वार्षिक प्रतिवेदन
Annual Report 2021

भाकृअनुप- प्याज एवं लहसुन अनुसंधान निदेशालय
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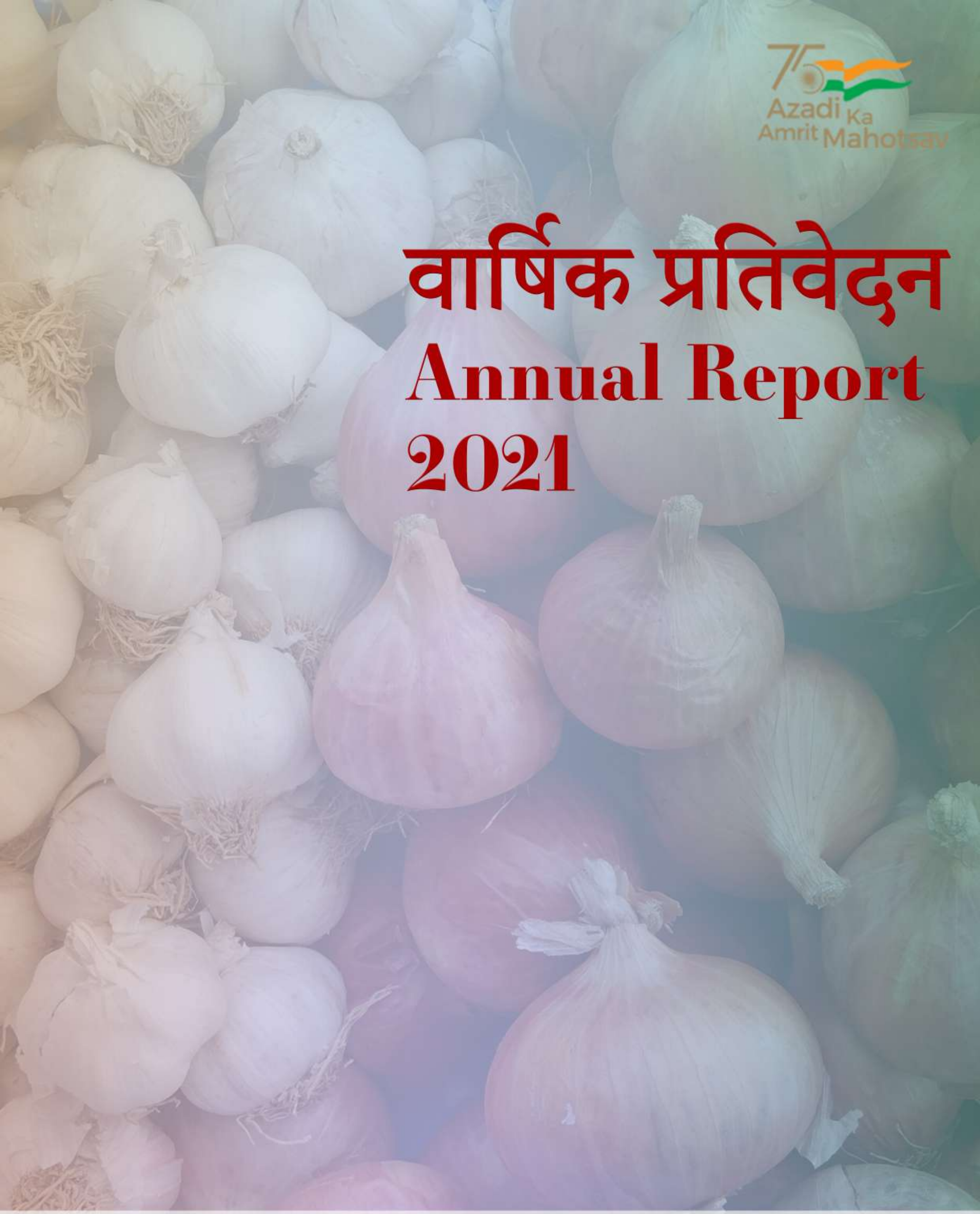

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ICAR-Directorate of Onion and Garlic Research

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Preface

It's my proud privilege to present the Annual Report of ICAR-Directorate of Onion and Garlic Research for the year 2021. In accordance with the mandate, ICAR-DOGR continued various research, extension, and developmental activities.

This year ICAR-DOGR evaluated 88 germplasm of white onion during three cropping seasons and we succeeded to get two promising lines for *Rabi* season namely W-045 GP and W-125 GP exhibiting higher marketable yield and higher TSS content of 11.24 and 11.78 °Brix respectively compared to the check variety Bhima Shweta.

ICAR-DOGR maintains a wider pool of accessions of red onion germplasm which was evaluated this year in late *kharif* (140 accessions), *rabi* (263 accessions), and *kharif* (160 accessions) along with the available check varieties. A far higher marketable yield of 63.56 t/ha was obtained for red onion accession 1319, compared to checks Bhima super (48.02 t/ha), Bhima Kiran (47.04 t/ha), Bhima shakti (46.23 t/ha) during late *kharif* 20-21. Moreover, it is quite satisfying to note that our short-day varieties of Bhima series are also being used for introgression breeding with long-day onion Brown Spanish at CITH Kashmir.

Additionally, the SSR markers have been used to generate information of polymorphic regions associated with waterlogging resistance and drought tolerance in onion breeding populations. These polymorphic regions are also being used for genotyping of F2 population and developing a linkage map. The research efforts undertaken to generate DREB1A gene-transformed onion plants and haploid induction through gynogenesis in onions are also noteworthy.

