, बेहतर भंडारण और पर्यावरणीय तनावों के प्रति सहनशीलता को लक्षित करता है। कुल 95 सफेद प्याज जननद्रव्यों का मूल्यांकन किया गया; जिनमें से रबी के दौरान डब्ल्यू-418 में सबसे अधिक उपज (50.83 टन/हेक्टेयर) पाई गई। कुल 131 प्रजनन वंशक्रमों का मूल्यांकन किया गया; जिनमें से डब्ल्यू-477 एम-5 की उपज सबसे अधिक (51.44 टन/हेक्टेयर) थी, और डब्ल्यू-218 एम-2 में रबी मौसम के दौरान न्यूनतम भंडारण क्षति (20%) देखी गई। उन्नत प्रजनन वंशक्रम डीओजीआर -1613 का पछेती खरीफ मौसम के दौरान बेहतर प्रदर्शन रहा। इस वंशक्रम में 90.82 ग्राम के औसत वजन के 88.5% विपणन योग्य कंदों के साथ 46.29 टन/हेक्टेयर की उपज प्राप्त हुई तथा उसके बाद वजन के साथ डीओजीआर -1043-डी आर, डीओजीआर -1608 और डीओजीआर -1654 का स्थान रहा। रबी मौसम में, डीओजीआर -1741 को तुलनीय किस्म से बेहतर पाया गया, इस में विपणन योग्य उपज 39.33 टन/हेक्टेयर दर्ज की गई, इसके बाद डीओजीआर -1822 और डीओजीआर -1751 का स्थान रहा। वंशक्रम डीओजीआर -1761 में सबसे कम भंडारण क्षति (16.65%) दर्ज की गई। ख़रीफ़ मौसम के दौरान, वंशक्रम डीओजीआर -1753 को तुलनीय किस्म से बेहतर पाया गया (विपणन योग्य उपज-39.30 टन/हेक्टेयर और विपणन योग्य कंद-91.61%), इसके बाद डीओजीआर-1749 और डीओजीआर-1774 का स्थान रहा। इसके अतिरिक्त, डीओजीआर-1753 में कटाई के लिए न्यूनतम दिन (82 दिन) दर्ज किए गए। पछेती ख़रीफ़ मौसम के दौरान, प्रारंभिक प्रजनन वंशक्रम एल के -07-सी2/ एल आर-4 में 54.67 टन/हेक्टेयर उत्पादन प्राप्त हुआ, जो कि तुलनीय किस्म से बेहतर था और इसके बाद एल के-07- सी2/ एल आर-4, रेड जीनपूल-7, और एल के -07- सी2/ एल आर-3 का स्थान रहा। रबी मौसम में, एलके-07-सी2/एलआर-4 ने 33.19 टन/हेक्टेयर विपणन योग्य उपज प्राप्त कर बेहतर प्रदर्शन दर्ज किया, इसके बाद एलके-07-सी2/एलआर-4, आर-केएच-एम-खखख और डीओजीआर-671-सेल का स्थान रहा। पांच अंतःप्रजात वंशक्रम (आई1-1664, आई1-1773, आई1-1737, आई1-1744, आई1-1729) ने उपज और शीघ्रता के मामले में तुलनीय किस्म भीमा शक्ति से बेहतर प्रदर्शन किया, जिसमें रोपाई के बाद परिपक्वता के लिए 111-115 दिन का समय लगता है। भीमा सुपर और भीमा डार्क रेड जैसे विविध पृष्ठभूमि में नर वंध्य वंशक्रमों का बीसी1 और बीसी3 चरणों (आई1 चरण में कुल 66 अंतर्जात रेखाएँ, आई2 में 20 और आई3 में 9) में मूल्यांकन किया जा रहा हैं। अखिल भारतीय प्याज एवं लहसुन नेटवर्क अनुसन्धान परियोजना के अंतर्गत, सात नए संकर प्रस्तावित किए गए, जिनमें डीओजीआर हाई-207, हाई-211, और हाई -212 (आई ई टी परीक्षण), और डीओजीआर हाई -56, हाई -155 (ए वी टी -I), और हाई -156, हाई -172 (ए वी टी -II) शामिल हैं। आईसीएआर-डीओजीआर लहसुन सुधार के लिए एक एकीकृत दृष्टिकोण अपनाता है, जिसमें संरक्षण, उत्परिवर्तन प्रजनन, तनाव सहनशीलता और उच्च उपज वाली और तनाव प्रतिरोधी वंशक्रमों के व्यावसायीकरण पर जोर दिया जाता है। निदेशालय ने अपने फील्ड जीन बैंक में तनाव प्रतिरोधी, गुण-विशिष्ट और उत्परिवर्तित (म्यूटेशन) वंशक्रमों सहित 715 लहसुन प्राप्तियों को संरक्षित कर रखा है। रबी 2022-23 के दौरान, 13 विशिष्ट वंशक्रमों का परीक्षण किया गया, जिनमें डीओजीआर -404 ने 96.9 क्विंटल/हेक्टेयर की उच्चतम उपज प्राप्त की और डीओजीआर -806 ने उच्चतम कुल घुलनशील ठोस पदार्थ (47° ब्रिक्स) दर्ज किए। उच्च उपज देने वाले उत्परिवर्तन वंशक्रम, जैसे कि बीपी-6 (कुल उपज 84.7 क्विंटल/हेक्टेयर), कंद वजन और कुल घुलनशील ठोस पदार्थ जैसे बेहतर लक्षण प्रदर्शित करते हैं। अपने स्वाद और छीलने में आसानी के लिए पहचानी जानी वाली, गहरे बैंगनी रंग के कलियों वाली सत्रह किस्मों का मूल्यांकन किया गया, जिसमें पीबी-डार्क-1 और डीओजीआर-756-डीआर ने क्रमशः 95.2 और 81.3 क्विंटल/हेक्टेयर की उच्चतम पैदावार हासिल की। उच्च तनाव की स्थिति में, डीओजीआर-24 ने डीओजीआर-28 की तुलना में बेहतर उत्तरजीविता दिखाई। डीओजीआर-555 और सीपीटी-11 एम4 जैसी किस्मों की पैदावार ख़रीफ़ मौसम के दौरान लगातार 5 टन/हेक्टेयर से अधिक रही। रोपण सामग्री के रूप में कठोर ग्रीवा वाली लहसुन कंदिकाओ के परीक्षणों में जुलाई के अंत में रोपण से कंद विकास के लिए सर्वोत्तम परिणाम मिले। 46° ब्रिक्स से अधिक उच्च कुल घुलनशील ठोस पदार्थ वाली डीओजीआर-806 और 404-एचवाई जैसे वंशक्रमों को प्रसंस्करण के लिए उपयुक्त के रूप में पहचाना गया। वर्तमान में, आईसीएआर-डीओजीआर ने रबी के लिए आईईटी परीक्षणों में दो लहसुन वंशक्रम (डीओजीआर-815 और डीओजीआर-569) और खरीफ किस्म परीक्षण मूल्यांकन के लिए दो वंशक्रम (डीओजीआर-555 और डीओजीआर-100) प्रस्तावित किए गए। डीओजीआर-404 और डीओजीआर-793 वंशक्रमों का एवीटी -I में परीक्षण किया गया, जबकि डीओजीआर-48-W और डीओजीआर-746 का मूल्यांकन एवीटी -II में किया गया। फसल सुधार के लिए अत्याधुनिक जैव प्रौद्योगिकी उपकरणों के एकीकरण पर जोर देते हुए, यह अनुभाग प्याज में अगुणित प्रेरण, जीनोम संपादन (एडिटिंग), तनाव प्रतिरोध

और सीएमएस विकास में प्रगति पर प्रकाश डालता है। फ्लो साइटोमेट्री का उपयोग करके कुल 275 पौधों (89.95%) की अगुणित के रूप में पुष्टि की गई, और 140 पौधे आगे के प्रजनन कार्यक्रमों के लिए कोल्चीसिन उपचार से जीवित रहे। विशिष्ट एक्सॉनों के लिए sgRNAs को डिज़ाइन करके *AcMYB1* और *AcCHS* जीन का लक्षित संपादन हासिल किया गया। *एग्रोबैक्टीरियम*-मध्यस्थता परिवर्तन का उपयोग करके प्याज और तंबाकू में एक द्विसंयोजक प्रोटीन, आर-पीबी अभिव्यक्त किया गया। आर-पीबी अभिव्यक्ति के लिए 67 ट्रांसजेनिक तंबाकू पौधों की पुष्टि की गई, जबकि प्याज कैली चयन चरण में हैं। प्याज में *AcCENH3* अभिव्यक्ति को कम करने के लिए आरएनए हस्तक्षेप (आरएनएआई) का उपयोग किया गया। ट्रांसजेनिक और वन्य प्रकार के पौधों के बीच विशिष्ट संकरण में अगुणित प्रेरण दक्षता (एचआईई) 4.63% तक पहुंच गई। एग्रोबैक्टीरियम आधारित परिवर्तन का उपयोग करके एसीएमएसएच1 जीन के लक्षित उत्परिवर्तन के परिणामस्वरूप 22 पुनर्जीवित पौधे प्राप्त हुए, जिनमें से 16 में उत्परिवर्तन होने की पुष्टि की गई। प्याज में संयुक्त लवणता और रोगज़नक़ तनाव के लिए आणविक प्रतिक्रियाएँ *WRKY* TFs पौधों की वृद्धि, विकास और जैविक और अजैविक तनावों की प्रतिक्रियाओं को विनियमित करने में महत्वपूर्ण हैं। कुल 54 कथित *WRKY* जीनों की पहचान की गई, जिन्हें *AceWRKY1* से *AceWRKY54* नाम दिया गया। यह अध्ययन प्याज में *WRKY* जीन परिवार के बारे में जानकारी प्रदान करता है, जो फसल में तनाव सहनशीलता को समझने और बढ़ाने में योगदान दे सकता है।

फ़सल उत्पादन

वर्ष 2023 के पछेती ख़रीफ़ मौसम और 2023 के रबी मौसम के दौरान प्याज और लहसुन की फसलों के लिए एकीकृत खरपतवार प्रबंधन मॉड्यूल विकसित करने के लिए किए गए एक क्षेत्रीय प्रयोग से पता चला कि रोपाई से 25 और 45 दिनों बाद पेंडिमिथालिन 30% ईसी 1 किग्रा ए.आई./हेक्टेयर और इसके बाद प्रोपाक्विज़फ़ॉप 10% ईसी @100 ग्राम ए.आई./हेक्टेयर + ऑक्सीफ्लोरफेन 23.5% ईसी 200 ग्राम का उपयोग, अथवा पेंडिमिथालिन 30% ईसी 1 किग्रा ए.आई./हेक्टेयर (पीआरई) और इसके बाद पॉलिथीन मल्चिंग से उच्च खरपतवार नियंत्रण क्षमता प्रदर्शित हुई और लहसुन की उपज खरपतवार-मुक्त स्थिति के बराबर प्राप्त हुई। प्याज के उत्पादन और मिट्टी की उर्वरता की स्थिति पर अकार्बनिक उर्वरकों और खादों के निरंतर उपयोग का आकलन करने वाले एक अन्य प्रयोग से पता चला कि एकीकृत पोषक तत्व प्रबंधन (आईएनएम) उपचार, खनिज उर्वरकों और केंचुएं की खाद के संयोजन से, मिट्टी में जैविक कार्बन और उपलब्ध पोषक तत्वों को बढ़ाया जा सकता है, जिससे प्रारंभिक मिट्टी की उर्वरता बनी रहेगी। हालाँकि, मृदा-जनित रोग के अधिक प्रकोप के कारण उपचार के दौरान सोयाबीन खंड में कंद की उपज कम हो गई। इसके अतिरिक्त, जैविक और प्राकृतिक खेती के प्रयोगों से पता चला कि रासायनिक उर्वरकों और आईएनएम भूखंडों से जैविक और प्राकृतिक खेती के तरीकों की तुलना में काफी अधिक कंद की पैदावार हुई, आईएनएम में जैविक/प्राकृतिक तरीकों की तुलना में 52.4-58.9% की वृद्धि देखी गई। मृदा विश्लेषण ने आईएनएम और पारंपरिक कृषि प्रणालियों की तुलना में जैविक भूखंडों में उच्च मिट्टी कार्बनिक कार्बन और उपलब्ध नाइट्रोजन का संकेत दिया। प्याज की वृद्धि, उपज और भंडारण में क्षति पर नाइट्रोजन उर्वरकों और सिंचाई विधियों के प्रभाव का मूल्यांकन करने वाले एक क्षेत्रीय प्रयोग से पता चला कि फव्वारा सिंचाई के माध्यम से लागू किए गए 100% और 150% नाइट्रोजन के साथ उपचार में टपक फर्टिगेशन की तुलना में उच्च पर्णहरित संकेद्रण (क्लोरोफिल कंसंट्रेशन) और पौधे के विभिन्न परिमाप में विकास पाया गया। हालाँकि, 100% नाइट्रोजन के साथ टपक और फव्वारा सिंचाई से बाढ़ सिंचाई की तुलना में प्याज की पैदावार में काफी वृद्धि हुई। आठ प्याज जीनप्रारूप (डब्ल्यू -355, प्राप्ति 1630, प्राप्ति 1666, और भीमा डार्क रेड) पर जलभराव तनाव के प्रभाव का आकलन करने वाले एक क्षेत्रीय प्रयोग में पाया गया कि भीमा डार्क रेड और प्राप्ति 1666 ने जलभराव की स्थिति में बेहतर प्रदर्शन किया। सहिष्णु जीनप्रारूप एसीसी 1666 और भीमा डार्क रेड ने संवेदनशील जीनप्रारूप की तुलना में उच्च जीवित रहने का प्रतिशत (90%), पर्णहरित सामग्री, कोशीय झिल्ली स्थिरता और कंद उपज का प्रदर्शन रहा। पोषक तत्व प्रबंधन प्रथाओं को विकसित करने के लिए विकास प्रदर्शन, शुष्क पदार्थ की उपज और पोषक तत्व ग्रहण का मूल्यांकन करने के लिए *एलियम ट्यूबरोसम* के तीन वंशक्रम लगाए गए। पौधे की ऊंचाई, पत्ती संख्या, टिलर (कल्ले) संख्या और पत्ते की उपज जैसे मापदंडों की 11 महीने तक मासिक निगरानी की गई। इस अवधि में, जीनप्ररूपों ने 8.84-9.82 टन/हेक्टेयर शुष्क पदार्थ का उत्पादन किया, जिससे प्रति हेक्टेयर 201-235 किलोग्राम नाइट्रोजन, 62-73 किलोग्राम फॉस्फोरस, 262-296 किलोग्राम पोटाश, और 41-54 किलोग्राम गंधक मिटटी से काम हो गया। यह व्यापक डेटा *एलियम ट्यूबरोसम* की खेती के अनुरूप उर्वरक कार्यक्रम तैयार करने के लिए मूल्यवान अंतर्दृष्टि प्रदान करता है, जो इसके टिकाऊ व्यावसायिक उत्पादन में योगदान देता है। आईसीएआर-सिरकोट ने नैनो-गंधक विकसित किया है, जिसे रसायन-यांत्रिक विधियों के माध्यम से मौलिक गंधक से संश्लेषित किया गया है, जिसका कण आकार 500-700 एनएम और 20%

(डब्ल्यू / वी) की सांद्रता है। आईसीएआर–डीओजीआर, पुणे में प्याज और लहसुन पर इसकी प्रभावकारिता का आकलन किया गया। अकेले नैनो– गंधक के उपयोग से विपणन योग्य उपज में 8–12% की वृद्धि हुई, जबकि गोबर की खाद (एफवाईएम) के साथ इसके संयोजन से प्याज की उपज में 3.8–8.3% और लहसुन की उपज में 10.8–16.3% की वृद्धि हुई, हालांकि गोबर के साथ उपयोग करने पर इसका प्रभाव कम था। आईआईटी–मुंबई के सहयोग से, मिट्टी की नमी, पीएच, विद्युत चालकता और मिट्टी में उपलब्ध एनपीके की लगातार निगरानी के लिए मल्टी–डेप्थ सेंसर से लैस ई–एग्रीस स्टेशनों को तैनात करते हुए एक प्रक्षेत्र प्रयोग शुरू किया गया। परिणामों से पता चला कि प्रयोगशाला डेटा सभी मापदंडों के लिए सेंसर डेटा में देखे गए रुझानों के साथ निकटता से जुड़ा हुआ है, जो सेंसर की प्रभावकारिता की पुष्टि करता है। जलभराव की तनाव की स्थिति में पौधों की वृद्धि और विकास पर सूक्ष्मजीवी टीकाकरण के प्रभाव का आकलन करने के लिए खरीफ 2022 के दौरान किए गए एक पॉट प्रयोग से पता चला कि पौधों को *एज़ोटोबैक्टर स्पीसीज* के साथ टीकाकरण से पौधों ने नियंत्रण और तनाव दोनों स्थितियों में बेहतर प्रदर्शन किया। प्याज की फसलों में जलभराव तनाव सहनशीलता को विनियमित करने वाले आणविक तंत्र को समझने के लिए, आरएनए–सीक्यू तकनीक का उपयोग करके जलभराव–सहिष्णु जीनप्रारूप (प्राप्ति 1666) और संवेदनशील जीनप्रारूप (डब्ल्यू–344) के पत्ती ऊतकों पर ट्रांसक्रिप्टोम अनुक्रमण किया गया। विभेदक जीन अभिव्यक्ति विश्लेषण से पता चला कि प्राप्ति 1666 में 1,629 जीन उन्नत और 3,271 जीन अवनत हुए, जबकि जलभराव तनाव के स्थिति में डब्ल्यू–344 में 2,134 जीन उन्नत और 1,909 जीन अवनत हुए। प्याज प्रजाति भीमा डार्क रेड पर विभिन्न पौधों के विकास नियामकों के प्रभाव का मूल्यांकन करने वाले जलभराव के तनाव के तहत एक प्रक्षेत्र प्रयोग से पता चला कि 50 पीपीएम की दर से मेलाटोनिन के पत्तियों पर प्रयोग से ऐसी परिस्थितियों में प्याज की फसल की वृद्धि में सुधार हुआ। प्याज की किस्मों भीमा शक्ति और भीमा किरण की वृद्धि और उपज पर उच्च तापमान के तनाव के प्रभाव का आकलन करने वाले एक पॉट प्रयोग से पता चला कि 42 डिग्री सेल्सियस और उससे ऊपर के तापमान ने फसल की वृद्धि और उपज को गंभीर रूप से नुकसान पहुंचाया।

फसल सुरक्षा

प्याज और लहसुन उगाने वाले विभिन्न क्षेत्रों से रोग के नमूने एकत्र किए गए, और रूपात्मक विशेषताओं और आणविक तकनीकों का उपयोग करके *अल्टरनेरिया अल्टरनेटा, कोलेटोट्रीकम ग्लोओस्पोरियोइड्स, फ्यूजेरियम एक्यूटेटम, एफ. फाल्सीफॉर्म, एफ. सोलानी* और *एफ. ऑक्सीस्पोरम* जैसे रोगजनकों की पहचान गई। ट्राइकोडर्मा स्पीसीज सहित अन्य कल्चर को संरक्षित किया गया और एनएआईएमसीसी, आईसीएआर–एनबीआईएएम, मऊ में जमा किया गया। तथा अनुक्रमों को विभिन्न परिग्रहण (एक्सेसन) संख्याओं के तहत एनसीबीआई जीन बैंक में जमा किया गया। इसके अलावा, *ट्राइकोडर्मा एसपीपी* को भी अलग किया गया, उसकी विशेषता बताई गई और उसका अनुक्रम बनाया गया। प्याज की वृद्धि और रोग प्रबंधन पर उनके प्रभाव के लिए ग्यारह *ट्राइकोडर्मा* आइसोलेट्स का मूल्यांकन किया गया। उनमें से, टी–8आर आइसोलेट सबसे प्रभावी था, जिसने *स्टेमफिलियम* रोग की 56% और एन्थ्रेक्नोज/ट्विस्टर की 39% तक रोकथाम की। इसके अतिरिक्त, नियंत्रण की तुलना में 20% उपज में वृद्धि देखी गई। प्याज में प्रमुख फफूंदीय रोगों के विरुद्ध उनकी प्रभावकारिता के लिए चार रोग प्रबंधन मॉड्यूल (एम1, एम2, एम3 और एम4) का परीक्षण वर्तमान उत्पादन पद्धतियां (ईपी), किसानों की उत्पादन पद्धतियां (एफपी) और पूर्ण नियंत्रण (एसी) के साथ किया गया। सभी मॉड्यूल में *स्टेमफिलियम* रोग (रबी मौसम के दौरान 21–40% रोकथाम) और एन्थ्रेक्नोज रोग (खरीफ मौसम के दौरान 6–58% रोकथाम) का रोकथाम पाया गया, जिसमें एम1 (गहन प्रबंधन) ने सबसे अधिक अवरोध (40%) दिखाया। अमृतपानी–आधारित जैविक फॉर्मूलेशन का मूल्यांकन किया गया, जिसमें खरीफ 2023 के दौरान डीओजीआरओ एफ3 से एन्थ्रेक्नोज का उच्चतम रोकथाम (26%) पाया गया। लहसुन जननद्रव्य के आणविक लक्षण वर्णन से *एफ. ऑक्सीस्पोरम* के फ्यूजेरियम बेसल रॉट रोग के रोगजनक की पुष्टि हुई। प्याज के खेतों से प्रमुख मिट्टी के सूक्ष्मजीवों को भी अलग किया गया और नौ कवक उपभेदों और दस जीवाणु उपभेदों की पहचान करते हुए रूपात्मक और आणविक तकनीकों का उपयोग करके उनका लक्षण वर्णन किया गया। कवक अलगावों में, सभी नौ एंटोमोपैथोजेनिक कवक (EPF) पाए गए, जबकि जीवाणु अलगावों में दो ज़िंक–घुलनशील और आठ फॉस्फेट–घुलनशील राइजोस्फीयर जीवाणु (PSB) शामिल थे। वन्य और प्याज खेती की राइजोस्फीयर मिट्टी की पूरी मेटाजेनोमिक अनुक्रमण ने प्रोटियोबैक्टीरिया, एक्टिनोबैक्टीरिया, फ़िरमिक्यूट्स और थुमारकेओटा को सबसे प्रचुर मात्रा में फ़ाइला के रूप में प्रकट किया। अल्फा–विविधता सूचकांक (शैनन इंडेक्स) में *एलियम एंगुलोसम* में सबसे अधिक माइक्रोबियल विविधता दिखाई दी, उसके बाद यह *एलियम हुकरी* में थी। प्याज के राइजोस्फीयर में जैवउर्वरक प्रभावों पर एक मेटाबारकोडिंग अध्ययन में 46 जीवाणु फ़ाइला और 481 जेनेरा की पहचान की गई, जिसमें प्रोटियोबैक्टीरिया प्रमुख थे, उसके बाद एक्टिनोबैक्टीरिया, फ़िरमिक्यूट्स, प्लैक्टोमाइसेट्स और क्रेनार्केओटा थे। अल्फा–विविधता सूचकांक (शैनन और सिम्पसन–ई) में

एज़ोटोबैक्टर-100-आरडीएफ-उपचारित मिट्टी में सबसे अधिक जीवाणु विविधता और एज़ोस्पिरिलम-100-आरडीएफ-उपचारित मिट्टी में सबसे कम जीवाणु विविधता के संकेत मिले। चाओ1 इंडेक्स से नियंत्रित -100-आरडीएफ मिट्टी में जीवाणुओं की बहुलता सबसे अधिक पाई गई। बीटा-विविधता विश्लेषण (भारित यूनीफ्रेक) ने जीवाणुओं के समुदायों में महत्वपूर्ण भिन्नताओं को प्रदर्शित किया, जिसमें पीसीओए विश्लेषण ने 48.5% और 21.1% की संचयी भिन्नता को प्रदर्शित किया गया। खरीफ और रबी (2023-24) के दौरान कर्नाटक और महाराष्ट्र में किए गए एक सर्वेक्षण से प्रमुख फफूंदीय रोगजनकों के लिए रोग गंभीरता मानचित्र का विकास हुआ। प्याज एन्थ्रेक्नोज-ट्विस्टर की संक्रमण प्रक्रिया का अध्ययन किया गया, जिसमें पता चला कि *सी. ग्लोओस्पोरियोइड्स* और *एफ. एक्यूटेटम* के साथ संयुक्त उपचार से ट्विस्टिंग लक्षण उत्पन्न हुए, जो एक सहक्रियात्मक प्रभाव के कारण जीए3 अनुप्रयोग के साथ तीव्र हो गए। विभिन्न प्याज किस्मों में फ्यूजेरियम बेसल रॉट संक्रमण प्रक्रिया ने गहरे रंग की किस्मों में अधिक संवेदनशीलता दिखाई। *सी. ग्लोओस्पोरियोइड्स, अल्टरनेरिया पोरी* और *स्टेमफिलियम वेसिकेरियम* के कारण होने वाले लहसुन संक्रमण में टीकाकरण के 5-7 दिनों के बाद (डीएआई) लक्षण दिखाई दिए। *सी. ग्लोओस्पोरियोइड्स, ए. पोरी, एस. वेसिकेरियम* और *फ्यूजेरियम स्पीसीज* के विरुद्ध ग्यारह ट्राइकोडर्मा उपभेदों की जांच की गई, जिसमें *ट्राइकोडर्मा लॉन्गिब्राचिएटम* ने सबसे अधिक अवरोध प्रतिशत प्रदर्शित किया। इसके अतिरिक्त, प्याज (11) और लहसुन (6) राइजोस्फीयर से 17 पीजीपीआर उपभेदों को अलग किया गया और आईटीएस और 16एस आरआरएनए (rRNA) प्राइमरों का उपयोग करके रूपात्मक, जैव रासायनिक और आणविक रूप से लक्षण वर्णन किया गया।

खरीफ और रबी प्याज (2023) में प्याज थ्रिप्स (*थ्रिप्स टैबैसी*) के खिलाफ *लेकेनिसिलियम लेकेनी, ब्यूवेरिया बेसियाना, मेटारिज़ियम एनिसोप्लाई* और नीम तेल (अकेले और संयोजन में) के प्रक्षेत्र में मूल्यांकन में थ्रिप्स की संख्या में महत्वपूर्ण कमी दिखाई दी। नीम तेल + *एल. लेकेनी* और नीम तेल + *एम. एनिसोप्लाई* जैव-एजेंटों में सबसे प्रभावी थे, जिन्होंने थ्रिप्स को 71-72.8% तक कम किया, इसके बाद नीम तेल + *बी. बेसियाना* का स्थान रहा। जैविक कीटनाशक स्पिनोसैड सबसे प्रभावी रहा, जिसने 77.6% (खरीफ) और 86.0% (रबी) संख्या में कमी हासिल की। एन्टोमोपैथोजेन्स में, *एल. लेकेनी* ने सबसे अधिक प्रभावकारिता दिखाई, उसके बाद *एम. एनिसोप्लाई* का स्थान रहा। खरीफ और रबी मौसम में प्याज थ्रिप्स के खिलाफ नई पीढ़ी के कीटनाशकों की प्रभावकारिता का मूल्यांकन किया गया। स्पिरोटेट्रामेट + इमिडाक्लोप्रिड ने थ्रिप्स में सबसे अधिक कमी (80%) दिखाई, उसके बाद प्रोफेनोफोस (81.8%) और स्पिनेटोरम (79%) ने थ्रिप्स प्रबंधन में उनकी प्रभावशीलता को साबित किया। *थ्रिप्स टैबैसी* और *थ्रिप्स परविसपिनस* के पूरे माइटोकॉन्ड्रियल जीनोम को अनुक्रमित किया गया और डेटा को एनसीबीआई जीनबैंक में जमा किया गया। कटाई के बाद के प्याज भंडारण कीटों और रोगजनकों के प्रबंधन पर सात वनस्पति उपचारों का परीक्षण किया गया। नियंत्रित संग्रह में सबसे अधिक भंडारण क्षति (49.12%) दिखाई दी। जबकि सीताफल और लेमन ग्रास उपचार के परिणामस्वरूप सबसे कम, क्रमशः 38.97% और 39.87% भंडारण क्षति हुई। यह निष्कर्ष प्याज में भंडारण के नुकसान को कम करने के लिए एक प्रभावी दृष्टिकोण के रूप में वानस्पतिक छिड़काव करने का संकेत देते हैं। नासिक और सातारा जिलों में प्याज के खेतों में डंक रहित मधुमक्खियों के लिए 20 स्थानों में किए गए सर्वेक्षण में परागण में उनकी महत्वपूर्ण भूमिका की पहचान की गई, जो चारा भ्रमण में 39% का योगदान देती है। मधुमक्खियों का चारा खोजने का व्यवहार सुबह 11:30 बजे के आसपास चरम पर रहा, जिसमें अधिकांश भ्रमण पराग संग्रह पर केंद्रित थे। एक डंक रहित मधुमक्खी प्रजाति *टी. इरिडिपेनिस* द्वारा उत्पादित शहद में *ए. मेलिफेरा* शहद की तुलना में अधिक विद्युत चालकता (EC), प्रोटीन एंटीऑक्सीडेंट और शर्करा का स्तर, लेकिन कम पीएच पाया गया। महाराष्ट्र के चार प्रमुख प्याज उत्पादन करने वाले वाले जिलों में एक सर्वेक्षण कर प्याज पारिस्थितिकी तंत्र में प्रमुख मधुमक्खी प्रजातियों का दस्तावेजीकरण किया गया, जिनमें सबसे प्रमुख *एपिस फ्लोरिया, ए. सेराना इंडिका* और *टेट्रागोनुला* स्पीसीज शामिल हैं। इनमें से *ए. सेराना इंडिका* में सबसे अधिक सक्रीय चारा भ्रमण पाया गया। एपिस प्रजाति के आंत माइक्रोबायोम का अध्ययन कल्चर-निर्भर और कल्चर से स्वतंत्र इस तरह के दोनों तरीकों का उपयोग करके किया गया, जिससे विविध जीवाणु समुदायों, विशेष रूप से *ए. फ्लोरिया* में लैक्टोबैसिलस प्रजातियों की प्रमुख भूमिका का पता चला। यह निष्कर्ष प्याज परागण में विशिष्ट मधुमक्खी प्रजातियों की महत्वपूर्ण भूमिका और उनके आंत माइक्रोबायोम के भीतर की सूक्ष्मजीवी विविधता पर प्रकाश डालते हैं। अनुक्रम डेटा एनसीबीआई बायो प्रोजेक्ट डेटाबेस में एक्सेसन क्रमांक पीआरजेएनए1065181 के साथ जमा किया गया।

कटाई उपरांत प्रौद्योगिकी

फसलोत्तर प्रौद्योगिकी के अंतर्गत प्याज का उपयोग करके नए प्रसंस्कृत उत्पाद विकसित करने के प्रयास किए गए। स्वः पात्रे (*इन–विट्रो*) मूल्यांकन की एक श्रृंखला के माध्यम से *एल. एसिडोफिलस*, *एल. फेरमेंटम*, *एल. रैम्नोसस*, *एल. हेल्वेटिकस*, *एल. डेलब्रुइकी*, *एल. प्लांटारम* और *एल. केसी* सहित विभिन्न लैक्टोबैसिलस उपभेदों की प्रोबायोटिक क्षमताओं का मूल्यांकन प्याज का प्रोबिओटिक पेय विकसित करने के लिए अध्ययन किया गया। प्रमुख मूल्यांकनों में सिम्युलेटेड जठरांत्रिय स्थितियों में जीवित रहना, आंतों की कोशिकाओं से चिपकना, रोगाणुरोधी गतिविधि और कम पीएच, पित्त लवण और पाचक रस के प्रति सहनशीलता शामिल है। कैटालेज़ परीक्षण ने पुष्टि की कि सभी उपभेद कैटेलेज़–निगेटिव और ग्राम–पॉजिटिव थे। स्वः पात्रे (*इन–विट्रो*) में, *एल. रैम्नोसस* ने उच्चतम अम्ल सहनशीलता प्रदर्शित की, जबकि यह *एल. एसिडोफिलस* में सबसे कम दिखाई दी। *एल. प्लांटारम* ने सिम्युलेटेड पाचक जूस में बेहतर उत्तरजीविता को प्रदर्शित किया, जबकि *एल. रैम्नोसस* में यह सबसे कम पाई गई। पित्त लवण सहनशीलता के संबंध में, सभी उपभेदों ने मध्यम लचीलापन दिखाया, *एल. प्लांटारम* और *एल. केसी* ने उल्लेखनीय उत्तरजीविता को प्रदर्शित किया। कोशिका की सतह की हाइड्रोफोबिसिटी अलग–अलग पाई गई, *एल. प्लांटारम* ने साइक्लोहेक्सेन और टोल्यूनि दोनों में उच्चतम चिपकाव प्रदर्शित किया। स्वयं–एकत्रीकरण परख में *एल. हेल्वेटिकस* और *एल. रैम्नोसस* ने मजबूत एकत्रीकरण क्षमता दिखाई, जो आंत उपनिवेशण (कोलोनाईजेन) के लिए महत्वपूर्ण है। *ई. कोली*, *माइक्रोकोकस ल्यूटस*, *लिस्टेरिया मोनोसाइटोजेन्स* और *स्टैफिलोकोकस ऑरियस* जैसे रोगजनकों के साथ सह–एकत्रीकरण परीक्षण में *एल. प्लांटारम*, *एल. फेरमेंटम*, और *एल. हेल्वेटिकस* ने महत्वपूर्ण सह–एकत्रीकरण प्रदर्शित किया, जो इन रोगजनकों के खिलाफ मजबूत प्रोबायोटिक क्षमता का सुझाव देता है। जैव रासायनिक विश्लेषण से पता चला कि सभी उपभेद अलग–अलग कार्बोहाइड्रेट किण्वन प्रोफाइल के साथ एस्कुलिन हाइड्रोलिसिस सकारात्मक पाए गए। यह प्रारंभिक निष्कर्ष *लैक्टोबैसिलस* उपभेदों की विविध विशेषताओं और वाणिज्यिक प्रोबायोटिक अनुप्रयोगों के लिए उनकी क्षमता में अंतर्दृष्टि प्रदान करते हैं। इन परिणामों की पुष्टि के लिए आगे के अध्ययन की आवश्यकता है। कच्चे प्याज के विकल्प के रूप में निर्जलित प्याज का उपयोग विभिन्न प्रकार के प्रसंस्कृत, पकाने के लिए तैयार और खाने के लिए तैयार खाद्य पदार्थों में किया जा सकता है, जिससे परिवहन, भंडारण, तैयारी और उपयोग में आसानी जैसे कई फायदे मिलते हैं। हालाँकि, भारतीय घरों में निर्जलित प्याज की खपत अपेक्षाकृत कम है। इसके उपयोग को बढ़ाने के लिए, निर्जलित प्याज को शामिल करके पकाने के लिए तैयार मिश्रण को विकसित करने के लिए परिक्षण किए गए। प्याज का पकोड़ा, भारत में एक लोकप्रिय नाश्ता है, जिसे तैयार करने में समय लगता है, खासकर प्याज को छीलने और काटने के लिए। इस चुनौती से निपटने के लिए, निर्जलित प्याज का उपयोग करके पकाने के लिए तैयार पकौड़ा स्नैक मिश्रण को निर्मित किया गया। यह उत्पाद न केवल नाशते की तैयारी के समय को कम करता है बल्कि अधिक सुविधा भी प्रदान करता है, साथ ही निर्जलित प्याज के लिए एक बड़ा बाजार भी तैयार करता है।

सड़न से होने वाली क्षति को कम करने के लिए प्याज की कटाई के बाद के प्रबंधन के अंतर्गत, प्याज के कंद के सामान्य जीवाणु रोगजनकों का एक तुलनात्मक जीनोमिक विश्लेषण किया गया, जिसके लिए जीनोमिक अनुक्रम उपलब्ध हैं। जीनोमिक विश्लेषण के लिए *पेंटोइया एनानाटिस*, *पेंटोइया एग्लोमेरन्स*, *इरविनिया पर्सिसिनिया*, *रूक्सिएला बैडेंसिस*, *स्यूडोमोनस उवाल्डेंसिस*, *ज़ैंथोमोनस एक्सोनोपोडिस*, *बर्कहोल्डरिया सेपेसियन* और *कर्टोबैक्टीरियम एली* के उपभेदों के सार्वजनिक रूप से उपलब्ध जीनोमिक अनुक्रम शामिल किए गए। तुलनात्मक जीनोमिक अध्ययन के लिए *पैन्टोइया अनानाटिस* के सभी उपलब्ध जीनोमों को सटीक किया गया और कंद के केंद्रीय सड़न का कारण बनने वाले इस विनाशकारी रोगज़नक़ के विभिन्न उपभेदों के बीच साझा किए गए सामान्य आनुवंशिक प्रदर्शनों का विश्लेषण किया गया। कंदों पर आक्रमण के लिए जिम्मेदार इसके आनुवंशिक तत्वों को समझने के लिए आगे के प्रयास जारी हैं।

विस्तार

अनुसंधान कार्य के अलावा, कई विस्तार गतिविधियाँ भी की गईं। अध्ययन के लिए संस्थान की परियोजना (30), अनुसूचित जाति उप–योजना (727), और मेरा गांव मेरा गौरव (60) के माध्यम से महाराष्ट्र और कर्नाटक राज्य में खरीफ (152), पछेती खरीफ (55) और रबी (610) मौसमों के दौरान कुल 817 प्रदर्शन आयोजित किए गए। ख़रीफ़ मौसम में प्रदर्शनों से पता चला कि भीमा सुपर का अंकुरण प्रतिशत (97), औसत कंद वजन (82 ग्राम) और उपज (25.5 टन/हेक्टेयर) सबसे अधिक थी। भीमा डार्क रेड (25.0

टन/हेक्टेयर) की पैदावार भी स्थानीय किस्म (18.5 टन /हेक्टेयर) से अधिक हुई। भीमा राज का अंकुरण प्रतिशत (95), औसत कंद वजन (85 ग्राम) और उपज (47.5 टन/हेक्टेयर) पछेती ख़रीफ़ प्रदर्शनों में सबसे अधिक पाई गई। भीमा रेड (45.0 टन /हेक्टेयर) की पैदावार भी पछेती ख़रीफ़ प्रदर्शनों में स्थानीय किस्म (24.0 टन/हेक्टेयर) से अधिक हुई। महाराष्ट्र में रबी में किए गए प्रदर्शनों से पता चला कि भीमा किरण का अंकुरण प्रतिशत (94), औसत कंद वजन (84 ग्राम) और विपणन योग्य उपज (42.5 टन /हेक्टेयर) सबसे अधिक थी और भीमा शक्ति (42.0 टन/हेक्टेयर) की उपज भी स्थानीय किस्म (27.5 टन/हेक्टेयर) से अधिक प्राप्त हुई। आईसीएआर-डीओजीआर द्वारा विकसित किस्मों को सभी प्रदर्शनों में स्थानीय किस्मों से बेहतर पाया गया। कृषि-ड्रोन परियोजना के तहत किसानों के खेतों पर ड्रोन आधारित छिड़काव तकनीक का प्रदर्शन किया गया। महाराष्ट्र के पुणे और अहमदनगर जिलों के 50 गांवों में 187 एकड़ भूमि पर प्याज की खेती के लिए कुल 135 प्रदर्शन आयोजित किए गए। प्रदर्शन में करीब 1200 किसान शामिल हुए। अनुसूचित जाति उप-योजना के तहत महाराष्ट्र में कुल 737 अग्रिम पंक्ति प्रदर्शन, महाराष्ट्र और उत्तर प्रदेश में जनजातीय उप-योजना के तहत 251 और पूर्वोत्तर पर्वतीय क्षेत्र में पूर्वोत्तर पर्वतीय योजना के तहत 63 प्रदर्शन आयोजित किए गए। वर्ष के दौरान, किसानों के लिए यूट्यूब चैनल पर नौ प्रौद्योगिकी और सलाह आधारित वीडियो तैयार कर प्रसारित किए गए। वीडियो शेयरिंग प्लेटफॉर्म यूट्यूब चैनल का उपयोग फसल उत्पादन से संबंधित 53 वीडियो प्रसारित करने के लिए किया गया, जिनको विभिन्न दर्शकों द्वारा 41,033 बार देखा गया, 1,914 सदस्य बनें और संबंधित वीडियो 1,300 घंटे देखे गए। एक मल्टीमीडिया-आधारित द्विभाषी (मराठी और हिंदी) समाचार बुलेटिन, प्याज एवं लहसुन समाचार के छह अंक यूट्यूब पर वेबकास्ट किए गए, जिनमें प्याज और लहसुन उत्पादन सलाह, विशेषज्ञ वार्ता और मासिक फसल स्थितियों के समसामयिक प्रश्नोत्तर सत्र शामिल थें। सामाजिक रूप से एकीकृत मैसेजिंग प्लेटफॉर्म को व्हाट्सएप एप्लिकेशन पर 116 किसान समूहों के माध्यम से देश भर में 9977 किसान सदस्यों को जोड़ने में प्रभावी पाया गया। इन समूहों का प्रमुख उत्पादक जिलों के लिए खंड -वार क्लस्टर तैयार किया गया और समय एवं स्थान विशिष्ट फसल उत्पादन सलाह देने और किसानों के प्रश्नों को संबोधित करने के लिए उपयोग किया गया। देश के विभिन्न भागों के किसानों को टेक्स्ट (21) ऑडियो (8) वीडियो (26) सलाह सहित कुल 52 समय पर सलाह भेजी गईं। पोषक तत्व प्रबंधन, कीट और बीमारियों, किस्म के चयन और दिन-प्रतिदिन के संचालन में त्वरित प्रबंधन के लिए निर्णय समर्थन प्रणाली निर्णय समर्थन प्रणाली युक्त एक सक्षम मोबाइल एप्लीकेशन विकसित किया गया। इसका उपयोग 1000 से अधिक किसानों और हितधारकों द्वारा किया जा रहा है।

अन्य गतिविधियों

विभिन्न संस्थागत गतिविधियाँ जैसे अनुसन्धान सलाहकार समिति, संस्थागत अनुसन्धान समिति, संस्थागत प्रबंधन समिति, आदि की बैठकें समय पर आयोजित की गईं। संस्थान में गणतंत्र दिवस, स्वतंत्रता दिवस, अंतर्राष्ट्रीय महिला दिवस, विश्व मृदा दिवस मनाया गया। साथ ही, सतर्कता जागरूकता सप्ताह भी मनाया गया। दैनिक कामकाज में हिंदी के महत्व को बढ़ाने के लिए हिंदी पखवाड़ा का आयोजन किया गया। निदेशालय में स्वच्छ भारत अभियान के दौरान विभिन्न गतिविधियाँ भी आयोजित की गई।

Executive Summary

The research, extension and development work of ICAR-Directorate of Onion and Garlic Research was carried out through institutional reseach projects and adhoc/externally funded projects during the year 2023. During the reporting period, ICAR-DOGR organized 103 trainings under SCSP, TSP, NEH, MGMG, ATMA, etc., schemes which were attended by 4760 farmers and other stakeholders and participated in 5 exhibitions to showcase onion and garlic technologies. Seventeen licensing Memoranda of Understanding (MoUs) were signed with 13 seed companies for the commercialization of four onion varieties (B. Kiran, B. Super, B. Shakti, B. Dark Red). Among these companies, two are Farmer Producer Companies (FPCs). The technology licensing activities generated revenue of ₹17 lakhs in 2023. Seven MoUs were signed for research collaboration and four MoUs for contract research which generated revenue of Rs. 92.48 lakh and 41.47 lakh, respectively. Till December 2023, total 164 licencingMoUs were signed with FPC/FPOs which generated revenue of Rs. 1.62 crore. Apart from the above-mentioned projects, six MoUs were signed with different institutions for academic purposes. During the year, ICAR-DOGR was granted its first patent for "A storage structure for storing onion bulbs and a method thereof" (Patent No. 469459). A patent application was also filed for "Methods and systems for pest and disease management of onion crop(s)" (Application No. 202321081043). Furthermore, a trademark application was filed for the logo of the ABI at ICAR-DOGR. The Agri-Business Incubation (ABI) Centre at ICAR-Directorate of Onion and Garlic Research (DOGR) provides essential support to entrepreneurs in the onion, garlic, and agriculture sectors by offering technical assistance, consultancy, infrastructure, and training to build sustainable businesses. During the year 2023, a total of five advisory committee meetings were conducted, in which five incubatees registered under the ABI Centre at ICAR-DOGR launched startups in onion and garlic processing. A two-day Entrepreneurship Development Programme (EDP) cum Training Programme on Post-Harvest Processing and Value Addition in Onion and Garlic was also conducted. Additionally, a National Symposium cum Industry Meet (NSIM) on "Agri-business in Alliums: Innovation, Promotion & Sustainability" was organized during 20-22 December 2023. Brief summary of the research, extension and development activities carried out in the year 2023 is presented below.

Crop Improvement

The ICAR-Directorate of Onion and Garlic Research (ICAR-DOGR) serves as a National Active Germplasm Site (NAGS), conserving 2200 accessions of onion and garlic germplasm, including wild and underutilized species. ICAR-DOGR maintains 89 underutilized *Allium* lines across 17 species for desired traits. In 2023, eight new species, including *Allium roylei*, *A. carolinianum*, and *A. ramosum*, were acquired for evaluation and introgression breeding programs. *Allium* species (17) grouped into subgenera, aiding species identification and understanding phylogenetic relationships screened using 50 ILP markers. The ICAR-DOGR is also developing a systemic value chain based on production, consumer response, and market potential for *A. tuberosum*. Interspecific hybrids (F1) (Crosses between *A. cepa* and *A. fistulosum*) were developed (45) using embryo rescue techniques, with several lines showing potential for bulb formation and perennial traits and aim to develop biotic and abiotic stress-resistant lines. White onion improvement highlights significant advancements in onion breeding, targeting higher yields, improved storage, and tolerance to environmental stresses. A total of 95 white onion germplasm evaluated; W-418 showed the highest yield (50.83 t/ha) during *rabi*. Total 131 breeding lines evaluated where W-477 M-5 had the highest yield (51.44 t/ha), and W-218 M-2 showed the minimum storage losses (20%) during *rabi* season. The advanced breeding line DOGR-1613 demonstrated superior performance during the late *kharif* season, achieving a yield of 46.29 t/ha with 88.5% marketable bulbs and an average bulb weight of 90.82 g followed by DOGR-1043-DR, DOGR-1608, and DOGR-1654. In the *rabi* season, DOGR-1741 found superior over check and recorded marketable yield 39.33 t/ha, followed by DOGR-1822 and DOGR-1751. Line DOGR-1761 recorded the lowest storage loss of 16.65%. During the *kharif* season, line DOGR-1753 found superior over check (MY-39.30 t/ha and 91.61% marketable bulbs), followed by DOGR-1749 and DOGR-1774. Additionally, DOGR-1753 recorded the minimum days to harvest (82 days). During the late *kharif* season, initial breeding lines LK-07-C2/LR-4 produced 54.67 t/ha, superior than the check variety and followed by LK-07-C2/LR-4, Red Genepool-7, and LK-07-C2/LR-3. In the *rabi* season, LK-07-C2/LR-4 recorded superior performance for Marketable yield 33.19 t/ha followed by LK-07-C2/LR-4, R-KH-M-III, and DOGR-671-Sel. Five inbred lines (I1-1664, I1-1773, I1-1737, I1-1744, I1-1729) out performed the check variety Bhima Shakti in terms of yield and earliness, with 111-115 days to harvest. Male sterile lines in varietal backgrounds such as Bhima Super and Bhima Dark Red are under evaluation at BC1 and BC3 stages with a total of 66 inbred lines in the I1 stage, 20 in I2, and 9 in I3.Under AINRPOG, seven new hybrids were introduced, including DOGR Hy-207, Hy-211, and Hy-212 (IET trials), and DOGR Hy-56, Hy-155 (AVT-I), and Hy-156, Hy-172 (AVT-II). ICAR-DOGR employs an integrated approach to garlic improvement, emphasizing conservation, mutation breeding, stress tolerance, and the commercialization of high-yielding and stress-resistant lines. The organization conserves 715 garlic accessions, including elite, trait-specific, and mutated lines, in its field gene bank. During *rabi* 2022-23, 13 elite lines were tested with DOGR-404 achieving the highest yield of 9.69 t/ha and DOGR-806 recording the highest TSS at 47° Brix. High-yielding mutation lines, such as BP-6GY (8.47 t/ha), exhibited improved traits like bulb weight and TSS. Seventeen accessions with dark purple cloves, valued for their flavor and ease of peeling, were evaluated, with PB-Dark-1 and DOGR-756-DR achieving the highest yields of 9.52 and 8.13 t/ha, respectively. Under high-stress conditions, DOGR-24 showed better survival compared to DOGR-28. Lines like DOGR-555 and CPT-11 M4 consistently yielded above 5 t/ha during the *kharif* season. Tests using hard-neck garlic bulbils as planting material demonstrated that planting in late July produced the best results for bulb development. Lines such as DOGR-806 and 404-HY, with high TSS values exceeding 46° Brix, were identified as suitable for processing. Presently, ICAR-DOGR introduced two garlic lines in IET trials (DOGR-815 and DOGR-569) for *rabi* and two lines (DOGR-555 and DOGR-100) for *kharif* varietal trial evaluation. Lines DOGR-404 and DOGR-793 were tested in AVT-I, while DOGR-48-W and DOGR-746 were evaluated in AVT-II. This section highlights advances in haploid induction, genome editing, stress resistance, and CMS development in onions, emphasizing the integration of cutting-edge biotechnological tools for crop improvement. Total 275 plants (89.95%) were confirmed as haploids using flow cytometry, and 140 plants survived colchicine treatment for further breeding programs. Targeted editing of *AcMYB1* and *AcCHS* genes was achieved by designing sgRNAs for specific exons. A bivalent protein, r-PB, was expressed in onion and tobacco using *Agrobacterium* mediated transformation. Transgenic tobacco plants (67) were confirmed for r-PB expression, while onion calli are in the selection stage. RNA interference (RNAi) was used to downregulate *AcCENH3* expression in onion. Haploid induction efficiency (HIE) reached 4.63% in specific crosses between transgenic and wild-type plants. Targeted mutagenesis of the *AcMSH1* gene using *Agrobacterium* transformation resulted in 22 regenerated plants, of which 16 were confirmed to carry the mutation. Molecular responses to combinatorial salinity and pathogen stress in onion *WRKY* TFs are crucial in regulating plant growth, development, and responses to biotic and abiotic stresses. Total 54 putative *WRKY* genes were identified, named *AceWRKY1* to *AceWRKY54*. This study provides insights into the *WRKY* gene family in onions, which may contribute to understanding and enhancing stress tolerance in the crop.

Crop Production

A field experiment conducted to develop integrated weed management modules for onion and garlic crops during late *kharif*-2023 season and *rabi*-2023 season revealed that the application of pendimethalin 30% EC @ 1 kg a.i./ha followed by propaquizafop 10% EC @ 100 g a.i./ha + oxyfluorfen 23.5% EC @ 200 g a.i./ha at 25 and 45 DAT, or pendimethalin 30% EC @ 1 kg a.i./ha (PRE) followed by polythene mulching, exhibited higher weed control efficiency and garlic yield comparable to a weed-free condition. Another experiment assessing the continuous use of inorganic fertilizers and manures on onion production and soil fertility status showed that integrated nutrient management (INM) treatments, combining mineral fertilizers and vermicompost, enhanced soil organic carbon and available nutrients, maintaining initial soil fertility. However, the bulb yield in the soybean block across the treatments decreased due to a higher incidence of soil-borne disease. Additionally, organic and natural farming experiments revealed that chemical fertilizers and INM plots yielded significantly higher bulb yields than organic and natural farming methods, with INM showing a 52.4–58.9% increase over organic/natural methods. Soil analysis indicated higher soil organic carbon and available nitrogen in organic plots compared to INM and conventional farming systems. A field experiment evaluating the effect of nitrogen fertilizers and irrigation methods on onion growth, yield, and storage losses demonstrated that treatments with 100% and 150% nitrogen applied via sprinkler irrigation exhibited higher chlorophyll concentration and plant growth parameters compared to drip fertigation. However, drip and sprinkler irrigation with 100% nitrogen significantly increased onion yield compared to flood irrigation. A field experiment assessing the effect of waterlogging stress on eight onion genotypes (W-355, Acc. 1630, Acc. 1666, and Bhima Dark Red) found that Bhima Dark Red and Acc. 1666 performed better under waterlogged conditions. The tolerant genotypes Acc. 1666 and Bhima Dark Red exhibited higher survival percentages (90%), chlorophyll content, cellular membrane stability, and bulb yield compared to the sensitive genotypes. Three lines of *Allium tuberosum* were planted to evaluate growth performance, dry matter yield, and nutrient uptake to develop nutrient management practices. Parameters such as plant height, leaf number, tiller number, and foliage yield were monitored monthly for 11 months. Over this period, the genotypes produced 8.84–9.82 t/ha of dry matter, removing 201–235 kg N, 62–73 kg P, 262–296 kg K, and 41–54 kg S per hectare. This comprehensive data provides valuable insights for devising a fertilizer schedule tailored to *Allium tuberosum* cultivation, contributing to its sustainable commercial production. ICAR-CIRCOT developed nano-sulphur, synthesized from elemental sulphur via chemo-mechanical methods, with a particle size of 500–700 nm and a concentration of 20% (w/v). At ICAR-DOGR, Pune, its efficacy was assessed on onion and garlic. Nano-sulphur application alone increased marketable yield by 8–12%, while its combination with farmyard manure (FYM) increased onion yield by 3.8–8.3% and garlic yield by 10.8–16.3%, though its impact was lower when used alongside FYM. In collaboration with IIT-Mumbai, a field experiment was initiated; deploying E-Agris stations fitted with multi-depth sensors to continuously monitor soil moisture, pH, electrical conductivity, and available NPK in the soil. Results revealed that laboratory data closely aligned with trends observed in sensor data for all parameters, confirming the sensors' efficacy. A pot experiment conducted during *kharif 2022* to assess the effect of microbial inoculation on plant growth and development under waterlogging stress conditions showed that seedlings inoculated with *Azotobacter* spp. performed better under both control and stress conditions. To understand the molecular mechanisms regulating waterlogging stress tolerance in onion crops, transcriptome sequencing using RNA-seq technology was performed on leaf tissues of the waterlogging-tolerant genotype (Acc. 1666) and the sensitive genotype (W-344). Differential gene expression analysis revealed that 1,629 genes were upregulated and 3,271 genes were downregulated in Acc. 1666, while in W-344, 2,134 genes were upregulated and 1,909 genes were downregulated under waterlogging stress. A field experiment evaluating the effect of different plant growth regulators on onion cv. Bhima Dark Red under waterlogging stress revealed that the foliar application of melatonin @ 50 ppm improved onion crop growth under such conditions. A pot experiment assessing the effect of high-temperature stress on the growth and yield of onion cultivars Bhima Shakti and Bhima Kiran demonstrated that temperatures of 42°C and above severely damaged crop growth and development.

Crop Protection

Disease samples were collected from various onion and garlic-growing regions, and the pathogens were identified as *Alternaria alternata*, *Colletotrichum gloeosporioides*, *Fusarium acutatum*, *F. falciforme*, *F. solani*, and *F. oxysporum* based on morphological characteristics and molecular techniques. The cultures were maintained and submitted to NAIMCC, ICAR-NBAIM, Mau, while the sequences were submitted to NCBI

GenBank under different accession numbers. In addition, *Trichoderma* spp. was also isolated, characterized, and sequenced. Eleven *Trichoderma* isolates were evaluated for their effect on onion crop growth and disease management. Among them, the T-8R isolate was the most effective, suppressing *stemphyllium* disease by 56% and anthracnose/twister by 39%. Additionally, a 20% yield increase over the control was observed. Four disease management modules (M1, M2, M3, and M4) were tested alongside existing practices (EP), farmers' practices (FP), and absolute control (AC) for their efficacy against major fungal diseases in onion. All modules inhibited *stemphyllium* disease (21-40% suppression during *rabi* season) and *anthracnose* disease (6-58% suppression during *kharif* season), with M1 (Intensive Management) showing the highest inhibition (40%). Amritpani-based organic formulations were also evaluated, where DOGROF3 provided the maximum inhibition (26%) of *anthracnose* during *kharif* 2023. The molecular characterization of garlic germplasm confirmed *F. oxysporum* as the causal pathogen of *Fusarium* basal rot disease. Key soil microorganisms from onion fields were also isolated and characterized using morphological and molecular techniques, identifying nine fungal strains and ten bacterial strains. Among the fungal isolates, all nine were entomopathogenic fungi (EPFs), while the bacterial isolates included two zinc-solubilizing and eight phosphate-solubilizing rhizosphere bacteria (PSB). Whole metagenomic sequencing of wild and cultivated onion rhizosphere soil revealed Proteobacteria, Actinobacteria, Firmicutes, and Thaumarchaeota as the most abundant phyla. Alpha-diversity indices (Shannon's index) showed that *Allium angulosum* had the highest microbial diversity, followed by *Allium hookeri*. A metabarcoding study on biofertilizer effects in the onion rhizosphere identified 46 bacterial phyla and 481 genera, with proteobacteria being dominant, followed by actinobacteria, firmicutes, planctomycetes, and crenarchaeota. Alpha-diversity indices (Shannon and Simpson-e) indicated the highest bacterial diversity in Azotobacter-100-RDF-treated soil and the lowest in Azospirillum-100-RDF-treated soil. Chao1 index revealed the highest bacterial richness in Control-100-RDF soil and the lowest in blank soil. Beta-diversity analysis (weighted UniFrac) demonstrated significant variations in bacterial communities, with PCoA analysis explaining 48.5% and 21.1% of the cumulative variance. A survey conducted in Karnataka and Maharashtra during *kharif* and *rabi* (2023-24) led to the development of a disease severity map for major fungal pathogens. The infection process of onion anthracnose-twister was studied, revealing that combined treatment with *C. gloeosporioides* and *F. acutatum* caused twisting symptoms, which intensified with GA3 application due to a synergistic effect. The *Fusarium* basal rot infection process across different onion varieties showed higher susceptibility in dark-colored cultivars. Garlic infections caused by *C. gloeosporioides, Alternaria porri*, and *Stemphylium vesicarium* exhibited symptoms within 5-7 days after inoculation (DAI). Eleven *Trichoderma* strains were screened against *C. gloeosporioides*, *A. porri*, *S. vesicarium*, and *Fusarium* spp., with *Trichoderma longibrachiatum* demonstrating the highest inhibition percentage. Additionally, 17 PGPR strains were isolated from the onion (11) and garlic (6) rhizosphere and characterized morphologically, biochemically, and molecularly using ITS and 16S rRNA primers.

Field evaluation of *Lecanicillium lecanii, Beauveria bassiana, Metarhizium anisopliae,* and neem oil (alone and in combination) against onion thrips (*Thrips. tabaci*) in *kharif* and *rabi* onion (2023) showed significant thrips population reduction. Neem oil + L. *lecanii* and Neem oil + *M. anisopliae* were the most effective among bio-agents, reducing thrips by 71-72.8%, followed by Neem oil + *B. bassiana*. Spinosad, the biological pesticide, was the most effective, achieving 77.6% (*kharif*) and 86.0% (*rabi*) population reduction. Among entomopathogens, *L. lecanii* showed the highest efficacy, followed by *M. anisopliae*. The efficacy of new generation pesticides against onion thrips was evaluated in *kharif* and *rabi* seasons. Spirotetramat + Imidacloprid showed the highest thrips reduction (80%), followed by Profenofos (81.8%) and Spinetoram (79%), proving their effectiveness in thrips management. The complete mitochondrial genome of *Thrips tabaci* and *Thrips parvispinus*, were sequenced and the data is submitted in the NCBI GeneBank. An experiment with seven botanical treatments assessed their impact on stored pests and pathogens in onion storage. The highest storage loss (49.12%) was in the untreated control. Custard Apple leaf powder showed the least storage loss (38.97%), followed by Lemon Grass (39.87%), indicating their potential in reducing onion storage losses. A survey across 20 locations in Nashik and

Satara districts identified stingless bees (*Tetragonula iridipennis*) as key non-Apis pollinators, contributing 39% of forage visits in onion. Their peak foraging activity occurred at 11:30 AM, with a focus on pollen collection. Onion-based stingless bee (*T. iridipennis*) honey showed higher EC, protein, antioxidants, and sugar content than *Apis mellifera* honey but had lower pH. A field survey in Maharashtra documented *Apis florea, A. cerana indica, A. dorsata*, and T. *iridipennis* as dominant pollinators, with *A. cerana indica* showing the highest foraging activity. Gut microbiome analysis of *A. florea* identified dominant bacterial phyla Proteobacteria, Firmicutes, and Actinobacteriota, with Lactobacillus species playing a key role. Culture-dependent and culture-independent methods confirmed diverse microbial communities. The findings highlight the important role specific bee species in onion pollination and their microbial diversity with the gut microbiomes. The sequence data deposited in the NCBI Bio Project database with accession no. PRJNA1065181.

Post-Harvest Technology

Under post-harvest technology efforts were made to develop new processed products using onion. A study was conducted to evaluate the probiotic potential of various *Lactobacillus* strains, including *L. acidophilus, L. fermentum, L. rhamnosus, L. helveticus, L. delbrueckii, L. plantarum*, and *L. casei*, through a series of *in vitro* assessments for the development of probiotic drink with onion. Key evaluations included survival in simulated gastrointestinal conditions, adhesion to intestinal cells, antimicrobial activity, and tolerance to low pH, bile salts, and gastric juice. The catalase test confirmed all strains were catalase-negative and Gram-positive. *In vitro,L. rhamnosus* exhibited the highest acid tolerance, while *L. acidophilus* showed the lowest. *L. plantarum* demonstrated superior survival in simulated gastric juice, while *L. rhamnosus* was less resilient. Regarding bile salt tolerance, all strains showed moderate resilience, with *L. plantarum* and *L. casei* exhibiting notable survival. Cell surface hydrophobicity varied, with *L. plantarum* displaying the highest adhesion in both cyclohexane and toluene. The auto-aggregation assay indicated that *L. helveticus* and *L. rhamnosus* showed strong aggregation potential, crucial for gut colonization. Co-aggregation assays with pathogens like *E. coli, Micrococcus luteus, Listeria monocytogenes,* and *Staphylococcus aureus* revealed that *L. plantarum, L. fermentum,* and *L. helveticus* exhibited significant co-aggregation, suggesting strong probiotic potential against these pathogens. Biochemical analysis showed that all strains were esculin hydrolysis positive, with varying carbohydrate fermentation profiles. These preliminary findings provide insights into the diverse characteristics of *Lactobacillus* strains and their potential for commercial probiotic applications. Further studies are needed to confirm these results *in vivo*. Further, an attempt was made to develop ready to cook snack mix using dehydrated onion. Dehydrated onion can be used in a variety of processed, ready-to-cook, and ready-to-eat foods as a substitute for raw onion, offering several advantages such as ease of transportation, storage, preparation, and use. However, the consumption of dehydrated onion in Indian households remains relatively low. To increase its usage, we explored the development of ready-to-cook mixes incorporating dehydrated onion. Onion pakoda, a popular snack in India, is known for its time-consuming preparation, especially the peeling and cutting of onions. To address this challenge, we optimized a ready-to-cook pakoda snack mix using dehydrated onion. This product not only reduces overall snack preparation time but also offers greater convenience, while simultaneously creating a larger market for dehydrated onion.

Under post-harvest management of onion for reducing rotting loss, a comparative genomic analysis was performed for common bacterial pathogens of onion bulb for which the genomic sequences are available (*Pantoeaananatis, Pantoeaagglomerans, Erwinia persicinia, Rouxiellabadensis, Pseudomonas uvaldensis, Xanthomonas axonopodis, Burkholderiacepacian,* and *Curtobacteriumalli)*. All the available genomes of the *Pantoeaananatis* were annotated for comparative genomic studies and the common genetic repertoire shared between the different strains of this devastating pathogen causing central rot of bulb have been analyzed. The further efforts are on to decipher its genetic elements responsible for invasion of the bulbs.

Extension

Apart from the research work, several extension activities were also carried out. Total 817 demonstrations were conducted in Maharashtra and Karnataka state during *kharif* (152), late *kharif* (55) and *rabi* (610) seasons through institute project (30), SCSP (727), and MGMG (60) for the study. The demonstrations in *kharif* season revealed that the germination percentage (97), average bulb weight (82 g) and yield (25.5 t/ha) of Bhima Super was the highest. Bhima Dark Red (25.0 t/ha) also yielded more than local variety (18.5 t/ha). The germination percentage (95), average bulb weight (85 g) and the yield (47.5 t/ha) of Bhima Raj were the highest in late *kharif* demonstrations. Bhima Red (45.0 t/ha) also yielded more than local variety (24.0 t/ha) in late *kharif* demonstrations. The demonstrations conducted in *rabi* in Maharashtra revealed that the germination percentage (94), average bulb weight (84 g) and marketable yield (42.5 t/ha) of Bhima Kiran were the highest and Bhima Shakti (42.0 t/ha) also yielded more than local variety (27.5 t/ha). The varieties developed by ICAR-DOGR were found superior over the local cultivars in all the demonstrations. Demonstrations were conducted on drone based spray technology at farmers' fields under Agri-drone project. A total of 135 demonstrations were conducted on 187 acres of land under onion cultivation in 50 villages of Pune and Ahmednagar districts of Maharashtra. Around 1200 farmers were participated in the demonstrations.A total of 737 frontline demonstrations were conducted in Maharashtra under SCSP, 251 under TSP in Maharashtra and Uttar Pradesh, and 63 under NEH Plan in NEH region. During the year, nine technology and advisory based videos were developed and disseminated over YouTube channel for the farmers. The video sharing platform YouTube channel has been used to disseminate 53 crop production related videos, garnering 41,033 views, 1,914 subscriptions, and 1,300 watch hours from a variety of viewers.Six issues of Onion and Garlic Samachar, a multimedia-based bilingual (Marathi and Hindi) news bulletin webcasted on YouTube, featuring onion and garlic production advisories, expert talks, and Q&A sessions contemporary to the monthly crop conditions. Socially integrated messaging platforms were found effective in connecting 9977 farmer 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 queries. A total of 52 timely advisories were sent to farmers of different pockets of the country including text (21) Audio (8) Video (26) advisories. A mobile application enabled with DSSs; decision support systems for prompt management decisions in nutrient management, pest and diseases, variety selection and day to day operations is developed being used by over 1000 farmers and stakeholders.

Other Activities

The various Institutional activities viz., RAC, IRC, IMC etc. meetings were held timely. Republic Day, Independence Day, International Women's Day, World Soil Day were celebrated. Vigilance awareness week was also observed. To increase the importance of Hindi in daily work Hindi Pakhwada was organized. ICAR-DOGR also conducted various activities during Swachchha Bharat Campaign.

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 28 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 atemperature range of 5.5-42.0 °Cand 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 *Alliums*. The internet and e-mail connectivity has been strengthened for easy literature access. The centre has its own website: www.dogr.icar.gov.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.

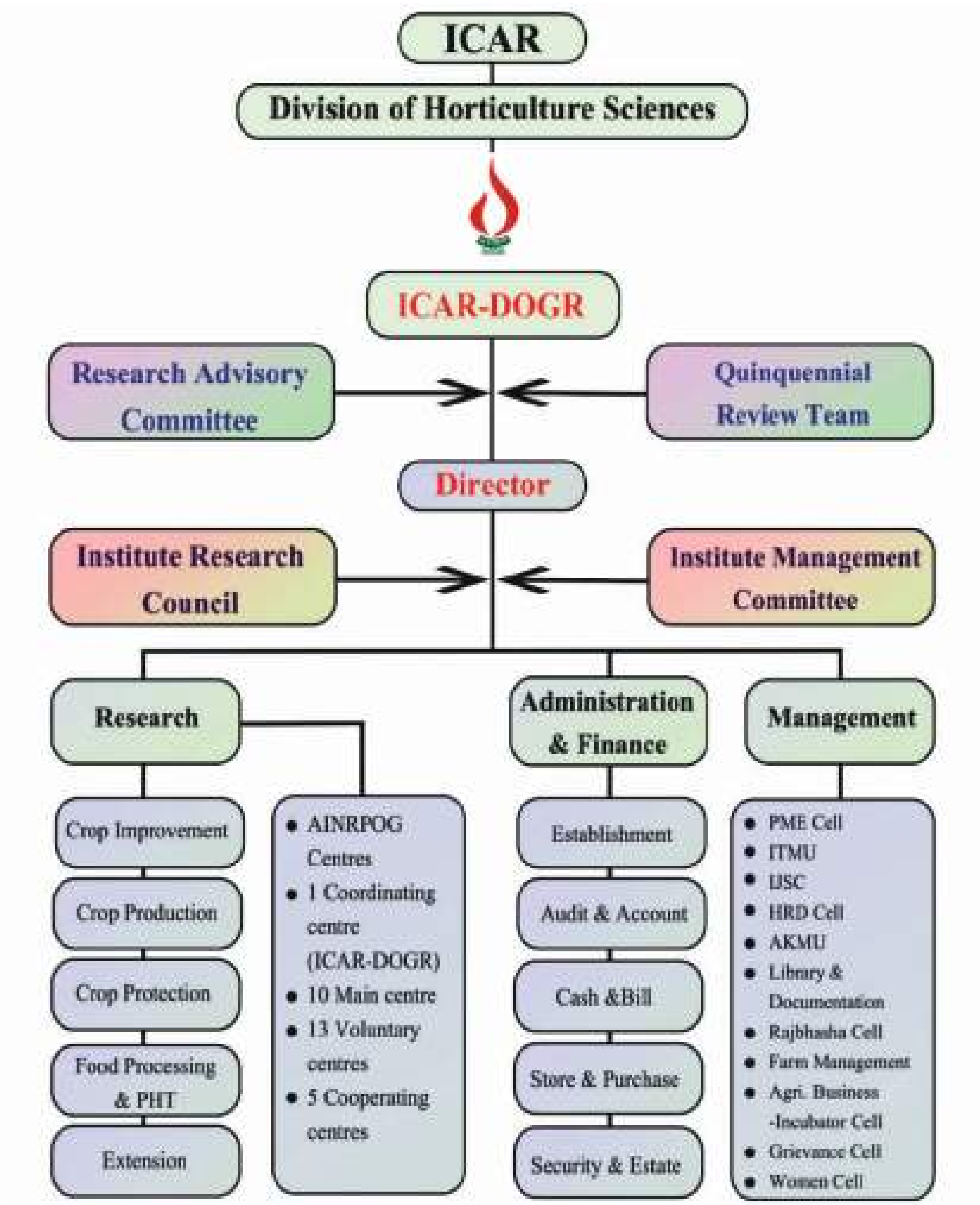
Mission

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


ICAR
Division of Horticulture Sciences
ICAR-DOGR
Research Advisory Committee
Quinquennial Review Team
Director
Institute Research Council
Institute Management Committee
Research
Administration & Finance
Management
Crop Improvement
Crop Production
Crop Protection
Food Processing & PHT
Extension
AINRPOG Centres
1 Coordinating centre (ICAR-DOGR)
10 Main centre
13 Voluntary centres
5 Cooperating centres
Establishment
Audit & Account
Cash &Bill
Store & Purchase
Security & Estate
PME Cell
ITMU
IJSC
HRD Cell
AKMU
Library & Documentation
Rajbhasha Cell
Farm Management
Agri. Business -Incubator Cell
Grievance Cell
Women Cell

ICAR-Directorate of Onion and Garlic Research

B. Research Achievements

1. Crop Improvement

1.1 Genetic improvement of white and yellow onion (including underutilized *Alliums*)

ICAR-Directorate of Onion and Garlic Research acts as National Active Germplasm Site (NAGS) for collection and conservation of onion germplasm. There are 2200 germplasm of wild/underutilized *Alliums*, short-day and long-day *A. sativum*, *A. cepa*. Short-day germplasms are being conserved at ICAR-DOGR, while long-day germplasm are maintained at ICAR-CITH, Srinagar.

Evaluation of white onion germplasm (Late *kharif*)

In late *kharif*, twenty-three white onion germplasm lines were evaluated along with the standard check Bhima Shubhra. There were serious bolting issues and anthracnose disease incidences which led to a reduction in yield. The marketable yield in the germplasm lines varied from 0.41 to 32.89 t/ha, while the check Bhima Shubhra recorded yield of 30.17 t/ha. The storage loss (after two months) varied from 18.51 to 48.73%. The germplasm line W-405 recorded the least storage loss (18.51%) followed by W-344 (19.23%) and W-208 (19.92%) when compared to check Bhima Shubhra (48.73%). TSS in the tested accessions ranged from 9.95-13.87 °Brix.

Evaluation of white onion germplasm (*Rabi*)

Fifty-five white onion germplasm accessions were multiplied and evaluated along with check Bhima Shweta during *rabi*. Marketable yield in these accessions ranged between 22.26 to 50.83 t/ha. Eleven lines exhibited significant superiority for marketable yield over check Bhima Shweta. The accession W-418 exhibited maximum marketable yield (50.83 t/ha) followed by W-344 (46.19 t/ha), W-364 (45.97 t/ha) as compared to Bhima Shweta (36.57 t/ha). Per cent bolting in the accessions ranged from 0 to 10.81%, and 58 lines were found to be bolter free. Storage loss (after 4 months) was minimum (20.57%) in W-385, followed by W-217 (20.64%) when compared to check Bhima Shweta (64.11%).

Figure 1.1 White onion germplasm (*Rabi*)

Evaluation of white onion germplasm (*Kharif*)

Seventeen white onion germplasm accessions were tested using Bhima Shubhra as the check. Among the tested accessions, W-443, White GP Comp-7, W-448 and W-405 were the highest yielder with marketable yield of 23.14, 19.98, 16.07 and 15.54 t/ha, respectively when compared to check Bhima Shubhra (11.43 t/ha). All of the lines were found to be bolter-free. The average bulb weight ranged from 30 to 59 g in the tested accessions. Total soluble solid (TSS) in these accessions ranged from 10.27 to 12.27 °Brix.

Evaluation of yellow onion germplasm (*Rabi*)

Three lines of yellow onion were evaluated along with the check Phule Suvarna. The line Y-027 recorded maximum marketable yield (40.44 t/ha) followed by Y-005 (39.89 t/ha) and Y-055 (31.18 t/ha), while the check Phule Suvarna recorded marketable yield of 22.47 t/ha). The lines Y-027 and Y-005 were bolter-free. Storage losses (after 4 month) varied from 14.81 to 51.24 %.

Evaluation of white onion breeding lines (Late *kharif*)

In late *kharif*, a total of 27 advance and initial breeding lines were assessed and compared with check Bhima Shubhra. The line W-208 AD-6 recorded high marketable yield (39.17 t/ha) followed by W 355 AD-6 (38.93 t/ha) and W-459 M-10 (38.85 t/ha). Three lines *viz*. W-178 AD-6, W-443 M-7 and W-459 M-10 were bolter-free. The storage losses (after two months) varied from 8.94 to 49.56%. The minimum storage loss was recorded in the line W-408 EL-10 (8.94%) followed by W-353 M-10 (15.04%) and W-504 M-4 (17.13%), respectively.

Evaluation of white onion breeding lines (*Rabi*)

A total of 81 white onion breeding lines were evaluated using the variety Bhima Shweta as the check. Thirty lines noted significantly superior marketable yield over the check. The maximum marketable yield was observed in the line W-477 M-5 (51.44 t/ha) followed by W-353 M-5 (50.72 t/ha), W-367 AD-6 (50.63 t/ha), W-414 M-5 (50.43 t/ha) and W-441 M-2 (50.33 t/ha). The check variety recorded yield of 36.57 t/ha. The line W-218 M-2 recorded minimum storage loss (20%) followed by W-353 M-5 (24%), W-444 M-2 (25%), W-407 AD-6 (26%) as compared to check Bhima Shweta (64%) after 4 months of storage period.

Figure 1.2 White onion breeding lines (Rabi)

Evaluation of white onion breeding lines (*Kharif*)

A total of twenty-three white onion germplasm lines were evaluated using the variety Bhima Shubhra as the check. The line W-085 AD-9 recorded marketable yield of 16.99 t/ha against 11.43 t/ha of marketable yield recorded by the check. Four lines *viz*., W-448 BR-11, W-172 AD-6, W-147 M-7 and W-208 AD-6 recorded marketable yield of 14.81, 11.97, 11.22 and 10.44 t/ha, and were found *at par* with check Bhima Shubhra. Average bulb weight in these lines ranged from 29.56 to 45.36 gm. These lines recorded total soluble solids (TSS) ranging from 10.27 to 12.27 °Brix.

Evaluation of white onion bolting tolerant lines (Late *kharif*)

Four bolting tolerant lines were evaluated with check Bhima Shubhra. Three lines were *at par* for marketable yield as compared to check variety. The line White GP Comp LG-209-7 was found to be bolter-free. Bhima Shweta LG-107-7 recorded highest marketable yield 30.02 t/ha, followed by White EL Comp LG-209-7 (28.48 t/ha) and White GP Comp LG-209-7 (27.63 t/ha) compared with check Bhima Shubhra (30.17 t/ha). Marketable yield ranged between 21.23 and 30.17 t/ha. Storage loss (after 2 months) ranged between 14.46 to 48.73%.

Evaluation of white onion high TSS lines (Late *kharif*)

A total of eleven high TSS *rabi* lines were evaluated along with check Bhima Shubhra. The yield was relatively low due to the significant anthracnose incidence. The TSS in these lines varied from 10.80 to 16.95 °Brix. The line WHTB-15-18-M-10-MC had the maximum TSS (16.95 °Brix) followed by the line WHTB-GT-18-M-11-SC (16.75 °Brix) over check with TSS of 10.80 °Brix. None of the tested lines were bolter-free.

Evaluation of white onion high TSS lines (*Rabi*)

A total of 68 high TSS lines were evaluated along with check Bhima Shweta. The line WHTS-15-18-M-8-MC-5 showed a considerably higher marketable yield (40.35 t/ha). The marketable yield in lines with high TSS varied from 14.31 to 41.35 t/ha. TSS in these lines varied from 11.40 to 20.27 °Brix. The maximum TSS of 20.27 °Brix was recorded in the line WHTB-GT-18-M-9-MC followed by WHTB-GT-18-M-10-SGT-18 (18.73 °Brix), WHTB-15-18-M-9-SC (18.53 °Brix), and WHTS-GT-18-M-9-MC (18.53 °Brix) (Table 1.1). There were 39 lines that showed no bolters. Storage losses (after four months of storage) in the tested lines ranged from 18.04 to 80.44%. Twenty lines recorded lower storage losses as compared to check Bhima Shweta. The lines WHTS-8H-GT-15-MC-M-7, WHTB-GT-18-M-11-MC-4, WHTS-2A-GT-18-SC-M-7 and HT-GR-2B-M-8-SGT-18 recorded least storage losses of 18.04, 18.16, 18.48% and 19.93%, respectively against the check Bhima Shweta (65.23%).

Table 1.1 Evaluation of white onion high TSS lines during *Rabi*

Entries	Percent bulbs (TSS >15 °Brix)	Average populationTSS (°Brix)
WHTB-GT-18-M-9-MC	100.00	20.27
WHTB-GT-18-M-10-SGT-18	97.14	18.73
WHTB-15-18-M-9-SC	98.28	18.53
WHTS-GT-18-M-9-MC	95.16	18.53
WHT-23A-2(18-20)-SGT-18	100.00	18.47
WHTB-3C-GT-18-MC-M-8	94.68	18.47
WHT-23A-2	96.97	18.40
WHTS-15-18-M-9-SC	82.76	18.33
HT-GR-2B-M-9-SGT-18	94.29	18.20
WHTB-GT-18-M-11-MC-2	100.00	18.20
Check varieties (8)	00.00	<14.76

Figure 1.3 White onion high TSS lines (*Rabi*)

Evaluation of white onion hybrids (*Rabi*)

Total six F_2 were evaluated along with check Bhima Shweta. Three F_2 recorded significantly superior performance as compared with check. The F_2 of the cross MS-100 × Phule Safed recorded highest marketable yield (43.35 t/ha) followed by that of LR-59 × W-448 (41.84 t/ha), MS-100 × W-408 (39.01 t/ha) when compared to Bhima Shweta (36.57 t/ha) (Table 1.2). The F_2 of the cross MS-100 x Phule Safed recorded maximum heterosis (18.54%) for marketable yield followed by that of LR-59 × W-448 (14.42%) and MS-100 × W-408 (6.68 %) over check Bhima Shweta. Four hybrids were found to be bolter free.

Table 1.2 Evaluation of white onion hybrids during Rabi

Crosses	MY (t/ ha)	Heterosis (%)	Bolters (%)	TSS (⁰ Brix)	SL4M (%)
MS-100 x P. Safed F2	43.35	18.54	2	12.13	37.05
LR-59 x W-448 F2	41.84	14.42	0	12.47	38.94
MS-100 x W-408 F2	39.01	6.68	0	11.73	72.01
Bhima Shweta	36.57		1.5	11.40	64.11

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

Evaluation of population developed through crosses between long day and short-day onion

Among six populations derived from the crosses between long-day and short-day onion lines, three populations were found to be better than the check for marketable yield. The hybrids F-6 × L-12 (W) F6M5 yielded higher marketable yield (45.01 t/ha) followed by F-6 × J-10 (W) F6M5 (42.10 t/ha) and F-6 × J-10 (Y) F6M5 (37.78 t/ha) than the check Arka Pitamber (30.93 t/ha) (Table 1.3). The maximum heterosis for marketable yield (45.52%) was noted for the population F-6 × L-12 (W) F6M5 followed by the population F-6 × J-10 (W) F6M5 (36.11%) when compared to check Arka Pitamber. Six hybrids were found to be bolter-free.

Table 1.3 Evaluation of crosses between long day and short-day onion during *rabi*

Crosses	MY (t/ ha)	Heterosis (%)	TSS (°Brix)	SL4M (%)
F-6 X L-12 (W) F6M5	45.01	45.52	14.00	100
F-6 X J-10 (W) F6M5	42.10	36.11	11.70	75.22
F-6 x J-10 (Y) F6M5	37.78	22.15	12.30	40.61
Arka Pitamber	30.93		11.31	67.49

Figure 1.4 Crosses between long day and short-day onion (*Rabi*)

Evaluation of white onion high TSS lines (*Kharif*)

Total eight high TSS lines were tested and compared to the check Bhima Shubhra. The yield was low due to the high anthracnose incidence. TSS in these lines ranged from 11.93 to 14.60 °Brix. All lines were free of bolters.

Maintenance and conservation of released varieties

Nucleus seed of all the three released varieties of white onion (Bhima Safed, Bhima Shubhra and Bhima Shweta) were produced following principles of maintenance breeding (Table 1.4).

Table 1.4 Nucleus seed production of white onion varieties

Variety	Quantity (kg)
Bhima Safed	2.23
Bhima Shubhra	1.68
Bhima Shweta	1.69

Maintenance and utilization of underutilized/wild alliums

Conservation of wild and underutilized *Alliums* at ICAR-DOGR

ICAR-DOGR maintains 89 underutilized *Allium* lines of 17 different species for different features. During this year (2023), eight new species namely *Allium roylei*, *A. carolinianum*, *A. ramosum*, *A. albidum*, *A. negianum*, *A. albidum*, *A. ampeloprasum* and *A. auriculatum* were acquired from ICAR-NBPGR, Regional Station, Bhowali. These lines are being evaluated for desirable traits and used in introgression breeding programme.

Flowering status of *Allium* species at ICAR-DOGR

Flowering trend was studied in twenty-six identified flowering *Allium* lines. The species *A. altaicum* Pall bloomed from January to May. The eleven *A. fistulosum* lines bloomed from January to March. Two lines of *A. schoenoprasum* bloomed in February whereas *A. tuberosum* bloomed in May. This flora of flowering *Allium* species is being used to create interspecific hybrids that carry desirable characteristics.

Evaluation of underutilized *Allium* species for popularization and commercialization for foliage consumption

Allium tuberosum is often known as "Chinese chives" or "Garlic chives," and is recognized for its softer, intermediate taste between garlic and onion, as well as its green foliage. Based on evaluation of production performance, investigation of consumer response and quality perceptions, and investigation of market potential and sustainability, a systemic value chain for *A. tuberosum* is being developed.

Interspecific hybridization in *Allium*

Development of pre breeding lines in *Allium* spp.

The interspecific cross between *A. cepa* and *A. fistulosum* has been attempted to develop biotic and abiotic stress resistant lines in Alliums.

Characterization of developed pre breeding lines:

Till the date, a total of 45 interspecific lines (F_1) have been developed through above crosses using embryo rescue technique. Four lines were able to produce bulb with some perennial habit alike *A. fistulosum*. The hybrids have been tested for pollen fertility (Table 1.5).

Table 1.5 Characterization of F1 interspecific hybrids for pollen fertility aspect

F_1 hybrid	Pollen fertility (%)	F_1 hybrid	Pollen fertility (%)
IH-101	52.37	IH-210	65.17
IH-111	19.30	IH-513	64.77
IH-203	24.68	IH-520	75.82
IH-106	18.93	IH-511	71.55
IH-203 (OFF SET)	16.38	IH-205	70.15
IH-206	23.06	IH-109	74.37
IH-107	67.47	IH-504	75.71
IH-204	84.73	IH-503	73.86
IH-202 (OFF SET)	70.54	IH-517	69.16
IH-518	65.55	IH-521	64.13
IH-110	29.17	IH-102	24.99
IH-301	75.92	IH-112	26.55
FI-1	87.59	IH-102 (OFF SET)	75.26
FI-2	91.68	B. SUPER	89.20
FI-3	89.39	*A. F* IC-321643-2	92.88

Use of pre breeding lines in advancement of generation

Seven F_1 hybrids lines showing variability in pollen fertility, pseudostem length, bulblet formation (bulging of base of pseudo stem), leaf texture, leaf waxy coating, disease tolerance to anthracnose and fusarium wilt are being advanced. Presently a total of 178 different lines are under evaluation.

Molecular diversity studies in wild and underutilized *Allium* species

A total of 17 *Allium* species including *A. cepa* and *A. sativum* screened using 50 polymorphic ILP markers. The dendrogram distinctly grouped species into sub genera and classification aligned with taxonomic classification (Figure 1.5). This set of primers will be useful for species identification as well as for studying the phylogenic relationship among *Allium* species.

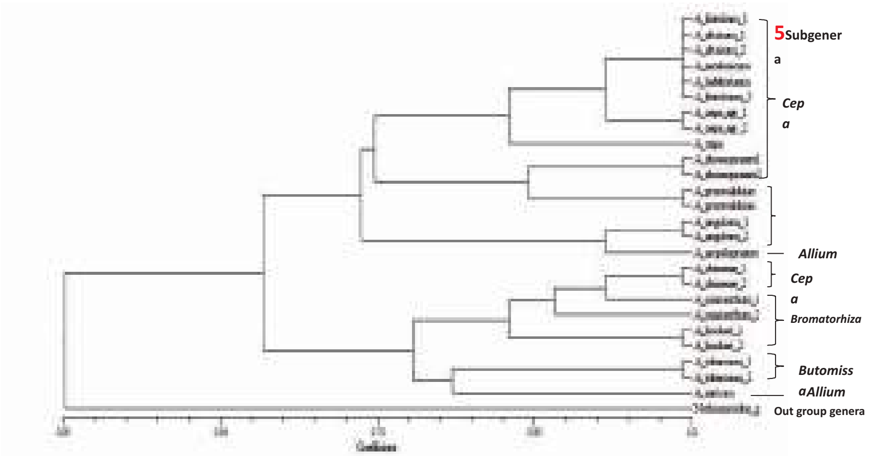


Figure 1.5 Dendrogram depicting genetic relationship among Allium species based on 50 ILP markers

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

Collection, evaluation, conservation and documentation of red onion germplasm

Onion germplasm was evaluated during *late kharif* (149 accessions), *rabi* (154 accessions) and *kharif* (163 accessions) along with checks. During late *kharif*, Acc. 1548, 1649, 1634, 1708, and 1214 produced more than 59 t/ha marketable yield and found superior over best check Bhima Shakti (42.04 t/ha). These accessions also recorded more than 98% marketable yield and were free from doubles and bolters. Minimum days to harvesting was recorded in Acc. 1655 (114 days) while in check Bhima Shakti (128 days). Minimum storage loss after four months of storage was recorded in 1718 (6.48%) followed by 1548 (9.09%) and 1822 (10.50%) over check Bhima Shakti (31.31%) (Table 1.6).

Table 1.6 Evaluation of red onion germplasm for yield and related traits (Late *kharif*)

Entries	MY (t/ha)	ABW (g)	Doubles (%)	Bolters (%)	TSS (°Brix)	DTH	E:P
1548	64.00	96.00	0.00	0.00	12.24	124.00	1.08
1649	63.67	111.42	0.00	0.00	11.56	117.00	1.07
1634	63.47	95.20	0.00	0.00	12.00	127.00	1.10
1708	60.44	93.79	0.00	0.00	12.40	124.00	1.14
1214	59.04	102.19	0.00	0.00	12.48	117.00	1.19
1655	58.50	100.29	0.00	0.00	11.60	114.00	1.11
1652	58.37	125.07	0.00	9.97	11.40	127.00	1.09

Entries	MY (t/ha)	ABW (g)	Doubles (%)	Bolters (%)	TSS (°Brix)	DTH	E:P
Bhima Shakti (C)	42.04	74.48	0.00	9.44	12.21	128.33	1.14
Bhima Kiran (C)	39.46	79.93	1.01	7.76	11.97	129.33	1.09
ALR (C)	30.60	67.17	0.00	30.91	12.08	124.00	1.10
CV (%)	10.45	12.35	10.64	10.05	2.06	3.43	-
LSD (P=0.05)	3.45	7.61	4.47	4.02	0.41	6.66	-

(MY-Marketable Yield, ABW-Average Bulb Weight, TSS-Total Soluble Solids, DTH-Days to Harvest, E:P-Equatorial to Polar diameter of bulb)

During *rabi*, Acc. 1211, 1262, 1757, 1748 and 1252 produced more than 47 t/ha marketable yield and found superior over best check Bhima Light Red (34.83 t/ha). These accessions also recorded more than 95% marketable yield. Acc. 1262, 1757 and 1748 were free from doubles and bolters. Days to harvest was recorded minimum in Acc. 1211, 1748 and 1252 (113 days) compared to check Bhima Light Red (118 days). Minimum storage loss after four months of storage was recorded in 1574 (19.90%) followed by 1748 (21.00%) and 1552 (23.69%) over check Bhima Shakti (37.58%).

During *kharif*, more than 37 t/ha marketable yield was recorded in Acc. 1445, 1624, 1772, 1312, 1628, 1616 and 1664 and found superior over best check Bhima Super (29.94 t/ha). These accessions also recorded more than 85% marketable yield. All the accessions were free from doubles and bolters. Minimum days to harvesting was recorded in Acc. 1664 (85 days), 1624, 1628 (87 days) followed by 1312 (89 days) and 1616 (90 days) (Table 1.7).

Table 1.7 Evaluation of red onion germplasm for yield and related traits (*Rabi*)

Entries	MY (t/ha)	ABW (g)	Doubles (%)	Bolters (%)	TSS (°Brix)	DTH	E:P
1211	51.31	82.73	1.31	0.00	11.55	113.33	1.06
1262	51.15	78.99	0.00	0.00	11.45	116.00	1.06
1757	50.76	77.47	0.00	0.00	11.39	117.33	1.08
1748	48.40	79.22	0.00	0.00	11.57	113.33	1.12
1252	47.69	79.74	1.43	2.28	11.40	113.33	1.08
1820	47.21	75.08	0.00	1.38	11.77	114.67	1.08
1750	45.07	70.28	0.00	0.00	11.72	114.67	1.09
BLR (C)	34.83	60.24	0.00	0.00	11.29	118.67	1.10
Bhima Shakti (C)	34.52	54.88	0.00	0.00	11.95	118.67	1.10
Bhima Kiran (C)	32.27	59.82	0.00	0.00	11.71	113.33	1.08
CV (%)	10.05	4.19	34.86	29.19	3.31	2.54	-
SE	3.10	2.99	0.64	1.12	0.22	1.69	-
LSD (P=0.05)	3.09	8.35	1.78	3.14	0.62	4.71	-

(MY-Marketable Yield, ABW-Average Bulb Weight, TSS-Total Soluble Solids, DTH-Days to Harvest, E:P-Equatorial to Polar diameter of bulb)

Table 1.8 Evaluation of red onion germplasm for yield and related traits (*Kharif*)

Entries	MY (t/ha)	ABW (g)	Doubles (%)	Bolters (%)	TSS (°Brix)	DTH	E:P
1445	44.00	79.20	0.00	0.00	12.16	93.00	1.08
1624	40.80	76.50	0.00	0.00	12.16	87.00	1.15
1772	39.62	77.47	0.00	0.00	11.89	98.33	1.13
1312	39.50	79.00	0.00	0.00	11.56	89.00	1.06
1628	38.33	57.50	0.00	0.00	11.65	87.00	1.14
1616	38.07	71.38	0.00	0.00	11.92	90.00	1.10
1664	37.31	68.51	0.00	0.00	11.87	85.33	1.18
Bhima Super (C)	29.94	55.60	0.53	0.00	11.61	101.00	1.16
BDR (C)	26.02	63.90	0.00	0.00	11.92	89.00	1.18
Bhima Red (C)	25.10	63.15	0.00	0.00	11.89	87.33	1.10
CV (%)	9.85	6.50	26.24	29.19	3.26	2.94	-
SE	0.85	2.51	1.88	0.18	0.22	1.65	-
LSD (P=0.05)	2.39	7.04	5.24	0.49	0.62	4.62	-

(MY-Marketable Yield, ABW-Average Bulb Weight, TSS-Total Soluble Solids, DTH-Days to Harvest, E:P-Equatorial to Polar diameter of bulb)

Breeding improved onion varieties for table purpose

Evaluation of red onion advance breeding lines

Advance breeding lines were evaluated during late *kharif* (39 lines), *rabi* (38 lines) and *kharif* (39 lines) along with checks for 24 important traits. During late *kharif,* more than 41 t/ha marketable yield was recorded in DOGR-1613, DOGR-1043-DR, DOGR-1608 and DOGR-1654 and found superior over best check Bhima Shakti (36.39 t/ha) with dark red, globe and medium sized bulbs (79-90 gm), more than 81% marketable yield. Line DOGR-1044-Sel and DOGR-1657 recorded less than 1% double bulbs. Minimum days to harvesting was recorded in DOGR-1043-DR (118 days) followed by DOGR-1657 (119 days), DOGR-1613 and DOGR-1654 (120 days). Minimum storage loss after four months of storage was recorded in DOGR-1043-DR (15.36%) followed by DOGR-1613 (15.95%) and DOGR-1172-DR (17.66%) whereas; check Bhima Shakti recorded 29.78% (Table 1.9).

Table 1.9 Evaluation of red onion advance breeding lines for yield and related traits (Late *kharif*)

Entries	MY (t/ha)	Mrk (%)	ABW (g)	Doubles (%)	Bolters (%)	TSS (°Brix)	DTH	E:P
DOGR-1613	46.29	88.50	90.82	2.17	8.60	11.12	120.00	1.09
DOGR-1043-DR	43.76	89.26	79.39	1.15	7.79	11.60	118.00	1.08
DOGR-1608	42.82	87.72	81.26	2.33	8.34	11.91	121.00	1.09
DOGR-1654	41.73	81.06	86.93	4.43	13.84	12.03	120.00	1.09
DOGR-1657	38.96	87.64	73.19	0.25	10.38	11.68	119.00	1.09
DOGR-1044-Sel	38.01	77.84	82.97	0.61	21.07	11.45	117.00	1.07
DOGR-1611	36.83	84.03	75.92	1.67	11.55	11.81	122.00	1.07
Bhima Shakti (C)	36.39	86.49	77.34	2.97	8.09	11.96	122.67	1.12
Bhima Red (C)	36.27	79.87	75.12	0.49	18.65	11.85	114.67	1.07
Bhima Kiran (C)	32.73	86.11	67.02	0.25	11.94	12.24	127.00	1.10

Entries	MY (t/ha)	Mrk (%)	ABW (g)	Doubles (%)	Bolters (%)	TSS (°Brix)	DTH	E:P
CV (%)	9.22	7.58	10.03	16.36	28.28	4.87	2.38	-
SE	0.91	2.18	2.67	0.81	1.84	0.33	1.64	-
LSD (P=0.05)	2.54	6.11	7.48	2.27	5.16	0.93	4.61	-

(MY-Marketable Yield, Mrk-Marketable bulbs, ABW-Average Bulb Weight, TSS-Total Soluble Solids, DTH-Days to Harvest, E:P-Equatorial to Polar diameter of bulb)

During late *kharif*, under bolting free group, Bhima Shakti (LG-107-3) (37.36 t/ha) was found superior over best check Bhima Shakti (35.02 t/ha). This accession also recorded more than 92% marketable yield and less than 1% double bulbs. Minimum days to harvesting was recorded in Bhima Raj (LG-107-3) (112 days) followed by Bhima Shakti (LG-107-3) (113 days) while in check Bhima Shakti it was 127 days. Minimum storage loss after four months of storage was recorded in DOGR-1168 (LG-107-3) (19.19%) followed by DOGR-1133 (LG-107-3) (23.62%), Bhima Shakti (LG-107-3) (24.58%) and Bhima Kiran (LG-107-3) (25.20%) whereas, check Bhima Shakti recorded 29.57% (Table 1.10).

Table 1.10 Evaluation of red onion advance breeding lines for yield and related traits (Late *kharif*)

Entries	MY (t/ha)	Mrk (%)	ABW (g)	Doubles (%)	Bolters (%)	TSS (°Brix)	DTH	E:P
Bhima Shakti (LG-107-3)	37.36	92.4	69.2	0.49	5.7	12.3	113	1.07
Bhima Raj (LG-107-3)	35.34	72.8	76.1	3.61	13.1	12.3	112	1.09
B-780 (5-3-1) (LG-107-3)	34.56	83.7	68.9	2.18	12.1	12.0	120	1.07
Bhima Kiran (LG-107-3)	33.98	86.1	69.5	3.75	7.0	12.1	123	1.10
NRCOG-1168 (LG-107-3)	33.32	89.5	65.9	1.36	7.7	11.9	121	1.05
RGO-53 (LG-107-3)	32.87	79.7	70.5	1.96	17.2	11.5	118	1.09
NRCOG-595 (LG-107-3)	31.70	83.2	72.8	0.81	14.4	12.1	118	1.06
Bhima Shakti (C)	35.02	85.8	71.3	5.35	7.5	12.0	127	1.08
Bhima Super (C)	31.64	79.3	69.3	1.95	17.5	11.8	116	1.08
Phule Samarth (C)	28.34	73.9	70.1	6.88	15.1	11.8	119	1.12
CV (%)	9.93	6.05	6.78	22.06	32.74	4.49	2.55	-
SE	0.85	2.85	2.72	1.43	2.65	0.31	1.77	-
LSD (P=0.05)	2.39	8.27	7.90	4.17	7.70	0.90	5.13	-

(MY-Marketable Yield, Mrk-Marketable bulbs, ABW-Average Bulb Weight, TSS-Total Soluble Solids, DTH-Days to Harvest, E:P-Equatorial to Polar diameter of bulb)

During *rabi,* DOGR-1741 (39.33 t/ha), DOGR-1822 (39.16 t/ha), DOGR-1751 (37.88 t/ha), DOGR-1773 (37.34 t/ha) and DOGR-1789 (36.89 t/ha) were found superior over best check Bhima Kiran (34.75 t/ha) with dark red, globe and medium sized bulbs (59-69 g), more than 95% marketable yield. All the lines were free from bolters and lines DOGR-1741 and DOGR-1789 were free from doubles. Minimum days to harvesting was recorded in DOGR-1741 (104 days), followed byDOGR-1751 (110 days), DOGR-1822 and DOGR-1773 (112 days). Minimum storage loss after four months of storage was recorded in DOGR-1761(16.65%) followed by DOGR-1784 (21.75%), DOGR-1818 (22.65%) and DOGR-1748 (22.68%) over check Bhima Shakti (29.81%) (Table 1.11).

Table 1.11 Evaluation of red onion advance breeding lines for yield and related traits (*Rabi*)

Entries	MY (t/ha)	Mrk (%)	ABW (g)	Doubles (%)	TSS (°Brix)	DTH	E:P
DOGR-1741	39.33	100	59.0	0	10.60	104	1.11
DOGR-1822	39.16	96.8	68.7	1.44	11.97	112	1.13
DOGR-1751	37.88	96.4	67.5	2.44	11.19	110	1.08
DOGR-1773	37.34	98.5	69.0	0.61	11.33	112	1.11
DOGR-1789	36.89	95.7	67.8	0	11.60	113	1.09
DOGR-1758	36.89	95.4	68.4	1.59	11.44	114	1.09
DOGR-1814	36.25	98.4	63.9	0	11.65	112	1.13
Bhima Kiran (C)	34.75	98.4	66.5	0	11.49	113	1.09
BLR (C)	33.38	96.0	63.8	0.79	11.55	114	1.09
Bhima Shakti (C)	32.03	97.2	63.9	0	11.81	110	1.08
CV (%)	8.38	2.98	11.08	25.08	3.44	3.44	-
SE	0.73	1.65	3.16	0.86	0.23	2.21	-
LSD (P=0.05)	2.06	4.63	8.86	2.42	0.64	6.20	-

(MY-Marketable Yield, Mrk-Marketable bulbs, ABW-Average Bulb Weight, TSS-Total Soluble Solids, DTH-Days to Harvest, E:P-Equatorial to Polar diameter of bulb)

During *kharif*, DOGR-1753 (39.30 t/ha), DOGR-1749 (38.64 t/ha), DOGR-1774 (36.64 t/ha) and DOGR-1768 (35.72 t/ha) were found superior over check Bhima Super (32.98 t/ha) with dark red, globe bulbs, more than 85% marketable yield. All the lines were free from doubles and bolters except DOGR-1768 (0.84% doubles). Minimum days to harvesting was recorded in DOGR-1753 (82 days) followed by DOGR-1774 (83 days) and DOGR-1768 (86 days) (Table 1.12).

Table 1.12 Evaluation of red onion advance breeding lines for yield and related traits (*Kharif*)

Entries	MY (t/ha)	Mrk (%)	ABW (g)	Doubles (%)	TSS (°Brix)	DTH	E:P
DOGR-1753	39.30	91.61	78.60	0.00	11.80	82.00	1.11
DOGR-1749	38.64	90.06	66.88	0.00	11.76	90.00	1.14
DOGR-1774	36.64	91.41	71.68	0.00	11.99	83.67	1.07
DOGR-1768	35.72	85.45	73.64	0.84	11.60	86.33	1.12
DOGR-1738	34.58	93.06	70.73	0.00	11.28	87.00	1.23
DOGR-1754	34.33	95.08	66.21	0.00	12.20	82.00	1.23
DOGR-1748	34.27	92.95	64.25	0.00	12.00	82.00	1.11
Bhima Super (C)	32.98	92.25	64.78	0.51	11.60	90.00	1.15
Bhima Red (C)	29.38	89.60	68.72	0.00	12.31	90.00	1.13
Bhima Dark Red (C)	27.40	90.11	66.25	0.00	12.00	90.00	1.10
CV (%)	10.26	9.99	12.22	24.32	2.75	3.56	-
SE	0.81	1.46	2.18	0.90	0.19	1.74	-
LSD (P=0.05)	2.26	4.11	6.10	2.53	0.53	4.87	-

(MY-Marketable Yield, Mrk-Marketable bulbs, ABW-Average Bulb Weight, TSS-Total Soluble Solids, DTH-Days to Harvest, E:P-Equatorial to Polar diameter of bulb)

Evaluation of red onion initial breeding lines

Fifty-one breeding lines were evaluated duringlate *kharif*, *rabi* and *kharif* along with checks. During *late kharif*, more than 42 t/ha marketable yield was recorded in LK-07-C2/LR-4, Red Genepool-7, LK-07-C2/LR-3, Red Genepool-6 and 1603 and found superior over best check Bhima Kiran (39.46 t/ha) with medium red, globe and medium sized bulbs (78-82 gm), more than 89% marketable yield. Days to harvesting were minimum in LK-07-C2/LR-4, Red Genepool-7, LK-07-C2/LR-3 and Red Genepool-6 (117 days) (Table 1.13). Minimum storage loss after four months of storage was recorded in LK-07-C2/LR-3 (25.32%) followed by R-LK-M-II (27.13%) and R-KH-M-II (27.17%).

Table 1.13 Evaluation of red onion initial breeding lines for yield and related traits (Late *kharif*)

Entries	MY (t/ha)	Mrk (%)	ABW (g)	Doubles (%)	Bolters (%)	TSS (°Brix)	DTH	E:P
LK-07-C2/LR-4	54.67	100	82	0	0	12.40	117	1.22
Red Genepool-7	53.38	100	80.1	0	0	12.72	117	1.08
LK-07-C2/LR-3	47.68	98.7	81.6	1.27	0	12.01	117	1.09
Red Genepool-6	44.53	94.4	81.7	0.59	3.48	12.01	117	1.11
1603	42.51	89.7	78.4	5.03	4.49	11.84	124	1.12
LK-07-C2/LR-2	42.03	86.9	78.4	2.04	9.68	11.89	122	1.09
LK-07-C2/LR-1	41.02	90.6	80	1.79	6.41	11.96	121	1.08
Bhima Shakti (C)	36.39	86.5	77.4	2.97	8.09	11.96	123	1.12
Bhima Kiran (C)	39.46	90.5	79.9	1.01	7.76	11.97	119	1.09
Bhima Super (C)	37.81	78.8	82.8	0.73	19.07	11.73	118	1.09
CV (%)	9.77	11.7	11.1	34.28	37.82	2.99	3.88	-
SE	1.19	3.16	2.60	2.26	1.23	0.21	2.69	-
LSD (P=0.05)	3.32	8.85	7.28	6.35	6.25	0.58	7.53	-

(MY-Marketable Yield, Mrk-Marketable bulbs, ABW-Average Bulb Weight, TSS-Total Soluble Solids, DTH-Days to Harvest, E:P-Equatorial to Polar diameter of bulb)

During *rabi*, LK-07-C2/LR-4 (33.19 t/ha), R-KH-M-III (30.96 t/ha), DOGR-671-Sel (29.75 t/ha), RGP-2-KH-Sel (28.51 t/ha) and C6-KM-1 (27.63 t/ha) were found superior over best check Bhima Kiran (23.63 t/ha) with dark red, globe and medium sized bulbs (54-61 gm), more than 96% marketable yield. All the lines were free from double bulbs except R-KH-M-III (0.33%) while LK-07-C2/LR-4 and DOGR-671-Sel were free from bolter bulbs. Minimum days to harvesting was recorded in RGP-2-KH-Sel (101 days) followed by C6-KM-1 (104 days) and DOGR-671-Sel (106 days) (Table 1.14). Minimum storage loss after four months of storage was recorded in DOGR-651-Sel (22.50%) followed by DOGR-1043-GLR (23.29%) over best check Bhima Shakti (28.19%).

Table 1.14 Evaluation of red onion initial breeding lines for yield and related traits (*Rabi*)

Entries	MY (t/ha)	Mrk (%)	ABW (g)	Double (%)	Bolters (%)	TSS (°Brix)	DTH	E:P
LK-07-C2/LR-4	33.19	100	61.43	0.00	0	11.59	113	1.08
R-KH-M-III	30.96	97.4	54.51	0.33	0.53	11.84	107	1.10
DOGR-671-Sel	29.75	97.2	54.60	0.00	0.00	11.21	107	1.10
RGP-2-KH-Sel	28.51	98.2	57.35	0.00	0.37	12.17	102	1.14
C6-KM-1	27.63	96.2	57.96	0.00	1.75	11.59	104	1.09
DOGR-670-Sel	27.38	95.9	55.41	0.00	0.00	11.40	113	1.11

Entries	MY (t/ha)	Mrk (%)	ABW (g)	Double (%)	Bolters (%)	TSS (°Brix)	DTH	E:P
LK-07-C2/LR-3	27.06	97.6	55.79	0.00	0.00	11.44	107	1.07
Bhima Kiran (C)	23.63	97.4	54.89	0.29	0.24	11.52	107	1.07
Bhima Shakti (C)	20.61	97.2	46.39	0.18	0.00	11.48	113	1.10
BLR (C)	18.02	96.4	47.87	0.00	0.00	11.60	114	1.08
CV (%)	11.27	1.92	8.63	16.36	15.80	2.87	3.37	-
SE	0.93	1.07	2.57	0.41	0.44	0.19	2.06	-
LSD (P=0.05)	2.60	3.00	7.22	1.16	1.23	0.54	5.78	-

(MY-Marketable Yield, Mrk-Marketable bulbs, ABW-Average Bulb Weight, TSS-Total Soluble Solids, DTH-Days to Harvest, E:P-Equatorial to Polar diameter of bulb)

During *kharif,* DOGR-1050-Sel (44.53 t/ha), Red Genepool-1 (34.49 t/ha), RGP-1-KH-Sel (32.50 t/ha), RGP-1-LK-Sel (32.24 t/ha) and DOGR-650-Sel (30.89 t/ha) were found superior over best check Bhima Dark Red (24.66 t/ha) with dark red, globe and medium sized bulbs (61-74 gm), more than 86% marketable yield (Table 1.15). All the lines were free from doubles and bolters. Minimum days to harvesting was recorded in Red Genepool-1 and RGP-1-KH-Sel (86 days) followed by RGP-1-LK-Sel (88 days).

Table 1.15 Evaluation of red onion initial breeding lines for yield and related traits (*Kharif*)

Entries	MY (t/ha)	Mrk (%)	ABW (g)	TSS (°Brix)	DTH	E:P
DOGR-1050-Sel	44.53	94.62	74.22	11.56	90	1.14
Red Genepool-1	34.49	87.74	68.68	11.60	86.6	1.09
RGP-1-KH-Sel	32.50	86.00	63.65	11.89	86.6	1.11
RGP-1-LK-Sel	32.24	88.99	71.27	11.60	88.3	1.15
DOGR-650-Sel	30.89	86.35	61.76	11.57	90.0	1.11
Red Genepool-3	29.65	83.61	69.46	11.92	85.0	1.11
Red Genepool-4	28.39	88.81	59.55	11.52	86.6	1.10
Bhima Dark Red (C)	24.66	87.82	60.31	11.63	88.6	1.08
Bhima Raj (C)	21.93	88.80	55.09	11.63	93.0	1.09
Bhima Super (C)	21.15	88.73	62.00	11.40	93.0	1.11
CV (%)	11.79	10.43	9.91	2.96	3.47	-
SE	0.75	2.21	3.21	0.20	1.75	-
LSD (P=0.05)	2.10	6.20	9.02	0.56	4.91	-

(MY-Marketable Yield, Mrk-Marketable bulbs, ABW-Average Bulb Weight, TSS-Total Soluble Solids, DTH-Days to Harvest, E:P-Equatorial to Polar diameter of bulb)

Onion lines under AINRPOG

Three red onion lines *viz.*; DOGR-1744, DOGR-1745, DOGR-1746 have been introduced in AINRPOG trials as IET during 2023. Whereas, DOGR-1757, DOGR-1758, DOGR-1773 being evaluated as AVT-I, and DOGR-1606, DOGR-1654 and DOGR-1657 as AVT-II during 2023.