This year directorate has conducted trials on organic farming in onion and has come out with good recommendations about the combined application of farm yard manure (10 t/ha), vermicompost (2.0 t/ha), neem cake (1 t/ha), phosphorus solubilizing bacteria and Azotobacter @ 5 kg each/ha with organic pest and disease management practices for significantly higher yields. The results about microbe-mediated increase in yield of onion ~10% and a higher NPKS uptake can be cost-effective method to increase crop yield while simultaneously improving soil health.

RNAseq analysis carried out to decipher the molecular responses underlying the purple blotch infection in resistant (Arka Kalyan; AK) and susceptible (Agrifound rose; AFR) onion genotypes are notable which would pave the way to further investigate the details of this severe disease of onion crop. Similarly, the RT-PCR-based information about the viruses associated with Garlic will also be important for understanding the virus associated with garlic germplasm and further producing virus-free garlic plants.

It is also noteworthy that this year ICAR-DOGR carried out 381 front-line demonstrations (FLDs) in different states viz., Maharashtra, Uttar Pradesh, Sikkim, Arunachal Pradesh, Manipur, and Tripura during *kharif* (164), late *kharif* (125) and *rabi* (92) seasons through SCSP, TSP, TSP-NEH and NEH Plan. Various newly developed ICT tools and training videos have been developed by the directorate, and maximum efforts are being put to reach all the stakeholders through TV talks and Radio talks by our dedicated team of scientists. Moreover, all throughout the year, the directorate observed various important days including Independence Day, Republic Day, Science Day, Hindi Pakhwara, Vigilance awareness week, and many others, and organized various activities involving all the staff, research scholars, and students working at this directorate. Overall, the year 2021 was full of accomplishments for the ICAR-DOGR and our staff has made its best efforts to cater to the needs of the onion and garlic farming community and all the stakeholders.

I extend my sincere thanks to the support extended by ICAR and encouragement and guidance by Dr. T. Mohapatra, Secretary, DARE, and Director General, ICAR; Dr. A.K. Singh, Deputy Director General (Horticulture Science) and Dr. Vikramaditya Pandey, Assistant Director General (Horticulture Science). I appreciate the efforts of all the scientific, technical, administrative, and supporting staff of the institute in all achievements. I hope the information provided in this report will be useful to the stakeholders of onion and garlic.

Date: July 2022 (Vijay Mahajan)
ICAR-DOGR, Pune

कार्यकारी सारांश

इस वर्ष भाकृअनुप-प्याज एवं लहसुन अनुसन्धान निदेशालय द्वारा रबी मौसम में सफेद प्याज के 40 जननद्रव्यों का, खरीफ मौसम में सफेद प्याज के 13 जननद्रव्यों का, तथा पछेती खरीफ में 35 प्याज के जननद्रव्यों का मूल्यांकन किया गया। रबी मौसम के लिए, इस वर्ष हम दो आशाजनक वंशक्रम; डब्ल्यू–045 जीपी एवं डब्ल्यू–125 जीपी पाने में सफल हुएं, जो कि तुलनीय किस्म भीमा श्वेता की तुलना में 11.24 और 11.78°ब्रिक्स के अच्छे कुल ठोस घुलनशील पदार्थों के साथ उल्लेखनीय रूप से उच्चतर विपणन योग्य प्याज का उत्पादन देते हैं। खरीफ मौसम में एन्थ्रेक्नोज के गंभीर संक्रमण के बावजूद, एन्थ्रेक्नोज प्रतिरोधी कंदों को एन्थ्रेक्नोज सहनशील प्याज प्रजातियां विकसित करने के लिए बरकरार रखा गया है। इसके अलावा, खरीफ पीले प्याज के 11 जननद्रव्यों का भी मूल्यांकन किया गया और हमने देखा कि वाई-005 वंशक्रम से खरीफ में बेहतर उत्पादन प्राप्त होता है। इसके अतिरिक्त, हमें सफेद प्याज के बेहतर उपज लक्षण और अच्छी भंडारण क्षमता वाले तीन प्रजनन वंशक्रम; डब्ल्यू-398 एडी-5,डब्ल्यू-085 एडी-6 एवं डब्ल्यू-355 भी मिले। इस साल की सबसे बढ़िया उपलब्धि है, 18° ब्रिक्स से ऊपर वाले उच्च कुल ठोस घुलनशील पदार्थों के पांच सफेद प्याज वंशक्रमों को विकसित करना, जो उपभोक्ताओं की पसंद को पूरा करेगी।