Evaluation of red onion F_1 hybrids developed through male sterile lines

Sixty-one F_1 hybrids along with their parents and checks were evaluated during late *kharif* season. Five F_1 hybrids *viz.* MS111A×KH-M-1, MS111A×546-DR, MS1600A×RGP-2, MS111A×1605 and MS1600A×1612 recorded more than 51% heterosis for marketable yield over best check Bhima Shakti (38.15 t/ha) with uniform bulbs. All the hybrids were free from doubles while MS111A×KH-M-1, MS111A×RGP-2 and MS111A×1605 were free from bolters. Minimum days to harvesting was recorded in MS111A×1605 (104 days) followed by MS111A×546-DR (108 days) and MS111A×RGP-2 (112 days) (Table 1.16). Minimum storage loss after four months of storage was recorded in MS111A×571-LR (21.04%) followed by MS222A×RGP-1 (21.23%) and MS111A×KH-M-1 (23.60%) against check Bhima Shakti (37.78%).

Table 1.16 Evaluation of red onion F_1 hybrids developed through MS lines (Late *kharif*)

Entries	MY (t/ha)	Mrk (%)	ABW (g)	Double (%)	Bolter (%)	TSS (°Brix)	DTH	E:P	Std heterosis
MS 111A ×KH-M-1 F_1	61	100	100	0.00	0.00	11.40	117	1.12	59.80
MS 111A ×546-DR F_1	59	97	95	0.00	2.56	11.44	108	1.09	55.26
MS 111A ×RGP-2 F_1	59	99	100	0.00	0.00	11.75	112	1.03	54.69
MS 111A ×1605 F_1	59	100	104	0.00	0.00	11.08	104	1.11	53.58
MS 111A × 1612 F_1	58	83	107	0.00	16.44	11.69	114	1.10	51.57
MS 11A×571-LR F_1	57	94	93	0.00	5.12	11.80	107	1.10	49.36
MS 111A ×KH-M-2 F_1	56	90	97	0.00	9.46	11.84	114	1.11	48.29
Bhima Shakti (C)	38	93	69	0.00	5.87	11.91	120	1.09	-
Bhima Kiran (C)	37	93	68	0.00	5.41	11.52	125	1.05	-
Jumbo (C)	32	89	69	6.35	0.00	11.81	117.3	1.12	-
Bhima Super (C)	29	83	60	0.00	16	11.53	126.3	1.13	-
Liberty (C)	21	84	53	12	0.00	11.53	119.3	1.12	-
CV (%)	11.26	9.14	11.31	19.80	58.64	3.27	3.76	-	-
SE	1.22	2.34	2.62	1.90	2.32	0.22	2.64	-	-
LSD (P=0.05)	3.44	6.55	7.35	5.34	6.50	0.62	7.39	-	-

(MY-Marketable Yield, Mrk-Marketable bulbs, ABW-Average Bulb Weight, TSS-Total Soluble Solids, DTH-Days to Harvest, E:P-Equatorial to Polar diameter of bulb)

During *rabi,* 47 F_1 hybrids were evaluated along with their parental lines and checks. Five F_1 hybrids *viz.* MS111A×1672, MS111A×KH-M-1, MS111A×1613, MS111A×RGP-3 and MS111A×KH-M-2 recorded more than 13% heterosis for marketable yield over best check Bhima Shakti (31.94 t/ha) with uniform bulbs and free from doubles and bolters. Minimum days to harvesting was recorded in MS111A×KH-M-1, MS111A×KH-M-2 (110 days) followed by MS111A×1672 and MS111A×RGP-3 (112 days) while in check Bhima Shakti it was 118 days (Table 1.17). Minimum storage loss after four months of storage was recorded in MS111A×RGP-1 (22.56%) followed by MS111A×1605 (32.22%) and MS111A×1613 (33.26%) over check Bhima Shakti (44.74%).

Table 1.17 Evaluation of red onion F_1 hybrids developed through MS lines (*Rabi*)

Entries	MY (t/ha)	Mrk (%)	ABW (g)	TSS (°Brix)	DTH	E:P	Standard heterosis
MS 111A × 1672 F_1	43	100	70	11.43	112	1.13	34.94
MS 111A × KH-M-1 F_1	39.9	100	72	11.60	110	1.15	25.17
MS 111A × 1613 F_1	36.4	98	64	11.92	115	1.08	14.05
MS 111A × RGP-3 F_1	36.3	100	54	11.47	112	1.09	13.93
MS 111A × KH-M-2 F_1	36.1	99	66	11.64	110	1.11	13.21
MS 111A × 1612 F_1	35.8	100	63	11.47	111	1.10	-

Entries	MY (t/ha)	Mrk (%)	ABW (g)	TSS (°Brix)	DTH	E:P	Standard heterosis
MS 111A × 1605 F_1	35.1	100	61	11.08	111	1.08	-
Bhima Shakti (C)	31.9	98	55	11.39	118	1.09	-
BLR (C)	31.4	98	53	11.25	112	1.11	-
Bhima Kiran (C)	30.5	97	56	11.68	116	1.07	-
CV (%)	8.86	2.51	10	3.13	2.74	-	-
SE	0.87	1.42	2.71	0.21	1.79	-	-
LSD (P=0.05)	2.45	3.98	7.59	0.59	5.04	-	-

(MY-Marketable yield, Mrk-Marketable bulbs, ABW-Average Bulb Weight, TSS-Total Soluble Solids, DTH-Days to Harvest, E:P-Equatorial to Polar diameter of bulb)

During *kharif,* 65 F_1 hybrids were evaluated along with their parental lines and checks. More than 15% heterosis was recorded in MS111A×KH-M-1, MS111A×RGP-4, MS1600A×1613 and MS222A×1604 on marketable yield and found superior over best check Bhima Super (32.98 t/ha). These hybrids showed more than 91% marketable yield and were free from doubles and bolters (Table 1.18). Minimum days to harvesting was recorded in MS222A×1604 (84 days) followed by MS111A×KH-M-1, MS111A×RGP-4 (89 days) and MS1600A×1613 (92 days).

Table 1.18 Evaluation of red onion F_1 hybrids developed through MS lines (*Kharif*)

Entries	MY (t/ha)	Mrk (%)	ABW (g)	Double (%)	Bolter (%)	TSS (°Brix)	DTH	E:P	Standard heterosis
MS111A × KH-M-1 F_1	47.56	100	71	0	0	10.93	89.0	1.17	44.20
MS111A × RGP-4 F_1	40.07	91	75	0	0	10.60	89.0	1.06	21.50
MS1600A ×1613 F_1	38.33	93	77	0	0	11.53	92.0	1.17	16.24
MS222A × 1604 F_1	38.22	100	57	0	0	10.47	84.0	1.12	15.90
MS111A ×RGP-5 F_1	35.13	100	53	0.	0	10.92	89.0	1.11	-
MS111A × KH-M-2 F_1	33.87	86	85	0	0	10.40	89.0	1.07	-
MS111A × 1630 F_1	30.26	84	71	0	0	11.04	91.0	1.11	-
Bhima Super (C)	32.98	92	65	0.51	0.58	11.60	90.0	1.15	-
Bhima Dark Red (C)	30.41	84	70	0.66	0	11.17	92.0	1.12	-
Bhima Red (C)	26.04	89	65	0	0	11.28	92.0	1.10	-
Arka Lalima (C)	17.10	75	51	0	0	10.95	89.0	1.11	-
Orient (BSS-133) (C)	14.47	64	50.23	0	0	10.24	79.0	1.10	-
C.V (%)	7.87	6.68	10.09	29.75	0	3.84	3.56	-	-
SE	0.77	2.91	2.57	0.44	0	0.25	1.76	-	-
LSD (P=0.05)	2.15	8.16	7.19	1.24	0	0.69	4.96	-	-

(MY-Marketable Yield, Mrk-Marketable bulbs, ABW-Average Bulb Weight, TSS-Total Soluble Solids, DTH-Days to Harvest, E:P-Equatorial to Polar diameter of bulb)

Evaluation of Inbreds

Sixty-six inbreds along with the checks were evaluated during *rabi* 2022-23. Among these, I_1 -1664, I_1-1773, I_1-1737, I_1-1744 and I_1-1729 were found superior over best check Bhima Shakti (34.52 t/ha). These genotypes were free from doubles and bolters. Minimum days to harvesting was recorded in I_1-1737, I_1-1744 (111 days) followed by I_1-1664, I_1-1773 and I_1-1729 (115 days).

F_1 Hybrids under AINRPOG

Three red onion F_1 hybrids *viz.*; DOGR Hy-207, DOGR Hy-211 and DOGR Hy-212 have been introduced in AINRPOG trials as IET during 2023-24. However, DOGR Hy-56 and Hy-155 being evaluated as AVT-I, and DOGR Hy-156 and Hy-172 as AVT-II during 2023.

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 BC_1 stage and three combinations in BC_3 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). Inbred lines were developed from single bulb of selected parents. Currently, 66 inbreds are in I_1, 20 inbreds in I_2 and 9 inbreds in I_3 stage.

All India Network Research Project on Onion and Garlic

Evaluated IET (varieties/ hybrids) 29 entries during *kharif,* late *kharif* and *rabi* seasons; AVT-I (varieties/ hybrids) 12 during *rabi* season; AVT-II (varieties/ hybrids) 7 entries during *rabi* season. Storage trails of IET, AVT-I and AVT-II conducted during *kharif,* late *kharif* and *rabi*. A total of 23 red onion and 15 white onion lines were evaluated for multilocation trials. Nine advance lines and seven F_1 hybrids developed and being evaluated under AINRPOG trials. DOGR-1744, DOGR-1745, DOGR-1746, DOGR Hy-207, DOGR Hy-211 and DOGR Hy-212 evaluated as IET; DOGR-1757, DOGR-1758, DOGR-1773, DOGR Hy-56 and Hy-155 evaluated as AVT-I; DOGR-1606, DOGR-1654, DOGR-1657, DOGR Hy-156 and Hy-172 evaluated as AVT-II during *kharif*, late *kharif* and *rabi* 2023 under network varietal/ hybrid trials.

CRP on Onion Hybrid Technology

Research indicates that hybrid varieties exhibit higher heterosis compared to open-pollinated varieties. Despite the public sector released two hybrids in India, have not gained attention among farmers. However, ICAR-DOGR has developed five Male Sterile lines (MS 48A, MS 65A, MS 111A, MS 222A and MS 1600A) along with inbred lines. These are being utilized to develop stable F1 hybrids in onions that promise high yield, early maturity and good bulb storability.

Development of hybrids in onion: A Joint venture

Under development of F_1 hybrids in red onion, evaluated 65 F_1 hybrids during *kharif*, 61 F_1 hybrids during late *kharif* and 47 F_1 hybrids during *rabi.* Seven F_1 hybrids *viz.*; DOGR Hy-56, DOGR Hy-155, DOGR Hy-156, DOGR Hy-172, DOGR Hy-207, DOGR Hy-211 and DOGR Hy-212 being evaluated under AINRPOG trials for multi-location evaluation. Further, 115 F_1 hybrids of red onion were developed by crossing between five MS lines 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.

1.3 Genetic improvement of garlic through conventional and biotechnological approaches

Garlic maintenance at ICAR-DOGR

ICAR-DOGR serves as the National Active Germplasm Site for garlic germplasm. Under following categories garlic accessions (715) are being conserved at ICAR-DOGR in the field gene bank (Table 1.19). The short-day germplasm was planted using the recommended agronomic techniques at the ICAR-DOGR main campus and Kalus farm during *rabi* 2023. However, all long day germplasm including varieties have been maintained and conserved at ICAR-CITH, Srinagar.

Table 1.19 Garlic germplasm and varieties collection and maintenance at ICAR-DOGR

Particulars	**No. of Accessions**
Garlic elite lines	46
Trait specific identified line	20
Core collection garlic germplasm	32
Garlic with dark pink skin colour	15
Kharif suitable elite lines	11
Germplasm	483
GSGA lines number	19
Elite lines through mutation lines	33
Varieties	37
Mutated lines	450
Nucleus seed production	
Garlic var. Bhima Purple	45 kg
Garlic var. Bhima Omkar	30 kg

In-vitro maintenance of garlic germplasm

Core set collection of 32 accessions, manually developed core set collection of 49 accessions and two trait specific lines (DOGR-24 and DOGR-28) are under *in vitro* slow growth conservation at ICAR-DOGR.

Maintenance of garlic core collection

ICAR-DOGR has developed garlic core collection using entire set of 625 garlic accessions which containing 94% of genetic diversity generated through 23 agro-morpho traits (Table 1.20). Therefore, variability of core accessions is being maintained at ICAR-DOGR at field condition.

Table 1.20 Mean performance of garlic core set accessions for yield and contributing traits

Genotype	DTH	TY (t/ha)	PD (mm)	ED (mm)	ABW (g)	NCB	W50C (g)	TSS (°Brix)
357-C. R	141	3.55	23.7	28.3	8	19	30	43.2
448-C. R	131	6.59	30.5	34.0	12	8	36	42.6
258-C. R	141	5.14	26.8	31.5	10	14	37	41.9
532-C. R	141	4.49	26.4	31.5	11	14	29.5	42.9
415-C. R	135	4.79	27.7	32.8	10	13	28.5	43.9
432-C. R	141	6.22	27.1	32.9	12	6	83.0	43.7
294-C. R	135	1.36	27.0	31.6	10	9	35.5	43.6
32-C. R	135	5.18	28.1	32.8	12	12	46.5	43.6
437-C. R	135	6.45	28.6	36.3	12	17	42.5	43.5
571-C. R	135	5.10	26.6	31.2	11	10	35.5	42
503-C. R	141	2.36	26.0	30.8	9	10	37.5	42.3
436-C. R	141	4.18	28.5	29.8	9	8	70.5	42.7
28-C. R	135	4.55	26.5	32.4	9	12	37.5	45.1
570-C. R	116	2.93	24.5	29.6	7	16	17.5	40.8

Genotype	DTH	TY (t/ha)	PD (mm)	ED (mm)	ABW (g)	NCB	W50C (g)	TSS (°Brix)
214-C. R	141	7.28	28.5	36.4	13	16	35.5	45.2
418-C. R	135	6.23	25.8	32.7	12	15	34.5	41.6
283-C. R	141	7.63	29.6	35.8	12	14.2	35.5	42.4
415-P-C. R	141	4.63	30.1	32.6	10.3	14	35.0	42.6
161-C. R	141	4.12	28.8	31.3	10.4	9.6	46.0	43.8
355-C. R	135	4.36	25.4	31.3	8.7	14.2	26.0	44.3
426-C. R	135	3.67	27.3	31.5	9.3	9.4	32.5	42.4

TY-Total Yield, PD-Polar Diameter, ED-Equatorial diameter, TY- Total Yield, ABW- Average Bulb Weight, NCB-No. of Clove /Bulb, W50C-Weight of 50 Cloves, TSS-Total Soluble Solids

Evaluation of promising/elite garlic lines during *Rabi*

A total of 13 garlic elite line evaluated for yield and contributing traits. The marketable yield of these lines ranged from 6.7 to 9.6 t/ha. DOGR-404 was found to be superior in yield with 9.6 t/ha. TSS was ranges from 42 to 47 °Brix, highest TSS was recorded by DOGR-806 (47 °Brix) (Table 1.21). The bulbs of all the lines are compact in nature, with silvery white colour.

Table 1.21 Evaluation of elite garlic lines for high yield and contributing traits

Genotype	DTH	TY (t/ha)	PD (mm)	ED (mm)	ABW	NCB	W50C (g)	TSS (°Brix)
746	141	7.27	30.3	38.4	16.5	12.0	57.0	46.1
806	135	9.28	34.3	45.0	25.4	17.0	52.5	47.1
569	141	8.12	32.5	38.6	14.2	13.8	54.0	44.3
404	141	9.69	34.3	45.6	24.8	18.8	64.0	46.6
793	141	7.98	32.1	40.7	17.0	11.2	54.0	42.6
48-W	140	8.56	30.2	39.3	15.5	17.4	48.5	46.1
709	141	7.11	32.7	40.8	13.6	20.8	47.0	46.6
815	141	7.53	33.1	40.3	21.3	13.2	64.5	46.8
441	141	7.70	29.7	37.3	15.8	12.5	58.5	44.9
788	141	8.55	30.6	37.3	15.4	14.0	60.0	43.9
48-W	140	8.56	30.2	39.3	15.5	17.4	48.5	46.1
31	141	6.60	29.2	36.0	14.5	15.4	43.5	42
493	141	8.16	31.1	39.9	16.5	21.8	45.5	46.1
513	135	6.75	29.1	36.2	16.5	24.4	35.0	44.8
CD @0.5%	6.11	3.12	2.01	1.0	4.1	2.1	5.4	2.1

TY-Total Yield, PD-Polar Diameter, ED-Equatorial diameter, TY- Total Yield, ABW- Average Bulb Weight, NCB-No. of Clove /Bulb, W50C-Weight of 50 Cloves, TSS-Total Soluble Solids

A set of 40 promising lines evaluated for yield and related traits, among which nine lines mentioned in table 1.22. Among all, DOGR-320SN recorded highest marketable yield (9.0 t/ha) with 16 gm average bulb weight. All the lines possess more than 10 gm average bulb weight.

Table 1.22 Evaluation of garlic promising lines for high yield and related traits

Genotype	DTH	MY (t/ha)	PD (mm)	ED (mm)	ABW (g)	NCB	W50C (g)
787-SN	141	7.47	30.8	36.2	13.1	12.2	44
123-SN	141	7.26	31.2	37.2	17.3	12.6	56
701-SN	135	4.13	26.1	29.4	9.5	5.4	46
367-SN	141	5.96	30.5	36.7	14.2	11.4	52
784-SN	141	7.54	31.3	37.3	14.1	9.6	48
393-SN	141	7.46	32.5	36.9	15.7	10.6	48
705-SN	135	5.97	27.9	32.7	10.1	13.2	34
320-SN	141	9.06	29.1	34.6	16.6	11.6	39
102-SN	141	6.74	30.5	36.5	14.9	11.2	54
CD @ 0.5%	2.14	4.12	1.02	2.35	2.55	2.68	3.54

MY-Marketable Yield, DTH-Days to maturity, PD-Polar Diameter, ED-Equatorial Diameter, ABW-Average Bulb Weight, NCB-No. of Clove /Bulb, W50C-Weight of 50 Cloves

Evaluation of garlic for red clove skin colour

Dark purple skinned garlic cloves are mostly preferred by Indian people due to its intense characteristic flavour and taste. This phenomenon also helps to easy mechanical peeling of garlic in certain amount. Therefore, we emphasize on breeding for dark clove skinned, high yielding garlic with big clove size through clonal selection. Out of 700 garlic germplasm available at ICAR-DOGR, 17 accessions possess such a deep dark purple skin clove type (Table 1.23). Among them, PB-dark-1 and DOGR-756-DR recorded highest yield 9.5 and 8.1 t/ha respectively.

Table 1.23 Evaluation of red/dark pink clove colour garlic lines for yield and related traits

Genotype	MY (t/ha)	PD (mm)	ED (mm)	ABW	NCB	W50C (g)	TSS (°Brix)
266-DR	6.01	29.5	36.4	12.9	12.00	47	42.6
787-DR	6.66	30.2	36.5	12.6	10.67	44	42.3
63-DR	7.67	29.2	37.5	10.8	17.20	46.5	45.4
303-DR	5.64	27.7	33.1	10.4	10.40	39.5	44.12
258-DR	5.21	26.1	31.6	9.9	11.33	45.5	41.8
534-DR	6.44	28.8	35.1	11.5	11.00	40	42.8
PB-Dark-1	9.52	31.4	41.2	10.2	19.00	35.5	45.7
444-DR	6.78	31.1	34.0	13.7	8.40	48.0	41.8
34-DR	7.69	27.5	33.0	12.3	9.40	54.5	42.1
224-DR	6.55	29.3	36.0	12.2	12.00	45	44.2
353-DR	4.12	29.0	35.8	6.9	18.40	46	45.7
756-DR	8.13	29.4	35.4	8	17.00	35.5	44.1
388-DR	4.26	29.1	36.1	11.1	12.00	38.5	44.3
341-DR	5.22	24.9	35.7	9.5	8.80	58.5	36.3
301-DR	7.47	28.9	34.6	11	13.20	41.5	44.2
Godavari-DR	4.29	28.1	33.2	11.5	10.5	52.5	44.8
419-DR	3.71	28.0	33.4	10.2	9.6	38.5	40.6
CD @0.05%	7..4	3.01	3.12	2.14	2.58	3.58	3.41

MY-Marketable Yield, DTH-Days to Harvest, PD-Polar Diameter, ED-Equatorial Diameter, ABW-Average Bulb Weight, NCB-No. of Clove /Bulb, W50C-Weight of 50 Cloves, TSS-Total Soluble Solids

Figure 1.6 Red/pink clove skin colour garlic breeding lines

Evaluation of garlic lines for earliness (Early maturity)

A total of 350 garlic germplasm evaluated for earliness in garlic by following recommended package of practices during *rabi* season. The garlic germplasm screening was carried out on the basis of number of days require for maturity. Total nine genotypes (Table 1.24) were selected which matured before 120 days after planting for further improvement through clonal selection. Among selected lines, DOGR-359 and DOGR 430 recorded highest total yield with earliness.

Table 1.24 Evaluation of garlic lines for earliness (early maturity) with high yield

Genotype	DTH	TY (t/ha)	PD (mm)	ED (mm)	ABW	NCB	W50C (g)	TSS (°Brix)
693	106	3.14	24.4	29.7	8.2	11.0	46.5	41.1
SG-01	116	3.64	25.7	30.4	9.4	12.8	34.5	42.5
264	106	3.04	25.1	30.2	8.3	13.4	42.5	41.2
359	112	5.76	25.1	28.1	10.4	11.4	41.5	38.9
567	119	2.68	24.7	30.2	9.1	15.4	35.5	43.2
671	116	3.06	24.1	28.3	8.7	12.4	36.5	40.5
430	119	5.73	25.3	30.1	10.4	12.0	41.5	41.1
527	116	1.93	22.5	27.5	8.2	11.4	34.5	41.2
791	116	3.23	24.4	28.9	8.5	13.2	38.5	43.6
CD@0.5%	1.23	5.2	1.0	1.2	2.0	3.2	4.25	3.0

TY- Total Yield, DTH-Days to Maturity, PD-Polar Diameter, ED-Equatorial Diameter, ABW- Average Bulb Weight, NCB-No. of Clove /Bulb, W50C-Weight of 50 Cloves, TSS-Total Soluble Solids

Evaluation of garlic for high TSS

The trait total soluble solid (TSS) is crucial for breeding garlic varieties for processing purpose. A total of 200 garlic genotypes were screened for total soluble solids as well as yield and bulb parameters. Among all, 12 genotypes ranked superior for TSS (> 46°Brix). Further, 20 more genotypes (not listed here) recorded TSS in between 45°-46°Brix, however remaining all genotypes possessed 41-45°Brix TSS. Promising lines DOGR-806 and DOGR-347 recorded highest yield (Table 1.25) with high TSS.

Table 1.25 Evaluation of garlic lines for high TSS along with high bulb yield

Genotypes	DTH	TY (t/ha)	PD (mm)	ED (mm)	ABW	NCB	W50C	TSS (°Brix)
746-HY	141	7.27	30.3	38.4	16.5	12	57	46.1
DOGR -806-HY	135	9.28	34.3	45.0	25.4	17	52.5	47.1
404-HY	141	9.69	34.3	45.6	24.8	18.8	64	46.6
48-W-HY	140	8.56	30.2	39.3	15.5	17.4	48.5	46.1
709-HY	141	7.11	32.7	40.8	13.6	20.8	47	46.6
SG-1-HY	141	7.53	33.0	40.2	21.3	13.2	64.5	46.8
493-HY	141	8.16	31.0	39.9	16.5	21.8	45.5	46.2
347-Hy	141	9.06	29.8	34.9	11.2	11.8	40.5	46.2
539-p-Hy	141	7.93	27.9	35.6	11.9	13	38	46.2
B.O-5GY-80-M5	142	8.34	29.2	36.6	17.4	17.8	49	46.3
B.O-5GY-1-M5	141	5.95	32.8	39.5	19.9	21	54	46.7
B.O-1GY-9-M5	141	6.74	31.5	40.7	20.1	20.6	45.5	46.1
Bhima Purple	135	6.62	31.5	38.5	16.2	15.5	43.2	45.1
Bhima Omkar	130	8.11	31.1	39.1	16.4	11.2	46.2	44.2
CD @ 0.5%	2.14	6.1	2.1	3.01	3.1	2.0	3.01	1.5

DTH-Days to Maturity, TY-Total Yield, PD-Polar Diameter, ED-Equatorial Diameter, ABW- Average Bulb Weight, NCB-No. of Clove /Bulb, W50C-Weight of 50 Cloves, TSS-Total Soluble Solids

Evaluation of garlic bulbil as planting material

The hard neck type garlic, usually planted in hilly regions possesses bulbils i.e. bolted garlic bears small bulblets at apical end. The production of bulbils is in plenty; therefore, experiment has been planned to use bulbils as a planting material. Work on evaluation of suitable planting date for bulb development with clove formation was initiated with three different sowing dates at an interval of 15 days (Table 1.26). The planting date (20-25 July) found effective for bulb development with high total yield. Experiment will be repeated in next year to study the stability and environment effect.

Table 1.26 Evaluation of garlic bulbil as planting material during Late kharif -2023

Lines	DTH	TY (t/ha)	MY (t/ha)	PD (mm)	ED (mm)	ABW (g)	NCB	W50C	TSS (°Brix)
Bulbil-1	99	15.7	10.76	21.8	24.7	6.37	8.4	35	40.9
Bulbil-2	93	4.0	2.97	21.7	25.4	6.42	10.3	32.5	36.5
Bulbil-3	80	5.3	2.55	20.2	22.7	4.84	10.8	30.0	39.5
CD@0.5%	2.34	21.32	12.03	3.01	2.11	2.17	2.14	2.31	2.01

DTH-Days to Maturity, TY-Total Yield, PD-Polar Diameter, ED-Equatorial Diameter, ABW- Average Bulb Weight, NCB-No. of Clove /Bulb, W50C-Weight of 50 Cloves, TSS-Total Soluble Solids

Figure 1.7 Garlic developed through bulbils at different planting dates

Evaluation of garlic for *kharif* season suitability

A total of 15 garlic lines were evaluated for *kharif* season suitability and agro-morphological traits. Out of which first 12 lines evaluated consequently three years. The average marketable yield (> 5t/ha) was recorded by DOGR-555, DOGR-100 and CPT-11M4. The TSS content in the lines ranged from 41 to 46 °Brix (Table 1.27).

Table 1.27 Evaluation of kharif garlic elite lines for yield and related traits

Lines	MY (t/ha)	PD (mm)	ED (mm)	ABW (g)	NCB	W50C	TSS (°Brix)
G-282	2.50	25.1	30.1	7.8	6.6	46.5	41.7
296	1.47	23.6	26.9	5.3	6.5	30.5	41.5
282	2.35	24.2	26.8	5.9	6.5	58.2	42.2
555	5.90	26.6	30.6	8.8	6.8	55	41.8
324	3.23	25.8	28.8	6.1	8	44	43.1
G-41	2.66	28.5	30.9	9.7	9.1	49	41.9
26	2.74	26.1	32.3	9.5	8.8	60	44.1
27-W	3.35	25.6	31.4	9.2	8.3	50	46.1
100	5.26	27.8	32.4	10.5	5.6	70	44.1
23	3.15	26.7	32.6	9.2	6.7	56.5	45.5
Bhima Purple	2.21	25.9	30.2	7.3	6.5	44	43.1
PB-EMS-1	1.71	22.8	27.7	4.9	11.2	34	43.5
SAT-10.4 M4	2.73	25.8	28.4	6	8.5	40	43.2
CBS-6.7 M3	3.25	25.4	27.3	6.7	6.8	43.5	46.1
CPT-11 M4	5.18	28.3	31.2	9.61	9.80	51	43.6

MY-Marketable Yield, PD-Polar Diameter, ED-Equatorial Diameter, ABW-Average Bulb Weight, NCB-No of Clove /Bulb, W50C-Weight of 50 Cloves, TSS-Total Soluble Solids

Figure 1.8 *Kharif* season suitable garlic lines

In vitro evaluation of drought stress selected garlic lines DOGR-28 (susceptible) and DOGR-24 (tolerant) for osmotic stress

In previous studies, garlic genotypes DOGR-24 and DOGR-28 found abiotic stress (Drought) tolerant and susceptible respectively during field evaluation as well as biochemical and root studies. Therefore, for confirming the phenomenon, *in vitro* experiment under osmotic stress was carried out using osmotic agent mannitol. The 10 plantlets per replication were subjected to mannitol osmotic stress in concentration 100, 200, 400 and 600 mM with control. Concentrations 400 and 600 found most effective for causing stress in plants (Figure 1.9). Therefore, experiment was repeated only using 400 and 600 mM solution of mannitol. One week old *in vitro* established plantlets were used for experiment. Plants morphological traits also had been recorded (Table 1.28).

Figure 1.9 *In-vitro* osmotic stress responses of DOGR-28 and DOGR-24

Table 1.28 Quality parameters of garlic DOGR-24 and DOGR-28 after 3rd month of in-vitro osmotic stress

Parameters	DOGR-24	DOGR-28
Control		
Shoot Length (cm)	15.10^{bc}	22.25^{de}
Root Length (cm)	4.12^{b}	$7.\ 31^{d}$
Number of roots	5.10^{c}	4.67^{b}
Leaf and root quality	Poor	Poor
Survival %	Dry leaf	Dried leaf
400 mM mannitol stress		
Shoot Length (cm)	12.30^{bb}	15.89^{ab}
Root Length (cm)	7.45^{de}	6.14^{de}
Number of roots	5.2^{c}	5.1^{c}
Leaf & root quality	average	poor
Survival %	Green leaf	Yellow and dry leaf
600 mM mannitol stress		
Shoot Length (cm)	7.14^{a}	10.23^{ab}
Root Length (cm)	3.21^{ab}	6.14^{cd}
Number of roots	4.21^{b}	4.01^{b}
Leaf & root quality	Good	Yellow and dry leaf
Survival %	Green leaf	poor

Mutation Breeding in Garlic

Use of gamma irradiation for inducing mutation in garlic

Garlic is clonal propagated crop, therefore for creating genetic variability garlic varieties subjected to gamma irradiation in different doses. Total 200+ promising lines developed through mutation are under evaluation. Following are the most promising lines for yield parameters including storage life (Table 1.29).

Table 1.29 Evaluation of garlic lines developed through gamma irradiation for yield and yield contributing traits

Entry	PH (cm)	PL (cm)	PW (mm)	TY (t/ha)	PD (mm)	ED (mm)	ABW (g)	NCB	W50C (g)	TSS (°Bx)	SL (%)
BP-4GY	48	5.1	9.4	6.06	31.2	37.9	14.8	12.8	57	44.3	10
BP-5GY	55	5.8	8.8	3.39	29.1	38.0	15.4	11.2	60	43.3	8.2
BP-6GY	53	5.5	9.4	8.47	33.1	40.9	21.7	14.6	72	44.3	9.8
B0-3GY	53	4.7	8.5	6.07	29.6	36.7	13.3	11.4	49.5	44.3	12.1
BO-4GY	56	4.1	9.8	6.06	34.3	36.7	11.6	13	58.5	43.2	13.1
BO-5GY	52	3.8	8.1	3.35	29.3	33.8	12.7	13	51	43.0	10.4

PH-Plant Height, PL-Pseudo stem length, PW-Pseudo stem width, TY-Total Yield, PD-Polar Diameter, ED-Equatorial Diameter, ABW-Average Bulb Weight, NCB-No. of Clove /Bulb, W50C-Weight of 50 Cloves, TSS-Total Soluble Solids, SL-Storage Losses

Use of colchicine for mutation induction in garlic (*In vitro* condition)

In vitro established garlic plantlets of variety Bhima Purple were subjected to Colchicine treatment (2 concentrations as five plantlets in each replicate) with control in three replicates for 24 hours. Primarily treated plantlets were tested for ploidy using flowcytometry. Two plantlets of treatment concentration 2.5 mM had showed changes in ploidy (Figure 1.10). Further confirmation through cytology is in progress.

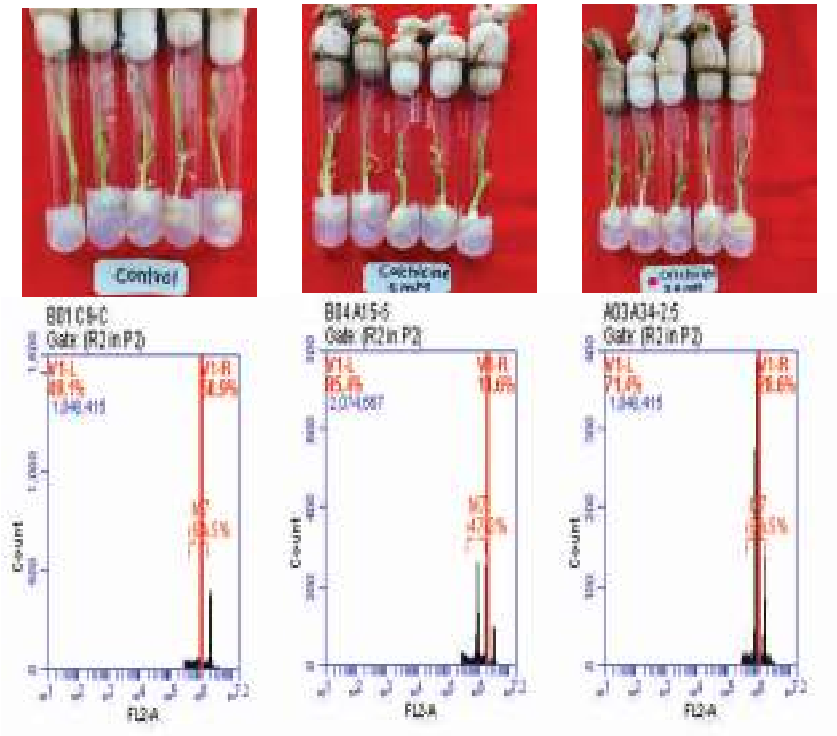


Figure 1.10 Use of Colchicine for ploidy induction in garlic

Development of Virus Free Garlic Planting Material

Application of electro therapy for virus elimination

Upon standardization and development of tissue culture-oriented meristem tip culture method in composition with heat and chemo therapy, electro therapy has been applied to tissue culture grown mericlones at four different currents (5, 15, 25, 35 mA) in three replicates for the period of 10, 15 and 20 min with control (no current). Total ten cloves/plants subjected to treatment per replicates. Random samples indexed for virus detection through multiplex PCR techniques. But no treatment could eliminate the targeted major garlic viruses i.e. Irish Yellow spot virus, Garlic common latent virus, Shallot latent virus and *Allexi* virus. In another experiment, general virus indexing was carried out from different parts of garlic *viz.* inner clove of bulb, outer clove of bulb, bulbil at apical end scape and bulbil at mid-length of scape. Multiplex PCR confirmed presence of virus in all parts of plant while qPCR results showed good amount of load of major four viruses in all studied samples.

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

Total three garlic varietal evaluation trials namely IET, AVT-I and AVT-II conducted at ICAR-DOGR in *rabi* season and one trial in *kharif* season (IET) and entries 7, 8, 7, 6 evaluated in each trial respectively.

Evaluation of ICAR-DOGR garlic entries under AINRPOG

Garlic entries introduced in AINRPOG IET trial are DOGR-815 and DOGR 569 for *rabi* season and DOGR-555, DOGR-100 for *kharif* season. Further DOGR-404 and DOGR-793 are being evaluated in AVT-I whereas DOGR-48-W and DOGR-746 in AVT-II.

1.4 Molecular responses to combinatorial salinity and pathogen stress in onion

Genome wide identification of WRKY transcription factors in Onion

WRKY transcription factors (TFs) are widely distributed in plants and play important regulatory role in plant growth, development and also involved in controlling the signaling cascade of responses to various biotic or abiotic stresses. WRKY transcription gene family members have a WRKY domain consisting of approximately 60 amino acids, with the conserved sequence WRKYGQK and a zinc finger motif (C2H2 or C2HC) at the C-terminus of the protein (Figure 1.11).

To identify the WRKY encoding genes in *Allium ce*pa, we first built a Hidden Markov Model profile of the WRKY DNA-binding domain (PF03106) and searched the sequences of WRKY genes from the draft genome data of *A. cepa* and the transcriptomics data obtained from NCBI database. After removing the incomplete and redundant sequences, a total of 54 putative WRKY genes were identified from the draft genome of *A. cepa*, and were designated as *AcWRKY1* to *AcWRKY54* (Figure 1.12). The deduced lengths of the *AcWRKY* proteins range from 149 (*AcWRKY49*) to 892 amino acids (*AcWRKY52*), whereas the molecular weight ranged from 17.43 kDa to 100.49 kDa. In addition, the isoelectric point ranged from 4.36 (*AcWRKY38*) to 10.05 (*AcWRKY18*).

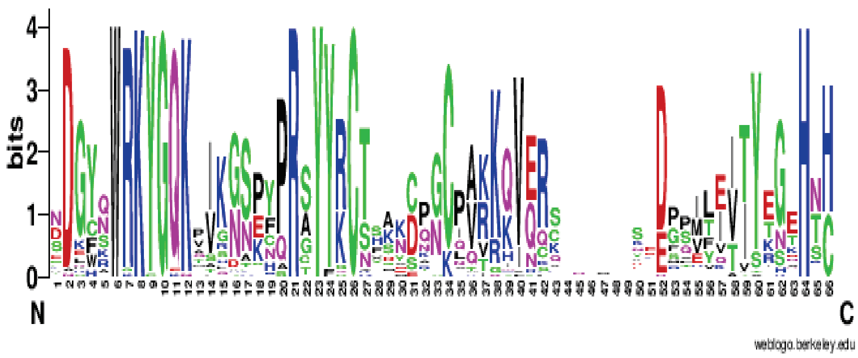


Figure 1.11 Consensus sequence of the WRKY domains representing the WRKYGQK at N terminal and C2H2 or C2HC motif at C terminal in the AcWRKY proteins.

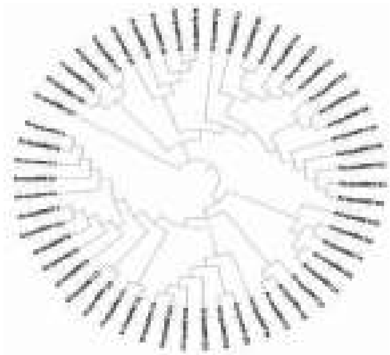


Figure 1.12 Phylogenetic analysis of A. cepa WRKY protein

1.5 Biotechnological approaches for improvement of onion

In vitro gynogenesis mediated haploid induction (in vitro)

A total of 12,000 immature flower buds from 11 onion genotype were cultured and obtained 302 plantlets that successfully developed into rooted plants. The regeneration efficiency was genotype-dependent, ranging from

1.5% to 13.1% of the buds cultured. The highest regeneration rate was observed in the genotype Arka Pitambar, whereas the regeneration rate from the Pusa White Flat genotype was notably low (Table 1.30). The nuclear DNA content of the 302 regenerated plants was assessed using flow cytometry. This analysis revealed that 275 plants (89.95%) were confirmed as haploid. The 275 haploid plants were subsequently treated with colchicine. Following this treatment, 140 plants survived and were transplanted into the field for further breeding programs. For the DH lines from last season five lines set seeds out of 68 bulbs.

Table 1.30 Development of DH lines through gynogenesis in various onion varieties

Variety	No. of flower bud inoculated	No. of shoots regenerated embryos	After multiplication	No. of plants tested	No. of Haploid	No. of Diploid	No. of plants in field
AFW	1408	71	102	56	52	4	24
Phule Safed	1457	61	96	57	53	4	29
Pusa white flat	1188	18	18	6	6	0	2
Phule Suvarna	500	13	13	8	6	2	1
Arka Kalyan	1600	52	76	48	47	1	21
ALR	1472	46	46	17	16	1	9
NHRDF Red	1760	63	98	73	65	8	40
Phule Samarth	1792	53	53	16	12	4	4
Arka Pitambar	320	42	42	10	8	2	9
PKV white	260	5	5	3	2	1	
B. Shakti	1200	45	45	8	8	0	1
Total	**12957**	**469**	**594**	**302**	**275**	**27**	**140**

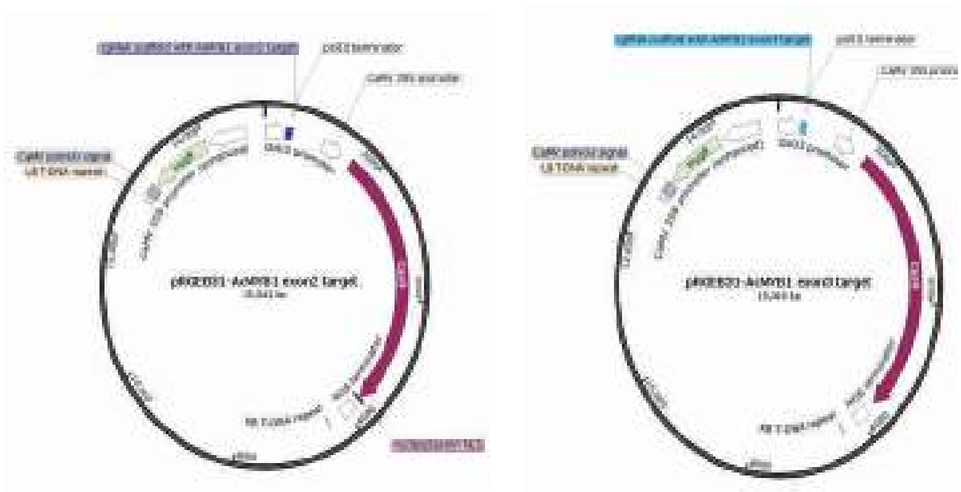
1.6 DBT sponsored Project: HI-Edit: One-step induction of genome editing and transgene elimination in onion (*Allium* cepa L.)

Amplification of AcMYB1 gene

The *MYB1* gene sequence of *Allium cepa* L. was retrieved from NCBI database (Acon No. KX772394). Internal primer sets were designed to amplify exon 2 and exon 3 sequences based on retrieved *AcMYB1* gene sequence. An amplicon of size 1250 bp containing exon 2 and exon 3 was amplified by PCR and sequenced.

Construction of CRISPR/Cas9 constructs targeting AcMYB1 gene

On the basis of sequencing results of exon 2 and exon 3 sequences of *AcMYB1* gene, 2 different sgRNA sequences were designed targeting exon 2 and exon 3 of *AcMYB1* and synthesized. The synthesized sgRNAs were cloned into CRISPR/Cas9 binary vector pRGEB31 independently. The resultant plasmids harboring exon 2 and exon 3 target sgRNA sequences were named as pRGEB31-*AcMYB1* exon 2 target and pRGEB31-*AcMYB1* exon 3 target, respectively (Figure 1.13).



a b

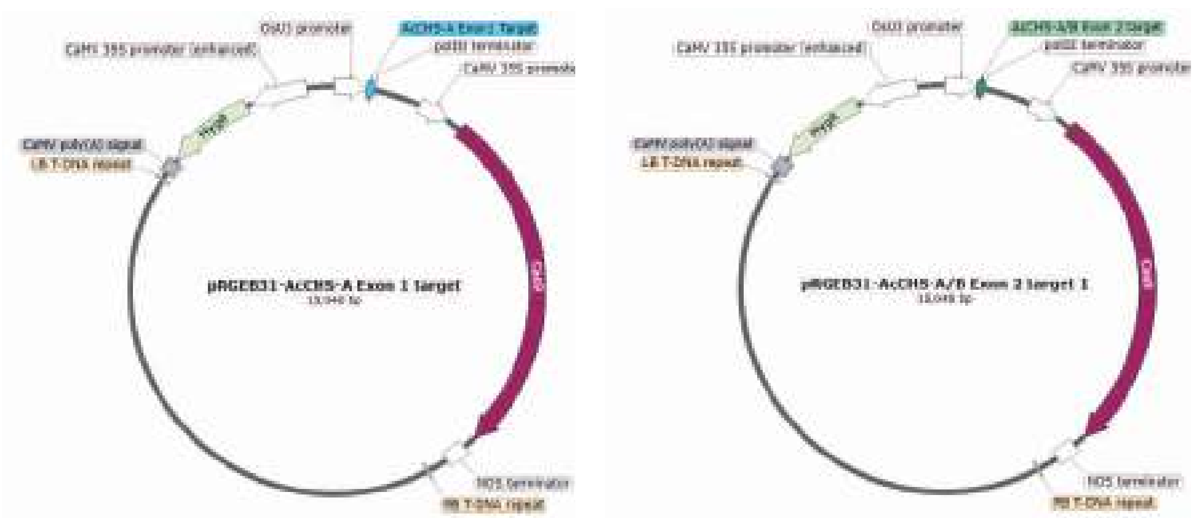
Figure 1.13 Vector map of CRISPR/Cas9 constructs targeting AcMYB1 gene
a. Vector map of pRGEB31-AcMYB1 exon2 target
b. Vector map of pRGEB31-AcMYB1 exon3 target

Amplification of *AcCHS* gene

Chalcone synthase (CHS) is one of the important proteins in flavonoid biosynthesis pathway. There are two homologs of CHS in onion CHS-A and CHS-B. *AcCHS*-A and *AcCHS*-B sequences were retrieved from onion genome database and primers were designed for amplification of these genes using DNA of onion cv. B. Super as a template PCR analysis resulted into amplification of partial sequence of *AcCHS*-A (750 bp) and complete CDS sequence of *AcCHS*-B (1182 bp). The amplified PCR products were sequenced.

Construction of CRISPR/Cas9 constructs targeting *AcCHS* gene

On the basis of sequencing results of partial *AcCHS*-A and complete *AcCHS*-8 genes, 2 different sgRNA sequences were designed targeting exon 1 *AcCHS*-A and exon 2 of *AcCHS*-A as well as *AcCHS*-B and synthesized. The synthesized sgRNAs were cloned into CRISPR/Cas9 binary vector pRGEB31 independently. The resultant plasmids harbouring exon 1 and exon 2 target sgRNA sequences were named as PRGEB31-*AcCHS*-A exon 1 target and pRGEB31-*AcCHS* A/B exon 2 target respectively.



a b

Figure 1.14 Vector map of CRISPR/Cas9 constructs targeting AcCHS genes
c. a. Vector map of pRGEB31-AcCHS-A exon 1 target
d. b. Vector map of pRGER31-AcCHS-A/B exon 2 target

Transformation of onion with knockout construct

The transformation of Construct PRGEB31 *AcMYB* exon 2 was carried out in 14 batches, resulting in 2002 onion calli, with 991 calli in the selection stage and 1009 in the shoot induction stage. The transformation of construct PRGEB31 *AcMYB* exon 3 was performed in 7 batches, yielding 1043 onion calli, with 480 in the selection stage and 463 in the shoot induction stages (Table 1.31 and Figure 1.15). The transformation of construct PRGEB31 *AcCHSa* Target 1 was carried out in 18 batches, resulting in 3784 onion calli, with 1369 calli in the selection stage and 2415 in the shoot induction stage (Figure 1.16).

Table 1.31 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
AcCHS a/b T1	18	3784	1369	2415	2
AcMYB exon 2	14	2002	991	1009	-
AcMYB exon 3	7	1043	480	463	-

Figure 1.15 Transformed of onion calli with MYB Target

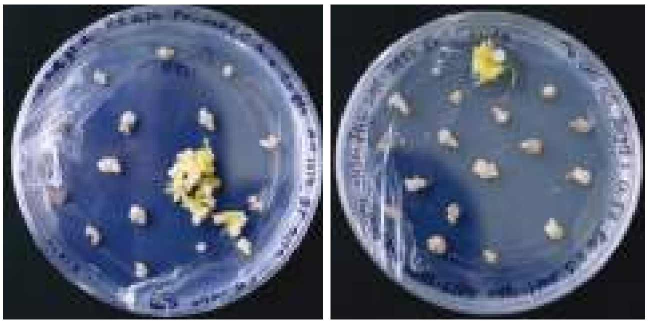


Figure 1.16 Transformed of onion calli with CHS target

1.7 DBT sponsored Project: DBT Network Program on Anthrax diagnosis and control in India: Component-12

A bivalent protein r-PB was targeted to express in plant. The sequence was codon optimized for plant-based expression. *Agrobacterium tumefaciens* strain LBA4404 harbouring pCAMBIA1300-r-PB was used for tobacco and onion transformation. Around 884 onion cv. Bhima Super was infected with r-PB construct (Figure 1.17). The calli are in selection stage. For evaluation of construct, tobacco was also transformed with r-PB construct. A total 67 plants were regenerated and selected 10 plants were confirmed for presence of transgene (Table 1.32). The expression of r-PB was confirmed by ELISA.

Figure 1.17 Regenerated onion calli infected r-PB construct on shooting medium

Table 1.32 Details of tobacco explants and onion calli in different stages of transformation co-cultivated by pCAMBIA1300-r-PB construct

Explants	No. of explants co-cultivated	Total no. of plants regenerated	Total no. of transgenic- *rPB* plants	Total no. of plants acclimatized
Tobacco leaf disc	815	130	80	67
Onion Calli	884	3	-	-

1.8 National Fellow Project: Haploid induction in Onion (*Allium* cepa L.) through genome elimination

In this study, RNA interference (RNAi) was used to downregulate the expression of *AcCENH3* in onion. The transgenic lines showed reductions in both transcript and protein levels of the native *AcCENH3* gene in transgenic lines E1, E2, E3, and E5 compared to wild-type (WT) plants. The knockdown *AcCENH3* transgenic plants exhibited decrease in seed setting efficiency relative to WT. In addition, outcrossing experiments between transgenic lines and WT showed reduced seed set compared to WT crosses. The RNAi-mediated suppression of *AcCENH3* resulted in haploid induction in onion when crossed with WT. Haploid induction was observed in crosses involving E1 and E2 with WT. Highest HI efficiency (HIE) of 4.63 % in progenies derived from crosses involving events E1 and WT (Table 1.33 and Figure 1.18).

Table 1.33 Evaluation of haploid induction efficiency in out crossing between transgenic lines and wild-type plants

Cross (♀) × (♂)	No. of plants tested	No. of haploids	No of aneuploids	HIE (%)
E1 ×WT	112	3	2	2.68
E2 ×WT	98	2	2	2.04
E5 ×WT	52	0	1	0
WT×E1	108	5	3	4.63
WT×E2	90	2	1	2.22
WT×E5	59	0	3	0
WT×WT	350	0	0	0

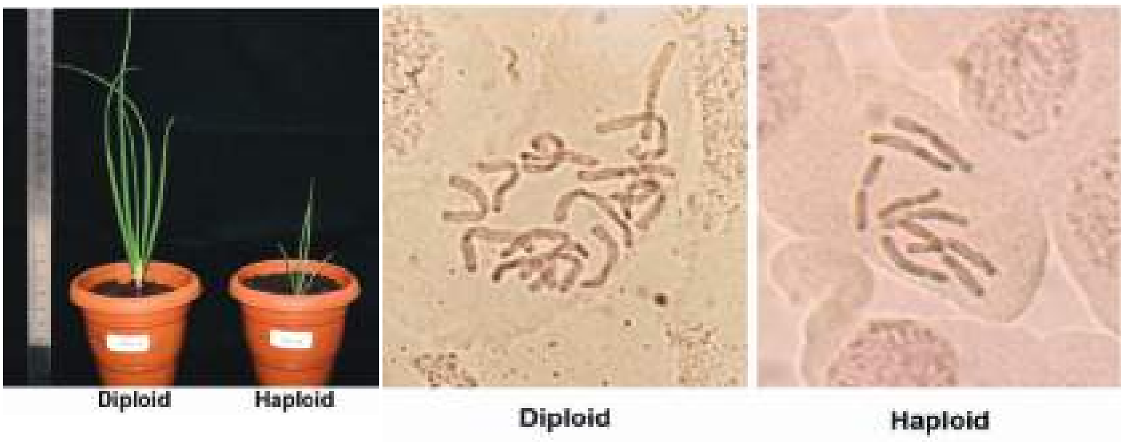


Figure 1.18 Diploid and haploid onion plantlets and their root cytology

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

Agrobacterium mediated transformation of pRGEB-AcMSH1 target construct in onion

A total number of 194 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 one batch. 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. A total of 22 plants regenerated from transformation were analyzed by PCR using primers OsU3 and PolIII. Only 16 plants showed presence of 400bp amplicon indicating the insertion of construct (Table 1.34 and Figure 1.19).

Table 1.34 Evaluation of different constructs for calli development and plant regeneration

Name of construct	No. of batches	No. of calli	No. of calli on selection	No. of calli on shooting	No. of plants regenerated
AcMSH1 T1	18	2295	-	-	19
AcMSH1 T2	3	383	-	-	0
AcMSH1 dual target	15	2042	-	-	3

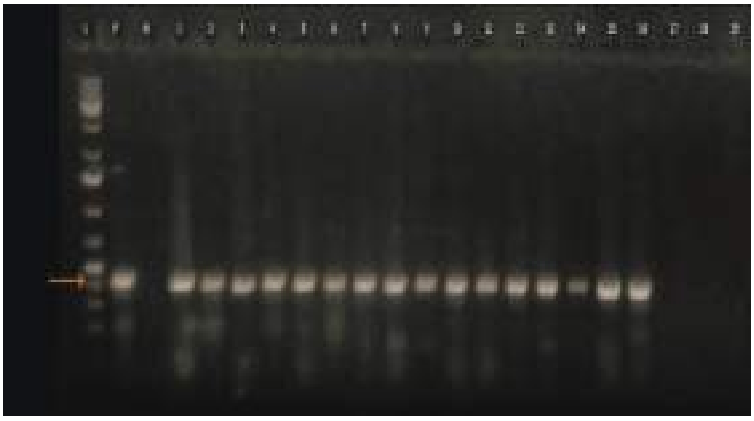


Figure 1.19 PCR analysis of *AcMSH1* transgenic plants (L: Ladder, P: pRGEB31-*AcMSH1* Plasmid (Positive control), N: Bhima Super (Negative control) 1 to19: Regenerated transgenic plants)

2. Crop Production

2.1 Developing improved agronomic practices for onion and garlic production

Integrated weed management for sustainable onion and garlic production

Onion

A field experiment was conducted to develop integrated weed management modules for onion and garlic crops during late *kharif* and *rabi* 2023. The experiment was performed in a randomized block design, and each treatment was replicated four times. Pre-emergence herbicides were applied in moist soil one day prior to transplanting, while post-emergence herbicides were applied 25 and 45 days after transplanting (DAT). The treatment combination involving pre-emergence application of Pendimethalin 30% emulsifiable concentrates (EC) at 1 kg active ingredients (a.i.)/ha, followed by post-emergence application of Propaquizafop 10% EC at 100 g a.i./ha + Oxyfluorfen 23.5% EC at 200 g a.i./ha (T1) at 25 and 45 DAT showed weed control efficiency (WCE) of 90.29% and 86.75% at 30 and 60 DAT, respectively, which was statistically similar to Pendimethalin 30% EC @ 1 kg a.i./ha (PRE) fb Polythene mulching, and weed free condition (Table 2.1 and 2.2). All these treatments showed significantly higher WCE compared to the plot that received pre-emergence herbicide, oxyfluorfen 23.5% EC @ 250 g a.i./ha followed by one hand weeding at 45 DAT. Additionally, the bulb yield increased by up to 20.2% in the plot-maintained weed free until harvest, and 16.1% in the treatment involving the application of pendimethalin 30% EC @ 1 kg a.i./ha as a pre-emergence herbicide and Polythene mulching compared to the existing recommendation (Oxyfluorfen 23.5% EC @ 250 g a.i./ha (PRE) + 1 HW (40 DAS)).

Table 2.1 Effect of different weed management strategies on weed control efficiency, weed index and bulb yield of onion cv. Bhima Super during late *kharif* 2023

Treatments	Weed control efficiency (%)		Weed Index (%)*	Bulb yield (t ha^{-1})
	30 DAT*	60 DAT*		
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 + 45 DAT	90.29bc (9.50)	86.75c (9.31)	5.13d (2.08)	33.87ab
Pendimethalin 30% EC 1 kg a.i./ha fb Fomesafen 11.1% SL + Fluazifop-p-butyl 11.1% + @ 250 g a.i./ha @ 25 DAT + 45 DAT	78.18e (8.82)	77.06e (8.77)	19.05bc (4.28)	29.02cde
Pendimethalin 30% EC @ 1 kg a.i./ha (PRE) fb Clodinafop propargyl 12.25% + Oxyfluorfen 14.7% EC @ 25 DAT + 45 DAT	81.25de (9.01)	78.03e (8.83)	26.31b (5.05)	26.13e
Pendimethalin 30% EC @ 1 kg a.i./ha (PRE) fb Polythene mulching	96.88ab (9.84)	93.25b (9.65)	7.14d (2.53)	32.71abc
Oxyfluorfen 23.5% EC @ 250 g a.i./ha (PRE) + 1 HW (40 DAS)	88.03cd (9.37)	85.80c (9.26)	20.59bc (4.46)	28.18de
Pendimethalin 30% EC @ 1 kg a.i./ha (PRE) fb Quizalofop Ethyl 5% @ 75 g a.i./ha + Oxyfluorfen 23.5% EC @ 200 g a.i./ha @ 25 DAT	83.47cde (9.127)	81.24d (9.01)	12.42cd (3.27)	31.32bcd
Weed free	100.0a (10.00)	100.00a (10.00)	0.00e (0.00)	35.68a
Weedy check	0.0f (0.0)	0.00f (0.00)	47.97a (6.92)	18.50f

Treatments	Weed control efficiency (%)		Weed Index (%)*	Bulb yield (t ha^{-1})
	30 DAT*	60 DAT*		
SEM±	0.15	0.93	0.46	1.33
LSD (p=0.05)	0.423	2.75	1.34	3.90
CV (%)	3.52	12.41	25.50	9.04

*Data transformed with square root method, DAT: Days after transplanting, fb: Followed by

Note: Treatments with same letters are not significantly different

Table 2.2 Effect of different weed management strategies on weed control efficiency, weed index and bulb yield of onion cv. Bhima Shakti during rabi 2023

Treatments	Weed control efficiency (%)		Weed Index (%)*	Marketable Bulb yield (t ha^{-1})
	30 DAT*	60 DAT*		
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 + 45 DAT	89.29b (9.45)	82.38bc (9.075)	18.18c (4.11)	29.57b
Pendimethalin 30% EC 1 kg a.i./ha fb Fomesafen 11.1% SL + Fluazifop-p-butyl 11.1% + @ 250 g a.i./ha @ 25 DAT + 45 DAT	76.68d (8.73)	75.19cd (8.660)	22.96bc (4.77)	27.75bc
Pendimethalin 30% EC @ 1 kg a.i./ha (PRE) fb Clodinafop propargyl 12.25% + Oxyfluorfen 14.7% EC @ 25 DAT + 45 DAT	80.75cd (8.98)	80.27bc (8.93)	25.70bc (5.06)	26.75bc
Pendimethalin 30% EC @ 1 kg a.i./ha (PRE) fb Polythene mulching	100.00a (10.00)	100.00a (10.00)	4.44d (2.05)	34.39a
Oxyfluorfen 23.5% EC @ 250 g a.i./ha (PRE) + 1 HW (40 DAS)	86.80bc (9.31)	85.05b (9.22)	27.63bc (5.10)	26.85c
Pendimethalin 30% EC @ 1 kg a.i./ha (PRE) fb Quizalofop Ethyl 5% @ 75 g a.i./ha + Oxyfluorfen 23.5% EC @ 200 g a.i./ha @ 25 DAT	84.75bc (9.20)	67.38d (8.18)	28.39b (5.31)	25.75c
Weed free	100.00a (10.00)	100.00a (10.00)	0.00e (0.00)	36.23a
Weedy check	0.00e (0.00)	0.00e (0.00)	46.87a (6.84)	19.12d
SEM±	0.15	0.18	0.39	1.15
LSD (P=0.005)	0.43	0.52	1.15	3.38
CV (%)	3.52	4.41	18.85	8.15

*Data transformed with square root method, fb: Followed by treatments with same letters are not significantly different

Garlic

A field experiment was conducted during the *rabi* season of 2023 at ICAR-DOGR, aimed at modifying the existing weed management practices for garlic and to incorporate newer chemicals in the module. The experiment consisted of 10 treatments laid out in a RBD with three replications. The results showed that treatment-maintained weed free until harvest through hand weeding recorded the highest clove yield (7.33 t/ha) which was closely followed by the treatment involving the application of pendimethalin 30% EC @ 1 kg a.i./ha as a pre-emergence herbicide along with Polyethylene mulching. With respect to herbicides, the application of pendimethalin 30% EC @ 1 kg a.i./ha followed by propaquizafop 10% EC @ 100 g a.i./ha + oxyfluorfen 23.5% EC @ 200 g a.i./ha @ 25 DAT and 45 DAT exhibited the highest yield (6.26 t/ha) (Table 2.3).

Table 2.3 Effect of different weed management strategies on WCE, weed index, phytotoxicity, and garlic yield cv. Bhima Purple during Rabi 2023

Treatments	Weed control efficiency (%)		Weed index*	Phytotoxicity (%) 30 DAP	Bulb yield (t/ha)
	30 DAT*	60 DAT*			
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	82.75ab (9.08)	65.39c (8.06)	26.62cde (4.78)	10.000b	5.76cd
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	78.18ab (8.82)	74.05b (8.60)	12.67e (3.56)	13.333b	6.75abc
Pendimethalin 30% EC 1 kg a.i./ha fb Fomesafen 11.1% SL + Fluazifop-p-butyl 11.1% + @ 250 g a.i./ha @ 25 DAT	25.53d (5.02)	18.36f (4.28)	50.20ab (6.98)	56.667a	3.90e
Pendimethalin 30% EC 1 kg a.i./ha fb Fomesafen 11.1% SL + Fluazifop-p-butyl 11.1% + @ 250 g a.i./ha @ 25 DAT and 45 DAT	42.48cd (6.09)	47.11e (6.86)	73.32a (8.56)	50.000a	2.09f
Pendimethalin 30% EC @ 1 kg a.i./ha (PRE) fb Clodinafop propargyl 12.25% + Oxyfluorfen 14.7% EC @ 25 DATand 45 DAT	85.20ab (9.21)	76.66b (8.75)	26.94cde (4.94)	10.000b	5.73cd
Oxyfluorfen 23.5% EC @ 250 g a.i./ha (PRE) + 1 HW (40 DAS)	57.49bc (7.54)	64.12c (8.01)	32.27bcd (5.61)	0.000c	5.31cde
Pendimethalin 30% EC @ 1 kg a.i./ha (PRE) fb Quizalofop Ethyl 5% @ 75 g a.i./ha + Oxyfluorfen 23.5% EC @ 200 g a.i./ha @ 25 DAT	74.62ab (8.64)	55.73d (7.46)	21.56de (4.37)	0.000c	6.15bcd
Weedy check	0.00e (0.00)	0.00g (0.00)	40.11bc (6.28)	0.000c	4.70de
Weed free	100.00a (10.00)	100.00a (10.00)	0.00f (0.00)	0.000c	7.83a
Pendimethalin 30% EC @ 1 kg a.i./ha (PRE) fb Polyethylene mulching	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	0.506
LSD (P=0.05)	1.835	0.48	1.87	8.019	1.505
CV (%)	14.37	3.78	23.34	33.39	15.70

*Data transformed with square root method

2.2 Development of improved nutrient management practices for onion and garlic

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

During the *rabi* season, 2013-14, a permanent experiment was initiated with four fertilizer treatments with soybean and maize as preceding crops. Vermicompost (10 t/ha) was added as a fifth treatment in 2015-16. The experiment aimed to evaluate the effect of cropping systems and fertilizer treatments on onion production, and soil fertility. Results showed that using maize as a preceding crop with inorganic fertilizers significantly increased onion bulb yield. Interestingly, plots receiving 75% RDF yielded similar results to those with 100% dose in both soybean and maize blocks (Figure 2.1). However, vermicompost alone produced comparable yields to mineral fertilizer treatments in soybean but significantly lower yields in maize. Over subsequent years, onion yield in all fertilizer treatments decreased notably in the soybean block compared to the maize block, attributed to *Stemphyllium* incidence and bulb rotting. INM treatments, combining mineral fertilizers and vermicompost, enhanced soil organic carbon and available nutrients, maintaining initial soil fertility.

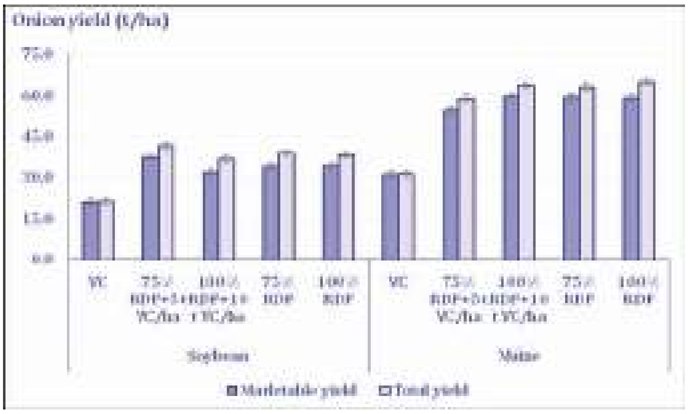


Figure 2.1 Effect of continuous use of inorganic fertilizers and manures on onion yield

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

In 2022-2023, a permanent organic and natural farming versus chemical-based farming experiment was initiated to study their effect on onion production and quality. Each block, comprising 14 beds, received specific treatments. Chemical and integrated nutrient management (INM) plots yielded significantly higher bulb yield than organic and natural farming methods, with INM showing a 52.4-58.9% increase over organic/natural methods (Figure 2.2). Marketable bulb yield didn't significantly differ between organic and natural farming practices. Chemical fertilizer treatments exhibited less storage losses after 5 months (Figure 2.3). Organic/natural farming methods showed higher total protein and antioxidant levels, while INM had higher pyruvic acid concentrations. Nutrient uptake (N, P, K, and S) was notably higher in conventional and INM plots than in organically treated plots (Figure 2.4). Soil analysis revealed higher soil organic carbon and available N in organic plots compared to INM and conventional farming, with the lowest levels in INM and conventional treatments.

Figure 2.2 Effect of organic/natural farming on onion yield compared to conventional farming

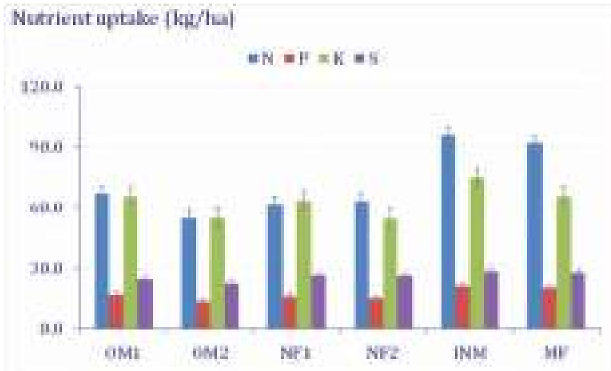


Figure 2.3 Effect of organic/natural farming on NPKS uptake compared to conventional farming

Figure 2.4 Effect of organic/natural farming on total storage losses (%) compared to conventional farming

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

A field experiment was conducted to assess the effect of nitrogen fertilizers and irrigation methods on onion growth, yield, and storage losses. The experiment, employing a strip plot design with four replications, evaluated drip, sprinkler, and flood irrigation alongside nitrogen levels at 0%, 50%, 100%, and 150% of recommended N levels. Results revealed that treatment with 100% and 150% nitrogen applied via sprinkler irrigation exhibited higher chlorophyll concentration and plant growth parameters compared to drip fertigation. However, drip and sprinkler irrigation with 100% nitrogen led to significantly higher onion yield compared to flood irrigation (Figure 2.5). Sprinkler irrigation with 100% and 150% nitrogen also showed increased levels of N, P, K, and S concentration. Moreover, drip fertigation with 100% nitrogen produced higher 'A' grade bulbs and equatorial and polar diameters, indicative of uniform and bigger bulb size. Additionally, 100% nitrogen application via drip reduced storage losses significantly compared to other methods (Figure 2.6).

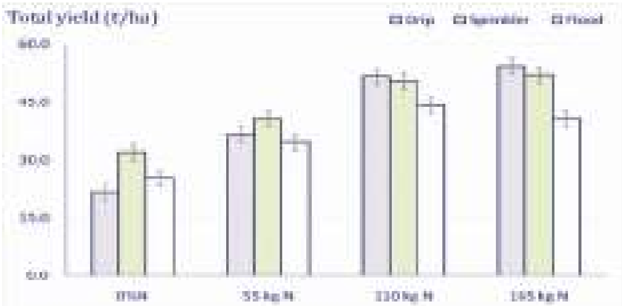


Figure 2.5 Effect of Nitrogen level and irrigation regimes on onion yield

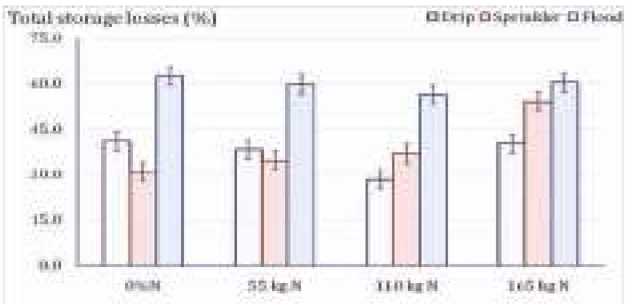


Figure 2.6 Effect of Nitrogen level and irrigation regimes on total storage losses (%)

Effect of water-logging on soil physical properties, nutrient availability and *kharif* onion production

A field experiment was conducted to evaluate the effect of water-logging stress in eight onion genotypes. Seedlings were transplanted on raised bed of 6 sqm by maintaining a spacing of 10x15cm. Waterlogging treatment was imposed on seedlings 45 days after transplanting for continuous 20 days by flooding. Additionally, field was irrigated through sprinkler system to stimulate the rainy condition daily from morning to evening. In addition to this, about 200 mm rainfall was received during 30 to 80 days after transplanting. Onion genotypes, Bhima Dark Red and Acc. 1666 performed better compared to the other genotypes under water-logged condition. The tolerant genotypes Acc. 1666 and Bhima Dark Red showed higher survival percentage (>90%), good plant stand, higher chlorophyll content, better cellular membrane stability. These two genotypes produced more B Grade bulbs (bulb size 30-60 mm diameter) under water-logging condition with less than 30% change in bulb weight compared to the control plants.

Assessing plant growth, dry matter yield, and nutrient uptake to standardize nutrient management practices for *Allium tuberosum*

Three lines of *Allium tuberosum* were planted to evaluate growth performance, dry matter yield, and nutrient uptake to develop nutrient management practices. Parameters like plant height, leaf numbers, tiller number, and foliage yield were monitored monthly for 11 months. The nutrient content of the leaves was analyzed, and the values were subsequently multiplied by the dry matter yield to calculate the nutrient uptake. *Allium tuberosum* CGN displayed better performance, with higher leaf numbers, plant height, foliage yield, and tiller numbers compared to other genotypes. *A. tuberosum* CGN and *A. tuberosum*Kazakhstan lines had higher dry matter yields and phosphorus and sulfur concentrations. Over 11 months, these genotypes harvested 8.84-9.82 t of dry matter per hectare, removing 201-235 kg N, 62-73 kg P, 262-296 kg K, and 41-54 kg S per hectare. This comprehensive data provides valuable insights for devising a fertilizer schedule tailored to the needs of *Allium tuberosum* cultivation, contributing to its sustainable commercial production.

Inter institutional Project: Efficacy evaluation of ICAR-CIRCOT Nano-Sulphur fertilizer formulation for different field crops

Sulphur, a vital macronutrient after NPK, is crucial for enhancing crop growth and yield. With sulphur deficiency rising in India's soils, effective sulphur application becomes imperative, especially for sensitive crops. ICAR-CIRCOT developed nano-sulphur, synthesized from elemental sulphur via chemo-mechanical synthesis, with a particle size of 500-700 nm and a concentration of 20% (w/v). At ICAR-DOGR, Pune, its efficacy was assessed on onion and garlic in a split-plot experiment with twelve treatments. Nano-sulphur application alone increased marketable yield by 8-12%, while combined with farmyard manure (FYM), it increased onion yield by 3.8-8.3% and garlic yield by 10.8-16.3%, although with a lesser impact when used alongside FYM. Notably, garlic benefited most from nano-sulphur application, while onion yields showed better result with bentonite sulphur application.

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

TIH, IIT-Bombay developed the E-Agris sensor designed to monitor real-time soil moisture, pH levels, electrical conductivity, and nutrient levels. Before its commercial deployment, the sensor needs rigorous calibration and validation. Collaborating with IIT-Bombay, a field experiment was initiated; deploying E-Agris stations fitted with multi-depth sensors to continuously monitor soil moisture, pH, electrical conductivity, and available NPK in soil. Soil samples were collected from four locations around each sensor, at depths of 0-15 cm and 15-30 cm, at alternate day from planting until 60 days post-transplanting. One set of these freshly collected samples were weighed and then dried in an oven at 108°C. After drying, the samples were re-weighed to determine soil moisture content. Another set of soil samples used for analysis of pH, electrical conductivity (EC), and the available nitrogen, phosphorus, and potassium (NPK). Results revealed that the laboratory data matched with the trends observed in sensor data for all parameters, indicating the sensors' efficacy.

POLY4 a natural source of Potassium and Sulphur in Onion and Garlic

In onion and garlic cultivation, addressing multi-nutrient deficiencies and unbalanced fertilizer application is crucial for sustainable agriculture. Polyhalite, comprising essential macro-nutrients like K, S, Mg, and Ca, may offer a solution to maintain or restore soil fertility. Hence, a field experiment with twelve treatments assessed the efficacy of POLY4 (Polyhalite) in enhancing yield, quality, K and S uptake in comparison to conventional sources. Results revealed that applying 100% recommended S and K through Poly4 alone or in combination with MOP produced bulb yields comparable to those with bentonite and MOP. These treatments also exhibited higher total nutrient uptake, pyruvic acid, total phenol, and total antioxidant content. However, onion and garlic crops removed higher total K than the quantity applied through Poly4. Thus, applying recommended S and K through Poly4 alongside MOP may support sustainable onion and garlic production.

2.3 Abiotic stress management in onion and garlic

Impact of plant growth promoting microbes on onion crop growth and yield subjected to waterlogging stress

Plant-associated microbial communities promote plant growth under extreme climatic conditions like waterlogging by mineral solubilization, phytohormone production and other mechanisms. A pot experiment was conducted during *kharif* 2022 where the seedlings of onion variety Bhima Dark Red and genotype Acc. 1666 were inoculated with the well-known plant growth promoting microbial strains including *Azotobacter spp.*, *Azospirillum spp.*, *Piriformospora indica spp.*, *Phosphorus Solubilizing* and *Potassium Mobilizing Bacteria* before transplanting. Waterlogging stress was imposed 45 days after seedling transplantation for continuous 5 days by creating an artificial water-logging condition in tanks. Various physiological biochemical and yield-contributing traits were evaluated in both controlled and treated plants. Waterlogging stress significantly reduced the leaf gas exchange traits like stomatal conductance, net photosynthesis, and transpiration rate (Figure 2.7). Seedling inoculated with Azotobacter followed by Azospirillum was able to maintain the crop photosynthesis rate under stress condition. Similarly, waterlogging significantly reduced the cellular membrane stability (indicated by MSI and TBARS contents) and chlorophyll level in response to stress as compared to control plants. Seedling treated with microbial inoculation specifically, *Azotobacter, Azospirillum* and *P. indica* maintained their cellular stability and greenness index under stress condition. Total antioxidant enzyme activity also recorded to be elevated under *Azotobacter, Azospirillum* and *P. indica* treatment compared to other treatments (Figure 2.8). This result herein revealed that microbial treatment helps the plant to maintain their growth and development under waterlogging stress condition. A significant difference in bulb yield was recorded under control and waterlogged condition. However, it was found that microbial treatments help plants to maintain the growth and bulb yield under waterlogged condition. Seedling inoculated with *Azotobacter* spp. performed better under control and stress conditions in both the genotypes based on the crop phenotypic growth and bulb weight performance (38-39 gm single bulb weight under waterlogging stress) (Figure 2.9). The study thus indicates that *Azotobacter* spp. plays significant role in onion crop under waterlogging stress.

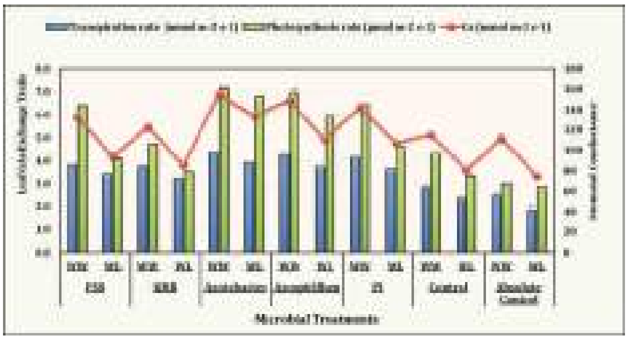


Figure 2.7 Effect of microbial treatments on leaf gas exchange traits in onion crop under water-logging stress (WW: Well-watered; WL: Waterlogging)

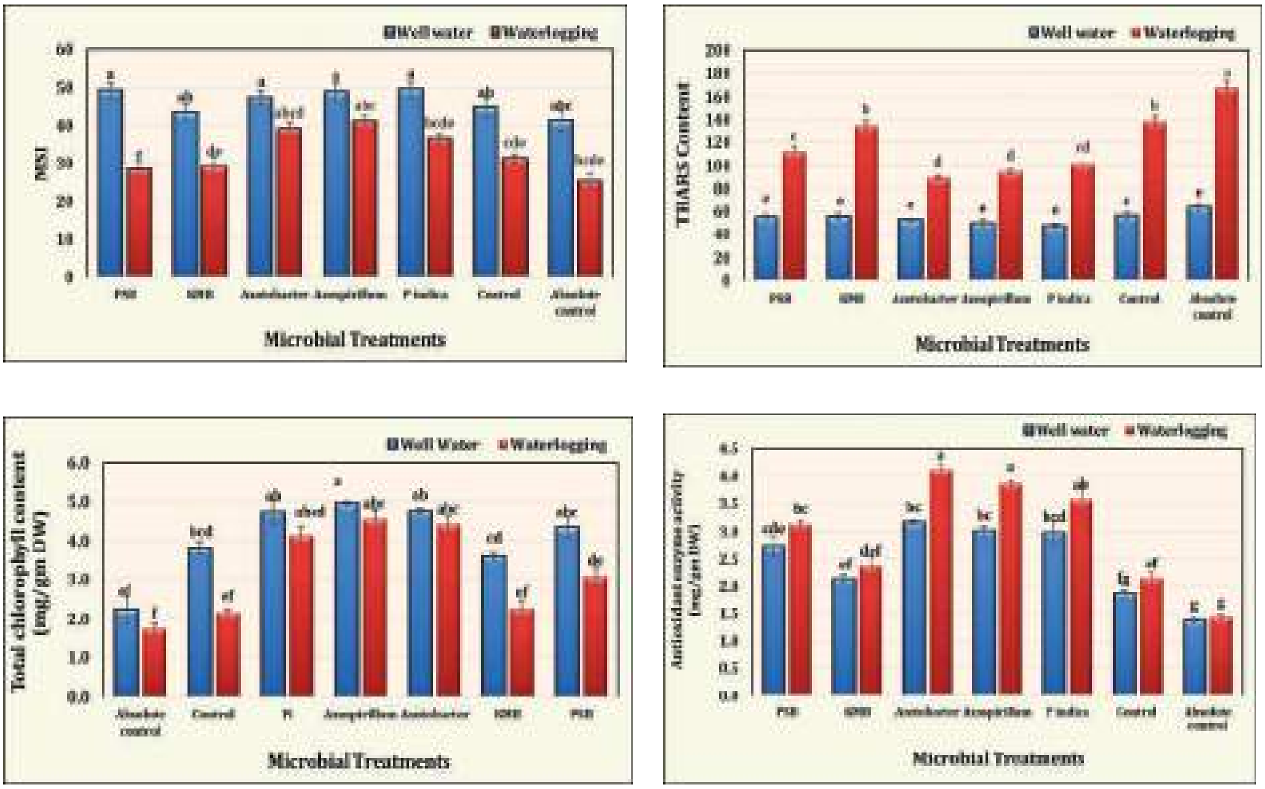


Figure 2.8 Effect of microbial treatments on biochemical traits and onion bulb yield under water-logging stress (WW: Well-watered; WL: Waterlogging)

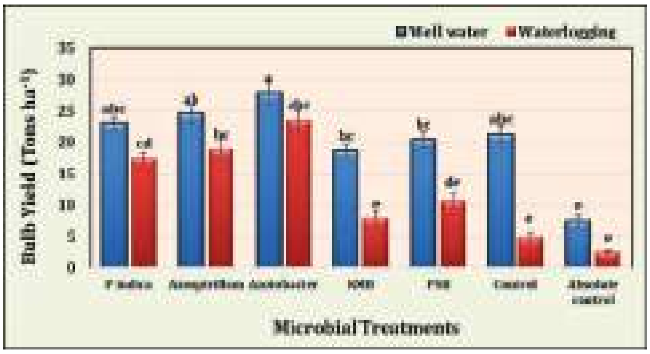


Figure 2.9 Effect of microbial treatments on onion bulb yield under water-logging stress

Identification and characterization of waterlogging responsive genes in contrasting onion genotypes using RNA seq. technology

To understand the molecular mechanism regulating waterlogging stress tolerance in onion crop, transcriptome sequencing using RNA seq. technology was done in leaf tissue to water-logging tolerant (Acc.1666) and sensitive (W-344) genotype. Differential gene expression analysis revealed that 1629 genes were upregulated and 3271 genes were downregulated in Acc. 1666, while in W-344, 2134 genes were upregulated and 1909 genes were downregulated under waterlogging stress (Figure 2.10). These DEGs regulate several key biological processes to combat waterlogging stress such as phytohormones biosynthesis, antioxidant enzymes activity, programmed cell death, aerenchyma formation, energy production etc. COG pathway analysis showed enrichment of post-translational modification, energy production, and carbohydrate metabolism- related pathways under waterlogging conditions. The higher number of waterlogging tolerance-related genes like group VII ERFs such as *RAP2-12* and *RAP2-3* that play a crucial role in developing waterlogging tolerance, were found to be exclusively upregulated in the tolerant genotype Acc.1666 compared to the sensitive genotype. These results suggest that significant fine reprogramming for gene expression was occurring in response to waterlogging stress in onion crop. The molecular information about DEGs obtained from the present study would be valuable for improving stress tolerance and developing waterlogging tolerant onion variety.

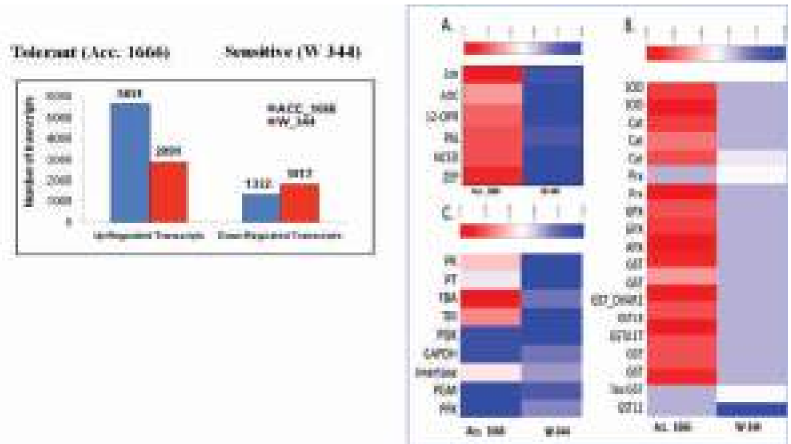


Figure 2.10 Differential gene expression analysis in contrasting onion genotypes under waterlogging stress

Effect of plant growth regulators on plant and yield of onion under waterlogging stress

Plant growth regulators (PGRs) play a significant role in plant developmental process and modulating plant replies to various abiotic constraints including waterlogging stress. A field experiment was conducted to evaluate the effect of different plant growth regulators namely, Putrescine (50, 100, 200 ppm), Spermine (50, 100, 200 ppm), Gibberellic acid (50, 100, 200 ppm), Salicylic acid (50, 100, 200 ppm), Kinetin (50, 100, 200 ppm) and Melatonin (50, 100, 200 ppm) in onion cv. Bhima Dark Red under waterlogging stress. Foliar application of PGRs was done 10 days prior to waterlogging treatment. Waterlogging stress was imposed 45 days after transplanting for continuous 5 days by creating an artificial water-logging condition in tanks. Different plant growth and yield contributing traits were assessed in both controlled and treated plants. Foliar spray of Melatonin @ 50ppm improved plant growth and bulb yield under both control (25-26 t/ha) and waterlogging stress (21-22 t/ha) compared to other treatments. Melatonin application improves the onion bulb yield by approximately 80% compared to control treatment with water spray (Figure 2.11). Thus, it can be said that foliar spray of Melatonin@ 50ppm improves onion crop growth under waterlogging stress. Further work is in progress to characterize the detail mechanism regulated by melatonin in onion crop in response to waterlogging stress.

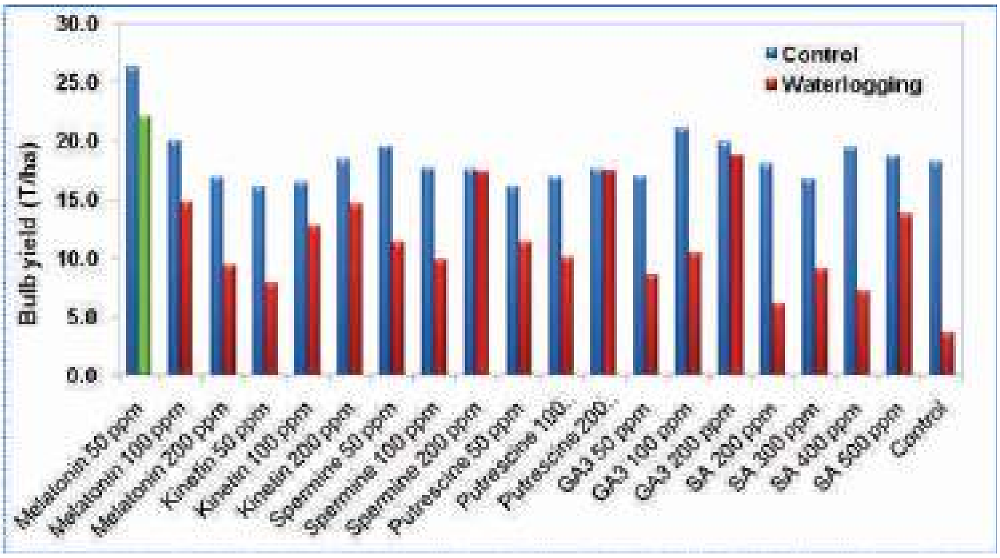


Figure 2.11 Effect of plant growth regulators on onion bulb yield under water-logging stress

Effect of high temperature stress on onion crop growth and yield

A pot experiment was conducted to evaluate the effect of high temperature stress on plant growth and yield of onion cultivars, Bhima Shakti and Bhima Kiran. Temperature conditions were set in growth chamber where 45 days old plants were exposed to increasing temperature range of 26, 30, 35, 38, 40, 42 and 45°C for 24 hours. A set of control plants were kept under normal growth condition (temperature 26 ± 1°C) in open field. No significant difference was recorded for the plant's morphological traits like plant height, leaf area, leaf senescence and chlorophyll content when plants were exposed to temperature of 26, 30 and 35°C compared to control plants. However, as the temperature increases beyond 35°C significant alteration in plant phenotypic growth like leaf temperature, plant height, leaf chlorophyll content and cellular membrane stability were recorded in both the variety. Reduction in leaf area and induction in leaf senescence were observed as the temperature increases. Plants exposed to 42°C recorded with wilting symptoms and poor plant growth during recovery time but get 50-60% recovered after stress period. However, plants exposed to 45°C failed to recover after stress period. The results from the study revealed that 42°C temperature and beyond are damaging for onion crop growth and development. The study will be further repeated for confirmation.

3. Crop Protection

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

Collection of samples, isolation, and identification of diseases

Diseased onion samples (anthracnose, purple blotch, stemphylium blight, white rot, basal rot, and post-harvest) were collected from the ICAR-DOGR field and from adjoining areas of Maharashtra, as well as from other onion growing states. Pathogens were isolated and cultures identified from *Colletotrichum* spp., *Fusarium* spp., *Alternaria* spp., *Stemphylium* spp. etc. based on morphological characters, and ITS/Tef1 α-based molecular markers. The cultures are maintained, as well as selectively submitted in culture collection of ICAR-NBIAM, Mau (OGRDFW1, *Fusarium acutatum,* NAIMCC-F-04492; OGRDFW2, *Fusarium acutatum,* NAIMCC-F-04493; OGRDFW3, *Fusarium falciforme,* NAIMCC-F-04495; OGRDFW4, *Fusarium acutatum,* NAIMCC-F-04494). Sequences have also been submitted to NCBI GenBank (OGRDCG1, *Colletotrichum gloeosporioides,* PP263370; OGRDFW5, *Fusarium acutatum,* PP332885; OGRDFW6, *Fusarium acutatum,* PP332886; OGRDFW7, *Fusarium falciforme,* PP332887; OGRDFW8, *Fusarium falciforme,* PP332888; OGRDFW9, *Fusarium falciforme,* PP332889; OGRDFW10, *Fusarium acutatum,* PP332890). In addition, *Trichoderma* spp. was also isolated, characterized, sequenced and submitted to ICAR-NBIAM, Mau (GRDT2, *Trichoderma harzianum,* NAIMCC-F-04513).

(a) **(b)**

Figure 3.1
(a) Experimental plot
(b) Basal rot symptom

Evaluation of *Trichoderma* species/isolates on crop growth of onion and disease management of onion under field conditions during *rabi* 2022-23 & kharif-2023

Crop Growth: Eleven *Trichoderma* spp./isolates were evaluated and observations on growth parameters were recorded. *Trichoderma* spp./isolate NRCG 8, enhanced plant height up to 3.5% during *rabi* 2023. However, during *kharif* 2023 *Trichoderma* spp./isolates T166 enhanced the plant height up to 5.2%over control.

Effect on diseases: Among the above eleven *Trichoderma* spp./isolates evaluated during *rabi* 2023 season, eight spp./isolates inhibited Stemphylium disease from 33-56% over control. The maximum (56%) inhibition was recorded with *Trichoderma* isolate T-354 at par with T-8R. Similarly, during *kharif* 2023 season, all the spp./isolates inhibited anthracnose/twister diseases over control. The maximum inhibition of anthracnose/twister (39%) was recorded with *Trichoderma* isolate T-8R. The disease magnitude increased in the month of October.However, crop recovered to some extent at the later stage in the month of November.

Bulb yield: Among the above 11 *Trichoderma* spp./isolates evaluated, all the spp./isolates enhanced the yield ranging from 3-40%. The maximum (40%) increase was supported by *Trichoderma* T-354 (25 t/ha) over control (17 t/ha) during *rabi* 2023 season. Whereas, during the *kharif* 2023 season, among the above 11 *Trichoderma* spp./isolates evaluated all spp./isolates enhanced the yield ranging from 1-20%. The maximum (20%) increase was supported by *Trichoderma* T-8R (20 t/ha) against the control yield (17 t/ha).

Molecular characterization: Molecular characterization of *Trichoderma* isolates was carried out using PCR and sequencing of internal transcribed spacer (ITS) and 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 Neighbour-Joining distance algorithm method. Sequences submitted to NCBI GenBank (KVRDT1, *Trichoderma asperellum*, PP390019; KVRDT1, *Trichoderma asperellum*, PP397110).

Tolerance to salt: *Trichoderma* spp./isolates were also tried for tolerance to salt and *T. longibrachiatum* was recorded as a promising isolate/spp. having a tolerance of 48-51% (against control) at 9% NaCl under *in vitro* condition.

Evaluation of modules for efficacy against major fungal diseases of onion

Effect on diseases: Four modules (M1, M2, M3, M4) with existing practice (EP), farmers' practice (FP), and absolute control (AC) were evaluated during *rabi* 2023. All the modules inhibited the Stemphylium disease, ranging from 21-40% over control. The maximum (40%) inhibition was recorded with M1 (Intensive management) being statistically at par with M2. During *kharif* 2023 season also, all the modules inhibited the Anthracnose disease ranging from 6-58% over control, being maximum with M1. While comparing with FP, the maximum inhibition was recorded with M1 (26%).

Bulb yield: Among the above four modules (M1, M2, M3, M4), M1 supported 22% and 14% higher yield over control (24 t/ha) and FP (21 t/ha) during the *rabi* 2023. Again, during *kharif* 2023 the pattern was the same, where M1 (24 t/ha) supported a 36% higher yield over control (18 t/ha).

Evaluation of *Amritpani-based* organic formulations

Effect on diseases: During *rabi* 2023, four *Amritpani-based* organic formulations were evaluated with control. Negligible disease was recorded hence not considered for reporting. During the *kharif* 2023 season, all formulations inhibited anthracnose disease, where maximum (26%) inhibition was supported by DOGROF3 (*Bajra flour, Calotropis leaves, Karanj leaves, Ginger powder, Turmeric powder, Hing powder to Water*), followed by DOGROF4 (25%) over control.

Bulb yield: DOGROF3 recorded with 18% higher yield (26 t/ha) than the control (22 t/ha) during *rabi* 2023. During *kharif* 2023 also, DOGROF3 supported a maximum 22% higher yield (18 t/ha) followed by DOGROF4 than the control (15 t/ha).

Evaluation of germplasm for diseases

***Kharif* 2023:** Among 80 white germplasm evaluated, all germplasm received higher anthracnose disease ranging from 48-100 PDI, hence not considered for reporting.

3.2 Biotechnological approaches for biotic stress management

Molecular characterization of garlic (*Allium sativum* L.) germplasm against Fusarium basal rot disease

Basal rot disease in garlic is one of the most serious diseases. The yield losses of the bulb and seed crops are in India due to the disease under favourable conditions. As a genus, *Fusarium* is a diverse and ubiquitous group of fungi having a high degree of variability in spore, shape, size and its pathogenicity. The main objective of the research was molecular characterization of a pathogen using molecular techniques and screening of garlic germplasm against fusarium basal rot disease. The associated fungi were isolated in pure culture on PDA and based on cultural and morphological characters, it was identified as *F. oxysporum*. Presence of mycelium, macro-conidia, micro-conidia and chlamydospores was recorded. The most profusely sporulating species was further confirmed as *F. oxysporum* using molecular characterization. A purified culture grown on the Potato Dextrose Agar was used for the extraction of DNA. The fungal genomic DNA was isolated using CTAB method and its quality and quantity was checked using UV-spectrophotometer. PCR was performed using fungus-specific ITS1/4 primer; fusarium specific TEF1 and T12 primers. The PCR reaction mixture at temperature at 95°C for 4 min for initial denaturation, 95°C for 1 min for final denaturation, 62-65°C for 1 min for annealing, 72°C for 1 min for extension and 72°C for 10 min for a final extension was performed. The amplified product size of ITS1/4, T12 and TEF1 were found to be 580bp, 560bp and 680bp respectively. The amplified product is sent for sequencing to determine the exact order of nucleotides in the barcode region. Once the sequence is identified (Figure 3.2); the pathogen's identity will be confirmed and compared with known plant pathogens.

Lane No	Sample	Primer	Length(bp)
1.	F1	ITS1/4	580
2.	F2	T12	560
3.	F3	TEF1	680

Figure 3.2 PCR amplification result of primer ITS, T12, TEF1

Isolation and characterization of plant growth promoting microorganisms (PGPM) and entomopathogenic microorganisms from the soil samples of onion field

The main objective of the study is to isolate and characterize important soil microorganisms in the fields of onion. The bacteria and fungus were isolated and pure culture was prepared. Their morphology was observed through microscopic examination. DNA was isolated from bacterial using commercial DNA extraction kit (e.g., Qiagen DNeasy Blood & Tissue Kit) and fungal DNA was isolated using phenol-chloroform method. The concentration and purity of the extracted DNA were checked using a Nanodrop spectrophotometer, measuring absorbance at 260/280 nm. For bacterial identification, the 16S rRNA gene region was amplified using universal bacterial primers. For fungal identification, the 18S ribosomal RNA Gene region of the fungal rRNA gene was amplified using universal fungal primers. The PCR reactions were set up in a total volume of 25 µL, consisting of 1 µL of template DNA, 10 µL of PCR master mix, 1 µL of forward and reverse primers (10 µM each), and 12 µL of nuclease-free water. PCR conditions involved an initial denaturation at 95°C for 5 minutes, followed by 30 cycles of denaturation at 95°C for 30 seconds, annealing at 55°C for 30 seconds, extension at 72°C for 1 minute, and a final extension at 72°C for 10 minutes. The purified PCR products were sent to a commercial sequencing facility. Sequencing reactions were carried out using the same forward and reverse primers used for PCR amplification. The isolated, characterized and sequenced data were submitted to NCBI. Nine fungal strains and ten bacterial strains were identified; among which 9 fungal strains were found to be entomopathogenic fungi (EPFs). Among the bacterial strains; 2 bacterial strains were found to be Zinc solubilizing rhizosphere bacterial strains and 8 phosphate solubilizing rhizospheres bacterial (PSB).

Nine-fungal strains isolated as entomopathogenic fungi (EPFs) (2022) and identified by 18S ribosomal RNA Gene, partial sequencing

OQ119733.1: *Aspergillus flavus* Strain EPF1

OQ119734.1: *Aspergillus oryzae* Strain EPF2

OQ119735.1: *Aspergillus oryzae* Strain EPF3

OQ119735.1: *Aspergillus niger* Strain EPF4

OQ119737.1: *Aspergillus tamarii* Strain EPF5

OQ119738.1: *Metarhizium album* Strain EPF7

OQ119738.1: *Beauveria bassiana* Strain EPF9

OQ119738.1: *Metarhizium anisopliae* Strain EPF10

OQ119741.1: *Trichoderma viride* Strain EPF11

Two bacterial stains isolated as Zinc solubilizing rhizospheric bacterial Strains (2022) and identified by 16S ribosomal RNA Gene, partial sequencing

OP899842.1: *Serratia marcescens* Strain SPUZNSB1

OP899843.1: *Bacillus cereus* Strain SPUZNSB2

Figure 3.3
Zinc solubilizing bacteria

Eight bacterial stains isolated as phosphate solubilizing rhizospheric bacterial (PSB) Strains (2022) and identified by 16S ribosomal RNA Gene, partial sequencing

OP897026.1: *Enterobacter ludwigii* Strain DOGRPSB1

OP897027.1: *Ralstonia pickettii* Strain DOGRPSB2

OP897035.1: *Microbacterium hydrocarbonoxydans* Strain SPUPSB3

OP897036.1: *Macrococ cuscaseolytic* Strain SPUPSB4

OP897037.1: *Stutzerimonas stutzeri* Srtain SPUPSB5

OP897038.1: *Bacillus inaquosorum* Strain SPUPSB6

OP897039.1: *Bacillus subtilis* Strain SPUPSB7

OP897040.1: *Bacillus mojavensis* Strain SPUPSB8

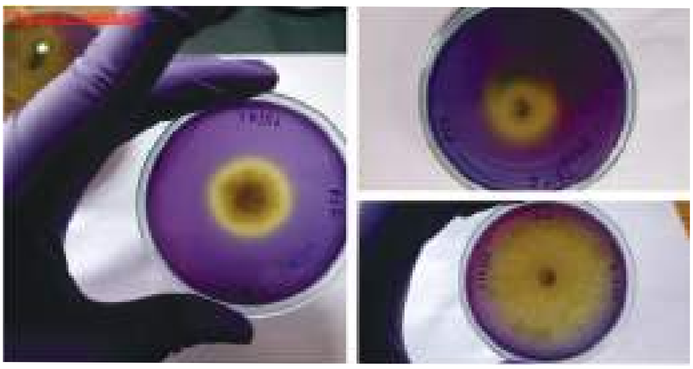


Figure 3.4
Phosphate solubilizing bacteria

Whole genome metagenomic sequencing of rhizosphere soil of wild and cultivated onion species

The objective of the current study was to use the metabarcoding technique to investigate the microbiome profiles of rhizosphere soils of *A. hookeri, A. angulosum, A. fistulosum, A. altaicum* and *A. cepa.* The samples were sent for sequencing and its functional annotation and taxonomic classification were analysed. It was found that the most abundant phyla were found to be *Proteobacteria* followed by *Actinobacteria*, *Firmicutes*, and *Thaumarchaeota.* There is high variation in diversity and species richness among the different treatments. Alpha-diversity indices (Shannon's index) showed that the diversity is higher in rhizospheres soil collected from *A. angulosum* followed by the *A. hookeri.*

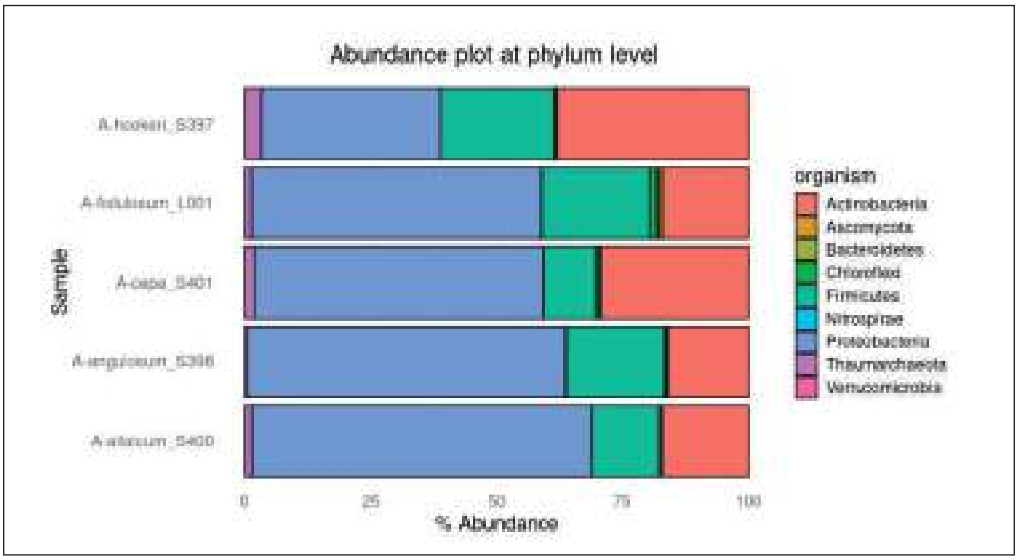


Figure 3.5 Stacked bar plot representing abundance at the phylum level

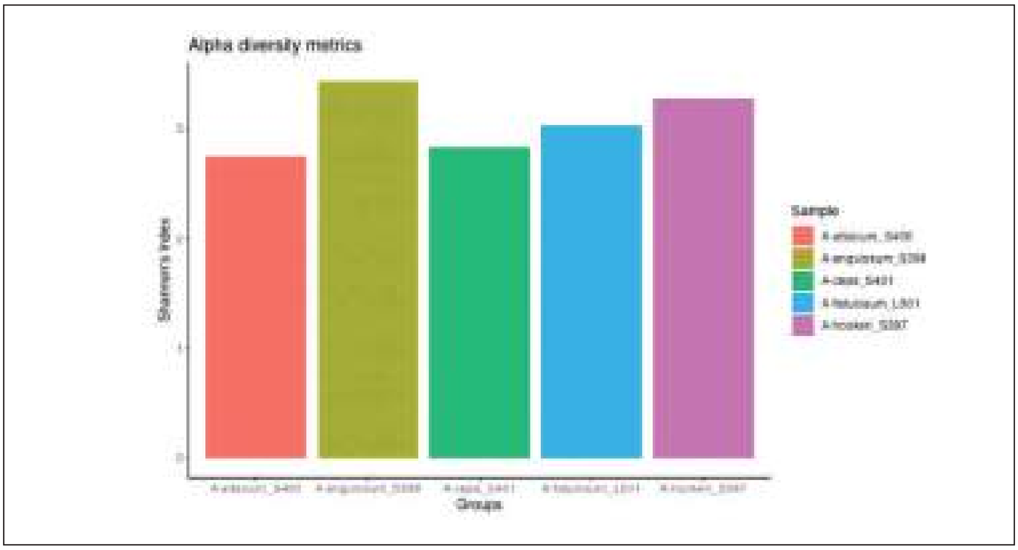
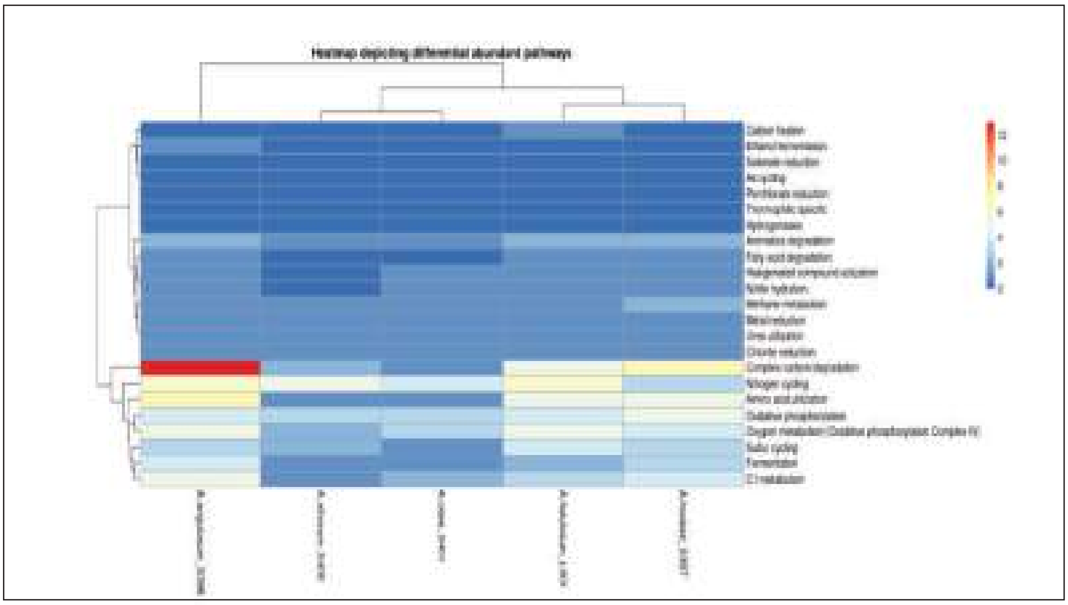


Figure 3.6 Alpha diversity metrics for all the samples

Through functional annotation it was found that the most of the pathways predicted from the protein sequences were pertaining to the pathways of Carbon fixation, Ethanol fermentation, Selenate reduction, Arsenate cycling and Perchlorate reduction present across all the samples supports the presence of similar rhizosphere microbial composition as all these plants belong to the same genus *Allium*. Despite this there were few pathways which are most common to one of the plants like complex carbon degradation in *Allium angulosum.*



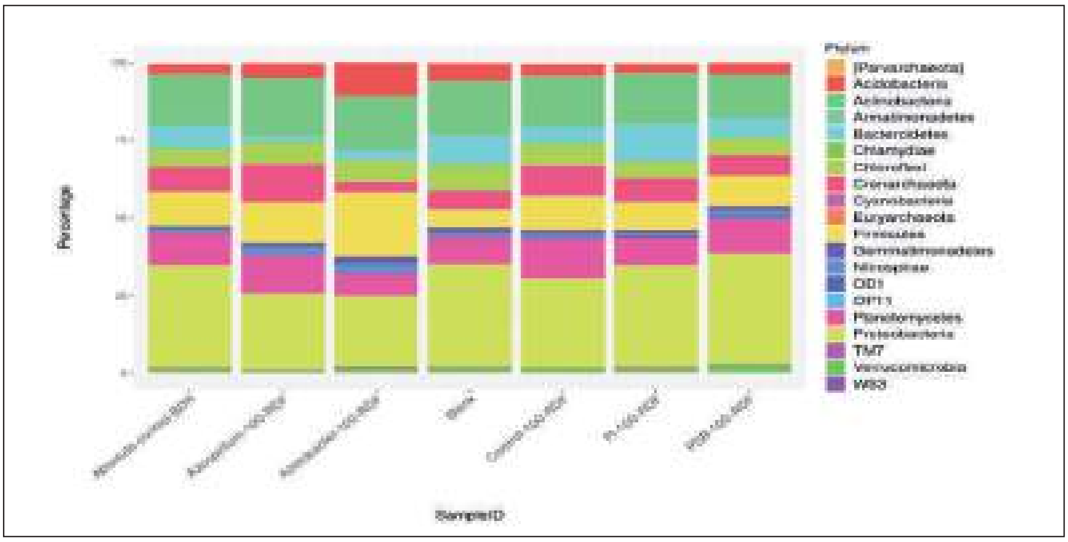


Figure 3.7 Heatmap showing differentially abundant pathways across the provided samples

Effect of biofertilizer on the plant growth and microbiome of onion rhizosphere

The objective of the current study was to use the metabarcoding technique to compare and investigate the bacterial profiles of onion rhizosphere with different biofertilizer treatment. The total environmental DNA was extracted from rhizosphere and the bacterial 16S rDNA was amplified and sequenced by NGS technology to profile each sample. The complete bacterial metagenome comprised of 1200 OTUs. These OTUs constituted 46 bacterial phyla of 481 identified genera. The most abundant phyla were found to be *Proteobacteria* followed by *Actinobacteria*, *Firmicutes*, *Planctomycetes* and *Crenarchaeota*. There is high variation in diversity and species richness among the different treatments. Alpha-diversity indices (Shannon, Simpson-e) showed that bacterial diversity is higher in Azotobacter-100-RDF treated soil and the lowest bacterial diversity was observed in soil sample treated with Azospirilum-100-RDF. Another alpha diversity index (Chao1) describes the species richness in each treatment and blank soil samples. Among all the treatments, bacterial richness is found to be highest in

Control-100-RDF, followed by PI-100-RDF treatment and the lowest in the Blank soil. Beta diversity considers the variations in bacterial community composition for different biofertilizer treatments. Bacterial diversity among the treatments was assessed using the weighted UniFrac approach. The PCoA plot suggests that there is high diversity among the bacterial communities of onion rhizosphere treated with different biofertilizer. PC-1 and PC-2 explain 48.5% and 21.1% cumulative variance in the microbiome respectively.

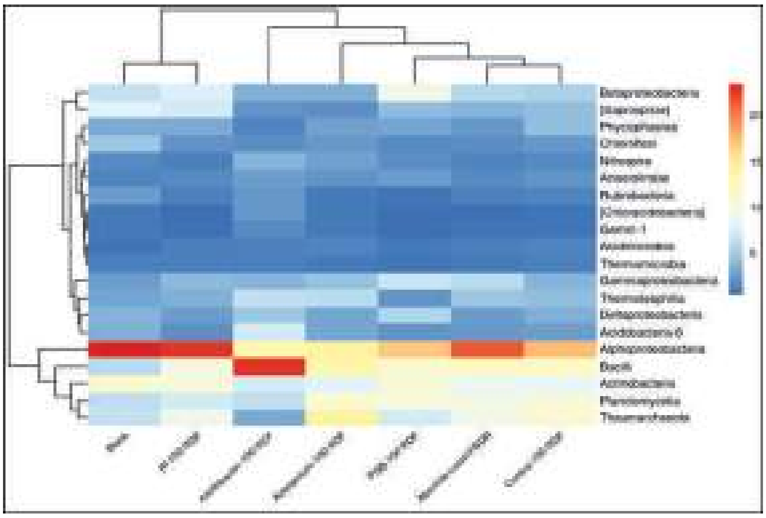
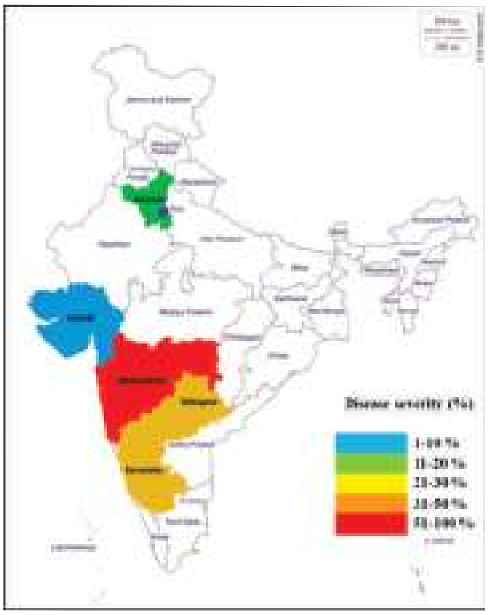


Figure 3.8 The relative abundance of dominant bacterial class represented in onion rhizosphere samples with different treatment

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

Survey for spatial distribution and developing forecasting models for major fungal diseases of onion-garlic

Roving survey was conducted in Karnataka and Maharashtra during *kharif* and *rabi*, 2023 to record the major fungal disease including anthracnose, *stemphylium* blight, purple blotch, *fusarium* basal rot and other minor diseases (Figure 3.9). In Karnataka, survey was carried out in four districts viz., Bijapur, Bagalkot, Belgaum and Dharwad. The severity of anthracnose disease ranged from 12-44%, stemphylium blight 8-22 %, purple blotch disease 6-28% and 4-14%. In Maharashtra we reported anthracnose, *stemphylium* blight, purple blotch and *Fusarium* basal rot as well as some minor diseases in five districts *viz*., Ahmednagar, Aurangabad, Nashik, Pune, and Solapur. Anthracnose disease severity ranged from 10-63%, *stemphylium* blight from 5-58%, purple blotch from 4-40% and *Fusarium* basal rot (FBR) incidence ranged from 12.00-80.50% among the surveyed districts.