इस साल निदेशालय ने 17 प्रजातियों के 89 वन्य और अध:उपयोगी *एलियम* वंशक्रमों के वांछनीय गुणधर्मों का मूल्यांकन करने के लिए प्रजनन कार्यक्रमों में उन्हें शामिल कर अपने प्रयासों को जारी रखा। *ए. ट्यूबेरोसम* कज़ाखिस्तान ऑल-1587' नामक वन्य प्रजाति में पत्तियों के उपयोग के लिए बेहतरीन सम्भावना दिखाई दी और इस बारे में 'किसान कनेक्ट' के साथ पहले से ही जून 2021 में इसी तरह के पहचाने गए *ए. ट्यूबेरोसम* के तीन वंशक्रमों को खाद्य उपयोग हेतु लोकप्रिय बनाने के लिए समझौता ज्ञापन किया गया है। जैव रासायनिक परीक्षण से इस निदेशालय में उपलब्ध कुछ वन्य प्रजातियों की पत्तियों में कुल फेनोलिक, ऐंथोसाइनिन, फ्लेवोनॉइड्स और कुल थायोसल्फिनेट की अधिक मात्रा पाई गई, जो उनकी संभावित क्रियाशील आहार के रूप में उपयोगीता को दर्शाती हैं। रोग एवं कीट प्रतिरोधी प्याज जननद्रव्य विकसित करने का प्रयास जारी रहा। सफ़ेद प्याज जननद्रव्य के 10 से कम का कीट रोग सूचकांक दर्शानेवाले 18 वंशक्रम विकसित किए गए। इसके अलावा, हमारी भीमा श्रृंखला की लघु-प्रकाश दिवसीय प्रजातियों का उपयोग सीआईटीएच, कश्मीर में दीर्घ-प्रकाश दिवसीय प्याज ब्राउन स्पैनिश के साथ अंतर्मुखता प्रजनन विकल्प विनियोजन में भी किया जा रहा है। इस निदेशालय ने लाल प्याज के उपलब्ध जीन पूल का मूल्यांकन किया, जिसमें पछेती खरीफ (140 प्राप्तियां), रबी (263 प्राप्तियां) और खरीफ (160 प्राप्तियां) की तुलना नियंत्रित किस्म के साथ की गई। वर्ष 2020-21 में पछेती खरीफ में लाल प्याज प्राप्ति 1319 का बहुत अधिक (63.56 टन/हेक्टेयर) विपणन योग्य उत्पादन हुआ, जो तुलनीय किस्म भीमा सुपर (48.02 टन/हेक्टेयर), भीमा किरण (47.04 टन/हेक्टेयर), भीमा शक्ति (46.23 टन/हेक्टेयर) की तुलना में अधिक था। इस प्राप्ति में कंद का औसतन वज़न 116.67 ग्राम था, तथा इसमें बिना तोर वाले और जोड़ कंद बिल्कुल नहीं पाए गए। तीन लाल प्याज के वंशक्रम अर्थात डीओजीआर -1606, डीओजीआर -1654 और डीओजीआर -1657 को वर्ष 2021-22 के दौरान आईइटी के रूप में अखिल भारतीय प्याज एवं लहसुन नेटवर्क अनुसन्धान परियोजना परीक्षणों में लिया गया, जबकि डीओजीआर -1627, डीओजीआर -1639 और डीओजीआर -1203-डीआर का मूल्यांकन वर्ष 2021-22 के दौरान एवीटी -II के रूप में किया जा रहा है। हालाँकि, दो लाल प्याज एफ-1 संकर अर्थात डीओजीआर हाइब्रिड -156 और हाइब्रिड -172 को वर्ष 2021-22 के दौरान आईइटी के रूप में अखिल भारतीय प्याज एवं लहसुन नेटवर्क अनुसन्धान परियोजना परीक्षणों में लिया गया, जबकि डीओजीआर हाइब्रिड-6, हाइब्रिड-73, हाइब्रिड-173 और हाइब्रिड-179 का वर्ष 2021-22 के दौरान एवीटी -II के रूप में मूल्यांकन किया जा रहा है।

इसके अलावा, प्याज की उत्पादकता में सुधार के लिए जैव-तकनीकी हस्तक्षेपों से जुड़े प्रयासों के तहत, एसएसआर मार्करों को नियोजित कर प्याज प्रजनन संख्या में जलभराव सहिष्णुता और सूखा सहिष्णुता के लिए बहुरूपी क्षेत्र की भी पहचान की गई है। इन बहुरूपी क्षेत्रों का उपयोग एफ$_2$ संख्या के जीनप्ररूप और श्रृंखला मानचित्र विकसित करने के लिए भी किया जा रहा है। प्याज में गाइनोजेनेसिस के माध्यम से *डीआरईबी1ए* जीन रूपांतरित प्याज के पौधे और अगुणित प्रेरण उत्पन्न करने के प्रयास भी किए जा रहे हैं। इसके अलावा, इस निदेशालय ने लहसुन के उपलब्ध जननद्रव्यों को 700 वंशक्रमों के साथ विकसित करना जारी रखा, जिसमें निदेशालय के पास वर्तमान में उपलब्ध लहसुन की किस्में, जननद्रव्य और बहुप्रजातियाँ शामिल हैं।

इस वर्ष निदेशालय ने प्याज में जैविक खेती पर परीक्षण आयोजित किए ताकि इसकी प्याज की पारंपरिक खेती के साथ तुलना की जा सके। इस के लिए खेती में गोबर की खाद (10 टन/हेक्टेयर), केंचुए की खाद (2 टन/हेक्टेयर), नीम केक (1 टन/हेक्टेयर) और फॉस्फोरस घोलनेवाले जीवाणुओं का संयुक्त अनुप्रयोग किया गया। प्रयोगशाला परिणामों के आधार पर, उच्च उत्पादकता के लिए अन्य जैविक उपचारों की तुलना में जैविक कीट एवं रोग प्रबंधन पद्धतियों के साथ एजोटोबैक्टर @ 5 किलोग्राम/हेक्टेयर की सिफारिश की जाती है। फॉस्फोरस घोलनेवाले जीवाणु और *पिरिफॉर्मोस्पोरा इंडिका* के टीकाकरण के प्रयोग से भी प्याज का उत्पादन 10% तक बढ़ने के अच्छे परिणाम दिखाई दिए है, और उच्च एनपीकेएस अंतर्ग्रहण और उनके अनुप्रयोग से जलभराव और सूखे मौसम परिस्थितियों का सामना किया जा सकता है। उर्वरक अनुप्रयोग की प्रसारण विधि की तुलना में टपक सिंचाई प्रणाली का उपयोग करके उर्वरकों के प्रयोग से प्याज की विपणन योग्य कंद उपज में महत्वपूर्ण वृद्धि देखी गई। इस वर्ष, जलभराव और सूखे स्थितियों के तहत चयनित प्याज जीनप्ररूपों में जड़ स्थापत्य के विस्तृत रूपात्मक - ऊतकीय परिवर्तनों को एसईएम-ईडीएस (स्कैनिंग इलेक्ट्रॉन माइक्रोस्कोपी) का उपयोग करके खोजा गया। 1 दिसंबर से 15 फरवरी तक, प्रत्येक