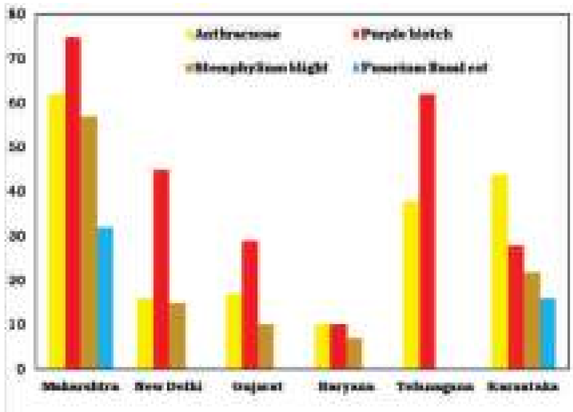


Figure 3.9 Disease severity map of Anthracnose, Stemphylium blight, Purple blotch and FBR diseases in India

Exploration, collection and characterization of major fungal diseases from major onion-garlic growing areas

The sick onion samples were collected from Maharashtra (Sade village and Khadmbe bk, Rahuri district) and Telangana (Madireddipally, Vikarabad district) states. The disease severity of *Stemphylium* blight ranged from 10-18%, and purple blotch severity of 12-24% in Rahuri samples and 54% in Vikarabad samples.

Collection of data from the AINRPOG coordinating centres

The analysis of reports of data on disease surveys of onion growing areas of Maharashtra from 1998 to 2023 was done from available reports of ICAR-DOGR (1998-2023) and AINROPG (2009-2023) with missing years from 2001 to 2006, where *Fusarium* basal rot (FBR) incidence varied from 11-50%, anthracnose severity varied from 12-79%, purple blotch (8-60%) and stemphylium leaf blight (14-71%) respectively (Figure 3.10).

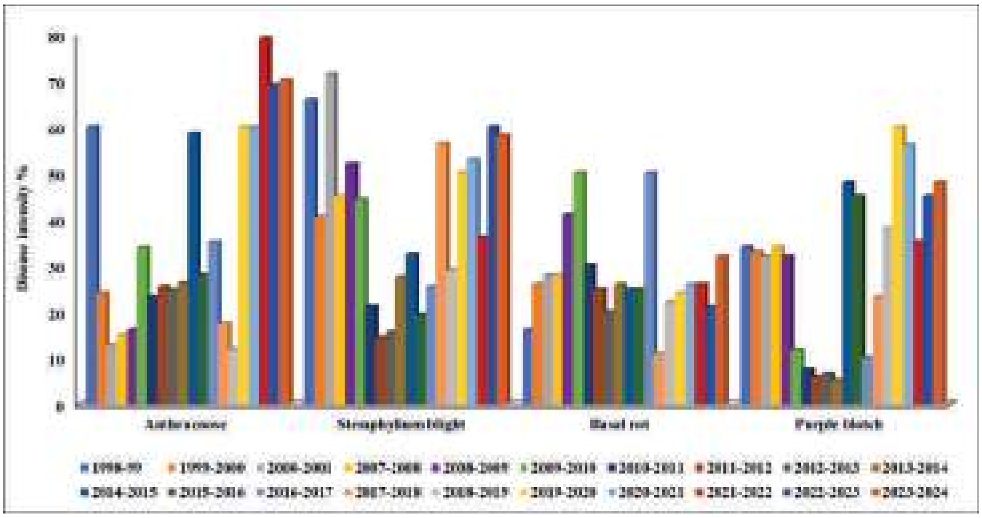


Figure 3.10 Major fungal disease incidence of onion in Maharashtra state from 1998 to 2023

Isolation, morphological and molecular characterization of fungal pathogens viz., *Stemphylium sp., Colletrotrichum sp., Alternaria sp., Fusarium Spp. Sclerotium sp.*

Infected onion and garlic samples were collected from Maharashtra, Karnataka and Telangana states. The fungal pathogens were isolated on potato dextrose agar. A total of 34 fungal cultures were isolated (24 onion and 10 garlic) and characterized based on culture morphology and spore characters. The prevalence of fungal pathogen including, *Alternaria* sp. *Stemphylium* sp, *Colletotrichum* sp., *Fusarium* spp., and *Sclerotium*sp in onion and garlic were identified. Further using *Its*/*tef* sequences the cultures were confirmed as *Alternaria alternata, Collettotrichum gleopsporoides, Fusarium acutatum, Fusarium falciforme, Fusarium solani and Fusarium oxysporum.* The cultures were deposited at NAIMCC, ICAR-NBAIM, Mau and sequences were submitted in NCBI.

Deciphering the infectious process of major fungal diseases of onion-garlic through basic, biochemical and molecular approach

Infection process of anthracnose on different varieties of onion

The infection process of *Colletotrichum gloeopsorioides* was done through pot culture experiment for ten varieties of Onion *viz.,* Bhima Super, Bhima Shakti, Bhima Shubra, Bhima Safed, Bhima Shweta, Bhima Raj, Bhima Kiran, Bhima Light red, Bhima Dark Red, and Bhima Red by spraying spore suspension of 1 x 10^6 spores/ml. Bhima super, Bhima Shakti, Bhima light red, and Bhima dark red varieties were the first to get infected, followed by Bhima Shubra, Bhima Shweta, and Bhima Raj. Bhima Safed and Bhima Kiran both developed infections 7 days later. The rate of infection was found to be higher in dark cultivars compared to white onions.

Infection process of *Colletotrichum gloeosporioides* and *Fusarium acutatum* causing anthracnose/-twister anthracnose-twister disease complex of onion

The pathogenicity and cumulative effect of *Colletotrichum gloeosporioides* and *Fusarium acutatum* was studied on onion plants (Bhima Super) under *in vitro*. The pot experiment was laid out to identify the cause responsible for inciting anthracnose-twister disease, whether the *Colletotrichum* or *Fusarium* or both, or the interaction of pathogens and GA3. The results of the pathogenicity test confirmed that *C. Gloeosporioides* and *F. acutatum* are both pathogenic. *C. gloeosporioides* caused twisting symptoms independently, while *F. acutatum* independently caused only neck elongation. The independent application of GA3 did not produce any symptoms, however, increased the plant height. The combined treatment of *C. gloeosporioides* and *F. acutatum* caused twisting, which enhanced upon interaction with GA3 application giving synergistic effect. The acervuli were found in lesions infected with *C. gloeosporioides* after 8 days of inoculation on the neck and leaf blades. Symptoms were not observed in untreated control plants. Koch's postulates were confirmed by reisolating the same pathogens from the infected plants (Figure 3.11).

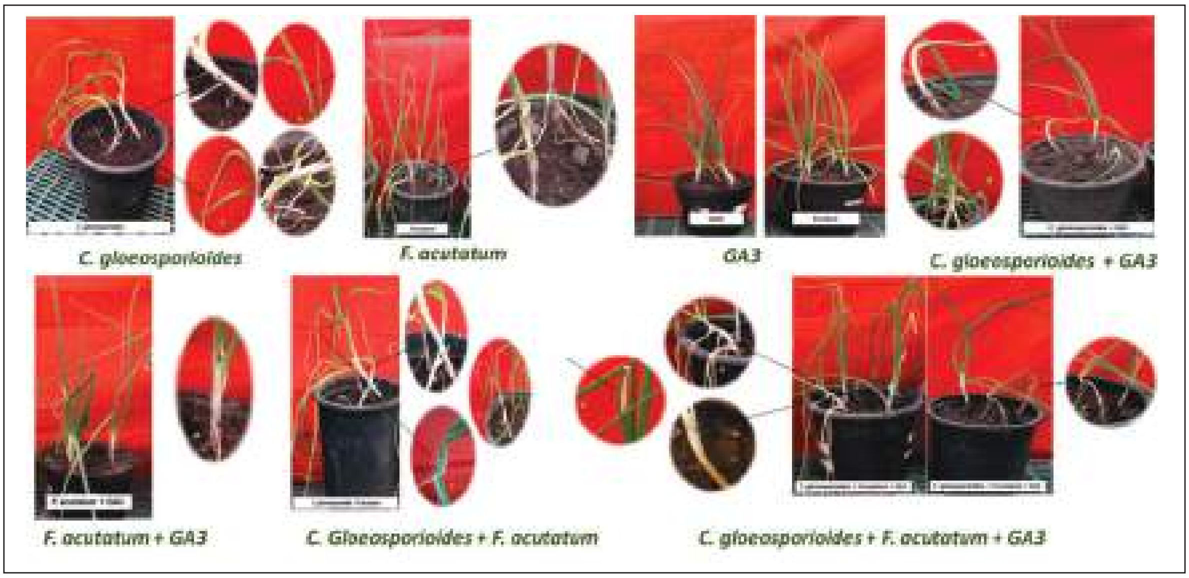


Figure 3.11 Development of infection of *C. gloeosporioides* and *F. acutatum* on onion plants

Infection process of Fusarium basal rot on onion

The infection process 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). 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 un-inoculated seedlings and bulbs remained healthy (Figure 3.12).

Figure 3.12 Infection assay of *F. falciforme* and *F. Acutatum* inoculated onion seedlings and bulbs

Infection process of *Fusarium* basal rot on different varieties of onion

Seed germination assay: *The* effect of *F. Acutatum* and *F. falciforme* were assessed through onion seeds inoculation assay on ten different varieties of onion *viz*., Bhima Super, Bhima Shakti, Bhima Shubra, Bhima Safed, Bhima Shweta, Bhima Raj, Bhima Kiran, Bhima Light red, Bhima Dark red, Bhima Red. Emergence rates varied with the varieties and *Fusarium* strains. Significant difference was recorded within the treatments with fungal strains. Furthermore, measurements of the length of the coleoptile showed that both *Fusarium* species induced a delayed growth of coleoptiles. *F. Acutatum* and *F. falciforme* significantly inhibited the growth of the coleoptile in comparison with the control. Significant difference was observed between varieties and *Fusarium* strains.

Bulb inoculation assay: *Fusarium acutatum* (OGRDFW4) was used for disc inoculation assay to study the infection process on different varieties of onion *viz*., Bhima Super, Bhima Shakti, Bhima Shubra and Bhima Shweta. The infection was more severe in dark varieties as compared to white onion and the volume of affected bulb and rotting percentage was more in Bhima Super than other varieties.

Infection process of anthracnose, *Stemphylium* leaf blight and purple blotch on garlic

Using conidial suspension (1 x 10^6/ml) of *Colletotrichum gloeopsorioides, Alternarria porii and Stemphylium vesicarium* infection process was studied under in vitro pot culture experiment. *C. Gloeopsorioides* expressed symptoms at 5 DAI and *A. porii* and *S. vesicarium* expressed the symptoms at 7 DAI.

Understanding the role of secondary metabolites of biocontrol agents against major fungal diseases of onion-garlic

Plant growth promoting rhizobacteria isolation and characterization from onion and garlic rhizosphere

Eight PGPR strains were isolated from onion rhizosphereof ICAR- DOGR, Kalus farm. All strains were characterized through cultural, morphological, gram straining, molecular and biochemical traits. One of the eight strains is G-negative, whereas the others are G-positive. The cultures were then characterized with 16sRNAITS primers. All eight strains were tested for biochemical (catalase, casein hydrolysis, starch hydrolysis, methyl red, and Voges Proskauer assays) and plant growth-promoting features (phosphorus solubilization, potassium solubilization, zinc solubilization, HCN, IAA, and siderophore production).

Six PGPR strains were identified from the garlic rhizosphere at ICAR-DOGR, Kalus farm. All isolates were identified using cultural, morphological, gram straining, molecular, and biochemical characteristics. One of the six strains is G-negative, whereas the others are G-positive. The cultures were also characterized using 16sRNA ITS primers. All six strains tested positive for catalase, three strains for casein hydrolysis, four for starch hydrolysis, and five for Methyl red biochemical tests. All six strains were tested for biochemical (catalase, casein hydrolysis, starch hydrolysis, methyl red, and Voges Proskauer assays) and plant growth-promoting traits (phosphate solubilization, potassium solubilization, zinc solubilization, HCN, IAA, and siderophore production).

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

Evaluation of entomopathogens formulations against onion thrips, *Thrips tabaci* Lindeman

Three insect pathogenic formulations namely *Lecanicillium lecanii*, *Beauveria bassiana*, *Metarhizium anisopliae*, and botanical insecticide, i.e., neem oil and their 1:1 combination with neem oil were field evaluated against onion thrips *T. tabaci in kharif* and *rabi* onion 2023. Spinosad, a biological pesticide, is taken as a positive control. The desired concentration of bio-agents and biological pesticides were applied as foliar spray starting from 35 days after transplanting. Three sprays were made at 10 days intervals. The number of thrips (nymphs and adults) was counted in ten randomly selected onion plants before and after treatment and percent population reduction over control was calculated. Results revealed that all three insect pathogens were effective against *T. tabaci* and produced significant population reduction over untreated control. The per cent thrips population reduction over control in *kharif* among the treatments T1: Neem Oil, T2: *Lecanicillium lecanii*, T3: *Metarhizium anisopliae*, T4: *Beauvaruia bassiana*, T5: Neem oil + *Lecanicillium*, T6: Neem oil + *Metarhizium*, T7: Neem Oil + *Beauvaria*, T8: Spinosad and T9: Untreated Control was 41.6, 47.8, 46.6, 45.0, 56.6, 52.4, 50.8, and 77.6%, respectively. The per cent thrips population reduction over control in *rabi* among the treatments T1: Neem Oil, T2: *Lecanicillium lecanii*, T3: *Metarhizium anisopliae*, T4: *Beauvaruia bassiana*, T5: Neem oil + *Lecanicillium*, T6: Neem oil + *Metarhizium*, T7: Neem Oil + *Beauvaria*, T8: Spinosad and T9: Untreated Control was 42.8, 54.5, 55.3, 53.0, 71.9, 72.8, 64.0 and 86.0%, respectively. Among the entomopathogens, *L. lecanii*was promising against onion thrips, followed by *Metarhizium anisopliae*. The combinations of neem oil and *L. lecanii* and Neem oil + *Metarhizium* showed better results against onion thrips, and that produced up to 71% population reduction, followed by the neem oil and *B. Bassiana* combination. Spinosad was the most effective treatment against thrips adults and nymphs, which produced a population reduction of 77.6% and 88.6%, thrips population reduction in *kharif* and *rabi* onion, respectively. The order of efficacy of insect pathogens and their combinations in *kharif* onion was spinosad > neem oil plus *L. Lecanii* > neem oil plus *M. Anisopliae* > neem oil plus *B. Bassiana* > *L. Lecanii* > *M. anisopliae B. Bassiana* > neem oil. The order of efficacy of insect pathogens and their combinations in *rabi* onion was spinosad > neem oil plus *M. anisopliae* > neem oil plus *L. Lecanii* > neem oil plus *B. Bassiana* > *M. Anisopliae L. Lecanii* >*B. Bassiana* > neem oil (Figure 3.13).

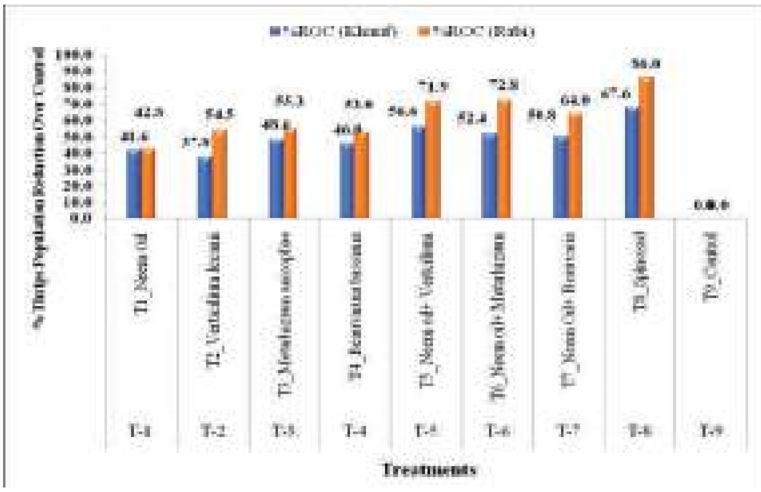


Figure 3.13 Bio-efficacy of insect pathogens, botanical and biological pesticide against onion thrips

Evaluation new-generation insecticides and its mixturesagainst onion thrips

The field efficacy of two new-generation insecticides includingmixture, Spiroteramat + Imidacloprid and Spinetoram 11.7 SC, along with Profenofos 50EC, were evaluated against the onion thrips during *kharif* and *rabi*. Results revealed that both the insecticides were effective against onion thrips,Spirotetramat + imidacloprid produced 82.4% thrips population reduction followed by profenofos (81.8%) and spinetoram (79.9%) over control in *kharif*, while in *rabi* Spirotetramat + imidacloprid and Spinetoram produced 80% and 79% population reduction, respectively (Figure 3.14 a and b).

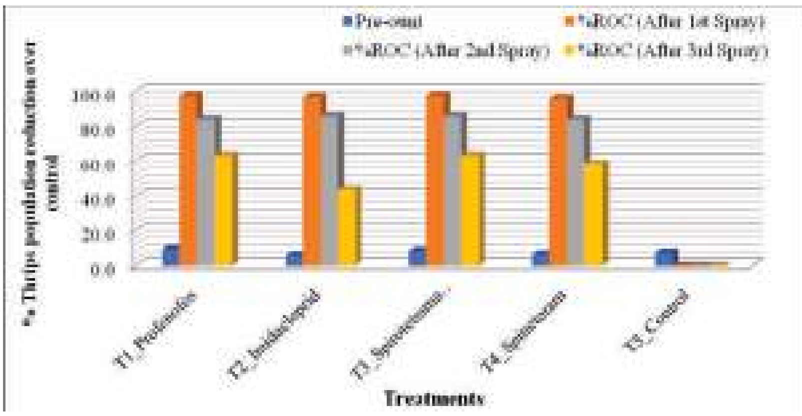


Figure 3.14 a. Bio-efficacy of new-generations insecticides against onion thrips (*Kharif*)

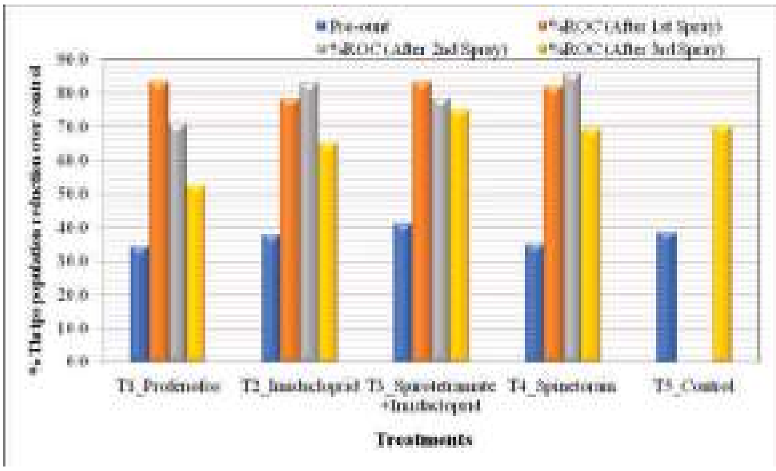


Figure 3.14 b. Bio-efficacy of new-generations insecticides against onion thrips *(Rabi)*

Characterization insect pest species

The complete mitochondrial genome of *Thrips tabaci* and *Thrips parvispinus*, were sequenced on IlluminaNextSeq 2000 sequencing platform using 300-cycle paired end chemistry. The data annotated using Mitos2 package. *T. tabaci* total genome size is 15,277 bp which includes 13 Protein coding genes (PCG's), 19 tRNA coding genes and 2 rRNA coding genes, The genes namely trnL2 (Leu), trnW (Trp) and trnV (Val) are missing in *T. tabaci* mitogenome. The *T. parvispinus* mitochondrial genome of size 15,285 bp, comprises of 13 PCG's, 18 tRNA coding genes and 2 rRNA coding genes. The genes trnH (His), trnL2 (Leu), trnW (Trp) and trnV (Val) are missing in *T. parvispinus* mitogenome (Figure 3.16).

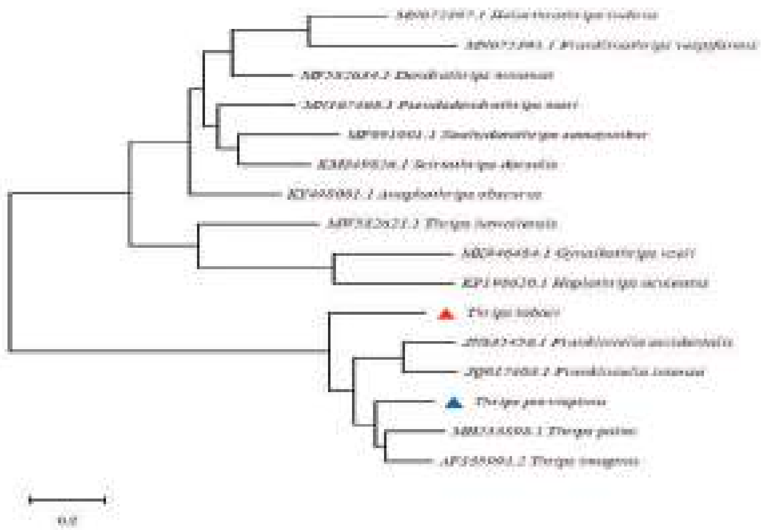


Figure 3.15 Phylogenetic tree of thrips species

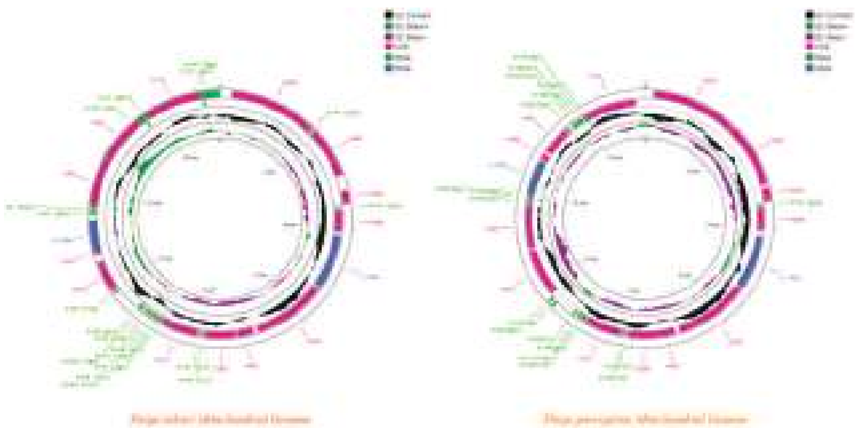


Figure 3.16 Circular mitogenome of T. tabaci and T. parvispinus

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

To study the impact of botanical on stored pests and pathogens in onion storage, an experiment was initiated with seven treatments in five replications. Each replication contained 10 kg of onion bulb from *rabi* 2022-23 harvested and placed in ventilated crates. About 30 gm of dried leaf powder of Neem, Karanj/Pongamia, Custard Apple, Eculyptus, Nirgudi, and Lemon Grass were used for dusting in each crate. A control set was kept without any treatment. The observations for weight loss and rotting were taken at a 30 days interval for 120 days. The control set of treatment observed the maximum storage losses (49.12%) after 4 months of storage. However, the treatment dusted with the dehydrated leaf powder of Karanj/Pongamia, Custard Apple, Eculyptus, Nirgudi and Lemon Grass showed significant difference in storage losses. The lowest storage losses were observed in the bulb dusted with Custard Apple followed by Lemon Grass 38.97% and 39.87%, respectively.

Externally Funded Projects

3.6. Taping the potential of native stingless bee *Tetragonula iridipennis* Smith for pollination enhancement and profitable onion seed production (SERB-DST, New Delhi)

Survey and sampling of stingless bee species associated with onion

A total of 10 locations each in the Nashik and Satara districts of Maharashtra were surveyed for stingless bee activity in seed onion at farmer fields. Among the 20 locations surveyed, the prevalence of stingless bees was documented in 8 locations (Figure 3.17 and 3.18). Wherein, the stingless species were predominant species in 3 locations including Lonand, Khandala, Andori of Satara district and 5 locations including Vinchur, Sogras, Dhodambe-1, Dhodambe-2, Lakhalgaon of Nashik district. This suggests that stingless bee species are one of the important non-Apis bee species contributing to onion pollination, and it almost contributes about 39% of forage visitation in onion seed crop.

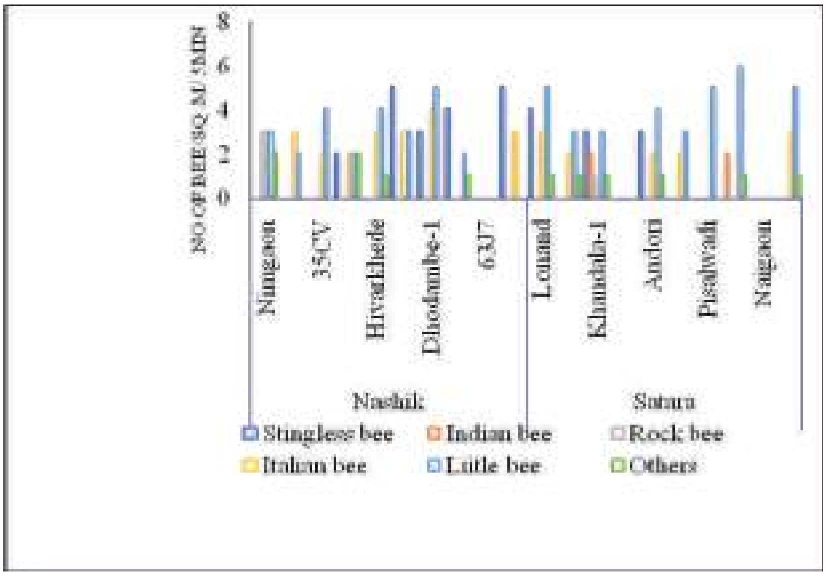


Figure 3.17 Survey data of honey bees of Nashik and Satara district

Figure 3.18 Stingless bee survey at farmers' fields (2023)

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

The diurnal activity of stingless bee in onion were studied from the morning 09:00 hrs and continued till 17:00 hrs. The result revealed that the forage visits started around 09.00 hrs in the morning, peak visits (Nos. of stingless bee visit/square meter area in 5 min) recorded around 11:30 hrs. Thereafter, the visitation rate was in decreasing trend (Figure 3.20). The trend was similar for visits of bees per unit (umbel) of time from 09:00 hrs to 17:00 hrs. An average of 2 to 4 bees was recorded on umbel per minute. Time spend per flower per unit time was in the range of 8-30 seconds/flower. The observation on purpose of visit and working behaviour of bees revealed that the majority of visits were made to collect pollen grains, with top-working behaviour being the most common. The average micro climate including temperature was 26 to 40℃ and humidity recorded between 36 to 45%. Physiochemical characterization of onion-based mono-floral stingless bee honey *viz.,* moisture content, pH, electrical conductivity, total protein content, sugars and antioxidants was also done. Hives of *T. iridipennis* and *A. mellifera* were re-located in onion seed plots at ICAR-DOGR, Pune and the honey was harvested from sealed honey pots within the hives. The samples were preserved in airtight containers and kept in dark at room temperature for quality analysis.

Figure 3.19 Field experimental setup

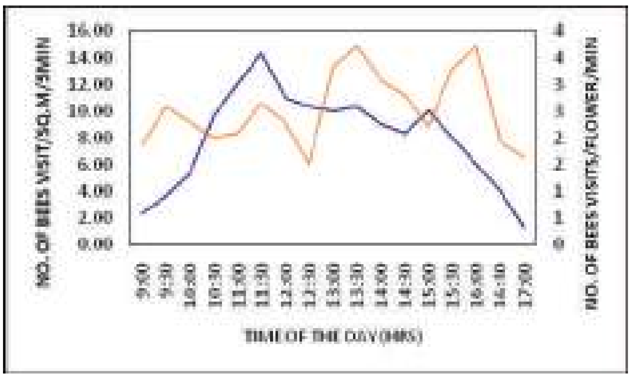


Figure 3.20 Foraging behaviour of *T. iridipennis* in onion

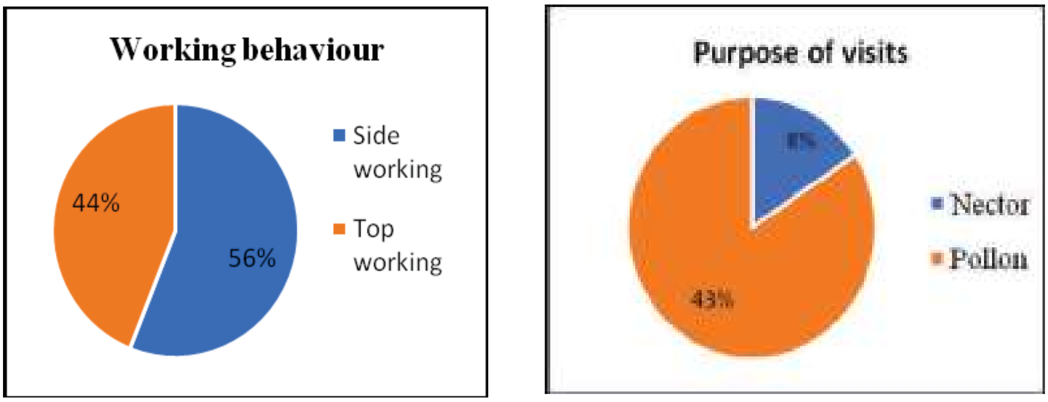


Figure 3.21 Working behaviour and purpose of visits of T. iridipennis in onion

Assessment of the honey production potential and honey quality of *T. iridipennis* when forages on onion ecosystem

The pH, EC and Moisture content of onion based stingless bee, *T. iridipennis* honey revealed marked difference in pH compared to *A. mellifera* honey sample (Figure 3.22). The stingless bee honey had less pH values than the *A. mellifera* honey sample. The pH of stingless bee honey was ranged from 3.36-3.46 whereas as pH of *A. mellifera* was 4.48. On the other hand, the EC values of *T. iridipennis* honey were high as compared to *A. mellifera* honey. The EC values of *T. iridipennis* honey were ranged from 1011.67-1127 µs/cm while in case of *A. mellifera* honey EC value was 578 µs/cm. Likewise; *T. iridipennis* honey had higher moisture content than *A. mellifera* honey sample. The moisture content values of *T. iridipennis* honey samples ranged from 16.07-19.79% whereas moisture content of *A. mellifera* honey sample was 13.60%. The total protein content estimated in stingless bee showed high (709-1184 µg/gm) total protein content compared to *A. mellifera* honey (529 µg/gm). Similarly, elevated amount of total antioxidant in *T. iridipennis* honey samples with the total antioxidant activity ranged from 288.85-353.47 mg/100gm was observed (Figure 3.23). The total sugar analysis showed high amount of total sugar, reducing sugar concentration in *T. iridipennis* honey compared to *A. mellifera* honey sample. The total sugar content and reducing sugar content in stingless bee honey were ranged from 78.46 - 81.68% and 73.69-78.32%, respectively. Amount of sugar content, and reducing sugar content in *A. mellifera* honey was 72.27% and 70.32%, respectively.

Figure 3.22 *T. iridipennis* and *A. mellifera* honey

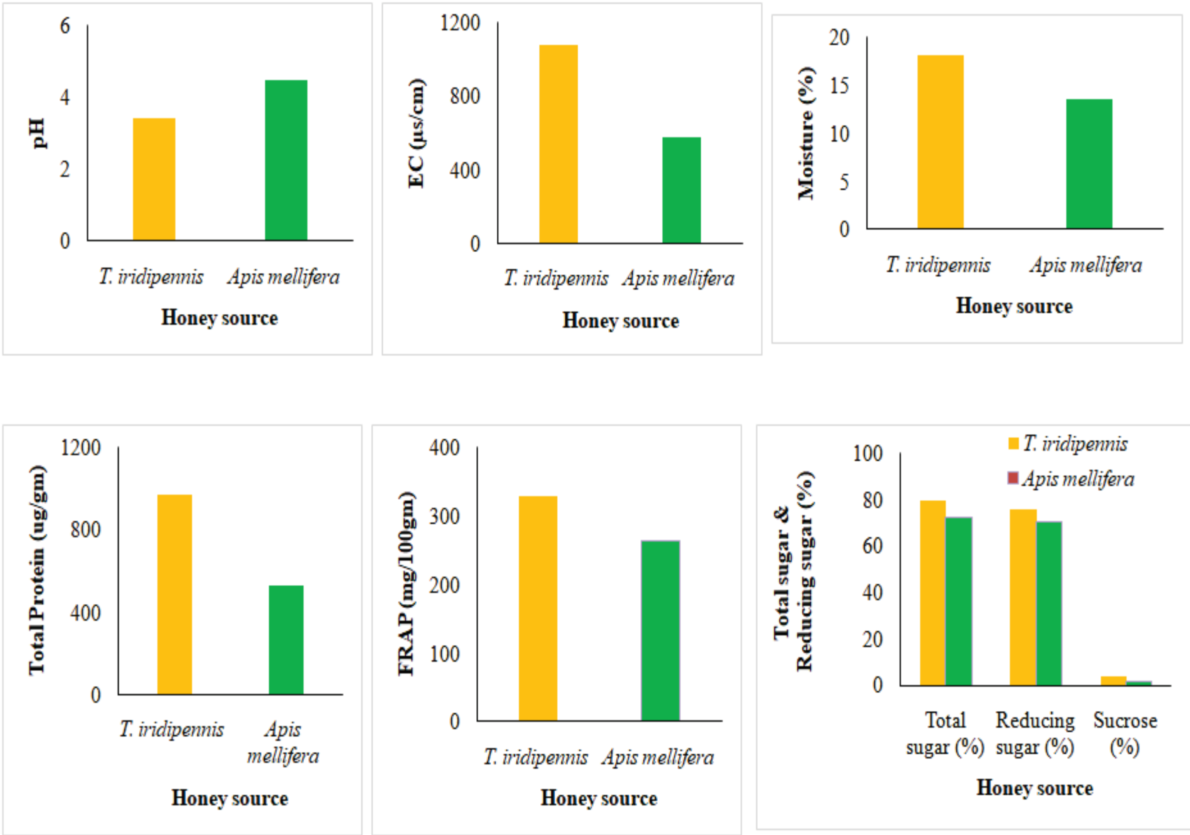


Figure 3.23 Physio-chemical Parameters of *T. iridipennis* and A. *mellifera* honey (pH, EC, Moisture, Protein, Antioxidant and Sugars)

3.7. Deciphering the gut microbiome profile of Apis species in onion (*Allium cepa*) to enhance ecosystem services (SERB-DST, New Delhi)

Survey and document the dominant bee species associated with onion ecosystem

A random field survey was conducted at four major onion seed growing districts of Maharashtra including Pune, Ahmednagar, Solapur and Satara for the documentation dominant bee species associated with onion ecosystem. For this study, two villages spanning ten randomly chosen fields with an aerial distance of at least 10 km was chosen. Sample collection was done using hand sweeping net. The specimens were identified using taxonomic keys (morphometric). Further, some specimens were stored for molecular characterization and isolation of gut microbiome. The initial field survey revealed the pollinator diversity and richness associated with onion ecosystem. Among the different insect orders pollinating onion, Hymenoptera (representing common bees and wasps) dominated the onion ecosystem in terms of species diversity, irrespective of the location. Within the order Hymenoptera, Apidae family dominated with eight different species, while Vespidae with two species. Irrespective to the location, the order of pollinator dominance was found to be *A. florea*>*A. cerana indica*>*A. dorsata*>*Tetragonula spp*. Apart from Hymneopteran insects, Lepidopteran and Dipteran orders were also found pollinating onion (Figure 3.24 and 3.25). On the basis of the data obtained from the survey, the catalogue of the honeybee species and their associated *Allium* flora was prepared. Also, the floral calendar for the Maharashtra region was prepared along with the Bee catalogue

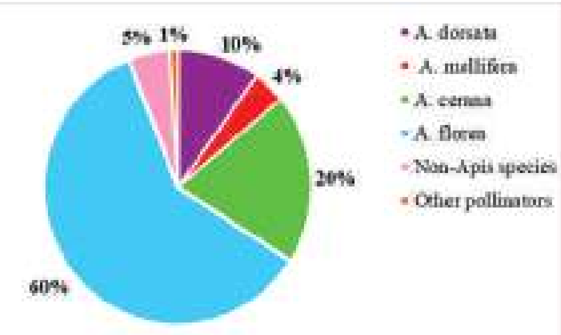


Figure 3.24 Abundance of onion pollinators in Maharashtra and Apis florae

Figure 3.25 Survey and documentation of dominant bee species associated with onion ecosystem

Study on foraging activity of dominant bee

The foraging activity of the *Apis* and stingless bee species in onion crop was recorded. Two experimental onion seed crop plots located at Rajgurunagar was regularly monitored for the foraging activity of the bees. *Apis mellifera, A. cerana indica* and *Tetragonula iridipennis* hives were installed in the vicinity of the onion seed production plots for the pollination services and to study their foraging behaviour. The *Apis mellifera, A. cerana indica* and *Tetragonula iridipennis* hive were installed in the onion seed production plots for the pollination services. In case of *A. florea* and *A. dorsata*, as they are non-domesticated, hives were not installed, yet their colonies are naturally available in the vicinity. Observations were taken in the 5 slots at 2 hrs time interval. The highest numbers of bee visits on onion flowers were observed in the species, *A. cerana indica* followed by *A. florea* and *T. iridipenis*. However, the time spent on single umble was highest for the *T. iridipenis* followed by *A. florea and A. cerana indica.* Irrespective of the species, all *Apis* bees found collecting both pollen and nectar, however stingless bee, *T. iridipenis* were observed collecting only pollen from anthers. This might be either due to the deep-seated nectaries in the florets or high sulphur-content in the nectar, which might have hindrance its nectar collection. The number of flowers visited on each umbel was highest for *A. cerana indica* followed by *A. florea* and *A. dorsata*. Average numbers of umbels visited in each flight was comparatively same for all the species. However, the lowest foraging activity was observed in *A. mellifera*. In conclusion the *A. cerana indica* and *A. florea* are the most suitable bee species for onion pollination.

Identify the gut microbiome of Apis species from onion seed crop using both culture dependent and culture-independent approaches

Culture-dependent honey bees gut microbiome study

The honeybee samples of the *A. cerana indica, A. florea, A. dorsata, A. mellifera* and *T. irridipennis* were collected from onion flowers and their guts were dissected in aseptic environment. The gut tissues were macerated in the saline solution and were spread on the nutrient agar plates. The isolated individual colonies were purified by streak plate technique. These isolated colonies were screened for lactose fermentation. About 12 bacterial species were isolated and purified on nutrient agar plates from *A. cerana indica*, *A. mellifera, A. florea* and *A. dorsata* dissected gut. The species were screen for lactose fermentation. Out of 12 species, 6 comprising 2 each from *A. cerana indica*, 1 from *Apis florea* and 3 from *A. mellifera* detected lactose fermenting gram-negative bacteria species. The cultures were maintained for further biochemical test.

Culture-independent honey bees gut microbiome study

The gut microbiome of *A. florea* was investigated by sequencing the V3-V4 region of 16S rRNA gene using Illumina MiSeq Platform. The obtained sequence was used for the bioinformatics analysis. Further, samples of other species namely *A. cerana indica, A. dorsata, A. mellifera* and *T. irridipennis* were sent for sequencing and are awaiting results. The gut microbiome of *A. florea* was investigated by sequencing the V3-V4 region of 16S rRNA gene using Illumina MiSeq Platform. The total of 138075 raw reads were obtained, from which 93,391 (67.60%) quality reads were analysed, which resulted in identification of 19464 operational taxonomic unit (OTU). The relative abundance of bacterial phyla Proteobacteria (55.15%), Firmicutes (38.10%), Actinobacteriota (5.38%), Bacteroidota (5.38%), Cyanobacteria (0.34%) and Chloroflexi (0.03%) were recognized in *A. florea* bee gut micro biome profiling. The 15,849 (81.43%) OUTs were identified at genus level and 4287 (22.03%) were identified at the species level (Figure 3.26). The identified species having the abundance in *A. florea* gut are from Lactobacillaceae family which includes *Lactobacillus mellis*, *Lactobacillus kunkeei*, *Lactobacillus mellifer,* and *Lactobacillus apinorum*. The non-parametric estimation of Shannon index (6.23) and Simpson index (0.98) among 142 observed features indicates a diverse and stable microbial community in the *A. florea* gut. The sequence data deposited in the NCBI BioProject database with accession no. PRJNA1065181.

Figure 3.26 Krona chart of microbial diversity in *Apis florea* gut

4. Post-Harvest Technology

4.1 Nutraceutical delivery potential of onions through probiotication

Characterizing lactobacillus strains: a preliminary examination and in vitroassessment of probiotic characteristics for commercial applications

Successfully evaluated the diversity and potential efficacy of various *Lactobacillus* strains, including *L. acidophilus, L. fermentum, L. rhamnosus, L. helveticus, L. delbrueckii, L. plantarum* and *L. casei*, through a preliminary in vitro examination for their probiotic potential. By conducting detailed analysis of these bacterial strains, we seek to identify their specific probiotic characteristics and assess their suitability for commercial use. Through in vitro examination, various probiotic characteristics of these strains were evaluated, including their ability to survive in simulated gastrointestinal conditions, adhesion to intestinal epithelial cells, antimicrobial activity, and acid and bile tolerance. This research lays the ground work for a deeper understanding of the specific attributes of these strains, informing future clinical applications and product development in the realm of probiotic supplementation.

Examination of Lactobacillus strains

The examination of various *Lactobacillus* strains for their potential as probiotics and commercial viability involved several key assessments, including the catalase test, Gram staining, and observation of colony characteristics. Among the strains evaluated, *Lactobacillus acidophilus* NCDC 15, *L. fermentum* NCIM 2165, *L. rhamnosus* NCDC 296, *L. helveticus* NCIM 2126, *L. delbrueckii* NCIM 2025, *L. plantarum* NCIM 2083, and *L. casei* NCIM 5752 were investigated. Firstly, all strains exhibited a negative catalase test result, indicating that they lack the enzyme catalase, a characteristic common to many *Lactobacillus* species. Gram staining revealed that all strains were Gram-positive, a typical trait of *Lactobacillus* bacteria. This staining property is important as it aids in the identification and classification of bacterial species.

In vitro tolerance to low pH

The in vitro assessment for tolerance of various *Lactobacillus* strains to low pH conditions, which is crucial for evaluating their potential as probiotics and commercial viability. The assessment involves measuring the colony-forming units (CFU) of each strain at both neutral (pH 6.5) and acidic (pH 2) conditions over a period of time (0 hours and 2 hours). At pH 6.5 (the control condition), all strains exhibit relatively high CFU counts, indicating robust growth and viability in neutral environments. However, when subjected to pH 2 conditions mimicking the acidity of the stomach, there was a notable decrease in CFU counts for all strains after 2 hours compared to the initial counts at 0 hours. Among the strains tested, *L. rhamnosus* NCDC 296 demonstrated the highest tolerance to low pH conditions, maintaining the highest CFU count at both 0 and 2 hours. Conversely, *L. acidophilus* NCDC 15 initially exhibited the lowest CFU count at pH 2, suggesting lower tolerance to acidity compared to the other strains. These findings suggest that while all tested Lactobacillus strains show some level of tolerance to low pH, there were variations in their abilities to withstand acidic conditions. This variability is important to consider when assessing their potential as probiotics, as strains with higher acid tolerance may have better survival rates in the harsh gastric environment and thus higher efficacy as probiotic supplements. Further studies, including in vivo assessments and clinical trials, would be necessary to validate these preliminary findings and determine the actual probiotic potential and commercial viability of these strains.

In vitro tolerance to simulated gastric juice

The in vitro tolerance of various *Lactobacillus* strains to simulated gastric juice was assessed in this study, representing a critical preliminary evaluation for their potential as probiotics and commercial viability. Survival rates of each strain were observed under acidic conditions simulating the stomach environment, at both pH 2 and pH 2.5, with measurement taken at 0 and 2 hours intervals. At pH2, *L. plantarum* NCIM2083 demonstrated the highest initial survival rate, recorded at 9.22 log CFU/ml, which gradually decreased to 8.91 log CFU/ml after 2 hours. In contrast, *L. rhamnosus* NCDC 296 exhibited a comparatively lower initial survival rate at 8.93 log CFU/ml, declining notably to 8.09 log CFU/ml after 2 hours, indicating a lower tolerance to acidic conditions. Similarly, at pH 2.5, *L. plantarum* NCIM 2083 maintained a relatively higher survival rate initially, recorded at 8.37 log CFU/ml, and decreased to 7.88 log CFU/ml after 2 hours. Conversely, L. casei NCIM 5752 showed a decline from 8.36 log CFU/ml to 7.67 log CFU/ml, indicating slightly lower tolerance to the simulated gastric environment. Overall, *L. plantarum* strains, particularly NCIM 2083, demonstrated robust tolerance to acidic conditions, suggesting their potential as effective probiotics. Conversely, *L. rhamnosus* NCDC 296 displayed lower survivability, indicating the need for further evaluation before considering it for probiotic applications. These findings provide valuable insights for future research and the selection of *Lactobacillus* strains for commercial probiotic products based on their gastric survival characteristics.

In vitro tolerance to high bile salt

In this study, the control samples (without bile salts) show relatively high initial bacterial counts (Log CFU/ml) ranging from approximately 9.82 to 10.18 across the different *Lactobacillus* strains. This indicates robust growth and survival under normal conditions. However, when exposed to 2% bile salt solution, there was a noticeable decline in bacterial counts for all strains after 2 hours. Initially, the bacterial strains were assessed for their viability both without bile salts (control) and in the presence of 2% bile salt solution, at 0 and 2 hours. The results revealed notable variations in tolerance levels among the different strains. Lactobacillus plantarum NCIM 2083 exhibited a decrease in colony-forming units (CFU/ml) when exposed to bile salts, indicating moderate tolerance to bile stress, as evidenced by a reduction in CFU/ml from 9.10 to 8.86 after2 hours. *Lactobacillus casei* NCIM 5752 demonstrated a similar trend, with its CFU/ml decreasing from 8.97 to 8.06 after 2 hours in the presence of bile salts, indicating a decrease in viability under bile stress. *Lactobacillus helviticus* NCIM 2126 displayed a comparable pattern, with a reduction in CFU/ml from 8.98 to 8.41 after 2 hours, suggesting a moderate tolerance to bile salts. *Lactobacillus fermentum* NCIM 2165 showcased a decline in CFU/ml from 8.89 to 8.04 after 2 hours, indicating a moderate tolerance to bile stress, similar to other strains. *Lactobacillus delbrueckii* NCIM 2025 exhibited a decrease in CFU/ml from 8.69 to 8.00 after 2 hours, indicating moderate tolerance to bile stress. *Lactobacillus acidophilus* NCDC 15 displayed a reduction in CFU/ml from 9.26 to 8.99 after 2 hours, suggesting a moderate tolerance to bile salts. Lastly, *Lactobacillus rhamnosus* NCDC 296 demonstrated a decrease in CFU/ml from 9.50 to 9.08 after 2 hours, indicating moderate tolerance to bile stress. Overall, the data suggests that while all strains experienced some reduction in viability when exposed to bile salts, they generally exhibited moderate tolerance to bile stress, indicating potential for survival and functionality as probiotics within the gastrointestinal tract, although further studies would be necessary to assess their efficacy in vivo and commercial viability. The cell surface hydrophobicity of *Lactobacillus* strains plays a significant role in determining their potential as probiotics and commercial viability. Among the strains tested, *L. plantarum* NCIM 2083 demonstrated the highest hydrophobicity, with 49.14% adhesion in cyclohexane and 58.62% adhesion in toluene. This suggests a considerable hydrophobic surface, potentially enhancing its adhesion to gut epithelial cells. Conversely, *L. casei* NCIM 5752 exhibited lower hydrophobicity compared to *L.*

plantarum, with 27.97% adhesion in cyclohexane and 49.15% adhesion in toluene. However, its higher adhesion in toluene indicates a distinct interaction with hydrophobic surfaces. Intermediate hydrophobicity was observed in *L. helviticus* NCIM 2126, *L. fermentum* NCIM 2165, and *L. delbrukii* NCIM 2025, and suggesting moderate adhesion abilities. *L. acidophilus* NCDC 15 and *L. rhamnosus* NCDC 296 displayed relatively high hydrophobicity, particularly in toluene, indicating potential strong adhesion in environments with high hydrophobicity. In summary, *Lactobacillus* strains exhibit varying levels of cell surface hydrophobicity, with *L. plantarum* NCIM2083, *L. acidophilus* NCDC 15, and *L. rhamnosus* NCDC 296 showing relatively higher levels. These differences can impact their efficacy as probiotics and their suitability for commercial applications, depending on specific environmental or application requirements.

Auto aggregation assay

The auto-aggregation assay results (%) of various *Lactobacillus* strains after 2 and 4 hours, serving as a preliminary in vitro assessment for their probiotic potential and commercial viability. Auto-aggregation is a crucial characteristic for probiotic bacteria as it signifies their ability to adhere to each other, which correlates with their ability to adhere to the gut epithelium and potentially confer health benefits. Among the strains tested, *L. helviticus* NCIM 2126 exhibited the highest auto-aggregation percentage after both 2 and 4 hours, with values of27.14% and 41.07% respectively. This suggests a strong tendency for cells of this strain to clump together, which could potentially enhance their ability to colonize the gut and exert probiotic effects. Following closely behind was *L. rhamnosus* NCDC 296, with notable auto-aggregation percentages of 14.10% and 41.03% after 2 and 4 hours respectively. This strain also demonstrated promising auto-aggregation characteristics, indicating its potential as a probiotic candidate. *L. plantarum* NCIM 2083 displayed moderate auto-aggregation, with values of18.81% and 47.85% after 2 and 4 hours respectively. While the initial aggregation percentage was lower compared to some other strains, it significantly increased after 4 hours, indicating a gradual strengthening of cell aggregation over time. Meanwhile, *L. fermentum* NCIM 2165, *L. acidophilus* NCDC 15, and *L. delbrukii* NCIM 2025 showed intermediate auto-aggregation abilities, with varying degrees of aggregation at both time points. On the other hand, *L. casei* NCIM 5752 exhibited comparatively lower auto-aggregation percentages, indicating a weaker tendency for cells to aggregate. However, it is worth noting that even though the initial aggregation percentage is lower, there is a significant increase after 4 hours, suggesting potential for improvement over time. In summary, the auto-aggregation assay results highlight the diverse characteristics of different *Lactobacillus* strains in terms of their ability to form aggregates, with some showing strong potential as probiotic candidates due to their high auto-aggregation percentages, while others may require further optimization to enhance their commercial viability.

Co-aggregation assay for *E. coli*

The percent co-aggregation assay data presents a comprehensive picture of the potential interactions between *E. coli* and various strains of *Lactobacillus* at different time intervals, offering insights into their probiotic potential and commercial viability. After 2 hours of incubation, *L. plantarum* NCIM 2083 showed the highest co-aggregation percentage at 22.00%, followed closely by *L. casei* NCIM 5752 at 16.92% (Lee et al., 2020). This suggests an early ability of these strains tointeract and potentially mitigates *E. coli* colonization. However, *L. fermentum* NCIM 2165 exhibited a lower co-aggregation percentage at 7.27%, indicating a slower initial response. As the incubation period progressed to 4 hours, there was a noticeable increase in co-aggregation percentages across all strains, with *L. plantarum* NCIM 2083 continuing to lead at 25.43%, followed by *L. casei* NCIM 5752 at 20.00%. This trend suggests a strengthening of interactions over time, which is crucial for sustained probiotic effects.

After 18 hours, significant variations emerged among the strains. *L. helviticus* NCIM 2126 demonstrated a remarkable increase in co-aggregation percentage to 22.71%, indicating a substantial potential for long-term interactions with *E. coli*. Similarly, *L. delbrukii* NCIM 2025 and *L. fermentum* NCIM 2165 also exhibited notable increases in co-aggregation percentages, suggesting continued efficacy. The 24-hour mark revealed further insights into the probiotic potential of the Lactobacillus strains. *L. plantarum* NCIM 2083 maintained its lead with a co-aggregation percentage of 44.29%, indicating robust and sustained interactions with *E. coli*. Notably, *L. helviticus* NCIM 2126 displayed a significant jump to 38.43%, reinforcing its potential as a probiotic candidate. *L. rhamnosus* NCDC 296 also showed a substantial increase to 35.71%, suggesting its viability for prolonged probiotic effects. Overall, the data underscores the importance of considering both short-term and long-term interactions in assessing probiotic potential.

Co-aggregation assay for *Micrococcus luteus*

The % co-aggregation assay shows the interaction between *Micrococcus luteus* and various *Lactobacillus* strains over different time intervals (2hr, 4hr, 18hr, and 24hr). Co-aggregation is a significant parameter in assessing the potential of *Lactobacillus* strains as probiotics, indicating their ability to interact and possibly adhere to other microorganisms or host cells. Analyzing the results, some interesting trends emerged. *L. delbrueckii* (NCIM 2025) showed consistently high levels of co-aggregation throughout the time points, with values ranging from 24.62% to 37.95%. This suggests a strong potential for this strain to interact with *Micrococcus luteus*, which could be indicative of its ability to compete with pathogenic bacteria or potentially modulate the host's immune response positively. On the other hand, *L. fermentum* (NCIM 2165) started with a relatively low co-aggregation percentage at 2hr (3.90%) but showed a substantial increase at later time points, reaching values comparable to other strains by 18hr and 24hr. This delayed but significant increase in co-aggregation indicated that this strain might take longer to establish interactions but can eventually form strong associations with Micrococcus luteus. Interestingly, *L. plantarum* (NCIM 2083) exhibited a gradual increase in co-aggregation over time, with the highest value observed at 24hr (41.21%). This indicated a progressive strengthening of interaction between this strain and *Micrococcus luteus*, which could be advantageous for sustained probiotic effects over time. Overall, these results suggest that different *Lactobacillus* strains exhibited varying degrees and kinetics of co-aggregation with *Micrococcus luteus*, which is crucial in evaluating their probiotic potential and commercial viability. Further studies could delve into the mechanisms underlying these interactions and their implications for host-microbe dynamics in the context of probiotic supplementation.