15 दिनों के अंतराल पर प्याज की रोपाई की छह कंपित तिथियां के आधार पर, प्रदर्शन के दृष्टिकोण से 1 जनवरी के करीब की रोपाई को अनुशंसित किया जाता है।

इसी तरह, इस वर्ष निदेशालय ने फसल संरक्षण के लिए भी महत्वपूर्ण काम किया है। प्याज के पत्ते और कंद को गंभीर नुकसान पहुंचाने वाले कई रोगजनक कवक एकत्र किए गए, अलग किए गए और उनका विशिष्ट लक्षण वर्णन किया गया। *कॉलेटोट्रिकम* संबंधी दस संयोजनों, *फ्यूज़ारियम* संबंधी दस संयोजनों, *ऑल्टरनारिया* संबंधी दस संयोजनों और *स्टेम्फिलियम* संबंधी दस संयोजनों का लक्षण वर्णन किया गया और प्रयोगशाला में इनका रखरखाव किया गया। इसके अलावा, जैव-नियंत्रण क्षमता वाले कुछ अन्त: पादपी परोपजीवीयों को पृथक किया गया और एन्थ्रेक्नोज रोगज़नक़ के खिलाफ *इन विट्रो* में परीक्षण किया गया। *ट्राइकोडर्मा* स्पीसीज के विविध मूल की 14 संयोजनों का खेत स्थितियों के तहत मूल्यांकन किया गया, जिसमे से संयोजन 'टी-4आर' एन्थ्रेक्नोज रोगज़नक़ को दबाने/अवरोधित करने में सबसे प्रभावी पाया गया, और इससे बायोमास और कंद उपज में भी वृद्धि हुई। *ट्राइकोडर्मा* टी-354 उपचारित भूखंड से निकासी की गई कंदों में सबसे कम भंडारण हानि (18%) दर्ज की गई।

इसके अलावा, मौजूदा अभ्यास (ईपी), किसानों के अभ्यास (एफपी), और पूर्ण नियंत्रण (एसी) के साथ खरीफ में प्याज के रोगों के खिलाफ चार आईडीएम मॉड्यूल का मूल्यांकन किया गया था, जहां मॉड्यूल एम1, अधिकतम प्रबंधन, एन्थ्रेक्नोज, स्टेमफिलियम घटना को नियंत्रित करने में और प्याज के प्याज के कंद उत्पादन को बढ़ाने में प्रभावी था। प्याज में एन्थ्रेक्नोज को नियंत्रित करने के लिए अमृतपानी आधारित जैविक योगों की क्षमता की जांच की गई। पानी में बाजरा का आटा, अरंडी के पत्ते, करंज (*पोंगामिया ग्लबरा*) के पत्ते, अदरक पाउडर, हल्दी पाउडर और हींग पाउडर के मिश्रण से एन्थ्रेक्नोज की घटनाओं में प्रभावी रूप से 79% की कमी आई। एन्थ्रेक्नोज रोग के प्रतिरोध के लिए बत्तीस लाल प्याज जननद्रव्यों का परीक्षण किया गया, इनमें से केवल कुछ ही आशाजनक पाए गए थे।

प्रतिरोधी (अर्का कल्याण; एके) और संवेदनशील (एग्रीफाउंड रोज़; एएफआर) जीनप्ररूपों पर आरएनए अनुक्रमण विश्लेषण का उपयोग करके बैंगनी धब्बा संक्रमण के लिए प्याज की आणविक प्रतिक्रिया का अध्ययन किया गया। एएफआर में 8,064 अपग्रेडेड जीन और 248 डाउनरेगुलेटेड जीन थे, जबकि एके में 832 अपग्रेडेड जीन और 564 डाउनरेगुलेटेड जीन पाए गए। कई प्रमुख पादप रक्षा जीनों की पहचान की गई, जिनमें रोगजनन-संबंधी (पीआर) प्रोटीन, रिसेप्टर-जैसे काईनेज, फाइटोहोर्मोन संवेदना, कोशिका भित्तिसंपूर्णता, साइटोक्रोम पी450 मोनोऑक्सीजेनेस और ट्रांस्क्रिप्शन कारक शामिल थे। प्रतिरोधी जीनप्ररूप में जीएबीए ट्रांसपोर्टर 1, एंकिरिन रिपीट डोमेन-सम्पन्न प्रोटीन, क्षिलोग्लुकन एंडोट्रांसग्लुकोसिलेज़/ हाइड्रोलेज, और पीआर-5 (थॉमेटिन-जैसे) का अधिशेष देखा गया।

आरटी-पीसीआर का उपयोग प्याज के पीले बौने विषाणु (ओवाईडीवी), लीक पीली धारी विषाणु (एलवाईएसवी), लहसुन आम अव्यक्त विषाणु (गारसीएलवी), आईरिस पीला धब्बा विषाणु (आईवाईएसवी), लहसुन विषाणु-ए (GarV-A), लहसुन विषाणु-बी (GarV-B), लहसुन विषाणु-सी (GarV-C), लहसुन विषाणु-डी (GarV-D), लहसुन विषाणु-ई (GarV-E) जैसे विषाणुओं की उपस्थिति के लिए लहसुन की 46 प्राप्तियों की जांच की गई। लहसुन में ओवाईडीवी एक सामान्य विषाणु के रूप में पाया गया।