Co-aggregation assay for *Listeria monocytogenes*

The assay measures the ability of *Lactobacillus* strains to aggregate with *Listeria* monocytogenes over different time intervals (2 hours, 4 hours, 18 hours, and 24 hours). Among the strains tested, *Lactobacillus plantarum* NCIM2083 exhibited gradual and substantial co-aggregation percentages over time, reaching 41.09% after 24 hours, indicating a strong potential for interaction with Listeria monocytogenes. Similarly, *L. casei* NCIM 5752 and *L. helviticus* NCIM 2126 also showed increasing co-aggregation percentages, suggesting their ability to form aggregates with the pathogen. Interestingly, *L. fermentum* NCIM 2165 showed a relatively low co-aggregation percentage after 2 hours but significantly increased to 39.38% after 24 hours, indicating a slower but eventual interaction with *Listeria monocytogenes*. Comparatively, *L. delbrueckii* NCIM 2025 exhibited a consistently high co-aggregation percentage across all time points, suggesting strong and consistent interaction potential with the pathogen. *L. acidophilus* NCDC 15 and *L. rhamnosus* NCDC 296 also displayed notable co-aggregation percentages, indicating their ability to aggregate with *Listeria monocytogenes*. Overall, the data suggests that certain *Lactobacillus* strains, such as *L. plantarum* NCIM 2083, *L. delbrueckii* NCIM 2025, and *L. acidophilus* NCDC 15, exhibited promising probiotic potential due to their ability to interact with *Listeria monocytogenes*, which is essential for potential applications in food safety and human health. Further studies are warranted to validate these findings and explore the commercial viability of these strains in probiotic products.

Co-aggregation assay for *Staphylococcus aureus*

Across the tested strains, there is a noticeable trend of increasing co-aggregation with *S. aureus* over time, indicating a potential for these *Lactobacillus* strains to interact and potentially inhibit the growth of this pathogen. *L. plantarum* NCIM 2083 demonstrates a consistent increase in co-aggregation percentage over the 24-hour period, reaching the highest percentage among all strains at 45.63+0.001%. This suggests its strong potential for inhibiting *S. aureus*. Similarly, *L. fermentum* NCIM 2165 also exhibits a notable increase in co-aggregation percentage, reaching 46.30+0.001% after 24 hours. This strain could also be a promising candidate for probiotic formulations targeting *S. aureus*. *L. helviticus* NCIM 2126 and *L. acidophilus* NCDC 15 both show significant co-aggregation with *S. aureus*, with values close to or above 40% after 24 hours, indicating their potential as effective probiotics in combating this pathogen. However, some strains like *L. rhamnosus* NCDC 296 show comparatively lower co-aggregation percentages, which might suggest a lesser potential in inhibiting *S. aureus* growth compared to other strains tested. Overall, these results suggest that *Lactobacillus* strains, especially *L. plantarum* NCIM 2083, *L. fermentum* NCIM 2165, *L. helviticus* NCIM 2126, and *L. acidophilus* NCDC 15, have promising probiotic potential against *S. aureus*, making them worthy of further investigation for commercial viability in probiotic products. Further studies could delve into the mechanisms underlying the observed co-aggregation and assess other aspects of probiotic functionality, such as antimicrobial activity and survivability in the gastrointestinal tract, to better evaluate their commercial potential.

Biochemical analysis of cultures

The biochemical analysis of various Lactobacillus strains using the HiLacto Identification Kitrevealed distinct metabolic characteristics among the tested strains. In this preliminary in vitro assessment for probiotic potential and commercial viability, several key observations emerged. Firstly, all tested strains exhibited esculin hydrolysis, indicating their ability to metabolize this compound, which is often associated with the hydrolysis of esculin to esculetin and glucose, suggesting a shared enzymatic activity across the strains. Secondly, the absence of catalase activity was noted across all strains, indicating a negative result for this test. Catalase-negative bacteria lack the enzyme catalase, which plays a role in the breakdown of hydrogen peroxide into oxygen and water. This characteristic is often associated with certain lactic acid bacteria, such as Lactobacillus species. Regarding carbohydrate fermentation, variations were observed among the strains. Xylose, cellobiose, arabinose, maltose, galactose, melibiose, and raffinose were positively fermented by most of the strains, suggesting their capacity to utilize these sugars as energy sources. However, mannose fermentation showed variability among the strains, with some exhibiting positive results, while others showed delayed or negative responses. Sucrose and trehalose fermentation also demonstrated variability, with some strains showing positive results, while others exhibited delayed or negative reactions. Overall, the data indicate that the tested Lactobacillus strains possess a range of metabolic capabilities, with similarities and differences observed in their ability to utilize specific carbohydrates. Further comprehensive studies are warranted to assess their probiotic potential and commercial viability, taking into account additional factors such as tolerance to gastro intestinal conditions, adherence to intestinal epithelial cells, and production of beneficial metabolites.

4.2 Development of ready to cook dehydrated onion-based snack mix

Onion (*Allium cepa* L.) is one of the most important and widely cultivated vegetable spices throughout the world. Though onion is widely consumed, it is not convenient to peel, cut and cook due to its pungency. Processing of onion into different value-added products would reduce the post-harvest losses and offer convenience to use. Dehydration of onions reduces the bulk to transport and also increases the shelf life of onions significantly due to less moisture, which arrests the growth of microorganisms. Dehydrated onion can be used in many processed or ready to cook and ready to eat foods in place of raw onion as it has several advantages such as convenience of transportation, storage, preparation and use. Howver, the market for dehydrated onion is very less in India. Inorder to increase the market for dehydrated onion, an experiment was planned to develop ready to cook snack mix with dehydrated onion. Onion pakoda is a popular snack in India, however peeling and cutting of onions is the major time-consuming process in the preparation of onion pakoda. Keeping this in view, ready to cook pakoda snack mix was optimized using dehydrated onion. This product will reduce the overall snack preparation time and offers convenience, besides increasing the market for dehydrated onion.

Figure 4.1 Different combinations of pakoda mix tested through RSM

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

Onion bulbs are susceptible to various sort of microbial pathogens that include viruses, phytoplasma, bacteria, and fungi causing various sort of disorders in stored onion bulbs. In instances here bulbs are not properly cured, or in the deskinned bulbs, or physically damaged bulbs pathogens can invade very easily and rapidly. Bacterial diseases of onion bulbs are particularly can cause significant storage losses, reducing the marketable yield of bulbs. Soft rot, slippery skin, and center rot are common bacterial diseases that degrade the onion's quality which are often ascribed to fungal pathogens but the bacterial pathogens are equally important. Since, bacterial pathogens have smaller genome size compared to fungal pathogens and thus more amenable to comparative genomic studies leading to better understanding of their virulence mechanisms, host-pathogen interactions for developing effective disease management strategies. Therefore, we performed a comparative genomic analysis of common bacterial pathogens of onion bulb for which the genomic sequences are available which included publicly available genomic sequences of strains of *Pantoea ananatis, Pantoea agglomerans, Erwinia persicinia, Rouxiella badensis, Pseudomonas uvaldensis, Xanthomonas axonopodis, Burkholderia cepacian, and Curtobacterium allii*. The phylogenetic relationship of these pathogens along with metadata (Year of isolation of pathogen, strain name and source country) is presented in the figure 4.2. We annotated all the available genomes of the *Pantoea ananatis* for comparative genomic studies and the common genetic repertoire shared between the different strains of this devastating pathogen causing central rot of bulb have been analyzed and represented in the figure 4.3 a and b. The further efforts are on to decipher its genetic elements responsible for invasion of the bulbs.

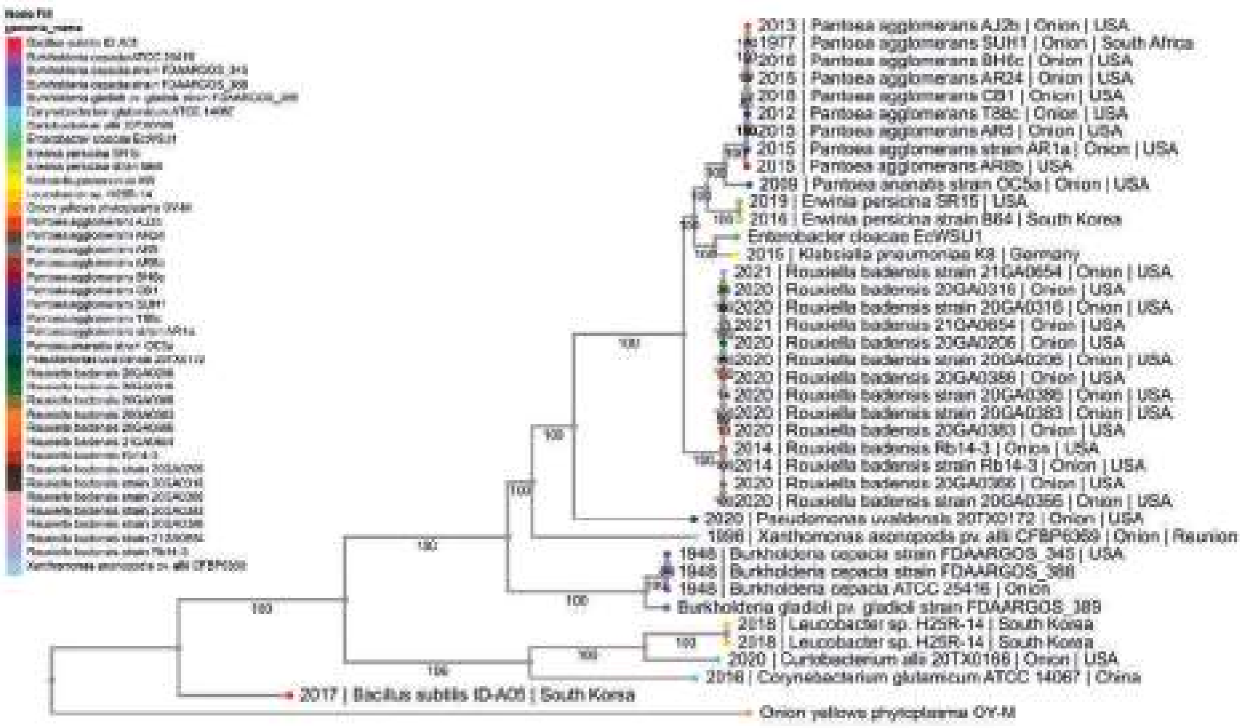


Figure 4.2 Dendrogram showing phylogenetic relationships of common bacterial pathogens of onion bulb constructed based on the whole genome alignment using RAxML (Randomized Axelerated Maximum Likelihood). The (Year of isolation of pathogen, strain name and source country) is also shown for different clades along with the bootstrap values

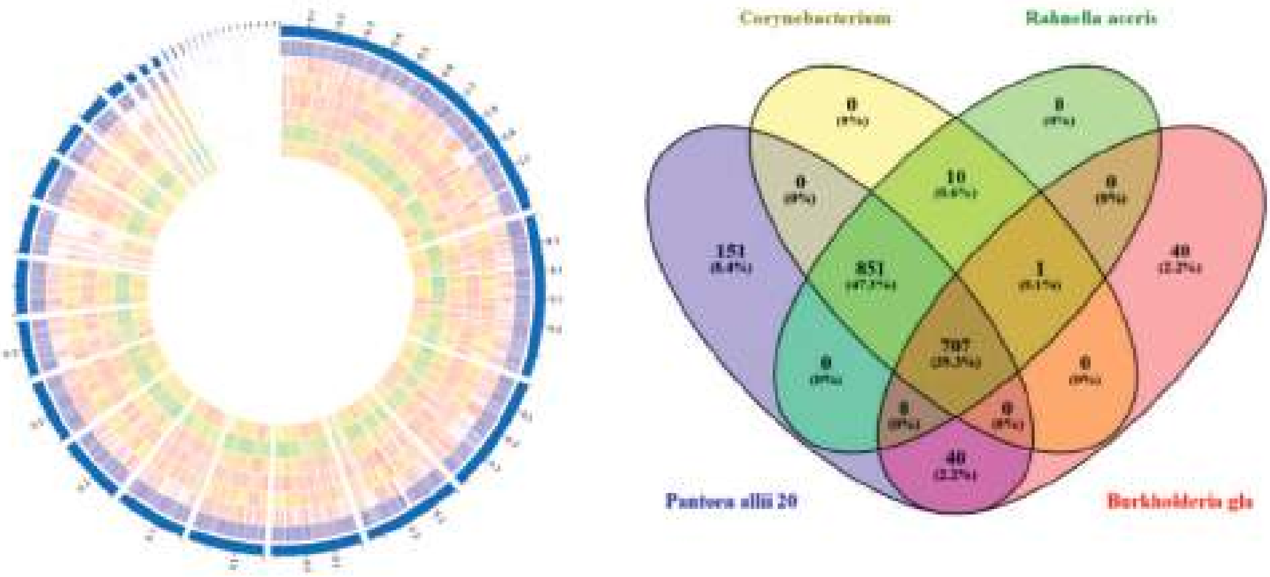


Figure 4.3 a) CG view of gene content shared between different pathogens as analyzed based on the bi-directional best hit using blast. List of tracks from outside to inside includes *Pantoea allii, Corynebacterium glutamicum, Rahnella aceris, Serratia sps, Pantoea annanatis, Erwinia persccina*

b) Venn diagram showing the shared genes between four different pathogens of onion bulb

5. Extension

5.1 Transfer of improved technologies of onion and garlic and impact assessment

Extension activities help to disseminate the technology and evaluate its impact 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 trainings. Total 817 demonstrations were conducted in Maharashtra and Karnataka state during *kharif* (152), late *kharif* (55) and *rabi* (610) seasons through institute project (30), SCSP (727), and MGMG (60) for the study.

Demonstrations in *kharif* season

Onion varieties; Bhima Super and Bhima Dark Red were selected for *kharif* in 2 districts *viz*., Pune and Ahmednagar of Maharashtra state and Bijapur district of Karnataka state. Total 152 *kharif* demonstrations (10 from institute project, 122 from SCSP and 20 from MGMG) were carried out in these districts. For demonstration purpose, about 2-3 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.

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 55 late *kharif* demonstrations (10 from institute project, 25 from SCSP and 20 from MGMG) were carried out in Pune district. For demonstration purpose, mostly 2 kg onion seed of each ICAR-DOGR developed variety was provided for each demonstration by the Directorate. Farmers arranged the onion seed of local variety for comparison of the performance with Directorate's onion varieties.

Demonstrations in *rabi* season

Onion varieties; Bhima Kiran and Bhima Shakti were selected for *rabi* demonstrations in Pune, Ahmednagar and Wardha districts of Maharashtra state. Total 610 *rabi* demonstrations (10 from institute project, 580 from SCSP and 20 from MGMG) were carried out in these districts. For demonstration purpose, mostly 2 kg onion seed of each ICAR-DOGR developed varities were 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. The cultural practices which were common to all 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 (2 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.

Nutrient management: Basal dose of FYM 15 t/ha with 25:40:40:30 kg NPKS/ha applied in *kharif*, FYM 15 t/ha with 40:40:60:30 kg NPKS/ha applied in late *kharif* and FYM 15 t/ha with 40:40:60:30 kg NPKS/ha applied in *rabi* season. First top dress doses (after 15 days of basal dose) were applied of 25 kg N/ha (*kharif*), 35 kg N/ha (late *kharif*), and 35 kg N/ha (*rabi*) and second top dress doses (after 15 days of 1st top dress) were applied of 25 kg N/ha (*kharif*), 35 kg N/ha (late *kharif*) and 35 kg N/ha (*rabi*). Besides NPKS, micronutrient spray (5 g/L) was applied as per requirement during growth stages.

Pest and disease management: Foliar sprays of carbosulfan (2 ml/L) with 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.

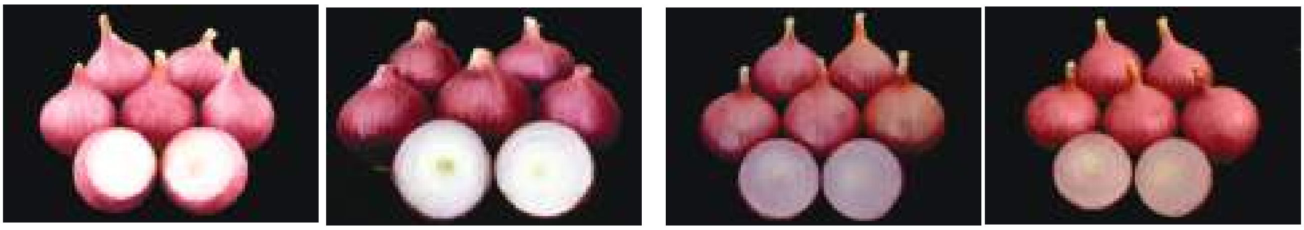
Harvesting: It was done at 50-60% neck fall stage.

Performance of frontline demonstrations (FLDs)

The demonstrations in *kharif* season revealed that the germination percentage (97), average bulb weight (82 g) and yield (25.5 t/ha) of Bhima Super was the highest. Bhima Dark Red (25.0 t/ha) also yielded more than local variety (18.5 t/ha). The germination percentage (95), average bulb weight (85 g) and the yield (47.5 t/ha) of Bhima Raj were the highest in late *kharif* demonstrations. Bhima Red (45.0 t/ha also yielded more than local variety (24.0 t/ha) in late *kharif* demonstrations. The demonstrations conducted in *rabi* in Maharashtra revealed that the germination percentage (94%), average bulb weight (84 g) and marketable yield (42.5 t/ha) of Bhima Kiran were the highest and Bhima Shakti (42.0 t/ha) also yielded more than local variety (27.5 t/ha). The varieties developed by ICAR-DOGR were found superior over the local cultivars in all the demonstrations. The performance of trials at different locations is given in table 5.1.

Table 5.1 Performance of frontline demonstration trials

Season	Variety	Germination Percentage	Av. bulb weight (g)	Marketable yield (t/ha)
Kharif	Bhima Super	97	82	25.5
	Bhima Dark Red	94	80	25.0
	Local	80	65	18.5
Late *kharif*	Bhima Raj	95	85	47.5
	Bhima Red	90	82	45.0
	Local	75	72	24.0
Rabi	Bhima Kiran	94	84	42.5
	Bhima Shakti	92	82	42.0
	Local	78	74	27.5



(a) *Kharif*: Bhima Super | Bhima Dark Red | (b) Late *kharif*: Bhima Raj | Bhima Red

(c) *Rabi*: Bhima Kiran | Bhima Shakti

Figure 5.1 Onion varieties of ICAR-DOGR performing better than local varieties in different seasons

5.2 Noval approaches for transfer of onion and garlic technologies

Social Media applications and ICT based interventions

Video production: During the year, 9 technologies and advisory based videos were developed and disseminated over youtube channel for the farmers. The video sharing platform YouTube channel has been used to disseminate 53 crop production related videos, garnering 41,033 views, 1,914 subscriptions, and 1,300 watch hours from a variety of viewers.

1 Controlled Onion Storage Structure Technology by ICAR-DOGR and Kala Biotech
2 Importance of Onion, Onion and Garlic crop production series
3 Onion Crop Advisor
4 कांदा पीक सल्लागार
5 प्याज फसल सलाहकार
6 प्याज का महत्व ।प्याज एवं लहसुन उत्पादन तंत्र शृंखला भाग–1
7 कांदयाचे महत्व। कांदा आणि लसूण उत्पादन तंत्र मालिका भाग–1
8 कांदा बीजोत्पादन यशोगाथा – सुधारित तंत्रज्ञानाचा वापर करून कांदा बीजोत्पादनातून आर्थिक सुबत्तता
9 प्याज बीजोत्पादन यशोगाथा – प्याज बीज उत्पादनमें उन्नत प्रौद्योगिकी के माध्यम से आर्थिक समृद्धि

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*). Six issues of this bilingual samacharhave webcasted on YouTube, featuring onion and garlic production advisories, expert talks, and Q and A sessions contemporary to the monthly crop conditions.

WhatsApp based advisories: Socially integrated messaging platforms were found effective in connecting 9977 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 queries. A total of 52 timely advisories were sent to farmers of different pockets of the country including text (21) Audio (8) Video (26) advisories.

Decision support system: A mobile application enabled with DSSs; decision support systems for prompt management decisions in nutrient management, pest and diseases, variety selection and day to day operations is developed being used by over 1000 farmers and stakeholders.

Externally Funded Projects

5.3 Capacity building and demonstration of improved technologies to enhance water use efficiency in onion

Under the CR Trails with ITC Mission *Sunehra Kal* project, Raised Bed with Drip Method (RBWD) for onion cultivation demonstrated to 200 farmers in the Ghod river basin in four prominent onion growing blocks. The participatory capacity building and monitoring program resulted in increased yields by 23.61% in *rabi* season, adding 7.06 tons per hectare, and by 13.70% in late *kharif*, adding 4.19 tons per hectare over the traditional flat bed with flood irrigation method (FBWD). RBWD improved the quality of produce, with a higher percentage of marketable bulbs 94.02% in *rabi* season compared to 88.96% with FBWD. Cultivation costs decreased by 16.53% in late *kharif* and 23.40% in *rabi*, while water consumption reduced by 28.79% and 24.52%. Water productivity improved significantly, producing 6.23 kg of bulbs per 1000 liters of water in the *rabi* season compared to 3.50 kg with traditional methods.

Impact of Raised Bed with Drip Irrigation Technology in Onion Farming

The impact of advanced irrigation technologies specifically, Raised Bed with Drip Irrigation (RBWD) on onion farming was studied in Pune and Ahmednagar District of Maharashtra. The study was conducted with objectives include a comparative analysis of technical efficiency, water productivity, and yield enhancement associated with RBWD and conventional Flat Bed with Flood Irrigation (FBWF) methods. Furthermore, the research investigated socio-economic factors that influence technology adoption and seasonal performance variations during the post-monsoon (*rabi*) and late-monsoon periods (Late *kharif*). A comprehensive study was conducted involving 480 onion farmers, with equal representation from those employing RBWD and drip irrigation technologies, as well as non-adopters reliant on traditional flood irrigation. The research encompassed four blocks: Junnar, Shirur, Parner, and Shrigonda, located in the Pune and Ahmednagar districts of Maharashtra. Employing a multi-stage random sampling method, data were collected through structured interviews, capturing socio-economic characteristics, farming practices, yield data, and constraints encountered by farmers. Further, farm level monitoring of water uses and harvest was made for each individual farmer. The technical efficiency of onion farming was evaluated using Stochastic Frontier Analysis (SFA), while Irrigation Water Productivity (IWP) was measured in kilograms of yield per cubic meter of water utilized. Logistic regression analysis was employed to identify the factors influencing technology adoption. Field demonstrations and capacity-building training sessions were conducted with 240 farmers to encourage the uptake of RBWD, supplemented by follow-up visits by scientist to ensure effective implementation.

Key Outputs and Findings

Technical Efficiency and Yield

- Farmers utilizing RBWD and drip irrigation exhibited significantly enhanced technical efficiency, with RBWD users achieving an impressive 92% production frontier as compared to a mere 65% for FBWF irrigation practitioners.
- Notable productivity improvements were recorded, with RBWD users attaining an average yield of 36.96 t/ha during the post-monsoon season, representing a 23.61% increase over flood irrigation yield and 35.43 t/ha in the late-monsoon season, compared to 29.90 t/ha for flood irrigation.

Water Use and Irrigation Water Productivity (IWP)

- RBWD systems demonstrated significant water saving, with users saving between 24.52% and 28.79% of water compared to flood irrigation.
- Average water usage was calculated at 58.73 hectare-centimetres per hectare for RBWD users, whereas flood irrigation users consumed 81.07 hectare-centimetres per hectare.

- The IWP for RBWD was markedly superior, reaching 6.29 kg/m³ in the post-monsoon season, highlighting a substantial improvement in water efficiency.

Adoption Drivers and Barriers

- Key determinants facilitating the adoption of RBWD and drip irrigation included access to extension services, larger landholdings, and educational attainment.
- Post-adoption challenges identified including a lack of adequate operational knowledge for managing the irrigation systems. Many adopters expressed a need for further technical training and assistance in system maintenance operation.

This research conclusively demonstrates that the adoption of Raised Bed with Drip Irrigation systems significantly enhances water-use efficiency, and increases crop yields, particularly during critical crop growth period. To facilitate broader adoption of these transformative technologies, it is imperative to implement targeted financial support mechanisms to mitigate initial investment costs and bolster comprehensive technical training programs. Additionally, strategic policy interventions and enhanced extension services are essential for scaling these innovations across India's onion farming sector, thereby promoting sustainable agricultural practices in water-scarce regions. The findings underscore the necessity for collaborative efforts among stakeholders to realize the full potential of RBWD technology, ensuring a resilient and productive agricultural future.

Table 5.2 Season-wise comparison of the performance of raised bed with drip irrigation systems (RBWD) and traditional flat bed with flood irrigation method (FBWF)

Sl. No.	Parameter	Season	RBWD	FBWF
1	Technical Efficiency (%)	Post-Monsoon	92%	65%
		Late Monsoon	91%	63%
2	Productivity (t/ha)	Post-Monsoon	36.96	30.49
		Late Monsoon	35.43	29.9
3	Water Use (ha.cm/ha)	Post-Monsoon	58.73	81.07
		Late Monsoon	60.5	84.5
4	Water Savings (%)	Post-Monsoon	24.52 - 28.79	-
		Late Monsoon	20.00 - 24.00	-
5	Irrigation Water Productivity (IWP) (kg/m³)	Post-Monsoon	6.29	4.01
		Late Monsoon	5.86	3.93

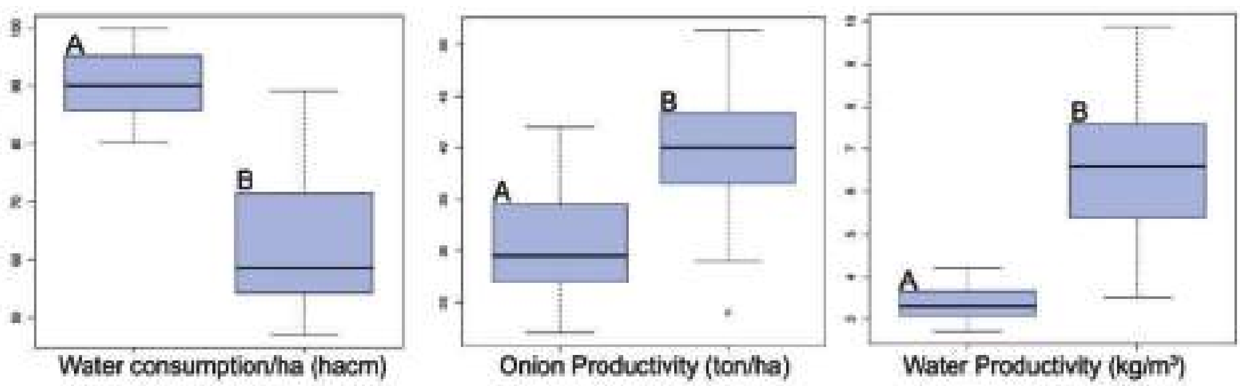


Figure 5.2 Comparative water use, onion productivity and water productivity by RBWD and FBWF method [A-Flat bed with flood method of irrigation (FBWF) B- Raised bed with drip irrigation (RBWD)]

5.4 Agri Drone Project

Demonstrations were conducted on drone based spray technology at farmers' fields under Agri-drone project. A total of 135 demonstrations were conducted on 187 acres of land under onion cultivation in 50 villages of Pune and Ahmednagar districts of Maharashtra. Around 1200 farmers were participated in the demonstrations. The project focused on eight key tahsils: Shirur, Khed, Junnar, and Ambegaon in Pune district, and Parner, Karjat, Sangamaner, and Akole in Ahmednagar district. 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 5.3 Demonstrations on drone-based spray technology

Type of chemical spray	No of demonstrations	Area covered (ha)
Fungicide	45	26.2
Insecticide	55	28.4
Weedicide	2	1.4
Nutrient	33	18.8
Total	135	74.8

Figure 5.3 Drone based demonstrations at farmers' fields

C. All India Network Research Project on Onion and Garlic

Summary of red onion germplasm at different locations

Twenty-three accessions along with two checks were evaluated at different locations during *Rabi*. More than 22.0 t/ha marketable yield was recorded in RO-1758 at Delhi, Karnal, Junagadh, Pune and Bengaluru; RO-1773 at Delhi, Karnal, Junagadh and Pune and RO-1784 at Karnal, Junagadh, Pune and Bengaluru; whereas, more than 25.0 t/ha total yield was recorded by RO-1758, RO-1761, RO-1770 and RO-1784 at Delhi, Karnal, Junagadh, Pune and Bengaluru. Acc.RO-1654, RO-1773 and RO-1784 produced more than 75 g average bulb weight at Junagadh, Pune and Bengaluru. Less than 115 days to maturity was recorded in RO-1672 at Karnal, Pune, Bengaluru and Coimbatore.

Summary of white onion germplasm at different locations

Fifteen accessions along with three checks were evaluated at different locations during *rabi*. More than 19.0 t/ha marketable yield was recorded in Acc. W-143 at Karnal, Junagadh, Pune, Bengaluru and Coimbatore; Acc. W-353 at Delhi, Junagadh, Pune and Bengaluru; whereas more than 20.0 t/ha total yield was recorded by Acc. W-143 and W-498 at Delhi, Karnal, Junagadh, Pune, Bengaluru and Coimbatore. Acc. W-208, W-498 and W-504 produced more than 66 g average bulb weight at Junagadh, Pune, Bengaluru and Coimbatore. Less than 114 days to maturity was recorded in W-246 and W-498 at Karnal, Pune and Bengaluru.

Onion Varietal Trial

Red onion varieties

In short day red onion varietal trial during *kharif,* 4 entries at 23 centres were evaluated in IET. In short day red onion varietal trial during late *kharif*, 4 entries at 22 centres were evaluated in IET. In Short day red onion varietal trial during *rabi*, 7entry at 23 centres, 4 at 23 centres, 4 at 23 centres were evaluated in IET, AVT-I and AVT-II. In Hill region, red onion varietal trial during *rabi* IET, 6 entries at 4 centres, in AVT-I, 4 at 4 centres and in AVT-II 4 at 4 centres, respectively were evaluated.

Red onion hybrid

In short day red onion hybrid trial during *rabi*, 2 entry each at 23 centres were evaluated for both in IET and AVT-I. In hill region during *rabi,* 2 entries at 4 centres in IET, and 3 entries at 4 centres in AVT-I were evaluated.

Garlic Varietal Trial

During *rabi*, garlic varietal trial was conducted at total 22 centers. The trials viz. IET, AVT-I& AVT-II were conducted in short day condition, In IET, 7 entries at 22 centres, 4 entries at 22in AVT-I and 3 entries at 22 centres in AVT-II were evaluated, respectively. In hill region during *rabi*, 9 entries at 4 centres in IET, 4 entries at 4 centres in AVT-I and 3 entries at 4 centres in AVT-II were evaluated.

Crop Production

In crop production, total four experiments conducted *viz*., i) fertilizer scheduling through drip irrigation system in onion seed crop, ii) weed management studies in onion seed cropand iii) effect of nano-urea on growth, yield and quality of onion (All main centres, Rahuri, Nasik of these three experiments conducted), iv) fertilizer scheduling through drip fertigation for long day onion at Srinagar.

Pest Management

Four experiments including (i) Survey and monitoring of insect pests of onion and garlic, (ii) Evaluation insecticide/miticide against sucking pests and mites of garlic, iii) Screening of onion and garlic varieties/lines for thrips resistance, and iv) Management of pest and diseases in garlic were conducted in *kharif* as well *rabi* 2022-23. Among the various insect pests infesting onion and garlic, onion thrips, and *Thrips tabaci* was the major pest recorded in all surveyed locations. The incidence of cutworm, Spodoptera species, red spider mites, and Tetranychus species and Eriophyid mites were recorded at Rajgurunagar. Green looper, *Chrysodeixis sp* damage reported at Rajgurunagar, Sikkim centres. Aphid incidence was reported at Rajgurunagar and Ludhiana. Besides, *Helicoverpa armigera* was reported at Tripura. Hairy caterpillar, maggot incidence recorded at Ludhiana. Predatory coccinellids were reported at Ludhiana and Rajgurunagar centres.

Disease Management

Total three pathological trials were conducted at the entire main and some voluntary centres. The major diseases recorded were stemphylium blight, purple blotch and anthracnose besides diseases like *Fusarium* Basal rot, Black mould, Downy mildew and Iris yellow spot virus were recorded at some centres. Combination of fungicides viz., CabrioTop (2g/L) + Cyantraniliprole (0.9 ml/L) and Amister Top (1.25 ml/L) + Cyantraniliprole (0.9 ml/L) positive control propiconazole were evaluated against major fungal diseases during *rabi* 2021-22 at main centers. The treatment, cyantraniliprole and its combinations were found effective in suppressing purple blotch and stemphylium blight incidence over control in many of locations and on with positive control Propiconazole in few locations.

AINRPOG Seed Production (Onion and Garlic)

Onion

- **Palampur**-Palam Lohit (0.1 q), Him Palam Shweta (0.02 q)
- **Srinagar**-Brown Spanish (0.1 q), Yellow Globe (0.25 q),
- **Ludhiana**- Punjab Naroya (1.25 q), PRO-6 (0.7 q), PRO-7 (5 q), PWO-2 (0.18 q), PYO-1 (0.1 q), POH-1 (F1) (0.28 q)
- **Kanpur**- Bhima Shakti (0.06 q)
- **Jabalpur**-Bhima Shakti (0.12 q)
- **Junagadh**-GJWO-3 (0.51 q), GJRO-11 (0.14 q)
- **Rahuri**- Phule Samarth (111.34 q), Baswant-780 (2.34 q)
- **Nashik**-Agrifound Dark Red (206.2 q), Agrifound Light Red (267.73 q), NHRDF Red-4 (168.49 q), NHRDF Fursungi (2.98 q), and Bhima Shakti (4.06 q)
- **Rajgurunagar**- Bhima Super (10.49 q), Bhima Raj (2.03 q), Bhima Red (2.16 q), BDR (5.44 q), Bhima Shakti (19.16 q), Bhima Kiran (3.76 q), BLR (0.09 q), Bhima Shubhra (1.61 q), Bhima Shweta (1.14 q), and Bhima Safed (0.81 q).
- **TNAU**- CO(On)5 (5.04 q), CO 6 (6.09 q)
- **Dharwad**- Bhima Super (15.11 q), Bhima Shakti (1.2 q), Bhima Red (1.1 q), Arka Kalyan (14.99 q)
- Overall total onion seeds production: 850.92 q (Onion) and 11.13 q (Multiplier Onion)

Garlic

- **Palampur**- GHC-1 (0.55 q)
- **Srinagar**- CITH-G-1 (1.2 q), CITH-G-3 (1.2 q)
- **Ludhiana**-PG-18 (98.5 q)

- **Sikkim-**SG-01 (0.95 q), SG-02 (0.3 q), SG-03 (0.3 q)
- **Junagadh-**GJG-5 (19.8 q)
- **Rahuri-**Phule Baswant (6 q), Phule Nilima (17 q)
- **Nashik-** Yamuna Safed-3 (G-282) (473.56 q), Yamuna Safed-5 (G-189) (28.08 q), Yamuna Safed-2(G-50) (70.31 q), Yamuna Safed-8(G-384) (16.37 q), Yamuna Safed-4(G-323) (3.58 q), Agrifound Parvati (G-313) (9.37 q), Yamuna Safed(G-386) (7.85 q), Agrifound Parvati-2 (G-408) (0.49 q), Yamuna Purple-10 (G-404) (99.04 q), Agrifound White (G-41) (3.85 q), and Yamuna Safed (G-1) (6.82 q).
- **Rajgurunagar-** Bhima Omkar (5.5 q), Bhima Purple (42.8 q)
- **Dharwad-** DWDG – 1(8.25 q), DWDG – 2 (5.35 q)
- Overall total garlic production: 927.07 q

D. Scheduled Caste Sub-Plan for Onion and Garlic

The main objective of this scheme is economic development of scheduled caste farmers by providing resources for filling up the critical gaps and providing missing vital inputs. During *kharif* season, 354 kg onion seed of Bhima Super and Bhima Dark Red were distributed among 122 scheduled caste farmers of districts *viz*., Ahmednagar and Pune of Maharashtra and Bijapur district of Karnataka. During late *kharif* season, 50 kg onion seed of Bhima Red and Bhima Raj were distributed among 25 scheduled caste farmers of Pune district of Maharashtra. During *rabi* season, 740 kg onion seed of Bhima Shakti and Bhima Kiran were distributed among 580 scheduled caste farmers of Pune, Ahmednagar and Wardha districts of Maharashtra. Onion bulbs of Bhima Shakti (5480 kg) were also distributed among 10 scheduled caste farmers of Ahmednagar and Pune districts. The fertilizers (52556 kg, 294 litres) and pesticides (205.2 kg, 1027.25 litre) were also distributed to scheduled caste farmers.

Development of Seed villages

Seed Village concept was implemented with theme of 'One variety One village' for high quality seed production. Gurav Pimpri Farmers Producer Company was established with the objective of empowering SC farmers in the region. 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. Total 3360 kg seeds were produced by the FPC. This FPC is distributing the seed among the farmers of the locality. FPC received revenue of ₹ 40,32,000/- through seed sale.

Training programmes under SCSP scheme

ICAR-DOGR regularly conduct training programmes for the dissemination of onion and garlic technologies to the targeted clientele. Total eight training programmes were organized for scheduled caste farmers in which total 690 scheduled caste farmers were participated. The farmers were provided onion seed, onion bulbs, fertilizers, pesticides and technical bulletins. Dr. S. S. Gadge, Principal Scientist (Agricultural Extension), Nodal Officer SCSP and Dr. R. B. Kale, Senior Scientist (Agricultural Extension) coordinated the training programmes.

The following training programmes were organized under SCSP in which total 850 farmers were participated.

1. Training programme on "Azadi ka Amrut Mahotsav: *Kharif* Onion Production Technology" attended by 40 farmers from District Pune on 27-29 March 2023 at KVK, Narayangaon.
2. Training programme on "*Kharif* onion production technology" attended by 25 farmers from District Pune and Ahmednagar (Maharashtra) on 16 June 2023 at ICAR-DOGR, Pune.
3. Training programme on "Value chain management in onion" attended by 10 farmers from District Bijapur (Karnataka) on 28 June 2023 at ICAR-DOGR, Pune.
4. Training programme on "Late *kharif* onion production technology" attended by 25 farmers from District Pune (Maharashtra) on 8 August 2023 at ICAR-DOGR, Pune.
5. Training programme on "Scientific cultivation of onion and garlic" attended by 80 farmers from District Pune (Maharashtra) on 18 October 2023 at KVK, Narayangaon, District Pune.
6. Training programme on "*Rabi* onion production technology" attended by 100 farmers from District Wardha (Maharashtra) on 17 November 2023 at Deoli, District Wardha.
7. Training workshop on "Onion production technology" attended by 400 farmers from District Ahmednagar (Maharashtra) on 29 November 2023 at Karjat, District Ahmednagar.
8. Training programme on "Onion seed production" attended by 10 farmers from District Pune and Ahmednagar (Maharashtra) on 21 December 2023 at Mulewadi, District Ahmednagar.


Training on Scientific cultivation of onion and garlic at Narayangaon on 18 October 2023


Distribution of inputs among the scheduled caste farmers

E. Tribal Sub-Plan for Onion and Garlic

Tribal Sub-Plan Activities by ICAR-DOGR

Tribal Sub-Plan (TSP) activities by ICAR-DOGR play 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 conducting field demonstrations of improved technologies at farmer's fields through improved seed/ bulb distribution, knowledge dissemination, capacity building and entrepreneurship building. About 1110 tribal farmers were selected from 111 farmers' groups in Nandurbar (Navapur, Akalkua and Dhadgoan Talukas); about 760 tribal farmers were selected from 76 farmers' groups in Pune (Khed and Ambegaon talukas) in Maharashtra; and about 200 tribal farmers were selected from 20 farmer's groups in Sonbhadra (Robertsganj) in Uttar Pradesh under TSP Scheme.

Field Demonstrations

A total of 123 demonstrations in *kharif* and 128 demonstrations in *rabi* were conducted under TSP during 2022-23. 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 five trainings/ field day (s) were organized under TSP in Maharashtra and Uttar Pradesh in which 347 tribal farmers participated.

Trainings/ Field Day/ Kisan Sangoshthi organized

Topic of Training	Sponsored Agency	Date and Venue	No. of Participants
Kisan Sangoshthi on Scientific cultivation of onion	ICAR-DOGR and Agrimitra FPC under TSP	12 March 2023 Purushottampur, Narayanpur, Mirzapur (UP)	82
Commercial cultivation of onion and garlic in tribal belts of Nandurbar	ICAR-DOGR under TSP	31 March 2023 Palipada in Navapur, Nandurbar	40
Commercial cultivation of onion	ICAR-DOGR and Agrimitra FPC under TSP	16-17 October 2023 Sonbhadra (UP)	145
Scientific cultivation of onion and garlic	ICAR-DOGR under TSP	26 October 2023 ICAR-DOGR, Pune (MS)	40
Scientific cultivation of onion and garlic	ICAR-DOGR under TSP	23 December 2023 ICAR-DOGR, Pune (MS)	40

Input distribution at ICAR-DOGR, Pune

Inputs ready for distribution under TSP at ICAR-DOGR, Pune

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.,* Gadakwadi, Varude, Gulani, Wafgaon, Jawulke, Khadakwadi, Loni, Pondewadi, Dhamni, Ranmala, Gosasi, Mitgudwadi, Kanhur Mesai, Khairewadi, Khairenagar, Kahu Koyali, Sakurdi, Vetale, Saigaon and Saburdi. Various activities were carried out in these twenty villages by four teams of scientists. 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. Scientists (21) of ICAR-DOGR provided scientific information to the farmers about improved technology of onion and garlic time to time. Activities to be undertaken in *Mera Gaon Mera Gaurav* project have been discussed with village officials and Sarpanch of the respective villages. 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, 2070 farmers of 20 villages were benefitted due to 88 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 Super, Bhima Dark Red, Bhima Red, Bhima Raj, Bhima Kiran and Bhima Shakti were conducted in the villages adopted in this scheme. Total 49 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 1279 farmers 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.

Training on Rabi onion production technology, Vigilance awareness and Swachhata programme at Dhamni on 30 October 2023

G. Distinctness, Uniformity and Stability

ICAR-DOGR is working as Nodal Centre for conducting DUS test of onion and garlic and also maintaining 55 onion and 29 garlic varieties under this project. These varieties of onion and garlic are treated as extant varieties. In case of onion, 45 *rabi* season varieties and 10 *kharif* season varieties and 29 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 (2022-23)

Forty-five *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-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 Madhavi, Pusa Red, Pusa Sona, Pusa Riddhi, Pusa White Round, PRO-6, PRO-7, PWO-2, POH-1, PYO-1, Phursungi Local, RO-01, RO-59, RO-252, Sukhsagar, Talaja Red, Telagi Local, Early Grano and Udaipur-102 were sown on 18th Nov, 2022 and transplanted on 17th Jan, 2023 in 3 replications with the plot size of 2×3 sq m. Crops were harvested in the month of April-May 2023 and all the observations were recorded as per DUS test guidelines.

Evaluation of DUS *kharif* onion varieties (2023)

Ten *kharif* onion varieties *viz.*, Agrifound Dark Red, Arka Kalyan, B-780, Bhima Raj, Bhima Red, Bhima Shubhra, Bhima Shweta, Bhima Super, Bhima Dark Red and Bhima Safed along with four farmers *viz.*2889/2141, 23ONBHTI02, 23ONBHED04 and 23ONBHER05 were sown on 9th June, 2023 and transplanted on 28th July, 2023 in 3 replications with the plot size of 1×6 sqm on raised beds. Crops were harvested in the month of November 2023 and all the observations were recorded as per DUS test guidelines.

Evaluation of DUS Garlic Varieties (2022-23)

Twenty-nine 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 and Silkuei Local were planted on 16th Nov, 2022 in 3 replications with the plot size of 3×2 sqm. Crops were harvested in the month of March 2023 and all the observations were recorded as per DUS test guidelines.

ICAR-DOGR Varieties Registered with PPV&FRA

DUS testing of four varieties along with reference varieties were conducted during *kharif*. Nine onion varieties (Bhima Kiran, Bhima Shakti, Bhima Light Red, Bhima Super, Bhima Red, Bhima Raj, Bhima Dark Red, Bhima Shubhra and Bhima Safed) as well as one garlic variety Bhima Omkar have been registered with PPV&FRA. One onion variety Bhima Shweta and one garlic variety Bhima Purple are under registration process with PPV&FRA.

Garlic varieties

Onion Varieties

Maintenance of onion and garlic varieties under DUS Project

H. Agri-Business Incubation

The Agri-Business Incubation (ABI) Centre at ICAR-Directorate of Onion and Garlic Research provides essential support to entrepreneurs in the onion, garlic and agriculture sectors, offering technical assistance, consultancy, infrastructure, and training to build sustainable businesses. ABI Centre conducts various programs to build capacity and foster innovation, providing training, industry meets, and entrepreneurial development programs that connect incubates with experts and advanced production techniques. During 2023, a total of five advisory committee meetings were conducted in which five incubatees registered under the ABI Centre at ICAR-DOGR and launched startups in onion and garlic processing. Their ventures include producing dehydrated products, onion and garlic paste, honeybee rearing for onion seed production, value chain development, and onion value addition. Some incubatees operate individually, while others are part of Farmer Producer Companies and Self-Help Groups.

Name of the incubatees	Name of the Start up	Technology incubated	Product profile
Mr. Siddu Pujari	Palandu FPC	Processing and Value Addition in Onion	
Mrs. Ashwini Deepak Narawade	Kukadimai: Kukadi Mahila Swayam SahayataSamuh	Onion Hair Oil	
Mr. Sunil Shamrao Ingawalay	AluntAgro Products Pvt. Ltd. Pune	Black Garlic	
Mr. Uddhav Asaram Khedekar	Keshavraj Agro Producer Company Ltd. Jalna	Honey bee rearing for onion seed production	

Activities and programmes

To motivate, guide, and develop the capacity of ABI incubatees, the ABI Centre at ICAR-DOGR organized an Entrepreneurship Development Programme (EDP), workshops on processing onion and garlic into value-added products and industry meet to connect incubatees with industry professionals, helping them commercialize their products.

Activities and programmes conducted under ABI project

Sl.No.	Name of the activity	Date
1.	One-day workshop on "Synergy of Innovation and Incubation in Agri Start-up Ecosystem"	13 March 2023
2.	Online Programme to Celebrate World Intellectual Property Day with a theme "Women and IP: Accelerating Innovation and Creativity"	26 April 2023
3.	One-day training programme on "Value Chain Management in Onion"	28 June 2023
4.	Two-day Entrepreneurship Development Programme (EDP) cum Training Programme on "Post-Harvest Processing and Value Addition in Onion and Garlic"	16-17 August 2023
5.	National Symposium cum Industry Meet (NSIM) on "Agri-business in Alliums: Innovation, Promotion & Sustainability"	20-22 December 2023

One-day workshop on "Synergy of Innovation and Incubation in Agri Start-up Ecosystem" was organized to bring maximum number of agripreneurs under one roof where they can put forth their innovations, ideas and business plans in the field of agriculture for a conducive discussion.

Two-day Entrepreneurship Development Programme (EDP) cum Training Programme on "Post-Harvest Processing and Value Addition in Onion and Garlic"

In the programme, experts discussed the medicinal and nutraceutical benefits of onion and garlic, as well as dehydration processe and the creation of value-added products. The session explored entrepreneurial opportunities in onion and garlic processing. Branding and digital marketing strategies for successful agri-business development were also highlighted. Participants engaged in hands-on training to create various dehydrated products like onion and garlic powder, flakes, paste, oil extraction from onion seeds, and garlic peeling.

Hands on training activity on Onion Dehydration Process

Entrepreneurship Development Programme (EDP) cum Training Programme

Online Programme to Celebrate World Intellectual Property Day with a theme "Women and IP: Accelerating Innovation and Creativity”

The programme aimed to highlight the "can do" attitude of women inventors, creators and entrepreneurs around the world and their ground-breaking work in IP rights, such as, patents, copyrights, designs, trademarks etc. encouraging innovation and creativity

National Symposium cum Industry Meet (NSIM) on "Agri-business in Alliums: Innovation, Promotion & Sustainability" from 20th to 22nd December 2023 at MCCIA, Pune.

This symposium aims to bring together researchers, policymakers, agripreneurs, startups, agro-industries, investors, and other stakeholders to share their expertise and experiences on agribusiness innovations and technologies in the onion and garlic sectors.

Glimeses of National Symposium cum Industry Meet (NSIM)

I. North East Hill Plan

ICAR-DOGR began carrying out different operations under the TSP-NEH scheme, NEH plan, and AINRPOG for the benefit of tribal people in order to promote onion farming in the NEH area. Arunachal Pradesh, Nagaland, Manipur, Tripura, and Sikkim were chosen as the five states to promote onion growing in the NEH area.

Demonstrations and Trainings

- In total, 63 field demonstrations were conducted in five NEH states: Arunachal Pradesh, Manipur, Nagaland, Tripura, and Sikkim, with directly benefitted 1704 farmers.
- The villages: Namsing, Kongkul, Mebo, Rani, East Siang, Regi, Leparada, Basar, and Ledum are villages in Arunachal Pradesh. Beisumpuikam, Molvom, Samziuram, Suchunoma, New Suchunoma, Renthan, Lotsu, Phek, and Medziphema are in Nagaland. The villages of Sikkim State include KVK, Namthang in South Sikkim, Pradhan Gaon, Pakyong, Namrang, Thanka, and Rumtek. East Sikkim, Dzongu: North Sikkim district. Tripura's villages include Lankamura, Belbari, Lembucherra, Poangbari, South Tripura, Shilghati, Gomati, Kushamara, Uttar Tulamura, Melagarh, Rangamati, and Lankamura. Manipur villages *viz*., Imphal East District (Moirang Kampu Sajeb Awang Leikai, Nongmai Turel Loukol Andro), Ukhrul District (Sinakeithel), Imphal West District (Lamshang, Lamlai), 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 *kharif* season and Bhima Shakti and Bhima Kiran in *rabi* season. Farmers also received demonstration kits including organic inputs.
- A total of 2151 farmers, both male and female, participated in 35 training sessions organised in these states to provide farmers with information on the *kharif* and *rabi* onion producing technology developed by ICAR-DOGR.

Farmers' training on pest management of onion and distribution of kits in Nagaland (New Socunoma village)

Farmers' training and distribution of kits in Sikkim

Farmers' training in Arunachal Pradesh

J. Transfer of Technology

Training programmes organized

Topic of Training	Sponsoring Agency	Date and Venue	Participants
Azadi ka Amrut Mahotsav: *Rabi* onion crop management	MGMG, ICAR-DOGR, Pune	3 January 2023 Khadakwadi, Pune	26 Farmers from Pune district
	MGMG, ICAR-DOGR, Pune	4 January2023 Gosasi, Pune	25 Farmers from Pune district
	MGMG, ICAR-DOGR, Pune	9 January 2023 Warude, Pune	24 Farmers from Pune district
	MGMG, ICAR-DOGR, Pune	10 January 2023 Khairenagar, Pune	26 Farmers from Pune district
	MGMG, ICAR-DOGR, Pune	16 January 2023 Kahu Koyali, Pune	27 Farmers from Pune district
	MGMG, ICAR-DOGR, Pune	24 January 2023 Sakurdi, Pune	35 Farmers from Pune district
	MGMG, ICAR-DOGR, Pune	30 January 2023 Vetale, Pune	30 Farmers from Pune district
	MGMG, ICAR-DOGR, Pune	3 February 2023 Saigaon, Pune	28 Farmers from Pune district
	MGMG, ICAR-DOGR, Pune	17 February 2023 Saburdi, Pune	32 Farmers from Pune district
	MGMG, ICAR-DOGR, Pune	21 February 2023 Jawulke, Pune	28 Farmers from Pune district
	MGMG, ICAR-DOGR, Pune	27 February 2023 Gulani, Pune	26 Farmers from Pune district
	MGMG, ICAR-DOGR, Pune	1 March 2023 Wafgaon, Pune	25 Farmers from Pune district
	MGMG, ICAR-DOGR, Pune	6 March 2023 Kanhur Mesai, Pune	27 Farmers from Pune district
Azadi ka Amrut Mahotsav: *Kharif* onion production technology	SCSP, ICAR-DOGR, Pune	27-29 March, 2023 KVK, Narayangaon, Pune	40 Farmers from Pune district
Azadi ka Amrut Mahotsav: Value chain management of onion	SMART-ATMA, Nashik	2-3 March 2023 ICAR-DOGR, Pune	56 Farmers Producer Company Members from Nashik district
Kharif onion nursery management	MGMG, ICAR-DOGR, Pune	22 May 2023 Loni, Pune	26 Farmers from Pune district
	MGMG, ICAR-DOGR, Pune	24 May 2023 Kanhur Mesai, Pune	25 Farmers from Pune district
	MGMG, ICAR-DOGR, Pune	26 May 2023 Vetale, Pune	22 Farmers from Pune district

Topic of Training	Sponsoring Agency	Date and Venue	Participants
	MGMG, ICAR-DOGR, Pune	6 June 2023 Wafgaon, Pune	21 Farmers from Pune district
	MGMG, ICAR-DOGR, Pune	12 July 2023 Khairewadi, Pune	32 Farmers from Pune district
	MGMG, ICAR-DOGR, Pune	18 July 2023 Saigaon, Pune	24 Farmers from Pune district
	MGMG, ICAR-DOGR, Pune	26 July 2023 Jawulke, Pune	27 Farmers from Pune district
	MGMG, ICAR-DOGR, Pune	28 July 2023 Ranmala, Pune	23 Farmers from Pune district
Nursery preparation of *kharif* onion	MGMG, ICAR-DOGR, Pune	19 May 2023 Gulani, Pune	30 Farmers from Pune district
Nursery management in *kharif* onion production	MGMG, ICAR-DOGR, Pune	22 June 2023 Dhamni, Pune	28 Farmers from Pune district
Kharif onion production technology	MGMG, ICAR-DOGR, Pune	10 May 2023 Mitgudwadi, Pune	23 Farmers from Pune district
	MGMG, ICAR-DOGR, Pune	16 May 2023 Sakurdi, Pune	27 Farmers from Pune district
	SCSP, ICAR-DOGR, Pune	16 June 2023 ICAR-DOGR, Pune	25 Farmers from Pune and Ahmednagar district
Kharif onion harvesting technology	MGMG, ICAR-DOGR, Pune	6 November 2023 Varude, Pune	22 Farmers from Pune district
	MGMG, ICAR-DOGR, Pune	10 November 2023 Mitgudwadi, Pune	24 Farmers from Pune district
	MGMG, ICAR-DOGR, Pune	13 November 2023 Saburdi, Pune	26 Farmers from Pune district
	MGMG, ICAR-DOGR, Pune	20 November 2023 Wafgaon, Pune	23 Farmers from Pune district
Late *kharif* onion nursery management	MGMG, ICAR-DOGR, Pune	2 August 2023 Khairenagar, Pune	25 Farmers from Pune district
	MGMG, ICAR-DOGR, Pune	7 August 2023 Saburdi, Pune	26 Farmers from Pune district
	MGMG, ICAR-DOGR, Pune	9 August 2023 Gadakhwadi, Pune	28 Farmers from Pune district
	MGMG, ICAR-DOGR, Pune	17 August 2023 Khadakwadi, Pune	22 Farmers from Pune district
	MGMG, ICAR-DOGR, Pune	18 August 2023 Gosasi, Pune	24 Farmers from Pune district
	MGMG, ICAR-DOGR, Pune	5 September 2023 Kahu Koyali, Pune	27 Farmers from Pune district
Rabi onion production technology	MGMG, ICAR-DOGR, Pune	5 October 2023 Gulani, Pune	23 Farmers from Pune district
	MGMG, ICAR-DOGR, Pune	30 October 2023 Dhamni, Pune	25 Farmers from Pune district
	SCSP, ICAR-DOGR, Pune	17 November 2023 Deoli, Wardha	100 Farmers from Wardha district
	MGMG, ICAR-DOGR, Pune	23 October 2023 Vetale, Pune	27 Farmers from Pune district
	MGMG, ICAR-DOGR, Pune	25 October 2023 Loni, Pune	24 Farmers from Pune district

Topic of Training	Sponsoring Agency	Date and Venue	Participants
Rabi onion crop management	MGMG, ICAR-DOGR, Pune	8 December 2023 Pondewadi, Pune	27 Farmers from Pune district
	MGMG, ICAR-DOGR, Pune	15 December 2023 Ranmala, Pune	26 Farmers from Pune district
	MGMG, ICAR-DOGR, Pune	18 December 2023 Kahu Koyali, Pune	25 Farmers from Pune district
Rabi onion harvesting and post-harvest management	MGMG, ICAR-DOGR, Pune	3 April 2023 Gadakhwadi, Pune	23 Farmers from Pune district
	MGMG, ICAR-DOGR, Pune	6 April 2023 Khadakwadi, Pune	28 Farmers from Pune district
	MGMG, ICAR-DOGR, Pune	10 April 2023 Gosasi, Pune	26 Farmers from Pune district
	MGMG, ICAR-DOGR, Pune	18 April 2023 Kahu Koyali, Pune	27 Farmers from Pune district
	MGMG, ICAR-DOGR, Pune	21 April 2023 Varude, District Pune	29 Farmers from Pune district
	MGMG, ICAR-DOGR, Pune	25 April 2023 Pondewadi, Pune	28 Farmers from Pune district
Scientific cultivation of onion and garlic	SCSP, ICAR-DOGR, Pune	18 October 2023 KVK, Narayangaon, Pune	80 Farmers from Pune district
	TSP, ICAR-DOGR, Pune	26 October 2023 ICAR-DOGR, Pune	40 Farmers from Pune district
	TSP, ICAR-DOGR, Pune	23 December 2023 ICAR-DOGR, Pune	40 Farmers from Pune district
Commercial cultivation of onion	TSP, ICAR-DOGR, Pune &Agrimitra FPC, Mirzapur	16-17 October 2023 Sonbhadra (UP)	145 Farmers from Mirzapur district (UP)
Commercial cultivation of onion and garlic in tribal belts of Nandurbar	TSP, ICAR-DOGR, Pune	31 March 2023 Palipada, Nandurbar	40 Farmers from Nandurbar district
Production technology of onion and garlic	Project Director ATMA, Chandrapur	5-7 December 2023 ICAR-DOGR, Pune	25 Farmers from Chandrapur district
Kisan Sangoshthi and training on Scientific cultivation of onion	TSP, ICAR-DOGR, Pune&Agrimitra FPC, Mirzapur	12 March 2023 Purushottampur, Mirzapur (UP)	82 Farmers from Mirzapur district (UP)
Onion seed production	SCSP, ICAR-DOGR, Pune	21 December 2023 Mulewadi, Ahmednagar	10 Farmers from Pune and Ahmednagar district
Onion and garlic crop management	MGMG, ICAR-DOGR, Pune	13 September 2023 Kanhur Mesai, Pune	22 Farmers from Pune district
Training workshop on Synergy of Innovation and Incubation in Agri Start-up Ecosystem	ABI, ICAR-DOGR, Pune	13 March 2023 NRC on Grapes, Pune	50 Incubatees from Maharashtra
Training programme (virtual mode) on creation of Agri-business ecosystem through farmer producer organizations	MANAGE, Hyderabad	1-5 May 2023 ICAR-DOGR, Pune	74 Members of FPCs throughout India
Training on Women and IP: Accelerating Innovation and Creativity (Virtual mode)	ABI, ICAR-DOGR, Pune	26 April 2023 ICAR-DOGR, Pune	30 scientists and researchers from Maharashtra

Topic of Training	Sponsoring Agency	Date and Venue	Participants
Training workshop on "Onion production technology"	SCSP, ICAR-DOGR, Pune	29 November 2023 Karjat, Ahmednagar	400 Farmers from Ahmednagar district
Value chain management in onion	ABI and SCSP, ICAR-DOGR, Pune	28 June 2023 ICAR-DOGR, Pune	27 Farmers from Palandu, Bijapur (Karnataka)
Post-harvest processing and value addition in onion and garlic	ABI, ICAR-DOGR, Pune	16-17 August 2023 ICAR-DOGR, Pune	25 Incubatees from Pune district
Intellectual property rights: empowering minds, igniting knowledge	ITMU, ICAR-DOGR, Pune	4 May 2023 ICAR-DOGR, Pune	46Scientists, researchers, young professionals from ICAR-DOGR

Beside these, 35 trainings were organized under NEH Plan by ICAR-DOGR in NEH Region for 2151 farmers.