फसल कीटों के जैविक नियंत्रण के लिए उपयुक्त शक्तिशाली स्वदेशी जैव सक्रिय रोगजनकों की खोज के लिए *स्पोडोप्टेरा एक्सिगुआ* के मृत शरीर से तीन देशी आइसोलेट्स, *एस. फ्रुगिपेर्डा* और *एस. लिटुरा* से दो और *सी. एकुटा* से पांच अलग-अलग कीट रोगजनकों को अलग किया गया। ये आइसोलेट्स सबकल्चर, अनुरक्षित, और आगे रूपात्मक और आणविक लक्षण में लाए गए। *ब्यूवेरिया बेसियाना, मेथेरिज़ियम एनिसोप्लिया, लेकेनिसिलियम लेकानी*, और वानस्पतिक कीटनाशक नीम के तेल सहित एंटोमोपैथोजेन के वाणिज्यिक योगों का अकेले और जैविक कीटनाशक 'स्पिनोसैड' के संयोजन में प्याज थ्रिप्स के खिलाफ परीक्षण किया गया। कीट रोगजनकों द्वारा *थ्रिप्स* की संख्या (अर्भक और वयस्क) को प्रभावी ढंग से कम किया गया। स्पिनोसैड सबसे प्रभावी था, वयस्कों और अर्भकों में क्रमशः 68.5% और 93.4% की कमी आई। प्याज में *थ्रिप्स* घनत्व और कंद उपज पर चयनित कीटनाशकों के चक्रीय प्रयोग के प्रभाव का आकलन करने के लिए किए गए एक अध्ययन में स्पाइनटोरम-फिप्रोनिल-प्रोफेनोफॉस-स्पिनोसैड *थ्रिप्स* की संख्या को कम करने और उच्च कंद का उत्पादन करने में सबसे प्रभावी था।

ग्रीन सेमी लूपर (*क्राइसोडिएक्सिस एकुटा* वॉकर) भारत में प्याज की फसल का उभरता हुआ कीट है। रूपात्मक विवरण के अलावा, इन कीटों को अलग करने के लिए डीएनए बारकोडिंग एक हालिया उपाय है। इसलिए, ग्रीन सेमिलूपर (*क्राइसोडिएक्सिस एक्यूटा*) के पूर्ण माइटोकॉन्ड्रियल जीनोम को अनुक्रमित किया गया था। सेमिलूपर का चक्र जीनोम लंबाई में 15,743 बीपी है। कुल 37 अनुक्रम तत्व मौजूद हैं जिसमें 13 प्रोटीन-कोडिंग जीन, 22 टीआरएनए जीन, दो आरआरएनए जीन और एक नियंत्रण क्षेत्र शामिल हैं। 395 बीपी की औसत जीन लंबाई के साथ अधिकतम और न्यूनतम जीन लंबाई क्रमशः 1749 बीपी और 63 बीपी थी, जबकि औसत जीन लंबाई 395 बीपी थी। वन्य में *सी. एक्यूटा* क्षति, साथ ही खेती योग्य *एलियम* का अनुमान लगाया गया है, और डेटा से पता चला है कि *एलियम फिस्टुलोसम* एल. जॉर्जियन में सबसे अधिक पर्ण क्षति (14%) थी,

जिसके बाद ए. *फिस्टुलोसम* ईसी 324643-1 और *ए फिस्टुलोसम* एनआईसी 20221 में पर्ण क्षति पाई गई। ए. *फिस्टुलोसम* ईसी 324643-1 में उच्च लार्वा घनत्व देखा गया।

वर्ष 2021 में, महाराष्ट्र के प्रमुख प्याज भंडारण क्षेत्रों पुणे, सोलापुर, नासिक, अहमदनगर, धुले, जलगाँव, अमरावती और अकोला में संग्रहीत प्याज से जुड़े कीट और रोगों के लिए एक निगरानी सर्वेक्षण किया गया। प्याज में मुख्य भंडारण जीव बैक्टीरियल सॉफ्ट रॉट, ब्लैक मोल्ड रॉट (*एस्परगिलस नाइगर*), फ्यूज़ेरियम बल्ब रॉट और नेक रॉट पाए गए। भंडारण में माध्यमिक मैगॉट संक्रमण भी आम था।

निदेशालय ने लाल प्याज के तले हुए फ्लेक्स के ब्राउनिंग, (जो लाल प्याज प्रसंस्करण में आम समस्या है) को नियंत्रित करने पर काम भी शुरू कर दिया है। इसके अलावा, किसानों तक पहुंचने के लिए एक आउटरीच गतिविधि के रूप में अनुसूचित जाति उपयोजना (एससीएसपी), जनजातिय उपयोजना (टीएसपी), जनजातिय उपयोजना-पूर्वोत्तर पर्वतीय (टीएसपी-एनईएच) और पूर्वोत्तर पर्वतीय योजना (एनईएच प्लान) जैसी योजनाओं के माध्यम से निदेशालय ने खरीफ (164), पछेती खरीफ (125) और रबी (92) के दौरान विभिन्न राज्यों जैसे महाराष्ट्र, उत्तर प्रदेश, सिक्किम, अरुणाचल प्रदेश, मणिपुर और त्रिपुरा में कुल 381 प्रदर्शन किए। निदेशालय द्वारा विभिन्न नवीनतम सूचना व संचार तकनीक साधन (आईसीटी टूल) एवं प्रशिक्षण वीडियो विकसित किए गए हैं, और हमारी वैज्ञानिकों की समर्पित टीम द्वारा दूरदर्शन एवं आकाशवाणी वार्ताओं के माध्यम से सभी हितधारकों तक पहुंचने के लिए अधिकतम प्रयास किए जा रहे हैं।

Executive Summary

This year ICAR-DOGR evaluated 40 germplasm of white onion during *rabi* season, 13 germplasm of white onion during *kharif* season, and 35 onion germplasm during late *kharif*. For *rabi* season, this year we succeeded to get two promising lines W-045 GP and W-125 GP with significantly higher marketable yield and good TSS content of 11.24 and 11.78 °Brix respectively compared to the check variety Bhima Shweta. Despite of the severe infestation of anthracnose during the *kharif* season, the anthracnose resistant bulbs have been maintained for breeding anthracnose tolerant onion varieties. Additionally, eleven lines of *kharif* yellow onion germplasm were also evaluated and we noticed that the line Y-005 resulted in superior yield in *kharif*. Moreover, we have got three breeding lines of white onion namely W-398 AD-5, W-085 AD-6 and W-355 showing superior yield traits and good sto*rabi*lity. The best part of this year achievement is the development of five high-TSS white onion lines having TSS content of above 18 °Brix which would meet the consumer preferences.

This year directorate continued its efforts to evaluate 89 wild and underutilized lines of *Allium* of 17 species for desirable traits and their inclusion in ongoing breeding programmes. The wild species '*A. tuberosum* kazakhistan All-1587' showed tremendous potential for foliage purpose and a MoU has already been signed with 'Kisan Konnect' in June 2021 for popularization of three identified lines of *A. tuberosum* for the table and culinary purpose consumption. The biochemical assays have indicated higher amount total phenolics, anthocyanin, flavonoids and total thiosulfinates in leaves of many wild species available with this directorate indicating their potential as functional food. Towards our efforts to generate the onion germplasm having disease and pest resistance, 18 lines of white onion germplasm showing PDI of less than 10 have been generated. Moreover, our short-day varieties of Bhima series are also being used for introgression breeding with long day onion Brown Spanish at ICAR-CITH, Srinagar. This directorate has also evaluated available germplasm of red onion in late *kharif* (140 accessions), *rabi* (263 accessions) and *kharif* (160 accessions) along with the checks. A far higher marketable yield of 63.56 t/ha was obtained for red onion accession 1319, compared to checks Bhima Super (48.02 t/ha), Bhima Kiran (47.04 t/ha), Bhima Shakti (46.23 t/ha) during late *kharif* 20-21. This accession was found to be having absolutely no doubles and bolters with higher ABW (average bulb weight) of 116.67g. Three red onion lines *viz.*; DOGR-1606, DOGR-1654 and DOGR-1657 have been introduced in AINRPOG trials as IET during 2021-22 whereas, DOGR-1627, DOGR-1639 and DOGR-1203-DR being evaluated as AVT-II during 2021-22. However, two red onion F_1 hybrids *viz.*; DOGR Hy-156 and Hy-172 have been introduced in AINRPOG trials as IET during 2021-22 whereas, DOGR Hy-6, Hy-73, Hy-173 and Hy-179 being evaluated as AVT-II during 2021-22.

Moreover, under the efforts involving biotechnological interventions to improve onion productivity, the polymorphic region for waterlogging tolerance and drought tolerance have also been identified in onion breeding populations employing SSR markers. These polymorphic regions are also being used for genotyping of F2 population and developing linkage map. The efforts are also being taken to generate *DREB1A* gene transformed onion plants and haploid induction through gynogenesis in onion. Further to this, this directorate also continued to enrich the available germplasm of garlic with 700 lines including germplasm, landraces and varieties of garlic currently available with directorate.

This year ICAR-DOGR has conducted trials on organic farming in onion to compare it with conventional practices of onion cultivation and the combined application of farm yard manure (10t/ha), vermicompost (2.0 t/ha), neem cake (1 t/ha), phosphorus solubilizing bacteria. Based on experimental results the *Azotobacter* @ 5 kg each/ha with organic pest and disease management practices is recommended for higher yield compared to other organic treatments.

The Inoculation of PSB and *Piriformospora indica* have also shown promising results in terms of increasing the yield of onion ~10% and higher NPKS uptake and their application has also been shown to cope with waterlogged and drought conditions. A significant increase in marketable bulb yield of onion have been shown with fertilizers application using drip irrigation system compared to broadcasting method of fertilizer application. This year, detailed morpho-histological changes in root architecture were deciphered using SEM-EDS (Scanning electron Microscopy) in selected onion genotypes under waterlogged and drought conditions. Experiments based on the six staggered dates of onion transplantation, in an order of increment of 15 days from 1 December to 15 February, the translation near 1 January is recommended as best in terms of performance.

On similar lines, this year directorate has done significant work for crop protection. Many pathogenic fungi causing severe damage to the onion foliage and bulb were collected, isolated and characterized. Ten cultures of *Colletotrichum* sp., *Fusarium* sp., *Alternaria* sp., and *Stemphylium* sp. were characterized and maintained in the lab. In addition, a few endophytes with biocontrol potential were isolated and tested in vitro against the Anthracnose pathogen. Among 14 cultures of diverse origin of *Trichoderma* sp. evaluated under field conditions, the culture 'T-4R' was found most effective in suppressing/inhibiting Anthracnose pathogen, and also increased biomass, and bulb yield. Bulbs harvested from *Trichoderma* T-354 treatment plots recorded least storage losses (18%).

Moreover, four IDM modules were evaluated against onion diseases in *kharif*, along with existing practice (EP), farmers' practice (FP), and absolute control (AC), where module M1, intensive management, was effective in controlling Anthracnose, Stemphylium incidence, and increasing onion bulb yield. The potential of Amritpani-based organic formulations to control anthracnose in onions was investigated. The mixture of bajra (pearl millet) flour, *Calotropis* leaves, karanj *(Pongamia glabra)* leaves, ginger powder, turmeric powder, and hing (asafetida) powder in water effectively reduced the incidence of anthracnose by 79%. Thirty-two red onion germplasms were tested for resistance to anthracnose disease, and only a few were found to be promising.

The molecular response of onion to purple blotch infection was studied using RNAseq analysis on the resistant (Arka Kalyan; AK) and susceptible (Agrifound rose; AFR) genotypes. AFR had 8,064 upregulated genes and 248 downregulated genes, while AK had 832 upregulated genes and 564 downregulated genes. Several key plant defense genes were identified, including pathogenesis-related (PR) proteins, receptor-like kinases, phytohormone signaling, cell-wall integrity, cytochrome P450 monooxygenases, and transcription factors. Overexpression of GABA transporter 1, ankyrin repeat domain-containing protein, xyloglucan endotransglucosylase/hydrolase, and PR-5 (thaumatin-like) was observed in the resistant genotype.