Participation in Exhibition

Date	Exhibition	Organizers	Venue
19-22 January, 2023	Krushik 2023	KVK, ADT, Baramati	KVK, Baramati
9-12 February, 2023	Global Farmers Krishi Mahotsav 2023	KVK, Gramonnati, Narayangaon	KVK, Narayangaon
28 February-01 March 2023	GMRT Science Exhibition 2023	Tata Institute of Fundamental Research (TIFR), Narayangaon	Giant Metrewave Radio Telescope (GMRT), Khodad
l6-18 July, 2023	95th Foundation Day/ Technology Day of ICAR Society and Exhibition	ICAR, New Delhi	NASC, Pusa, New Delhi
24 October, 2023	ICAR-IIHR, Industry Meet	ICAR-IIHR, Bengaluru, Karnataka	ICAR-IIHR, Bengaluru, Karnataka

Lectures Delivered

Topic	Event and organizer	Date and Venue
V. Mahajan		
Natural farming	Special technical session on Natural Farming and Millets organized by ICAR-ATARI, Pune	19 January 2023, IARI, Pune
Breeding for processing traits in onion and garlic	3rd National Symposium on Emerging Technologies and Trends in Sustainable Production and Value chain Management of Onion, Garlic and other *Allium* species organized by JISL, Jalgaon	11-14 February 2023, JISL, Jalgaon
Onion bulb and seed production technology	Two days training programme on "Value chain management of onion" organized by ICAR-DOGR, Pune	2-3 March 2023, ICAR-DOGR, Pune
Scientific production of onion and garlic	Training programme organized by SAGE University, Indore	29 September 2023, Indore
Scientific production of onion and garlic	National Conference on Spices, Aromatic and Medicinal Plants for Economic Prosperity and Ecological Sustainability-2023 organized by ICAR-CIARI, Port Blair	5-6 October 2023, ICAR-CIARI, Port Blair
Prospects in underutilized allium for food, medicine, processing and export achievements	International Seminar on Exotic and Underutilized Horticultural Crops: Priorities and Emerging Trends	17-19 October 2023, ICAR-IIHR, Bengaluru

Topic	Event and organizer	Date and Venue
Scientific production of onion and garlic	10th Indian Horticulture Congress, Indian Academy of Hort. Science, New Delhi	6-9 November 2023, College of Veterinary Science, Assam Agriculture University, Khanapara, Guwahati
A. J. Gupta		
Onion bulb production	Three days training programme on onion production, post-harvest and processing technology for farmers of Nashik District	8 January 2023, ICAR-DOGR, Pune
Scientific cultivation of onion	Kisan Sangoshthi on Scientific cultivation of onion organized by ICAR-DOGR and Agrimitra FPC organized under TSP scheme by ICAR-DOGR, Pune	12 March 2023, Purushottampur, Chunar, Mirzapur (UP)
TSP activities and improved varieties of onion and garlic	Training on commercial cultivation of onion and garlic in tribal belts of Nandurbar organized under TSP scheme by ICAR-DOGR, Pune	31 March 2023, Palipada, Nandurbar
Onion and garlic production	Three days training programme on production technology of onion and garlic organized under ATMA scheme by ICAR-DOGR, Pune	5 December 2023, ICAR-DOGR, Pune
S. S. Gadge		
Onion crop management for *rabi* season	Training on Azadi ka Amrut Mahotsav: *Rabi* onion crop management organized under MGMG scheme by ICAR-DOGR, Pune	3 January 2023, Khadakwadi, Pune
Onion crop management for *rabi* season	Training on Azadi ka Amrut Mahotsav: *Rabi* onion crop management organized under MGMG scheme by ICAR-DOGR, Pune	4 January 2023, Gosasi, Pune
Rabi onion crop management	Training on Azadi ka Amrut Mahotsav: *Rabi* onion crop management organized under MGMG scheme by ICAR-DOGR, Pune	9 January 2023, Warude, Pune
Rabi onion crop management	Training on Azadi ka Amrut Mahotsav: *Rabi* onion crop management organized under MGMG scheme by ICAR-DOGR, Pune	10 January 2023, Khairenagar, Pune
Onion crop management for *rabi* season	Training on Azadi ka Amrut Mahotsav: *Rabi* onion crop management organized under MGMG scheme by ICAR-DOGR, Pune	16 January 2023, Kahu Koyali, Pune
Onion crop management for *rabi* season	Training on Azadi ka Amrut Mahotsav:*Rabi* onion crop management organized under MGMG scheme by ICAR-DOGR, Pune	24 January 2023, Sakurdi, Pune
Onion crop management for *rabi* season	Training on Azadi ka Amrut Mahotsav: *Rabi* onion crop management organized under MGMG scheme by ICAR-DOGR, Pune	30 January 2023, Vetale, Pune
Rabi onion crop management	Training on Azadi ka Amrut Mahotsav: *Rabi* onion crop management organized under MGMG scheme by ICAR-DOGR, Pune	3 February 2023, Saigaon, Pune

Topic	Event and organizer	Date and Venue
Rabi onion crop management	Training on Azadi ka Amrut Mahotsav: *Rabi* onion crop management organized under MGMG scheme by ICAR-DOGR, Pune	17 February 2023, Saburdi, Pune
Rabi onion crop management	Training on Azadi ka Amrut Mahotsav: *Rabi* onion crop management organized under MGMG scheme by ICAR-DOGR, Pune	21 February 2023, Jawulke, Pune
Onion crop management for *rabi* season	Training on Azadi ka Amrut Mahotsav: *Rabi* onion crop management organized under MGMG scheme by ICAR-DOGR, Pune	27 February 2023, Gulani, Pune
Onion crop management for *rabi* season	Training on Azadi ka Amrut Mahotsav: *Rabi* onion crop management organized under MGMG scheme by ICAR-DOGR, Pune	1 March 2023, Wafgaon, Pune
Onion crop management for *rabi* season	Training on Azadi ka Amrut Mahotsav: *Rabi* onion crop management organized under MGMG scheme by ICAR-DOGR, Pune	6 March 2023, Kanhur Mesai, Pune
Kharif onion production technology	Training on Azadi ka Amrut Mahotsav: *Kharif* onion production technology organized under SCSP scheme by ICAR-DOGR, Pune	27-29 March 2023, KVK, Narayangaon, Pune
Rabi onion harvesting and post-harvest management	Training on *Rabi* onion harvesting and post-harvest management organized under MGMG scheme by ICAR-DOGR, Pune	3 April 2023, Gadakhwadi, Pune
Post-harvest management for *rabi* onion	Training on *Rabi* onion harvesting and post-harvest management organized under MGMG scheme by ICAR-DOGR, Pune	6 April 2023, Khadakwadi, Pune
Post-harvest management for *rabi* onion	Training on *Rabi*onionharvesting and post-harvest management organized under MGMG scheme by ICAR-DOGR, Pune	10 April 2023, Gosasi, Pune
Rabi onion harvesting and post-harvest management	Training on *Rabi* onion harvesting and post-harvest management organized under MGMG scheme by ICAR-DOGR, Pune	18 April 2023, Kahu Koyali, Pune
Rabi onion harvesting and post-harvest management	Training on *Rabi* onion harvesting and post-harvest management organized under MGMG scheme by ICAR-DOGR, Pune	21 April 2023, Varude, Pune
Post-harvest management for *rabi* onion	Training on *Rabi* onion harvesting and post-harvest management organized under MGMG scheme by ICAR-DOGR, Pune	25 April 2023, Pondewadi, Pune
Kharif onion production technology	Training on *Kharif* onion production technology organized under MGMG scheme by ICAR-DOGR, Pune	10 May 2023, Mitgudwadi, Pune
Kharif onion production technology	Training on *Kharif* onion production technologyorganized by MGMG by ICAR-DOGR, Pune	16 May 2023, Sakurdi, Pune
Nursery preparation of *kharif* onion	Training on Nursery preparation of *kharif* onion organized under MGMG scheme ICAR-DOGR, Pune	19 May 2023, Gulani, Pune

Topic	Event and organizer	Date and Venue
Nursery preparation of *kharif* onion	Training on *Kharif* onion nursery preparation organized under MGMG scheme by ICAR-DOGR, Pune	22 May 2023, Loni, Pune
Kharif onion nursery management	Training on *Kharif* onion nursery management organized under MGMG scheme by ICAR-DOGR, Pune	24 May 2023, Kanhur Mesai, Pune
Kharif onion nursery management	Training on *Kharif* onion nursery management organized under MGMG scheme by ICAR-DOGR, Pune	26 May 2023, Vetale, Pune
Kharif onion nursery management	Training on *Kharif* onion nursery management organized under MGMG scheme by ICAR-DOGR, Pune	6 June 2023, Wafgaon, Pune
Nursery preparation of *kharif* onion	Training on *Kharif* onion production technology organized under SCSP scheme by ICAR-DOGR, Pune	16 June 2023, ICAR-DOGR, Pune
Nursery management in *kharif* onion	Training on Nursery management in *kharif* onion production organized under MGMG scheme by ICAR-DOGR, Pune	22 June 2023 Dhamni, Pune
Onion crop management	Training on Value chain management in onion organized under SCSP scheme by ICAR-DOGR, Pune	28 June2023 ICAR-DOGR, Pune
Onion nursery management	Training on Onion nursery management organized under MGMG scheme by ICAR-DOGR, Pune	12 July 2023, Khairewadi, Pune
Onion nursery management	Training on Onion nursery management organized under MGMG scheme by ICAR-DOGR, Pune	18 July 2023, Saigaon, Pune
Nursery management in onion crop	Training on Onion nursery management organized under MGMG scheme by ICAR-DOGR, Pune	26 July 2023, Jawulke, Pune
Nursery management in onion crop	Training on Onion nursery management organized under MGMG scheme by ICAR-DOGR, Pune	28 July 2023, Ranmala, Pune
Late *kharif* onion nursery management	Training on Late *kharif* onion nursery management organized under MGMG scheme by ICAR-DOGR, Pune	2 August 2023, Khairenagar, Pune
Late *kharif* onion nursery management	Training on Late *kharif* onion nursery management organized under MGMG scheme by ICAR-DOGR, Pune	7 August 2023, Saburdi, Pune
Late *kharif* onion nursery management	Training on Late *kharif* onion nursery management organized under MGMG scheme by ICAR-DOGR, Pune	9 August 2023, Gadakhwadi, Pune
Nursery management in late-*kharif* onion crop	Training on Late *kharif* onion nursery management organized under MGMG scheme by ICAR-DOGR, Pune	17 August 2023, Khadakwadi, Pune
Nursery management in late-*kharif* onion crop	Training on Late *kharif* onion nursery management organized under MGMG scheme by ICAR-DOGR, Pune	18 August 2023, Gosasi, Pune
Nursery management in late-*kharif* onion crop	Training on Late *kharif* onion production technology organized under MGMG scheme by ICAR-DOGR, Pune	5 September 2023, Kahu Koyali, Pune

Topic	Event and organizer	Date and Venue
Onion and garlic crop management	Training on Onion and garlic crop management organized under MGMG scheme by ICAR-DOGR, Pune	13 September 2023, Kanhur Mesai, Pune
Rabi onion production technology	Training on *Rabi* onionproduction technology organized under MGMG scheme by ICAR-DOGR, Pune	5 October 2023, Gulani, Pune
Onion and garlic cultivation technology	Training on Scientific cultivation of onion and garlic organized under SCSP scheme by ICAR-DOGR, Pune	18 October 2023, KVK, Narayangaon, Pune
Rabi onion production	Training on *Rabi* onion production technology organized under MGMG scheme by ICAR-DOGR	23 October 2023, Vetale, Pune
Rabi onion production	Training on *Rabi* onion production technology organized under MGMG scheme by ICAR-DOGR, Pune	25 October 2023, Loni, Pune
Rabi onion production technology	Training on *Rabi* onion production technology organized under MGMG scheme by ICAR-DOGR, Pune	30 October 2023 Dhamni, Pune
Kharif onion harvesting technology	Training on *Kharif* onion harvesting technology organized under MGMG scheme by ICAR-DOGR, Pune	6 November 2023, Varude, Pune
Kharif onion harvesting technology	Training on *Kharif* onion harvesting organized under MGMG scheme by ICAR-DOGR, Pune	10 November 2023, Mitgudwadi, Pune
Kharif onion harvesting technology	Training on *Kharif* onion harvesting organized under MGMG scheme by ICAR-DOGR, Pune	13 November 2023, Saburdi, Pune
Kharif onion harvesting technology	Training on *Kharif* onion harvesting organized under MGMG scheme by ICAR-DOGR, Pune	20 November 2023, Wafgaon, Pune
Improving socio-economic status of onion and garlic producing farmers through self-help groups	Training on Production technology of onion and garlic organized by Project Director (ATMA), Chandrapur	5-7 December 2023, ICAR-DOGR, Pune
Onion crop management in *rabi* season	Training on *Rabi* onion crop management organized under MGMG scheme by ICAR-DOGR, Pune	8 December 2023, Pondewadi, Pune
Rabi onion crop management	Training on *Rabi* onion crop management organized under MGMG scheme by ICAR-DOGR, Pune	15 December 2023, Ranmala, Pune
Onion crop management in *rabi* season	Training on *Rabi* onion crop management organized under MGMG scheme by ICAR-DOGR, Pune	18 December 2023, Kahu Koyali, Pune
S. J. Gawande		
Management of viral diseases in onion and Garlic	Three days training programme on production technology of onion and garlic organized under ATMA scheme by ICAR-DOGR, Pune	5-7 December 2023 ICAR-DOGR, Pune
S. Anandhan		
Exploring genome editing in genetically complex crops	NAHEP-CAAST training programme on “Genome editing: next frontiers in agriculture innovation”	5September 2023, IARI, New Delhi

Topic	Event and organizer	Date and Venue
Kalyani Gorrepati		
Storage of onions: traditional and advanced structures	One day training programme on "Value chain management in onion" for the farmers of Palandhu FPCL, Bijapur, Karnataka	28 June 2023, ICAR-DOGR, Pune
Dehydration in onion and garlic: product, process and opportunities	Entrepreneurship Development Programme (EDP) cum training programme on "Post-harvest processing and value addition in onion and garlic"	16-17 August 2023, ICAR-DOGR, Pune
Keynote presentation on Innovations in storage of onion	National Symposium cum Industry Meet (NSIM) 2023 on Agribusiness in Alliums: Innovation, Promotion and Sustainability (Theme 2: Processing and post-harvest management) organized by ICAR-DOGR	20-22 December 2023, Pune
Rajiv B. Kale		
Onion crop management for *rabi* season	Training on Azadi ka Amrut Mahotsav: *Rabi* onion crop management organized under MGMG scheme by ICAR-DOGR, Pune	3 January 2023, Khadakwadi, Pune
Technology transfer: concepts of yield gaps. FLD and OFT in relation to TOT programmes. Farming System Research and Extension (FSR&E) and participatory development approaches	Online guidance programme on ICAR NET/ SMS/STO Exam. Preparation for students organized by MPKV Rahuri during 25 March-20April 2023.	6 April, 2023 Virtual mode
Monitoring, evaluation and Impact analysis of extension programmes	Online guidance programme on ICAR-NET/ SMS/STO Exam. Preparation for students organized by MPKV Rahuri during 25March to 20April 2023	11 April 2023, Virtual mode
Satish Kumar		
Advances in exploring microbial communities of stress Niches: A microbiome perspective	21 days winter school on "Climate change & Abiotic Stress Management Solutions for Enhancing Water Productivity, Production quality, and Doubling Farmers income in Scarcity Zones organized at ICAR-NIASM, Baramati, Pune	5-25 January 2023, ICAR-NIASM, Baramati, Pune
Pranjali A. Gedam		
Abiotic stress management in onion and garlic	Three days training programme on "Production technology of onion and garlic" under ATMA scheme	5-7 December 2023 ICAR-DOGR, Pune
Soumia P.S.		
Insecticide safety management	Three days training programme on "Production technology of onion and garlic" under ATMA scheme	5-7 December 2023 ICAR-DOGR, Pune
Bhushan Bibwe		
Entrepreneurship in Onion and garlic Processing	Entrepreneurship Development training program on: "Agril. Food Processing, Packing &Marketing"	14 Aug - 8 Sep 2023
Processing in onion and garlic	Production Technology, of onion and garlic under ATMA scheme	5-7 December 2023

Topic	Event and organizer	Date and Venue
Processing and Value Addition of Onion	Program One day training programme on "Value chain management in onion" for the farmers of Palandhu FPCL, Bijapur, Karnataka	28 June 2023
Value added products in onion and garlic and opportunities for entrepreneurship	Entrepreneurship Development Program on Post Harvest Processing and Value addition in onion and garlic	16-17 August 2023
Sanket More		
Environment- Option for a Sustainable Future	World Environment Day- 2023, College of Agriculture, JAU, Junagadh	5 June 2023, College of Agril, JAU, Junagadh
Cultivation of underutilized crops in Hydroponics	Training program on Hydroponics and Vertical Farming, College of Agriculture, JAU, Junagadh	28 June 2023, College of Agriculture, JAU, Junagadh
High-Tech horticulture for sustainable production of undervalued fruit crops special reference to hydroponics	Training program on Automation in Protected Cultivation, College of Agriculture, JAU, Junagadh	7 December 2023, College of Agriculture, JAU, Junagadh
Seed production of commercially important vegetable crops	Training program on Promoting FPOs and Supporting Supply Chain, ICAR-KVK, Narayangaon	29 December 2023, ICAR-KVK, Narayangaon, Pune

K. 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. ,V. Karuppaiah, Dr. Kalyani Gorrepati, Mrs. Ashwini P. Benke, Dr. Pranjali A. Gedam, Dr. Manjunath Gowda DC., Dr. Y.P. Khade and Dr. Rajkumar Dagadkhair

IXX16120: Genetic improvement of white and yellow onion

PI: Dr. V. Mahajan and **Co-PIs:** Dr. A. J. Gupta, Dr. Ram Dutta, Dr. S.J. Gawande, Dr. Karruppaiah, Mrs. Ashwini P. Benke, Dr. Pranjali A. Gedam, Dr. Manjunath Gowda D C., Dr. Soumia P.S., Dr. Y. P. Khade, Dr. Shabeer Ahmed (NRCG, Pune) and Dr. Geetika Shameer (CITH, Srinagar)

IXX16060: Development of onion hybrids for quality and yielding traits

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

IXX16059: Genetic improvement of garlic through conventional and biotechnological approaches

PI: Dr. A. J. Gupta and **Co-PIs:** Dr. V. Mahajan, Dr. S.J. Gawande, Dr. Pranjali A. Gedam, Dr. Manjunath Gowda D C. and Dr. Geetika Shameer (CITH, Srinagar) (* Mrs Ashwini Benke PI of project on study leave)

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. V. Mahajan, Dr. A. J. Gupta, Dr. Pranjali A. Gedam and Mr. Radhakrishna A.

IXX16221: Abiotic stress management in onion and garlic

PI: Dr. Pranjali A. 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 (NRCG, 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 A. Gedam, Dr. Bhushan Bibwe and Dr. Shabeer Ahmed (NRCG, 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-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 A. 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 A. 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 Dr. Pranjali A. 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 and 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: Department of Science and Technology, New Delhi

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

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

Project 20: Evaluation of AgroNestsmart warehouse in reducing storage losses & prolonging the storage life of onions

PI: Dr. Bhushan Bibwe, Co-PI: Rajkumar Dagadkhair, Funding: Tata Steel

Project 21: Evaluation of IOT based device developed by GODAAM INNOVATIONS

PI: Dr. Bhushan Bibwe, Co-PI: Kalyani Gorrepati, Funding: GODAAM Innovations

Project 22: Capacity building and demonstration of improved technologies to enhance water use efficiency in onion

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

Funding: Development Support Centre, Narayangaon, Pune

L. Awards, Honours and Recognitions

Awards

- Ram Dutta, Jayalakshmi K, Satish Kumar, Radhakrishna A. and Vijay Mahajan conferred a best Poster Award for 'Trichoderma in Improving Storage Shelf life and Onion Health' in National Symposium cum Industry Meet on Agri-business in Alliums: Innovation, Promotion & Sustainability, organized by ICAR- DOGR, Pune during 20-22 December 2023.

- Gupta, A. J. conferred ISHRD Fellows Award-2019 and 2020 by Indian Society of Horticultural Research & Development (ISHRD) for his outstanding contribution in the field of Horticulture during Progressive Horticulture Conclave (PHC-2023) held at GBPUA&T, Pantnagar during 3-5 February 2023.

- Thangasamy, A., Komal Gade, Payal Arun Mahadhule, and Vijay Mahajan received "Best Oral Presentation Award" for paper entitled 'Nutrient uptake based NPKS scheduling through drip irrigation system for higher yield and nutrient uptake in onion seed crop'during Global Conference on Precision Horticulture for Improved livelihood, Nutrition and Environmental Services held at JISL, Jalgaon, Maharashtra, India during 28-31May 2023.

- Karuppaiah, V., Gadge, A.S., Shirsat, D.V., Soumia, P.S., Mainkar, P., Kumar, S., Jaiswal, D.K. and Mahajan, V. conferred Best Poster Paper Presentation award for 'Complete mitochondrial genome of Tetragonulairidipennis: An important non-Apis pollinators of onion' in 3rd National Symposium on Emerging Technologies and Trends in Sustainable Production and Value chain Management of Onion, Garlic and other Allium species held during 11–14 February, 2023 at Jain Hills, Jalgaon, Maharashtra

- Karuppaiah, V., Gadge, A. S., Pote, C. L., Shirsat, D. V., Soumia, P.S., Sawant, S.S., Pandit, T. R., Gurav, V. S., Ram Dutta and Mahajan, V.conferred Best Oral Paper Presentation award for 'Stingless bees in onion pollination: an assessment and scope for quality onion seed production' in National Symposium cum Industry Meet (NSIM) 2023 on Agribusiness in Alliums: Innovation, Promotion and Sustainability during 20-22 December 2023 organized at Pune.

- Karuppaiah, V., Pote, C. L., Shirsat, D. V., Soumia, P.S., Sawant, S.S., Pandit, T. R., Mahadule, P., Gade, K., Thangasamy, A, Kumar, S. and Mahajan, V.conferred best Poster Paper Presentation award for 'Nutraceutical and antioxidant properties of honey of stingless bee for aging onion' in National Symposium cum Industry Meet (NSIM) 2023 on Agribusiness in Alliums: Innovation, Promotion and Sustainability during 20-22 December 2023 organized at Pune.

- Pandit, T. R., Karuppaiah, V., Dwivedi, S. K., Soumia, P.S., Pawar, A.R. Patil, M. B., Pote, C. L., Shirsat, D. V. and Mahajan, V. conferred best poster paper presentation award for 'Role of Abiotic Drivers in Plant-Pollinator Associations for Quality Seed Production in Onion' in National Symposium cum Industry Meet (NSIM) 2023 on Agribusiness in Alliums: Innovation, Promotion and Sustainability during 20-22 December 2023 organized at Pune.

- Kalyani Gorrepati, Bhushan Bibwe, Rajkumar Dagadkhair and Vijay Mahajanconferred a Best Poster Paper Presentation award for 'Development of ready to cook dehydrated onion-based snack mix' inNational Symposium cum Industry Meet (NSIM) 2023 on Agribusiness in Alliums: Innovation, Promotion and Sustainability during 20-22 December 2023 at MCCIA trade tower Pune, Maharashtra**.**

- Kale R.B., Thangasamy A., Gadge S.S., More S., Singh S.V., Shah K. and Bhole N. conferred Best Poster Presentation Award for the paper 'ONDSS: A decision support system for balanced nutrition management in onion' in "3rd National Symposium on Emerging Technologies and Trends in Sustainable Production and Value Chain Management of Onion, Garlic and Other Allium Species" organized by Indian Society of Alliums, ICAR-DOGR and Jain Irrigation during 11-14 February 2023 at Jalgaon, Maharashtra.

- Gaikwad S., Singh S.V., Gavhane S.D., Kale R.B. and Gadge S.S.conferred Best Poster Presentation Award for the paper 'Harnessing benefits of social media for transfer of onion and garlic technologies' presented in "3rd National Symposium on Emerging Technologies and Trends in Sustainable Production and Value Chain Management of Onion, Garlic and Other Allium Species" organized by Indian Society of Alliums, ICAR-DOGR and Jain Irrigation during 11-14 February 2023 at Jalgaon, Maharashtra.

- Kiran Khandagale, Sunil Dalvi, Pravin Khambalkar, Indira Bhangare, Anusha R, Rajiv B. Kale and Suresh Gawande conferred Best Poster Presentation Award for the paper 'Chitosan-Nano Conjugate Promotes Growth and Stemphylium Leaf Blight Resistance in Onion' in "3rd National Symposium on Emerging Technologies and Trends in Sustainable Production and Value Chain Management of Onion, Garlic and Other Allium Species" organized by Indian Society of Alliums, ICAR-DOGR and Jain Irrigation during 11-14 February 2023 at Jalgaon, Maharashtra.

- Yogesh Mhaske, Abhishek Wakchaure, Rajiv B Kale, Bhushan Bibwe, Abhishek Gavhane, Shivam Gaikwad, Sharadveer Singh and Kiran Khandagaleconferred Best Poster Presentation Award for the paper 'Spraying the skies: comparative business perspectives on agricultural UAVs and traditional methods' in National symposium cum Industry meet on 'Agri-business in Alliums: Innovation, Promotion and sustainability, organized by ICAR-DOGR, MCCIA, Pune and Indian Society of Alliums during 20-22 December 2023 at MCCIA trade tower Pune, Maharashtra

- Sharadveer Singh, R. B. Kale, S.S. Gadge, Shivam Y Gaikwad and Rohini Bhat conferred Best Poster Presentation Award for the paper 'Mapping onion market dynamics in India: a comprehensive analysis of seasonal fluctuations, regional disparities and strategies for market stability ' in National symposium cum Industry meet on 'Agri-business in Alliums: Innovation, Promotion and sustainability, organized by ICAR-DOGR, MCCIA, Pune and Indian Society of Alliums during 20-22 December 2023 at MCCIA trade tower Pune, Maharashtra

- Rohini Bhat, Rajiv B Kale, Kalyani Gorrepati, Bhushan Bibwe and Rajkumar Dagadkhair conferred Best Oral Presentation Award for the paper 'Seeds of innovation nurturing agri-startups and FPOs at agri business incubation centre, ICAR-DOGR, Pune' in National symposium cum Industry meet on 'Agri-business in Alliums: Innovation, Promotion and sustainability, organized by ICAR-DOGR, MCCIA, Pune and Indian Society of Alliums during 20-22 December 2023 at MCCIA trade tower Pune, Maharashtra.

- Benke Ashwini, Mahajan V., and Mokat D.N. conffered best oral presentation "Garlic (*Allium sativum* L.) essential oil: Bioactive compound diversity" in National Symposium cum Industry Meet 2023 on Agribusiness in Allium: Innovation, Promotion & Sustainability organized by ABI centre and ITMU, ICAR-DOGR in collaboration with Indian Society of Alliums and MCCIA, Pune held at MCCIA, Pune.

- Radhakrishna A, Ram Dutta, Jayalakshmi K, Satish Kumar, Manjunathagowda DC, Kiran Bhagat, Ashwini Benke, Sharath MN, Vishal Gurav and Vijay Mahajan conferred a best Oral Paper Presentation award for 'Bio-control potential of Trichoderma for Anthracnose-Twister disease of onion' authored by in 3rd National Symposium on Emerging Technologies and Trends in Sustainable Production and Value Chain Management of Onion, Garlic and Other Allium Species, 11-14 February 2023, Jalgaon, Maharashtra.

- Pranjali A. Gedam, A. Thangasamy, D. V. Shirsat, Rajiv Kale, Yash Wakodikar and Tanmayi Chaturvedula, Snehal Bhandari and Vijay Mahajan conferred a best Poster Presentation Award for 'Effect of Plant Time on onion crop growth and yield' authored by during 3rd National Symposium on Emerging Technologies and Trends in Sustainable Production and Value Chain Management of Onion, Garlic and Other Allium Species 11-14February, 2023 Jalgaon, Maharashtra.

- Durga Aware, Kalyani Gorrepati, Bhushan Bibwe, Ashok Kumar and Vijay Mahajan conferred a Best Poster Paper Presentation award for shelf-life and quality changes in green onion stored at different temperatures during 3rd National Symposium on Emerging Technologies and Trends in Sustainable Production and Value Chain Management of Onion, Garlic and Other Allium Species 11-14 February, 2023 Jalgaon, Maharashtra

- Bhushan Bibwe, Kalyani Gorrepati, Rajkumar Dagadkhair, Sanket More, Rajiv B. Kale, Indrajeet Girase and Vijay Mahajanconferred a Best Oral Paper Presentation award for 'Extraction and characterization of onion seed oil for medicinal and industrial uses' in National Symposium cum Industry Meet (NSIM) 2023 on Agribusiness in Alliums: Innovation, Promotion and Sustainability during 20-22 December 2023 during 20-22 December 2023 at MCCIA trade tower Pune, Maharashtra**.**

- Dagadkhair R.A, Raichurkar S.J, Athawale G.H Sarkate S J, Sasane A.K., Shaikh A. R, Shengale P. K.conferred a Best Poster Paper Presentation award for Garlic juice extract as a natural preservative in egg omelet Ready-mixduring 3rd National Symposium on Emerging Technologies and Trends in Sustainable Production and Value Chain Management of Onion, Garlic and Other Allium Species 11-14 February, 2023 Jalgaon, Maharashtra

- Sahu P.K., Jayalakshmi K, Tilgam J, Gupta A, Nagaraju Y, Kumar A, Hamid S, Singh HV, Minkina T, Rajput VD and Rajawat MVS**,** conferred a Best Publication Award: Kanwar Veeerendra Singh Memorial All India best publication award by Sadhana, Society for advancement of human and nature, Dr YS Parmar University of Horticulture and Forestry, PO Nauni, Solan, Himachal Pradesh, India 15 Feb, 2023 for publication 'ROS generated from biotic stress: Effects on plants and alleviation by endophytic microbes'.

M. Publications

Publication in referred journals

1. Benke, A.P., Krishna, R., Khandagale, K., Gawande, S., Shelke, P., Dukare, S., Dhumal, S., Singh, M. and Mahajan, V., 2023. Efficient elimination of viruses from garlic using a combination of shoot meristem culture, thermotherapy, and chemical treatment. Pathogens, 12(1), p.129.

2. Bhushan, B., Bibwe, B., Pal, A., Mahawar, M.K., Dagla, M.C., Yathish, K.R., Jat, B.S., Kumar, P., Aggarwal, S.K., Singh, A. and Chaudhary, D.P., 2023. FTIR spectra, antioxidant capacity and degradation kinetics of maize anthocyanin extract under variable process conditions. Applied Food Research, 3(1), p.100282.

3. Gedam, P.A., Khandagale, K., Shirsat, D., Thangasamy, A., Kulkarni, O., Kulkarni, A., Patil, S.S., Barvkar, V.T., Mahajan, V., Gupta, A.J. and Bhagat, K.P., 2023. Elucidating the molecular responses to waterlogging stress in onion (*Allium cepa* L.) leaf by comparative transcriptome profiling. Frontiers in Plant Science, 14, p.1150909.

4. Giri, M.S., Rabinal, C.A., Raju, J. and Jayalakshmi, K., 2023. Isolation and screening of anti-microbial compounds produced by fluorescent pseudomonads against *Xanthomonas axonopodis*Pv. Punicae. 109-114.

5. Gowd, T.Y.M., Deo, C., Manjunathagowda, D.C., Mahajan, V., Bhutia, N.D. and Singh, B., 2023. Allelic variability and transferability of atp6 gene among Allium species. Genetic Resources and Crop Evolution, 70(1), pp.281-287.

6. Gowd, T.Y.M., Deo, C., Manjunathagowda, D.C., Mahajan, V., Dutta, R., Bhutia, N.D., Singh, B. and Mounika, V., 2023. Deployment of Intron Length Polymorphic (ILP) markers in dissipating diversity of Allium species. South African Journal of Botany, 160, pp.157-165.

7. Gupta AJ, Khade YP, Mahajan V, Hange SR, Shalaka RS and Singh M. 2023. Morphological and molecular characterization of multiplier onion (*Allium cepa* var. aggregatum) genotypes.*Plant Molecular Biology Reporter* 42:224-234.https://doi.org/10.1007/s11105-023-01415-4

8. Jayaswall, K., Sharma, H., Jayaswal, D., Sagar, R., Bhandawat, A., Kumar, A., Sharma, I., Chaturvedi, P., Manjunathagowda, D.C., Kumar, D. and Mahajan, V., 2023. Development of chloroplast derived SSR markers for genus Allium and their characterization in the allies for genetic improvement of Alliums. South African Journal of Botany, 162, pp.304-313.

9. Kale R.B., Gadge S.S., Gupta A.J. and Mahajan V. 2023. Technologies in boosting production and improving socio-economic development of the farmers. In: book of Abstracts-Lead Papers: Third National Symposium on Emerging Technologies and Trends in Sustainable Production and Value Chain Management of Onion, Garlic and other Allium Species. Eds.

10. Karuppaiah, V., Gadge, A.S., Shirsat, D.V., Soumia, P.S., Mainkar, P., Kumar, S., Jaiswal, D.K. and Mahajan, V., 2023. The complete mitochondrial genome of the Indian dammer bee, *Tetragonulairidipennis*, and the phylogenomics of Meliponini. Frontiers in Ecology and Evolution, 11, p.1171242.

11. Karuppaiah, V., Maruthadurai, R., Das, B., Soumia, P.S., Gadge, A.S., Thangasamy, A., Ramesh, S.V., Shirsat, D.V., Mahajan, V., Krishna, H. and Singh, M., 2023. Predicting the potential geographical distribution of onion thrips, *Thrips tabaci* in India based on climate change projections using MaxEnt. Scientific Reports, 13(1), p.7934.

12. Karuppaiah, V., Soumia, P.S. and Singh, M., 2023. Bioefficacy, phytotoxicity and safety of Virtako 1.5 Gr a premixed commercial insecticide against thrips, black cutworm and natural enemies in onion. Journal of Environmental Biology, 44(2), pp.200-206.

13. Kumar, N., Chandan, K., Bhushan, S., Singh, D. and Satish, K. (2023). Health risk assessment and metal contamination in fish, water and soil sediments in the East Kolkata Wetlands, India, Ramsar site. Scientific Reports. 13, 1546 (2023).

14. Kumar, N., Singh, A.K., Kumar, S., Kumar, T., Kochewad, S.A., Thorat, S.T., Patole, P.B. and Gite, A., 2023. Nano-copper enhances thermal efficiency and stimulates gene expression in response to multiple stresses in *Pangasianodonhypophthalmus* (Striped catfish). Aquaculture, 564, p.739059.

15. Kumar, S., Bhushan, B., Wakchaure, G.C., Dutta, R., Jat, B.S., Meena, K.K., Rakshit, S. and Pathak, H., 2023. Unveiling the impact of heat stress on seed biochemical composition of major cereal crops: Implications for crop resilience and nutritional value. Plant Stress, 9, p.100183.

16. Mahajan, V. and Gupta, A.J., 2023. Onion: Breeding and Genomics. Vegetable Science, pp.244-260.

17. Mainkar, P., Manape, T.K., Satheesh, V. and Anandhan, S., 2023. CRISPR/Cas9-mediated editing of PHYTOENE DESATURASE gene in onion (*Allium cepa* L.). Frontiers in Plant Science, 14, p.1226911.

18. Manape, T.K., Soumia, P.S., Khade, Y.P., Satheesh, V. and Anandhan, S., 2023. A glossy mutant in onion (*Allium cepa* L.) shows decreased expression of wax biosynthesis genes. Frontiers in Plant Science, 14, p.1245308.

19. Mangal, V., Bhandari, H., Meena, J.K., Kumar, A.A., Thribhuvan, R., Chourasia, K.N., Bairwa, R.K. and Kar, C.S., 2023. Genetic diversity analysis for seed yield attributing traits in white jute (*Corchorus Capsularis* L.). Indian Journal of Plant Genetic Resources, 36(01), pp.31-36.

20. Meena, K.K., Bitla, U., Sorty, A.M., Kumar, S., Kumar, S., Wakchaure, G.C., Singh, D.P., Stougaard, P. and Suprasanna, P., 2023. Understanding the interaction and potential of halophytes and associated microbiome for bio-saline agriculture. Journal of Plant Growth Regulation, 42(10), pp.6601-6619.

21. More, S.J., Bardhan, K., Ravi, V., Pasala, R., Chaturvedi, A.K., Lal, M.K. and Siddique, K.H., 2023. Morphophysiological responses and tolerance mechanisms in cassava (*Manihot esculenta* Crantz) under drought stress. Journal of Soil Science and Plant Nutrition, 23(1), pp.71-91.

22. More, S.J., Ravi, V., Sreekumar, J., Kumar, J.S. and Raju, S., 2023. Exogenous application of calcium chloride, 6-Benzyladenine and salicylic acid modulates morpho-physiological and tuber yield responses of sweet potato exposed to heat stress. South African Journal of Botany, 155, pp.60-78.

23. Roylawar, P., Khandagale, K., Nanda, S., Soumia, P.S., Jadhav, S., Mahajan, V. and Gawande, S., 2023. Colonization of *Serendipita indica* promotes resistance against *Spodoptera exigua* in onion (*Allium cepa* L.). Frontiers in Microbiology, 14, p.1190942.

24. Rupawate, P.S., Roylawar, P., Khandagale, K., Gawande, S., Ade, A.B., Jaiswal, D.K. and Borgave, S., 2023. Role of gut symbionts of insect pests: A novel target for insect-pest control. Frontiers in Microbiology, 14, p.1146390.

25. Sahu, P.K., Shafi, Z., Singh, S., Ojha, K., Jayalakshmi, K., Tilgam, J., Manzar, N., Sharma, P.K. and Srivastava, A.K., 2023. Colonization potential of endophytes from halophytic plants growing in the "Runn of Kutch" salt marshes and their contribution to mitigating salt stress in tomato cultivation. Frontiers in Microbiology, 14, p.1226149.

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27. Thangasamy, A., Gedam, P. A., Soumia, P. S., Sourav Ghosh, Karuppaiah, V., Vijay Mahajan and Major Singh., 2023. Inter-annual variability in monsoon rainfall and its distribution on plant growth and yield of *kharif* onion in tropical region of India. *Current Science*. 124(6):713-721.

28. Vijaykumar, K.N., Kulkarni, S., Hiremath, S.M., Shashidhar, T.R., Kambrekar, D.N., Mahajan, V., Khar, A. and Patil, P.V., 2023. Field Screening of Garlic Genotypes for Identification of Resistant Sources against Purple Blotch Disease. International Journal of Plant & Soil Science, 35(14), pp.365-370.

29. Wakchaure, G.C., Khapte, P.S., Kumar, S., Kumar, P.S., Sabatino, L. and Kumar, P., 2023. Exogenous growth regulators and water stress enhance long-term storage quality characteristics of onion. Agronomy, 13(2), p.297.

30. Wakchaure, G.C., Minhas, P.S., Kumar, S., Khapte, P.S., Dalvi, S.G., Rane, J. and Reddy, K.S., 2023. Pod quality, yields responses and water productivity of okra (*Abelmoschus esculentus* L.) as affected by plant growth regulators and deficit irrigation. Agricultural Water Management, 282, p.108267.

31. Wakchaure, G.C., Minhas, P.S., Kumar, S., Khapte, P.S., Rane, J. and Reddy, K.S., 2023. Bulb productivity and quality of monsoon onion (*Allium cepa* L.) as affected by transient waterlogging at different growth stages and its alleviation with plant growth regulators. Agricultural Water Management, 278, p.108136.

32. Wakchaure, G.C., Minhas, P.S., Kumar, S., Mane, P., Kumar, P.S., Rane, J. and Pathak, H., 2023. Long-term response of dragon fruit *(Hylocereus undatus*) to transformed rooting zone of a shallow soil improving yield, storage quality and profitability in a drought prone semi-arid agro-ecosystem. Saudi Journal of Biological Sciences, 30(1), p.103497.

33. Yalamalle, V.R., Dinesh, I., Gawande, S.J. and Khandagale, K., 2023. *Piriformospora indica* promotes plant growth, reduces lodging, and enhances seed yield and quality in onion (*Allium cepa* L). Indian Journal of Agricultural Sciences 94: 3.

Papers and abstracts in Conference/ Seminar/ Symposia/ Workshop

1. Mahajan V, 2023. Lead Lecture on Breeding for processing traits in onion, during 3rd National symposium on emerging technologies and trends in sustainable production and value chain management of onion, garlic and other *Allium* species, 11-14 Feb 2023 organized by ISA, Pune

2. Gupta AJ, Mahajan V and Singh M 2023. Lead Lecture on Status of onion breeding and future challenges in India during 3rd National symposium on emerging technologies and trends in sustainable production and value chain management of onion, garlic and other *Allium* species, 11-14 Feb 2023 organized by ISA, Pune.

3. Gupta AJ presented lead paper in "Progressive Horticulture Conclave-2023 on Transforming Horticultural: Science into Technology" organized by ISHRD and GBPUAT at Pantnagar during 3-5 Feb 2023.

4. Gedam PA. 2023. Lead paper presentation on "Abiotic stresses and their impact on onion production" during 3rd National Symposium on Emerging Technologies and Trends in Sustainable Production and Value Chain Management of Onion, Garlic and Other Allium Species February 11-14, 2023; Jalgaon, Maharashtra.

5. Satish Kumar, invited as lead speaker for the topic 'Advances in exploring microbial communities of stress Niches: A microbiome perspective' in 21 days winter school on "Climate change & Abiotic Stress Management Solutions for Enhancing Water Productivity, Production quality, and Doubling Farmers income in Scarcity Zones organized at ICAR-NIASM, Baramati, Pune from 5-25 January 2023.

6. Satish Kumar. 2023. Lead Presentation on Biological management of Anthracnose -Twister disease for maintaining supply chain and round the year availability of onion. during 3rd National Symposium on Emerging Technologies and Trends in Sustainable Production and Value Chain Management of Onion, Garlic and Other Allium Species February 11-14, 2023; Jalgaon, Maharashtra.

7. Kalyani Gorrepati, 2023. Delivered a keynote presentation on Innovations in storage of onion in National Symposium cum Industry Meet (NSIM) 2023 on Agribusiness in Alliums: Innovation, Promotion and

Sustainability (Theme 2: Processing and Post-Harvest Management) during 20-22 December 2023 organized at Pune.

8. Rajiv Kale, 2023, invited as a lead speaker on “Onion production technology” for 91st farmer scientist farmer programme (1 Oct.2023) organized by KVK, Chhatrapati Sambhajinagar.

9. Bhushan Bibwe, Kalyani Gorrepati, Rajkumar Dagadkhair, Sanket More, Rajiv B. Kale, Indrajeet Girase and Vijay Mahajan (2023). Extraction and characterization of onion seed oil for medicinal and industrial uses. National Symposium cum Industry Meet (NSIM) 2023 on Agribusiness in Alliums: Innovation, Promotion and Sustainability during 20-22 December 2023 organized at MCCIAPune.

10. Gaikwad S., Singh S.V., Gavhane A.D., Kale R.B. and Gadge S.S. 2023. Harnessing benefits of social media for transfer of onion and garlic technologies. Eds. Mahajan V., Dutta R., Gupta A.J., Gawande S.J., Anandhan S., Gadge S.S., Thangasamy A., Karuppaiah V., Kale R.B., Satishkumar, Soumia P.S., Bibwe R.B., Khade Y.P., Dagadkhair R, Bhat R. and Singh P.R., ISA, ICAR-DOGR, Pune & Jain Irrigation, Jalgaon. pp. 154-155.

11. Gedam PA, Thangasamy A, Bhagat K, Rane J, Kumar M, Gupta AJ, Bhandari S, More S, Khade YP, Salunkhe VN and Mahajan V 2023. Sensor-based high-throughput phenotyping to dissect genotypic differences in onion genotypes for drought tolerance. National Symposium cum Industry Meet on Agribusiness in Alliums, Innovations, Promotion and Sustainability, 20-22 Dec, 2023 organized by ICAR-DOGR, Pune. pp 36-37.

12. Gupta AJ, Mahajan V and Singh M 2023. Genetic improvement in onion for wide adaptability. Souvenir-cum-Compendium of Abstracts: Progressive Horticulture Conclave: Transforming horticulture science into technology, 3-5 Feb, 2023 organized by ISHRD and GPUA&T, Pantnagar, Uttarakhand. p. 18.

13. Gupta AJ, Mahajan V, Mainkar P and Gorrepati K 2023. Investigating the impact of massing cages with variable dimensions on bulb-to-seed production in onion. National Symposium cum Industry Meet on Agribusiness in Alliums, Innovations, Promotion and Sustainability, 20-22 Dec, 2023 organized by ICAR-DOGR, Pune. pp 27-28.

14. Gupta AJ, Mahajan V, Singh M, Patil HB, Kadam G and Takale TM 2023. Enhancing onion production through the outstation bulbs to seed approach: A multi-location analysis. National Symposium cum Industry Meet on Agribusiness in Alliums, Innovations, Promotion and Sustainability, 20-22 Dec, 2023 organized by ICAR-DOGR, Pune. pp 78-79.

15. Kale R.B., Gadge S.S., Gupta A.J. and Mahajan V. 2023. Technologies in boosting production and improving socio-economic development of the farmers. In: book of Abstracts-Lead Papers: Third National Symposium on Emerging Technologies and Trends in Sustainable Production and Value Chain Management of Onion, Garlic and other Allium Species. Eds. Mahajan V., Dutta R., Gupta A.J., Gawande S.J., Anandhan S., Gadge S.S., Thangasamy A., Karuppaiah V., Kale R.B., Satish kumar, Soumia P.S., Bibwe R.B., Khade Y.P., Dagadkhair R, Bhat R. and Singh P.R., ISA, ICAR-DOGR, Pune & Jain Irrigation, Jalgaon. p.23.

16. Kale R.B., Gadge S.S., Mahajan V., Gupta A.J., Khade Y.P., More S., Gaikwad S., Gavhane A.D., Shah K. and Bhole N. 2023. Smart Onion: ICAT based variety selection and cultivation advisor for farmer. In: book of Abstracts-Lead Papers: Third National Symposium on Emerging Technologies and Trends in Sustainable Production and Value Chain Management of Onion, Garlic and other Allium Species. Eds. Mahajan V., Dutta R., Gupta A.J., Gawande S.J., Anandhan S., Gadge S.S., Thangasamy A., Karuppaiah V., Kale R.B., Satishkumar, Soumia P.S., Bibwe R.B., Khade Y.P., Dagadkhair R, Bhat R. and Singh P.R., ISA, ICAR-DOGR, Pune & Jain Irrigation, Jalgaon. p.153.

17. Kale R.B., Thangasamy A., Gadge S.S., More S., Singh S.V., Shah K. and Bhole N. 2023. 'ONDSS': A Decision Support System for balanced nutrition management in onion. In: book of Abstracts-Lead Papers: Third National Symposium on Emerging Technologies and Trends in Sustainable Production and Value Chain Management of Onion, Garlic and other Allium Species. Eds. Mahajan V., Dutta R., Gupta A.J., Gawande S.J., Anandhan S., Gadge S.S., Thangasamy A., Karuppaiah V., Kale R.B., Satishkumar, Soumia P.S., Bibwe R.B., Khade Y.P., Dagadkhair R, Bhat R. and Singh P.R., ISA, ICAR-DOGR, Pune & Jain Irrigation, Jalgaon. p.154.

18. Kale RB, Gadage SS, Mahajan V, Gupta AJ, Khade YP, More SJ, Gaikwad S, Gavhane AD, Shah K, Bhole N. 2023. Smart Onion: ICT Based Variety Selection and Cultivation Advisor for Farmers. 3rd National Symposium on Emerging Technologies and Trends in Sustainable Production and Value Chain Management for Onion, Garlic, and Other *Allium* Species, held at Jain Hill, Jalgaon, from March 11 to 14, 2023.

19. Karuppaiah, V. (2023). 'MaxEnt modeling for predicting habitat suitability and potential distribution onion thrips, *Thrips tabaci* in India'. International on Conference Plant Health Management (ICPHM -2023) during 15-18 November, Hyderabad.

20. Karuppaiah, V. (2023). 'Predicting the potential geographical distribution of onion thrips, *Thrips tabaci* in India under climate change cmip6 projection using MaxEnt modeling'. 3rdNational Symposium on Emerging Technologies and Trends in Sustainable Production and Value chain Management of Onion, Garlic and other Allium species during 11–14 Februaty, 2023 at Jain Hills, Jalgaon, Maharashtra.

21. Karuppaiah, V. (2023). 'Stingless bees in onion pollination: an assessment and scope for quality onion seed production'. National Symposium cum Industry Meet on Agri-business in Alliums: Innovation, Promotion & Sustainability (NSIM-2023) during 20-23 December, 2023 at Maratha Chamber of Commerce, Industries and Agriculture, Pune.

22. Karuppaiah, V., Gadge, A. S., Pote, C. L., Shirsat, D. V., Soumia, P.S., Sawant, S.S., Pandit, T. R., Gurav, V. S., Ram Dutta and Mahajan, V. Stingless bees in onion pollination: an assessment and scope for quality onion seed production. National Symposium cum Industry Meet (NSIM) 2023 on Agribusiness in Alliums: Innovation, Promotion and Sustainability during 20-22 December 2023 organized at Pune.

23. Karuppaiah, V., Pote, C. L., Shirsat, D. V., Soumia, P.S., Sawant, S.S., Pandit, T. R., Mahadule, P., Gade, K., Thangasamy, A, Kumar, S. and Mahajan, V. Nutraceutical and antioxidant properties of honey of stingless bee foraging onion. National Symposium cum Industry Meet (NSIM) 2023 on Agribusiness in Alliums: Innovation, Promotion and Sustainability during 20-22 December 2023 organized at Pune.

24. Khade YP Shalaka RS, Singh PR, Radhakrishna A and Mahajan V. (2023). "Genetic studies and molecular characterisation of late *kharif* onion (*Allium cepa* L.)". 3rd National Symposium on Emerging Technologies and Trends in Sustainable Production and Value Chain Management of Onion, Garlic and other Allium species during 11-14th February 2023.

25. Khade YP Shalaka RS, Singh PR, Radhakrishna A and Mahajan V. (2023) "Genetic studies and molecular characterisation of late *kharif* onion (*Allium cepa* L.)" authored during 3rd National Symposium on Emerging Technologies and Trends in Sustainable Production and Value Chain Management of Onion, Garlic and other Allium species from 11-14th February 2023.

26. Mahawar MK, Bharimalla AK, Thangasamy A, Vigneshwaran N, Dhakane-Lad J, Bibwe B., 2023. Efficacy evaluation of ICAR-CIRCOT Nano-sulphur on growth parameters of Onion and Garlic. In: 2nd International conference on "Prospects and Challenges of Environment and Biological Sciences in Food Production System for Livelihood Security of Farmers (ICFPLS-2023)" during 18-20th September, 2023, pp: 38-39

27. Manape TK, Soumia PS, Khade YP, Viswanathan S and Anandhan S. (2023). "RNA-seq and physiochemical analyses of glossy mutant of Indian short-day onion'. 3rd National Symposium on Emerging Technologies and Trends in Sustainable Production and Value Chain Management of Onion, Garlic and other Allium species duri 11-14th February 2023.

28. Pandit, T. R., Karuppaiah, V., Dwivedi, S. K., Soumia, P.S., Pawar, A.R. Patil, M. B., Pote, C. L., Shirsat, D. V. and Mahajan, V. Role of Abiotic Drivers in Plant-Pollinator Associations for Quality Seed Production in Onion. National Symposium cum Industry Meet (NSIM) 2023 on Agribusiness in Alliums: Innovation, Promotion and Sustainability during 20-22 December 2023 organized at Pune.

29. Ram Dutta, Jayalakshmi K, Satish Kumar, Manjunathagowda DC, Radhakrishna A, Kiran Bhagat, Ashwini Benke, Sharath MN, Vishal Gurav and Vijay Mahajan. Bio control potential of *Trichoderma* for anthracnose-twister disease of onion in Maharashtra. 3rd National Symposium on Emerging Technologies and Trends in Sustainable Production and Value Chain Management of Onion, Garlic and Other Allium

Species. By Indian Society of Alliums, ICAR-DOGR, Pune, Jain Irrigation Systems Limited, Jalgaon,11-14 February, 2023,106p

30. Ram Dutta, Jayalakshmi K, Satish Kumar, Radhakrishna A and Vijay Mahajan (2023). Trichoderma in Improving Storage Shelf life and Onion Health. National Symposium cum Industry Meet on Agri-business in Alliums: Innovation, Promotion & Sustainability, ICAR- DOGR, Pune 20-22nd December, 2023 49-50p.

31. Ram Dutta, Satish Kumar, Jayalakshmi K, Radhakrishan A, Manjunath Gowda, Kiran Bhagat, Vijay Mahajan. Field application of different trichoderma strains boost up the plant growth, final yield, and bulb quality in *rabi* onion. 3rd National Symposium on Emerging Technologies and Trends in Sustainable Production and Value Chain Management of Onion, Garlic and Other Allium Species. By Indian Society of Alliums, ICAR-DOGR, Pune, Jain Irrigation Systems Limited, Jalgaon,11-14 February, 2023,107p.

32. Singh S.V., Gaikwad S., Gavhane A.D., Kale R.B. and Gadge S.S. 2023.Onion price volatility and technological options to minimize price shocks. Eds. Mahajan V., Dutta R., Gupta A.J., Gawande S.J., Anandhan S., Gadge S.S., Thangasamy A., Karuppaiah V., Kale R.B., Satishkumar, Soumia P.S., Bibwe R.B., Khade Y.P., Dagadkhair R, Bhat R. and Singh P.R., ISA, ICAR-DOGR, Pune & Jain Irrigation, Jalgaon. pp.155-156.

33. Soumia, P. S., Shirsat, D. V., Gorrepati, K., Karuppaiah, V. and Mahajan, V. (2023). First record of *Carpophilushemipterus* (*Nitidulidae, Coleoptera*), a dried-fruit beetle, in stored onions. National Symposium cum Industry Meet (NSIM) 2023 on Agribusiness in Alliums: Innovation, Promotion and Sustainability during 20-22 December 2023 organized at Pune.

34. Thangasamy, A., Komal Gade, Payal Arjun Mahadhule, and Vijay Mahajan (2023). Nutrient uptake based NPKS scheduling through drip irrigation system for higher yield and nutrient uptake in onion seed crop. Global Conference on Precision Horticulture for Improved livelihood, Nutrition and Environmental Services.JISL, Jalgaon, Maharashtra, India during May 28-31, 2023.

35. Thangasamy, A., presented POLY4 a natural source of Potassium and Sulphur in Onion and Garlic during technical Session-III: “Efficient nutrient management in Industrial and Cash crops”. Research Co-operator's Conference organized by Division of Agronomy, ICAR-IARI, New Delhi from 11-13 December 2023 at NAAS, NASC Complex, ICAR, New Delhi 110012

Book/ Report/ Proceedings

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N. Institutional Activities

Dr. Vijay Mahajan Assumes Charge as Director of the Institute

Dr. Vijay Mahajan took over charge of Director at the Institute on 22 February 2023. Prior to this appointment, he served as Principal Scientist and Acting Director of ICAR-DOGR, Pune. Dr. Mahajan has made significant contribution to the agricultural research, notably in development of two fruit cultivars, ten onion varieties and two garlic varieties. His research has been widely recognized with many publications in reputed national and international journals that are highly cited in the field. In addition to his research expertise, he has played a key role in extension activities, which has led to development of several seed villages and the popularization of technologies developed by ICAR-DOGR. His leadership and expertise are expected to greatly benefit the institute as it continues to make excellence in onion and garlic research.

ICAR-DOGR celebrated International Women's Day 2023

The Women Cell of ICAR-DOGR organized an International Women's Day 2023 with the theme "Women DigitALL: Innovation and Technology for Gender Equality" at the conference hall of ICAR-DOGR, Rajgurunagar on Wednesday, March 8, 2023. During the first part of the program, Dr. Pranjali A. Gedam, Chairperson of the Women Cell, ICAR-DOGR welcomed all the Women staff of ICAR-DOGR including students, YPs/SRF and RA; and highlighted the significance of celebrating the International Women's Day by recognizing the social, economic, cultural, and political accomplishments of women. This programme was chaired by Dr. Vijay Mahajan, Director, ICAR-DOGR. Dr. Mahajan reminisced the history of Women's Day and the need for gender equality, and the empowerment of women. Dr. Ram Dutta, Principal Scientist (Plant Pathology), ICAR-DOGR, in his address, emphasized on people of all genders should be treated equally. Dr. Amar Jeet Gupta, Principal Scientist (Horticulture), ICAR-DOGR shared success stories on role of women in agricultureand highlighted the equal contribution of both women and men to the betterment of the home and society. Mrs. Poonam Shelke, Member of women cell committee, ICAR-DOGR, spoke on the freedom of women in the work place and their importance in both family and nations progress. Later, several competitions were held and prizes were distributed to the winners. In total, 80 participants attended the programme. The event was successful in making women more aware of their equality and individuality. Vote of thanks was proposed by Dr. Soumia P.S., Scientist (Agricultural Entomology) and Member of women cell committee.

III[rd] National Symposium on Alliums

The Indian Society of Alliums, in collaboration with ICAR-Directorate of Onion and Garlic Research (ICAR-DOGR), Pune and Jain Irrigation Systems Pvt. Ltd., Jalgaon organized the III[rd] National Symposium on Emerging Technologies and Trends in Sustainable Production and Value Chain Management of Onion, Garlic, and Other Allium Species during 11-14 February 2023 at Jain Irrigation Systems Pvt. Ltd., Jalgaon, Maharashtra. The symposium attracted 166 delegates from various parts of India, including representatives from the Agricultural Department, Marketing Board, Agricultural Universities, industries, agri-start-ups, Farmer Producer Organizations, exporters, and progressive farmers. The inaugural session was graced by distinguished guests such as Dr. S. N. Puri, Ex-Vice Chancellor, CAU Manipur; Dr. H. P. Singh, Ex-DDG (Horticultural Sciences), ICAR; Sri Anil Jain, Vice Chairman/MD, Jain Irrigation Systems Pvt. Ltd.; and Dr. Sudhakar Pandey, ADG (Vegetables), ICAR, New Delhi, among others. The symposium consisted of seven technical sessions focusing on topics such as crop improvement, stress management, post-harvest management, processing and value addition, mechanization, and supply chain management. Twenty lead papers and 32 oral papers were presented over the four-day event, with additional poster sessions held on seven themes. Deliberations led to the identification of key action points and recommendations for researchers and policymakers. An exposure visit was organized to onion and garlic demonstration plots, a processing unit, a tissue culture laboratory, and various facilities at Jain Irrigation Systems Pvt. Ltd. The demonstration included over 80 varieties of onion and garlic and various farming machineries. The delegates expressed their appreciation for the symposium and the collaborative efforts of the Indian Society of Alliums, ICAR-DOGR, and Jain Irrigation Systems Pvt. Ltd. for organizing the successful event.

ICAR-DOGR organizes Kisan Sangoshthi

ICAR-Directorate of Onion and Garlic Research, Pune, organized a Kisan Sangoshthi on the scientific cultivation of onion at Purushottampur, Narayanpur, Mirzapur on 12 March 2023, in collaboration with Agrimitra FPO. A total of 82 progressive farmers from different parts of Mirzapur, Varanasi and Sonbhadra participated in this program. The chief guest of the program was Hon'ble Dr. A.K. Singh, DDG (Horticultural Science), ICAR, New Delhi and the guest of honour was Dr. V. Mahajan, Director, ICAR-DOGR, Pune. Dr. A.J. Gupta, Principal Scientist (Horticulture) coordinated the Kisan Sangoshthi. Dr. Singh, Chief Guest, praised the farmers of Mirzapur and adjoining areas for their pioneering role in adopting new agricultural technologies keeping in mind the food security. He appreciated the efforts of DOGR in the development of improved technologies on onion and garlic and transfer in the country. Furthermore, he emphasized the need to increase the storage capacity of onion bulbs. He highlighted significant role of the commercial cultivation of *kharif* onion in stabilizing prices and doubling the farmer's income. He encouraged the adoption of new techniques to increase income and reduce costs to ensure sustainable agriculture. In addition to increasing vegetables production, emphasis should also be given on its quality. Dr. A. K. Singh honoured the progressive farmers by preenting them with appreciation certificate for their valuable contribution and also visited their fields. Dr. Mahajan, the special guest of the program, stated that there is immense potential for onion cultivation in this area, and farmers must adopt advanced onion cultivation techniques, with continued cooperation from DOGR. He stressed the importance of farmers organizing themselves and engaging in commercial farming. Dr. A.J. Gupta emphasized the current status of onion cultivation and the livelihood security it provides to farmers through the commercial cultivation of *kharif* onion. He appreciated the farmers for their active participation in onion cultivation in the Chunar tehsil of Mirzapur. The adoption of ICAR-DOGR technologies has resulted in a significant increase in the production and productivity of onions in Mirzapur, with support from Agrimitra and GKRDF. Dr. G.N. Singh mentioned that Mirzapur, in eastern Uttar Pradesh, is proving to be suitable for *kharif* onion production and is likely to become a hub for *kharif* onion production in the future. On this occasion, Dr. A. J. Gupta, Principal Scientist (Horticulture) was awarded an appreciation certificate by Agrimitra FPO, Mirzapur, for promoting improved onion varieties and production technologies.

ICAR-DOGR organizes training programme for farmers under ATMA scheme

A training program on "Production Technology of Onion and Garlic" was organized by ICAR-Directorate of Onion and Garlic Research under the ATMA scheme for 25 farmers from Chandrapur district, Maharashtra. It was sponsored by the Project Director (ATMA), Chandrapur. The program was organized during 5-7 December 2023. Dr. Rajiv Kale, Senior Scientist welcomed the participants. Dr. S. S. Gadge, Principal Scientist, briefed the attendees on the topics to be covered in the training program. Dr. Vijay Mahajan, Director, ICAR-DOGR, discussed the importance of soil and water quality in achieving higher yields of onion and garlic. Various topics related to onion and garlic cultivation were covered by ICAR-DOGR scientists during the training. Agro-practices were demonstrated to farmers at the main farm of the Directorate, where they were exposed to different agro-innovative techniques. After the training program, an interactive session was conducted in which farmers' queries were addressed by the scientists. During the valedictory function, certificates were distributed to the participants. Dr. Vijay Mahajan, Director, ICAR-DOGR, motivated the participants to adopt advanced technologies for the scientific cultivation of onion and garlic. The program concluded with a vote of thanks by Dr. S. S. Gadge. The training program was coordinated by Dr. S. S. Gadge, Dr. R. B. Kale, and Dr. Pranjali A. Gedam.

Vigilance Awareness Week

ICAR-Directorate of Onion and Garlic Research, Pune has observed the Vigilance Awareness Week-2023 during 30 October to 5 November 2023 with the theme "Say No to Corruption; commit to the Nation". The observance of Vigilance Awareness Week was commenced with pledge taking ceremony on 30 October 2023 by all the staff members of the Directorate to maintain public service, truthfulness, honesty and transparency without corruption in this Institution. All the staff of the Directorate also took 'Online Integrity Pledge' (e-pledge) by visiting the CVC's website (https://www.cvc.gov.in). During observance week, various activities were organized, such as the display of banners and posters, a pledge-taking ceremony, competitions such as debate and rangoli for staff, and a drawing competition for school children to create awareness among the employees and school children against corruption. The certificates and prizes were distributed to the winners of various competitions organized during Vigilance Awareness. During the valedictory function, Dr. Vijay Mahajan, Director, ICAR-DOGR substantiated their remarks on various activities of this vigilance awareness week and on improving productivity and its internal processes, increased transparency in the decision making and bringing in citizen participation. The Director stressed the importance of transparency and integrity for the public servants. The Vigilance Awareness Week was concluded on 9November, 2023 with vote of thanks given by Dr. Shailendra Gadge, Principal Scientist and Vigilance Officer of ICAR-DOGR.

Research Advisory Committee (RAC) Meeting

The 24th Research Advisory Committee (RAC) meeting of ICAR-DOGR was held on 11April 2023 under the chairmanship of Dr. H.P. Singh, Ex-Deputy Director General (Horticulture), ICAR, New Delhi. The RAC members, including Dr. Ajmer Singh Dhatt, Professor & ADR, PAU, Ludhiana (Member), Dr. A.N. Ganeshmurthy, Ex-Head, IIHR, Bengaluru (Member), Dr. S. K. Dash, Dean, OUAT, Bhubaneswar (Member), Dr. A.B. Rai, Ex Head, IIVR, Varanasi (Member), Dr. Kaushik Banerjee, Director, NRCG, Pune (Member), Dr. Vikramaditya Pandey, Principal Scientist, ICAR, New Delhi (Ex-officio member), Dr. Vijay Mahajan, Director, ICAR-DOGR, Pune (Ex-officio member), and Mr. Ashok Allapur, Progressive Farmer (Non-official member) were also attended the meeting. The meeting began with the ICAR song, followed by welcoming remarks from Dr. Vijay Mahajan, Director of ICAR-DOGR, who provided an overview of the ongoing research programs and key achievements. Dr. Singh emphasized the critical importance of onion and garlic research, identifying key areas for further development. The committee discussed the challenges facing research in these areas and explored potential solutions. The Member Secretary Dr. S.J. Gawande presented the Action Taken Report (ATR) from the 23rd RAC meeting, which was reviewed and accepted after in-depth discussion. The meeting concluded with the presentation of progress reports by Principal Investigators (PIs) of various research projects, which were carefully reviewed and discussed in detail.

Institutional Research Council (IRC) Meeting

The 28th Institutional Research Council (IRC) meeting was held during 3 July 2023 at ICAR-Directorate of Onion and Garlic Research, Pune under the chairmanship of Dr. Vijay Mahajan, Director. All the scientists of the Directorate presented the progress report and salient achievements of the projects in the meeting. Recently joined scientists also made their new proposals. After thorough discussion of on-going projects and new proposals, recommendations were made. Chairman of IRC, praised all the scientists for their research achievements and encourage the scientist for publications and externally funded projects. Meeting ended with vote of thanks expressed by Dr. Amar Jeet Gupta, Member Secretary, IRC of ICAR-DOGR, Pune.

IRC Meeting of ICAR-DOGR held on 3July 2023

Technology demonstration to farmers

A demonstration and evaluation of the Arka Onion Detopper developed by ICAR-IIHR was conducted on 9 May 2023 at Ambi-Jalgaon, Tal. Karjat, Ahmednagar. The event was led by Dr. Sanket J. More and Dr. Bhushan Bibwe from ICAR-DOGR, Pune, Dr. Caroline Rethinakumari from ICAR-IIHR, Bengaluru, and Dr. Vivek Bhoite from

KVK, Baramati. The event was organized in collaboration with KVK, Baramati under the guidance of Shri Rajendra Pawar and Shri Rohit Pawar from the Agricultural Development Trust, Baramati. The program aimed at enhancing agricultural practices and benefited 50 farmers, providing them valuable insights into innovative farming techniques.

हिंदी पखवाड़ा का आयोजन

भा.कृ.अनु.प.–प्याज एवं लहसुन अनुसंधान निदेशालय, पुणे में 14 सितंबर 2023 से 30 सितंबर 2023 तक हिंदी पखवाड़ा बड़े उत्साह और जोश के साथमनाया गया। इस आयोजन का मुख्य उद्देश्य हिंदी भाषा के प्रति जागरूकता बढ़ाना और इसे राजभाषा के रूप में अधिकाधिक प्रयोग में लना था। हिंदी पखवाड़ा के दौरान, संस्थान में कई प्रतियोगिताओं का आयोजन किया गया, जिनमें सभी वर्गों के कर्मचारियों और छात्रों एवं निदेशालय के कर्मचारियों ने सक्रिय रूप से भाग लिया। इस दौरान विभिन्न प्रतियोगिताओं का आयोजन किया गया जिसमे कि आशुभाषण प्रतियोगिता, हिंदी कविता पाठ प्रतियोगिता, हिंदी निबंध लेखन, हिंदी प्रश्नोत्तरी प्रतियोगिता एवं हिंदी वादविवाद प्रतियोगिता को मुख्यरूप से आयोजित किया गया। हिंदी पखवाड़ा के दौरान, इन प्रतियोगिताओं ने न केवल हिंदी भाषा के प्रयोग को प्रोत्साहित किया बल्कि प्रतिभागियों को अपनी भाषा क्षमता, सृजनात्मकता, और तर्क शक्ति को प्रदर्शित करने का अवसर भी प्रदान किया। हिन्दी पखवाड़ा का समापन समारोह 03/10/2023 को संस्थान के सभागार में आयोजित किया गया जिसमें कि समापन समारोह के मुख्य अतिथि श्री सतीश गोफ ने, शाखा प्रबंधक, स्टेट बैंक ऑफ इंडिया, राजगुरुनगर एवं संस्थान के निदेशक डॉ विजय महाजन ने सभी पुरस्कार विजेताओं को प्रमाणपत्र एवं पुरस्कार वितरित किए।

सितंबर माह दौरान 12/11/2023 को एकदिवसिय हिन्दी कार्यशाला का भी आयोजन किया गया जिसमें कि डॉ मधुकर बाबूराव राठौड़, सह–प्राध्यापक, प्रो रामकृष्ण मोरे कला, वणिज्य एवं विज्ञान महाविद्यालय, पुणे ने कार्यशाला का सम्पादन किया। इस आयोजन ने हिंदी को राजभाषा के रूप में मजबूती प्रदान करने और संस्थान में इसके प्रयोग को बढ़ाने में महत्वपूर्ण योगदान दिया।

Swachchta activities at ICAR-DOGR

As per guidelines of the Council, a committee was constituted in the Directorate to implement cleanliness campaign. Cleanliness programs were organized at different places of the Directorate on Wednesdays of the second and fourth week of every month. As per instructions of ICAR regarding Special Campaign 3.0 for improving Swachhta and disposal of pending references, the following activities were performed by ICAR-DOGR during during 2-31October 2023.

- Cleanliness Campaign at outside the ICAR-DOGR campus on 6, 13, 20 and 27 Oct, 2023.
- Cleanliness activities, space management and beautification of offices etc. at ICAR-DOGR campus on daily basis during 3-31 October 2023 (16.30-17.30) except outside the ICAR-DOGR campus Swachhta activities.
- Cleanliness activities at Primary School and Panchayat Office of Chandoli village to create awareness in the students and village persons on 6 October 2023 (9.30 to 13.00).
- Cleanliness activities were performed in villages adopted under *Mera Gaon and Mera Gaurav* on 13 and 20 October 2023.
- Cleanliness activities were performed in Shiroli village on 27 October 2023.


Swearing ceremony cleanliness drive organized at tractor shade


Cleanliness drive at cold storage and threshing yard of ICAR-DOGR


Cleanliness drive at residential quarters premises of ICAR-DOGR

Swachhta Pakhwada during 16-31 December 2023

The Swachhta Pakhwada banner was displayed and the importance of Swachhata Mission was briefed 16-31 December 2023. The Nodal Officer gave a briefing on the daily actions scheduled from December 16 to December 31, 2023 for the smooth rollout of Pakhwada. ICAR-DOGR staff including temporary workers and outside visitors attended the event. Director, ICAR-DOGR planted a tree sapling at institute premises on this particular occasion. The Swachhta Pakhwada banner was displayed and the importance of Swachhata Mission was briefed. The Nodal Officer gave a briefing on the daily actions scheduled from Dec 16-31, 2023, for the smooth functioning of Pakhwada. All ICAR-DOGR staff, including temporary workers and outside visitors took the Swachhta pledge. Director, ICAR-DOGR planted a tree sapling at institute premises on this particular occasion. The cleanliness drive has been carried out at ICAR-DOGR, Pune office premises, corridors and farm roads. The dealing staff has emphasized the digitalization of office records and the implementation of e-office or office records. Review of progress on maintaining housekeeping service with high cleanliness standards, weeding out/ disposal old records/ furniture/ junk materials was done on 17.12.2023.

Cleaning office premises on 18.12.2023

Cleaning office premises on 19.12.2023

Celebrated Kisan Divas-2023 and Cleanliness drive at main office area on 23.12.2023

Cleanliness drive conducted at main building premise garden on 22.12.2023

Cleaning activities at nursery and garden on 26.12.2023

Cleaning activities at guest house premises on 27.12.2023

Cleaning activities at backside of main office building on 28.12.2023

Cleaning activities at Manjari Farm on 30.12.2023

Cleaning activities at Kalus Farm on 31.12.2023

National Symposium cum Industry Meet (NSIM) on "Agri-business in Alliums: Innovation, Promotion & Sustainability"

The Agri-business Incubation Centre and ITMU Unit of ICAR-Directorate of Onion and Garlic Research (ICAR-DOGR), in collaboration with the Mahratta Chamber of Commerce, Industries, and Agriculture and the Indian Society of Alliums, successfully organized the National Symposium cum Industry Meet (NSIM) on "Agri-business in Alliums: Innovation, Promotion & Sustainability", which was scheduled during 20-22 December 2023 in Pune, Maharashtra. More than 200 participants joined the event. NSIM-2023 underscores ICAR-DOGR's dedication to promoting comprehensive discussions and collaborative efforts aimed at boosting innovation, promotion, and sustainability within this vital sector. This symposium offered a unique platform for the amalgamation of innovative ideas, expertise, and experiences. Through engaging discussions, enlightening presentations, and interactive sessions, the goal is to delve into the various facets of *Allium* agri-business.

World Soil Day 2023

ICAR-DOGR organized World Soil Day 2023 in collaboration with ICAR-NRCG, Pune and ICAR-DFR, Pune on 5 December, 2023. The programme was celebrated to raise awareness on the importance of soil to the sustenance of the life on earth. The theme for world soil day 2023 is Soil and Water: A source of Life. Posters on World Soil Day were displayed inside and outside the campus to raise awareness among the people. Dr. Rajiv Kale, Scientist welcomed all the guests and participants. Dr. Thangasamy, A., Senior Scientist and Nodal Officer, Soil Health Card Scheme briefed about the programme. Dr. Ram Dutta, Principal Scientist, ICAR-DOGR delivered lecture on Improvement of Soil Health and Water Quality through Organic Amendments". Dr. A. K. Upadhyay, Principal Scientist, ICAR-NRCG, Pune attended as special guest and delivered a talk on Advanced Management Practices for Sustaining Soil Health. Dr. Vijay Mahajan, Director, ICAR-DOGR, Pune in his remarks stated about the importance of soil health and water quality for achieving higher yield and sustaining soil health. Dr. K. V. Prasad, Director, ICAR-DFR, Pune and Chief Guest of the function distributed soil health cards to the farmers and sensitized the farmers about application of fertilizer and agrochemicals to sustain soil health and reduce water pollution. He also stressed about the importance of organic farming in crop production. All the scientists and Staff's from ICAR-DOGR were participated in the event. Seventy-five farmers and fifteen students from Pune district were participated in the event. During 2023, 273 soil health cards were distributed to the farmers of different places. Dr. Sanket More, Scientist, ICAR-DOGR, Pune proposed vote of thanks.

Glimses of World Soil Day 2023 at ICAR-DOGR

Celebration of 74th Republic Day

ICAR-DOGR celebrated 74th Republic Day on 26 January 2022 with immense enthusiasm and patriotism. Dr. Vijay Mahajan, Director of ICAR-DOGR, hoisted the national flag, symbolizing unity and freedom. Mr. H.S.C. Shaikh, I/c. Administrative Officer, extended a warm welcome to all the guests. The campus was beautifully decorated in tri colors, fostering a deep sense of national pride. Staff and students gathered to honor 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 programmes and sports competitions for the children of the DOGR staff, 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.

Prize distribution on the occasion of 74th Republic Day

Celebration of 76th Independence Day

ICAR-DOGR celebrated India's 76th Independence Day on 15 August 2023 with great enthusiasm. As part of the *Azadi Ka Amrit Mahotsav* celebrations, the '*Har Ghar Tiranga*' campaign was actively celebrated by the DOGR employees. The DOGR campus was illuminated with lightening and decorated with tricolor flags and balloons. The beautification and decoration with tricolor theme were done right from the main gate to office. Dr. Vijay Mahajan, the Director, hoisted the flag, symbolizing our freedom, Dr. Vijay Mahajan, in his address, highlighted the importance of the 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 also felicitated by the Director, A flag march past, also known as a parade or procession, is planned in the DOGR campus and residential areas. The employees of directorate were encouraged to click selfie with Tiranga and upload it on their social media handles using the tag # har ghar tiranga. 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.

Glimses of 76th Independence Day celebration at ICAR-DOGR

Quinquennial Review Team (QRT)

The Indian Council of Agricultural Research (ICAR), New Delhi constituted a Quinquennial Review Team (QRT) consisting of Dr. Prakash S. Naik, Former Director, ICAR-Indian Institute of Vegetable Research (ICAR-IIVR), Varanasi as Chairman, and Dr. Satish Bhonde, Former Additional Director, National Horticultural Research and Development Foundation (NHRDF), Nashik; Dr. Sharad K. Choudhary, Dean, College of

Agriculture, (RVSKVV), Indore as a Member; Dr. Harikesh B. Singh, Former Head, Mycology and Plant Pathology, Banaras Hindu University (BHU),Varanasi; Dr. M. N. Dabhi, Professor and Head, Department of Processing and Food Engineering, College of Agriculture Engineering and Technology, Junagadh Agricultural University (JAU), Junagadh; and Dr. D. Sreenivasa Murthy, Principal Scientist, ICAR-Indian Institute of Horticultural Research (ICAR-IIHR), Bengaluru as Members to review the progress of research achievements made by the ICAR- Directorate of Onion and Garlic Research (ICAR-DOGR), Puneand All India Network Research Project on Onion and Garlic (AINRPOG), Pune from 01.04.2017 to 31.03.2022. Dr. Ram Dutta, Principal Scientist (Plant Pathology), ICAR-DOGR served as Member Secretary and was instrumental in coordinating & preparing the QRT report.

QRT conducted all together 17 visits, first from 20-22 December, 2022 and final meeting from 2-4 May, 2023. Meetings were held with scientists to review research and other activities of ICAR-DOGR through presentations and discussions. Interactions were also held with technical staff, administration, finance, and various committees of ICAR-DOGR. The QRT visited all the Directorate's laboratories, experimental fields, and facilities. The QRT also visited and interacted with AINRPOG centres at Nashik, Junagadh, Mandsaur, Kanpur and Coimbatore, and on-line presentations were made by remaining AINRPOG centres. Interactions were also held with farmers, traders, exporters, processors, and other stakeholders in Maharashtra (Nashik and Lasalgaon), Gujarat (Junagadh

Field Visits by Quinquennial Review Team and Mahua), Madhya Pradesh (Indore and Mandsaur) and Tamil Nadu (Coimbatore and Ooty). Several pertinent and important issues emerged during these interactions and have been incorporated in different recommendations. The report was developed with deliberations from all the stakeholders of the institute and centers of the AINRPOG and finally submitted to the honourable Director General, ICAR, New Delhi on 27 June 2023. A Summary of the report is presented below:

ICAR-DOGR maintaining and evaluating 1258 short day onion accessions, 245 long day onion accessions, 637 garlic accessions and 18 wild *Allium* species. One *Allium tuberosum* accession (All-1587) was identified for foliage consumption based on its consumer acceptability and high foliage yield (129 t/ha). The Directorate has developed three onion varieties namely Bhima Light Red, Bhima Safed and Bhima Shakti. Bhima Light Red is suitable for cultivation in *rabi* in Karnataka and Tamil Nadu with an average yield of 38.5 t/ha. Bhima Safed is a *kharif* variety suitable for growing in eight states with an average yield of 18.5 t/ha. Whereas, Bhima Shakti can be grown in late *kharif* (yield 35-40 t/ha) as well as in *rabi* (yield 28-30 t/ha) in 13 states. In general, farmers get a net return up to ₹ 2 Lakh/ha by cultivating these varieties in different crop seasonsand hence, there is a great demand for them by the farmers.

Two garlic varieties namely Bhima Purple and Bhima Omkar were also developed during the period 2017-2022. Garlic variety Bhima Purple (yield 8-10 t/ha) is suitable for growing in eight states during *rabi* season. The Directorate also registered two valuable unique genetic stocks of onion with the ICAR-National Bureau of Plant Genetic Resources (ICAR-NBPGR), namely INGR22082 (tolerance to water logging) and INGR22083 (tolerance to drought).

Quality seed is the single most important input for successful onion and garlic production. With available resources, the Directorate produced and distributed 7819 kg of high-quality onion seeds and 6341 kg garlic planting material during 2017-2022. In addition, the Directorate has also given non-exclusive license for seed production to >111 seed companies and FPOs in India. It is estimated that the variety Bhima Super alone covered cumulative area of 328000 ha and contributed a gross value of about ₹ 3.8 billion till 2020-21 at the current price.

The major recommendations are: the development of early, multipurpose, and robust onion and garlic varieties; bridging gaps between demand and production of quality seeds; development of economically viable and environment-friendly production and protection technologies for onion and garlic; boosting mechanization in onion and garlic cultivation to enhance efficiency and reduce the cost of cultivation; reduction in post-harvest storage losses; and effective dissemination of varieties and technologies.

Kisan Diwas Celebration

ICAR-Directorate of Onion and Garlic Research, Pune celebrated the Kisan Diwas (National Farmers Day) on 23

December 2023 to commemorate the Birth Anniversary of 5th Prime Minister of India, Shri. Choudhary Charan Singh as a part of Swachchta Pakhwada programme. The farmer beneficiaries of Tribal sub-plan (TSP) and Schedules Caste Sub-Plan (SCSP) were invited for this special day to recognize the devotion and sacrifice of farmers and to raise awareness among people to ensure farmers' valuable contribution to the overall socialand economic development of the nation along with farm workers of directorate. The programme initiated with pledge taking ceremony which was administered by Dr. Sanket More, Scientist (Veg Scientist). Dr. Bhushan Bibwe, Scientist (Agricultural Engineering) welcomed and felicitated the chief guest of the function Shri. Jagdish Ghadge, Khed Taluka Coordinator, Water Supply and Sanitation Department, Govt. of Maharashtra. On this special day, Stewardship lecture on SOPs for Safe and Responsible Use of Pesticides for Onion and Garlic cultivation' was delivered by Mr. Sandeep Mirzapure, Area Marketing Manager, Coromandel International Limited, Pune and demonstrated the usage of safety kit and apron to the participants. Programme was ended with the vote of thanks presented by Dr. Yogesh Khade, Scientist (Vegetable Scientist).

O. Technology Licensing, Commercialization, Collaborations

The activities of the Intellectual Property and Technology Management Unit (ITMU) from January to December 2023 are summarized as follows. During this period, ITMU excelled in technology licensing, professional services, outreach initiatives, and intellectual property protection. The total revenue generated from these activities in 2023 amounted to ₹143.25 lakhs.

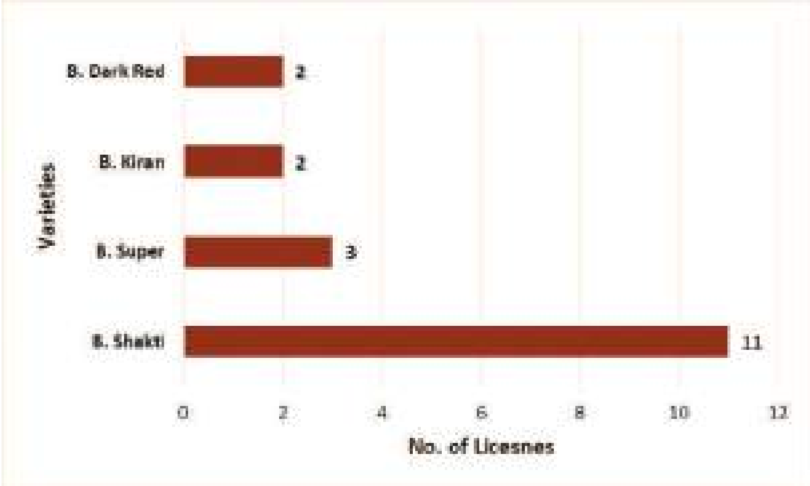
ITMC Meetings

A total of 8 ITMC meetings were conducted in year 2023.

Technology Licensing

Seventeen licensing Memoranda of Understanding (MoUs) were signed with 13 seed companies for the commercialization of four onion varieties (B. Kiran, B. Super, B. Shakti, B. Dark Red). Among these companies, two are Farmer Producer Companies (FPCs). The technology licensing activities generated revenue of ₹17 lakhs in 2023.

Sr. No	Licensee	Variety	Fees (₹)
1.	Saradnya Seeds Pvt Ltd, Nashik	B. Kiran	100000
2.	Rushee Seeds Pvt Ltd, Newasa	B. Super, B. Shakti	200000
3.	Mayuresh Seeds, Jalgaon	B. Shakti	100000
4.	Padmini Seeds Pvt Ltd, Parbhani	B. Super	100000
5.	VSRO Bio Organics, Patas, Pune	B. Shakti	100000
6.	YNK Seeds Pvt Ltd, Chikhli, Dist. Buldhana, Maharashtra	B. Shakti	100000
7.	Semeza Crop Systems, Jalgaon (MH)	B. Shakti, B. Dark Red	200000
8.	Songro Natural Seeds Private Ltd, Jalna	B. Super, B. Shakti	200000
9.	Kille Galna FPC, Malegoan	B. Shakti	100000
10.	Narmada Traders, Sangamner (MH)	B. Shakti	100000
11.	Prosperra Genetics Pvt Ltd., Hyderabad	B. Shakti	100000
12.	Alamdar Seeds, Kutch	B. Shakti, B. Kiran	200000
13.	Rahimatpur Vibhag Shetkari Producer Company, Satara	B. Shakti	100000
	Total		**₹ 1700000**



Contract research

Three Memoranda of Understanding (MoUs) were signed for contract research projects with Coromandel International, Secunderabad, and RCF Ltd. These agreements pertain to the evaluation of various fertilizer formulations. The total revenue generated from these projects amounted to ₹ 3377514.

Collaborative research

The five collaborative research projects were signed with the TIH Foundation for IoT and IoE, IIT Bombay: The total revenue generated from these projects amounted to ₹ 9248930

- Multi-parameter, Remote-controlled Energy-Autonomous Smart Agristation (EAgriS) and Data Analytics: ₹275000
- O-Scan (Onion-Scan): Image-based Intellectual Diagnosis System for pest, disease, and abiotic stress management in Onion Crop: ₹ 2617221
- I-DiagnOCe: IoT-based Intelligent Detection and Prediction Platform for Diseases and thrips attack in Onion Crops based on real-time Captured Data: ₹ 2263629
- Smart-SNWM: Smart Soil-specific Nutrient and Water Management at different depths using IoT and AI/ML: ₹ 2084220
- Multi-modal Image Data Analysis for Aerial Phenotyping: ₹ 2008860

MoUs for academic purpose

In addition to above mentioned projects, Six MoUs were signed with different institutions for academic purpose as mentioned in table below.

Sr. No.	Partner	Purpose
1.	Lovely professional University	MSc/PhD Students Training/Research
2.	M.P.K.V. Rahuri	MSc/PhD Students Training/Research
3.	Shri Shiv Chatrapati College, Junnar	MSc/PhD Students Training/Research
4.	Dr.YSR Horticultural University, Andhra Pradesh	MSc/PhD Students Training/Research
5.	Vasantdada Sugar Institute, Pune	Evaluation of chitosan and other nano particles in onion and garlic
6.	IDEA, NAARM, Hyderabad	Co-operation in incubation programme of NAARM to promote entrepreneurship in Agri and allied sector

IP Protection

- **Trademark Renewal:** ICAR-DOGR logo registered for Trade Mark in year 2014 is renewed (Trademark No. 2701085, valid up to March 2034).
- **Trademark Application:** Trademark application made for the registration of trademark of logo of ABI of ICAR-DOGR (Trademark No. 6097874 submitted 6-9-2023)
- **Patent Application:** “Methods and systems for pest and disease management of onion crop(s)” (Application No. 202321081043) filed on 29-11-2023
- **Patent Granted:** Patent granted to ICAR- DOGR, Pune in collaboration with Kala Biotech Pvt. Ltd, Pune for the technology "A STORAGE STRUCTURE FOR STORING ONION BULBS AND A METHOD THEREOF" with a Patent number 469459. Contributors: Kalyani Gorrepati, Major Singh, Phutane S.C and Phutane P.C.

P. Human Resource Development

Training Programmes Attended

Title	Date and Venue
Vijay Mahajan	
Training on Leadership Development	21-26 August 2023, ICAR-NAARM, Hyderabad
S. Anandhan	
Training on a comprehensive training program on Gene Editing and Technology Management	10 - 14 July 2023, NAARM, Hyderabad
A. Thangasamy	
Training Programme on Analysis of Experimental Data using R	21-25 August 2023, ICAR-NARRM, Hyderabad
Hem Raj Bhandari	
Training on Data Science in Agriculture (Online mode)	4-15 September 2023, ICAR-IASRI, New Delhi
V. Karuppaiah	
Training Programme on "Enhancing Pedagogical Competencies for Agricultural Education" (IARI hubs Faculties)	31 July- 05 August 2023, NAAS, New Delhi
Training on Statistical analysis and interpretation of Agricultural Data (Online mode)	01-10 March 2023, ICAR – IASRI, New Delhi
Satish Kumar	
Assessor training programme (Accreditation Criteria ISO/IEC 17025:2017) by National Accreditation Board for Testing and Calibration Laboratories (NABL), of Conformity assessment bodies (CABs)	15-19 May 2023, ICAR-CIFE, Mumbai
Kalyani Gorrepati	
Training on कृषि में सांख्यिकीय और मशीन लर्निंग तकनीक का परिचय (Virtual mode)	06-12 June, 2023, ICAR-IASRI, New Delhi
Auji Radhakrishna	
Laboratory Assessor's Training Course (Accreditation Criteria ISO/IEC 17025:2017) by National Accreditation Board for Testing and Calibration Laboratories (NABL), Gurugram	15-19 May 2023, ICAR-CIFE, Mumbai
Pranjali A. Gedam	
Summer School on 'Emerging research techniques for sustainable agriculture and natural resource management'	03-23 July 2023, MGGV, R.S. Krishi ShodhSansthan, UP

Title	Date and Venue
Hindi Workshop on Application of statistically Software for Analysis of Agricultural and Survey Data	06-13 September 2023, ICAR-IASRI, New Delhi
Jayalakshmi K.	
Hindi Workshop on "Application of Statistical software for agricultural and survey data"	06 -13 September 2023 ICAR-IASRI, New Delhi.
Training programme on "Blended Learning Techniques for Quality Higher Education"	19-26 December 2023, ICAR – IASRI, New Delhi

Conferences/Symposiums/Seminars/Workshops/Group Meetings

Title	Date and Venue
Vijay Mahajan	
Meeting for HACKATHON on Grand Onion Challenge	4 January 2023, ICAR-DOGR
QRT of ICAR-DOGR visiting to review research progress of AINRPOG	8 - 12 January 2023, NHRDF, Nashik, JAU Junagadh
Workshop on Natural Farming and Millets	19 January 2023, ICAR-ATARI, Pune
Meeting for HACKATHON on Grand Onion Challenge	24 January 2023, ICAR-DOGR
ITMC, ICAR-DOGR, Pune for discussion and signing of MoU with Saradnya Seeds Pvt. Ltd.	27 January 2023, ICAR-DOGR, Pune
QRT of ICAR-DOGR visiting to review research progress of AINRPOG	29 January to 3 February 2023, Mandsaur (MP), Kanpur
National Symposium of Allium at Jain Irrigation	6 - 16 February 2023, Jalgaon, Maharashtra
Meeting on "Current Status and Future Plans of AgroInnovate India Limited"	20 February 2023, ICAR-DOGR
Annual Conference of Vice-Chancellors (VCs) ofAgriculturalUniversities and Directors Conference of ICAR	4-5 March 2023, New Delhi
ITMC, ICAR-DOGR, Pune for signing of MoU with VSI, Pune, AnnasahebAwate College Manchar, Shri Shiv Chhatrapati College, Junnar	14 March 2023, ICAR-DOGR
International millets conference on 'Enhancing Productivity and Value addition in Millets	18 March 2023, NASC Complex, New Delhi
171st Meeting of Managing Committee of NHRDF	31 March 2023 Bagwani Bhawan, New Delhi
QRT of ICAR-DOGR visiting to review research progress of AINRPOG centers	24-27 April 2023, TNAU, Coimbatore, Ooty (TN)
Meeting and Discussion with Hon'ble Vice Chancellor of Dr BSSKKV Dapoli on Evaluation of Internal Ranking of Universities	16 - 17 May 2023, Dr. BSSKKV, Dapoli
Preliminary Meeting in connection with QRT of ICAR-Directorate of Onion & Garlic Research, Pune at DG's Committee Room	26 - 28 June 2023 KrishiBhavan, New Delhi

Title	Date and Venue
95th Foundation Day/Technology Day of the ICAR Society and Exhibition	l6-18 July 2023, New Delhi
XXVII Meeting of ICAR Regional Committee No. VII 18 August 2023	18 August 2023, ICAR-CIAE, Bhopal
Zonal Workshop of KVKs of ICAR-ATARI	19 August 2023, ICAR-CIAE, Bhopal
ITMC, ICAR-DOGR, Pune for discussion and signing of MoU with Godaam Innovations Pvt Ltd	7 September 2023, ICAR-DOGR, Pune
Global Symposium on Farmers Rights from	12-15 September 2023, ICAR Convention Centre, New Delhi
173rd meeting of Managing Committee of NHRDF	15 September 2023, NHRDF, New Delhi
National Conference on Spices, Aromatic and Medicinal Plants for Economic Prosperity and Ecological Sustainability-2023	5-6 October 2023, Port Blair
XVI Agricultural Science Congress 2023	10-13 October 2023, Kochi
International Seminar on Exotic and Underutilized Horticultural	17-19 October 2023, Bengaluru
10th Indian Horticulture Congress-2023	6-9 November 2023, College of Veterinary Science, Assam Agriculture University, Khanapara, Guwahati
National Symposium cum Industry Meet (NSIM) 2023 on Agri-business in Alliums: Innovation, Promotion & Sustainability.	20-22 December 2023, ICAR-DOGR, Pune
IBSC meeting of ICAR-DOGR	23 December 2023, ICAR-DOGR, Pune
S. S. Gadge	
Co-convener of National Symposium cum Industry Meet 2023. Acted as Co-chairperson to Session: Marketing & Supply Chain Management in the National Symposium cum industry Meet.	20-22 December 2023, MCCIA, Pune
Participated as expert in Agricultural Exhibition "Global Krishi Mahotsav" organized by KVK, Narayangaonto showcase ICAR-DOGR technologies.	9-12 February 2023, KVK, Narayangaon
Participated as expert in "Science Exhibition" organized by GMRT, Khodadto showcase ICAR-DOGR technologies.	28 February - 01 March 2023, GMRT, TIFR, Khodad
S. Anandhan	
IBSC meeting of ICAR-DOGR	26 September 2023, ICAR-DOGR, Pune
A. Thangasamy	
National Symposium cum Industry Meet (NSIM) 2023, on Agri-business in Alliums: Innovation, Promotion & Sustainability	20-22 December 2023, MCCIA, Pune
Global Conference on Precision Horticulture for Improved livelihood, Nutrition and Environmental Services	28-31 May 2023, JISL, Jalgaon, Maharashtra, India

Title	Date and Venue
Karuppaiah V.	
3rd National Symposium on Emerging Technologies and Trends in Sustainable Production and Value chain Management of Onion, Garlic and other Allium species	11-14 February 2023, Jain Hills, Jalgaon, Maharashtra
DST-SERB Project Review Meeting	30 May 2023, ICGEB, New Delhi
Review meeting for status of Onion in major producing States (Online)	30 June 2023, DA&FW, New Delhi
National Conference on Generative AI in Practice for Empowering Agricultural Research Productivity	11-12 September 2023, ICAR-NRC Grapes, Pune
National Symposium Cum Industry Meet on Agri Business in Alliums	20-22 December 2023, MCCIA, Pune
International Conference on Plant Health Management	15-18 November 2023, NIPHM, Hyderabad
National Symposium on Floriculture Nurtures Pollinators	23-24 June 2023, ICAR-DFR, Pune
Rajiv Kale	
Organising secretory of National Symposium cum Industry Meet (NSIM) 2023 on Agri-business in Alliums: Innovation, Promotion & Sustainability in association with MCCIA, Pune and ISA, Pune.	20-22 December 2023, MCCIA, Pune
Participated as expert in Agricultural Exhibition "Global Krishi Mahotsav" organized by KVK, Narayangaonto showcase ICAR-DOGR technologies.	9-12 February 2023, KVK, Narayangaon
Participated as expert in "Industry Meet 2023" organized by ICAR-IIHR, Bengaluru to showcase ICAR-DOGR technologies.	31 October 2023, GMRT, TIFR, Khodad
Coordinated Village Adoption Programme-18 of NIFTEM	16-25 December 2023, Donde Village, Khed, Pune
Participated as expert in workshop for preparation of District Strategic Plan for Pune District at	30 August 2023, Yashada, Pune
Participated as expert in meeting called by Hon'ble Secretary, Agriculture, Maharashtra for the action plan on onion storage	2 August 2023 (Virtual mode)
Participated as expert in "Stakeholder Workshop on Identifying, Prioritizing, and Bundling Innovations" organized by World Veg & IRRI	1-2 August 2023, Bhubaneswar, Orrisa
Review meeting for "Status of Onion" under the Chairmanship of Additional Secretary, DA&FW, New Delhi	30 June 2023, Krishi Bhawan, New Delhi
"SAMAGRA Enabling the Incubators" a sensitization workshop of ICAR-ABIs'	21-22 September 2023, NASC, New Delhi
Expert in Staff Selection Committee Member for SMS Agri. Extn and SMS Home Science-KVK Babhaleshwar, Ahmednagar	23 September 2023, KVK Babhaleshwar, Ahmednagar
Review meeting of onion grand challenge programme jointly organized by Ministry of Consumer affairs and ICAR-DOGR, Pune (Stage 2)	27 July 2023 (Virtual mode)
Review meeting of onion grand challenge programme jointly organized by Ministry of Consumer affairs and ICAR-DOGR, Pune (Stage 2)	11-21 August 2023 (Virtual mode)
Prepared exam paper for Final theory examination, 2nd Semester, 2022-23 for M.Sc. Agriculture, II Semester. Course Title & Code ICTS For Agriculture Extension and Advisory Services (EXT 506) of Banda University of Agriculture & Technology, Banda, UP	June 2023, Banda University of Agriculture and Technology, Banda,UP

Title	Date and Venue
Acted as external expert/examinor for the thesis of Ms. Mathi Girishma (Roll No.21591) ICAR-IARI, New Delhi, titled "ACCESS TO EXTENSION AND ADVISORY SERVICES: DIVERSITY AND IMPACT IN INDIA"	ICAR-IARI, New Delhi
Participated as expert in ABI advisory committee meeting of ABI-NRCG, Pune	03, 27 and 31 October 2023, ICAR-NRCG, Pune
Fifth Panel Meeting of Warehouse Management Services SSD 18: P-2	19 May 2023, (Virtual mode)
Ashwini P. Benke	
National Conference "Big Data Analysis in Agriculture"	9-10 March 2023, ICAR-NAARM, Hyderabad (Virtual mode)
National Symposium "Agri-Business in Alliums: Innovation, Promotion & Sustainability"	20-21 December 2023, ICAR-DOGR
Pranjali A. Gedam	
National Conference on Generative AI in Practice for Empowering Agricultural Research Productivity	11-12 September 2023, ICAR-NRC Grapes, Pune
National Symposium cum Industry Meet (NSIM) 2023 on Agribusiness in Alliums: Innovation, Promotion and Sustainability	20-22 December 2023, ABI-ICAR-DOGR at Pune
Soumia P. S.	
Two-day National Conference on 'Generative AI in Practice for Empowering Agricultural Research Productivity'	11-12 September 2023, ICAR-NRCG, Pune (Online)
National Symposium cum Industry Meet (NSIM) 2023 on Agribusiness in Alliums: Innovation, Promotion and Sustainability	20-22 December 2023, ABI, ICAR-DOGR, Pune
Bhushan Bibwe	
Entrepreneurship Development Program on Post Harvest Processing and Value addition in onion and garlic	16-17 August 2023
Training Program One day training programme on "Value chain management in onion" for the farmers of Palandhu FPCL, Bijapur, Karnataka	28 June 2023
Organized the One-day Workshop on Onion crop cultivation and Demonstration cum evaluation of Arka onion de-topper organized by ICAR-DOGR, KVK Baramati and Karjat-Jamkhed development trust at Ambi-Jalgaon, Dist: Ahmednagar.	09 May 2023
Meeting regarding understanding the onion value chain in India, WRI- India.org	Dec 2023
Online meeting with a team from Wageningen Food and Biobased Research (WFBR) Follow up visit of Dr Ramesh Chand (Member, NITI Ayog).	03 July 2023
VC Meeting to Review Onion Status under the Chairmanship of Additional Secretary, DA&FW, Krishi Bhawan, New Delhi.	30 June 2023
Review meeting of HACKATHON on Grand Onion Challenge	04-24 Jan 2023
Review meeting of onion grand challenge programme jointly organized by Ministry of Consumer affairs and ICAR-DOGR, Pune stage 2	11-21 August 2023 (Virtual mode)
Co-organising secretory of National Symposium cum Industry Meet (NSIM-2023) on Agri-business in Alliums: Innovation, Promotion & Sustainability in association with MCCIA, Pune and ISA, Pune.	20-22 December 2023 MCCIA, Pune

Q. Personnel

Retirement/ Superannuation, Promotion, Joining

(January-December 2023)

A. Retirement/ Superannuation

Sr. No.	Name	Designation	Date of Birth	Date of Superannuation
A.	**Administrative Staff**			
1	Shri. Mangale Jayvant Ramu	Finance & Accounts Officer	12.11.1963	30.11.2023

B. Promotion/ Assessment

Sl.No	Name and Designation	Pay Band & Grade Pay	Promoted post	Promoted post-Pay Band & Grade Pay	Date of Promotion
A.	**Scientific**				
1.	Dr. Shailendra Shankarrao Gadge, Sr. Scientist	Grade Pay Rs.8000/-	Senior Scientist	Grade Pay ₹ 9000/-	09.01.2023 (from 10.07.2012)
B.	**Technical**				
1	Dr. A.R. Wakhare	PML-7	Sr. Technical Officer	PML-10	01.08.2023
2	Sh. B.A. Dahale	PML-6	Technical Officer	PML-7	09.06.2023
3	Sh. H.S. Gawali	PML-5	Sr. Tech. Assistant	PML-6	06.06.2023
C.	**Administrative**				
1	Sh. N.S. Warkar	PML-4	Assistant	PML-6	12.07.2023

Staff Position (As on 31.12.2023)

Category	Sanctioned Posts	Filled Up Posts	Vacant Posts
Scientific	22+1	19+1	03
Technical	10	10	00
Administration	15	05	10
Skilled Support Staff	11	07	04
Total	**58+1**	**41+1**	**17**

Scientific Staff Position (Revised Cadre Strength)

S. No.	Name of Discipline	Revised Cadre Strength							
		Scientist		Senior Scientist		Principal Scientist		Total	
		SS	IP	SS	IP	SS	IP	SS	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 & 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 & Technology*	1	0	0	0	0	0	1	1
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**

*Adjusted with Food technology as per council order

List of Staff

Scientific Staff (As on 31.12.2023)

Sr. No.	Name	Designation
1	Dr. V. Mahajan	Director
2	Dr. Ram Dutta	Pr. Scientist
3	Dr. A.J. Gupta	Pr. Scientist
4	Dr. S.J. Gawande	Pr. Scientist
5	Dr. S. Anandhan	Pr. Scientist
6	Dr. S.S. Gadge	Sr. Scientist
7	Dr. A. Thangasamy	Sr. Scientist
8	Dr. V. Karuppaiah	Sr. Scientist
9	Dr. Kalyani Gorrepati	Sr. Scientist
10	Dr. Satish Kumar	Sr. Scientist
11	Dr. Rajiv Kale	Sr. Scientist

Sr. No.	Name	Designation
12	Sh. Radhakrishana A.	Scientist (SS)
13	Mrs. Ashwini Benke	Scientist (SS)
14	Dr. Pranjali Gedam	Scientist (SS)
15	Dr. Rajkumar Dagadkhair	Scientist (SS)
16	Dr. Soumia P.S.	Scientist (SS)
17	Dr. Bhushan R. Bibwe	Scientist (SS)
18	Dr. Yogesh Khade	Scientist
19	Dr. Sanket More	Scientist (SS)
20	Dr. Jayalakshmi K	Scientist

Administrative Staff

Sr. No.	Name	Designation
1.	Sh. J.R. Mangale	Finance and Accounts Officer
2.	Mrs. Mangala S. Salve	Asstt. Administrative Officer
3.	Mrs. Neha R. Gaikwad	Assistant
4.	Sh. Rajan K. Dedage	Assistant
5.	Sh. Nilesh S. Warkar	Assistant

Technical Staff

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

Skilled Supporting Staff

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

R. Financial Statement

ICAR-DOGR, Pune (Rupees in Lakhs)		
Budget Head	**Budget Allocation**	**Expenditure**
SALARY	758.50	758.50
PENSION		127.66
Total (A)	**886.16**	**886.16**
Capital	81.00	79.99
General	427.55	277.40
Network Project	125.05	125.05
NEH-General	100.00	100.00
TSP-General	20.00	19.99
SCSP-Capital	01.00	01.00
SCSP-General	30.00	29.99
Total (B)	**784.6**	**₹ 633.42**
Grand Total (A+B)	**1600.76**	**₹ 1519.58**

Revenue Generation	**Rupees (in Lakhs)**
Sale of Farm Produce	3.62
Sale of Publication	0.14
Licensing Fees	3.74
Analytical Testing Fees	1.80
Interest from STD/TDR	12.58
Other Income	0.68
Total	**₹ 22.56**

S. Meteorological Data

(January-December 2023)

Month	Avg. Temperature (°C)		Avg. Relaive Humidity (%)		Wind velocity (km/hr)	Av. Sunshine (hrs. /day)	Total Rainfall (mm)	Avg. Evaporation (mm)
	Max	Min	Max	Min				
January	29.4	11.7	78	42	3.2	7.4	0.0	3.4
February	32.3	12.7	66	49	2.5	9.5	0.0	5.0
March	33.2	16.0	69	47	4.9	8.8	0.0	5.4
April	36.6	20.0	70	45	4.1	8.7	0.0	5.8
May	37.4	21.6	73	68	7.0	9.2	5.2	6.4
June	32.7	22.1	76	63	9.3	6.9	59.0	5.6
July	27.9	21.8	88	84	7.6	1.3	126.1	1.6
August	28.1	21.8	87	77	7.6	5.0	23.4	1.8
September	29.3	21.4	88	75	5.7	4.8	218.6	2.1
October	32.8	20.0	79	59	2.2	7.1	38.6	3.0
November	31.2	17.1	65	54	2.4	6.8	13.4	3.5
December	29.1	12.6	78	60	2.5	7.9	0.0	4.0

वार्षिक प्रतिवेदन
Annual Report
2023

भाकृअनुप – प्याज एवं लहसुन अनुसंधान निदेशालय
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