RT-PCR was used to screen 46 garlic accessions for the presence of viruses like onion yellow dwarf virus (OYDV), leek yellow stripe virus (LYSV), garlic common latent virus (GarCLV), iris yellow spot virus (IYSV), garlic virus-A (GarV-A), garlic virus-A (GarV-

B), garlic virus-C (GarV-C), garlic virus-D (GarV-D), garlic virus-E (GarV-E). OYDV was noticed to be a common virus in garlic.

Three native isolates of insect pathogens were isolated from the cadaver of *Spodoptera exigua*, two from *S. frugiperda* and *S. litura*, and five from *C. acuta* in search of potent indigenous bioactive pathogens suitable for biological control of crop pests. These isolates were sub-cultured, maintained, and further taken into morphological and molecular characterizations. Commercial formulations of entomopathogens, including *Beauveria bassiana*, *Metarhizium anisopliae*, *Lecanicillium lecanii*, and the botanical pesticide neem oil, were tested against onion thrips, both alone and in combination with the biological pesticide 'Spinosad'. *Thrips* populations (nymphs and adults) were effectively reduced by insect pathogens. Spinosad was the most effective, with adults and nymphs reduced by 68.5% and 93.4%, respectively. The spray sequence spinetoram-fipronil-profenofos-spinosad was most effective in minimizing thrips population and producing a higher bulb yield in a study to assess the effect of rotation application of selected insecticides on thrips density and bulb yield in onions.

The green semi looper (*Chrysodeixis acuta* Walker) is an emerging pest of the onion crop in India. Besides morphological description, DNA barcoding is a recent approach to distinguish these pests. Therefore, complete mitochondrial genome of Green Semilooper (*Chrysodeixis acuta*) was sequenced. The circle genome of the Semilooper is 15,743 bp in length. A total of 37 sequence elements are present, including13 protein-coding genes, 22 tRNA genes, two rRNA genes, and a control region. The maximum and minimum gene lengths were 1749 bp and 63 bp, respectively, with average gene length of 395 bp. The *C. acuta* damage in the wild, as well as cultivated *Alliums* has been estimated, and data revealed that *Allium fistulosum* L. Georgien had the highest foliage (leaf) damage (14%) in followed by *A. fistulosum* EC324643-1 and *A. fistulosum* NIC20221. The higher larval density was noticed in *A. fistulosum* EC324643-1.

In 2021, a monitoring survey for pests and diseases associated with stored onions was conducted in Maharashtra's major onion storage areas of Pune, Solapur, Nasik, Ahmednagar, Dhule, Jalgoan, Amravati, and Akola. The main storage organisms in onions were bacterial soft rot, black mould rot (*Aspergillus niger*), Fusarium bulb rot, and neck rot. Secondary maggot infestation was also common in storage.

Directorate has also initiated the work on controlling the browning of fried flakes of red onion which is common problem in red onion processing. Moreover, as an outreach activity to reach out to the farmers, ICAR-DOGR carried out 381 demonstrations in different states viz., Maharashtra, Uttar Pradesh, Sikkim, Arunachal Pradesh, Manipur and Tripura during *kharif* (164), late *kharif* (125) and *rabi* (92) seasons through SCSP, TSP, TSP-NEH and NEH Plan. Various newly developed ICT tools and training videos have been developed by Directorate, and maximum efforts are being put to reach to the all the stake holders through TV talks and Radio talks by our dedicated team of scientists.

A. Introduction

The Directorate

Realizing the importance of onion and garlic in the country, Indian Council of Agricultural Research (ICAR) established National Research Centre for Onion and Garlic in VIIIth Plan at Nashik in 1994. Later, the Centre was shifted to Pune on 16 June 1998. Due to expansion of R&D activities of onion and garlic, the center was rechristened and upgraded to ICAR-Directorate of Onion and Garlic Research (ICAR-DOGR) in December 2008. Besides the R&D at main Institute, ICAR-DOGR also has All India Network Research Project on Onion and Garlic with 11 main (including ICAR-DOGR as a coordinating unit), 13 voluntary and 4 cooperating centres across the country.

Location and weather

The Head Quarter of Directorate located at Chandoli, Pune, Maharashtra on Pune -Nashik Highway. It is 18.32 N and 73.51 E at 553.8m above msl (mean sea level) with a temperature range of 5.5 °C to 42.0 °C and having annual average rainfall of 669 mm.

Infrastructure

The Directorate has 55 acres of research farm with perennial irrigation facilities at Rajgurunagar, 56 acres at Kalus and 10 acres at Manjari. The center has research laboratories for biotechnology, biochemistry, soil science, plant protection, seed technology and post-harvest technology with modern state of the art equipment. The library at ICAR-DOGR has extensive collection of books, journals, e-sources on *Alliums*. The internet and e-mail connectivity has been strengthened for easy literature access. The center has its own website: http://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.

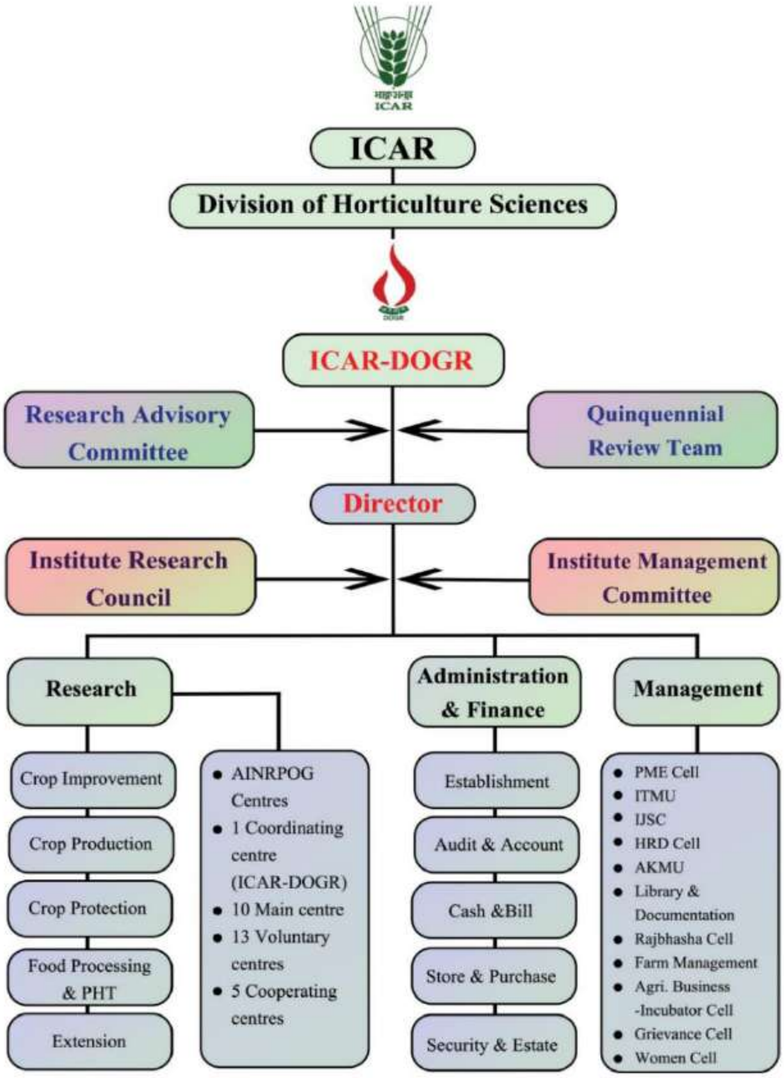
Mission

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 the productivity of onion and garlic
- ❖ Coordinate research and validation of technologies through AINRP on onion and garlic

Organogram



ICAR
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

B. Research Highlights

1. Crop Improvement

1.1 Genetic Improvement of White and Yellow Onion (including underutilized *Alliums*)

Wide genetic base is the backbone of any breeding programme. The available germplasm can be used as a base material for breeders to identify the desirable traits including resistance to diseases and pests, biochemical, nutritional richness and tolerance to abiotic stresses. India has wide geographical variability; hence this germplasm can be exploited for the development of varieties suitable for different agro-climatic conditions. Collection of other *Allium* species available in India and introduction of available exotic cultivated and wild *Allium* genetic resources will help to create variability and its utilization in breeding programme after evaluation. This will help to develop trait specific pre-breeding lines that will be useful for use in further improvement in breeding programs. Wild *Allium* species can be exploited from consumption point of view during off-season besides its nutritional properties and resistance to pest and diseases. With this aim, the project was undertaken at ICAR-DOGR.

India though started late in processing, is now gaining momentum. About 80 big to medium processing plants were established and still more are coming up in Maharashtra, Gujarat, Madhya Pradesh and Rajasthan competing in world market. Some of the Women SHGs (Self Help Groups) also started processing of onion at small scale. Indian export of processed onion has increased from 4124 to 59134 tons over last ten years. India has got special advantage being located in tropics as onion produced in tropical countries has got high pungency and flavor, which adds to processed products also. Present day, processing industries are suffering from non-availability of high TSS white onion varieties, irregular year-round supply, poor seed supply, high post-harvest losses, etc. There is need for averting the situation. Coordinated efforts of scientific research, Processing and Agriculture Ministry, processing units, progressive entrepreneurs and farmers have taken up a momentum in India.

Some of the short-day white onion varieties developed by various research organizations in the country but they do not offer TSS range more than 12 per cent. ICAR-DOGR, Pune has started research programme since last eighteen years for the development of high TSS white onion variety from available germplasm. The research efforts have now resulted in stable high TSS lines in short-day white onion and four lines are being evaluated at different locations in the country and further improvement work is in progress. Results of germplasm and breeding in white and yellow onion and underutilized *Allium* species evaluated during this year are briefly given in this report.

1.1.1 Evaluation of white onion germplasm during different seasons

During *rabi* 2020-21, 40 white onion germplasm were multiplied and evaluated along with check Bhima Shweta. Two lines showed significant superiority for marketable yield and total yield over check Bhima Shweta. Line W-045 (Fig-1) exhibited highest total yield (42.63 t/ha) and marketable yield (41.87 t/ha), followed by W-125 total yield (39.93 t/ha) and marketable yield (39.74 t/ha) compared with check Bhima Shweta total yield (32.43 t/ha) and marketable yield (32.01 t/ha). Marketable yield ranged between 16.82 to 41.87 t/ha and bolters ranged from 0 to 13.08% (Table-1). Thirty-four lines were found to be bolter free. Storage losses in W-408 were minimum (30.52%) followed by W-405 (33.15%) after 4 months of storage as compared with check Bhima Shweta (66.42%). The maximum storage losses were recorded up to 71.91%. Total Soluble Solids ranged between 10.28 to 14.64%. Line W-284 recorded with highest TSS (14.64%) followed by W-431 (13.31%).

Table 1.1. Evaluation of white onion germplasm during *rabi*

Lines	TY (t/ha)	MY (t/ha)	MBW (g)	Bolter (%)	TSS (° Brix)	SL4M (%)
W-045 GP	42.63	41.87	50.30	0.00	11.34	71.20
W-125 GP	39.93	39.74	60.60	0.00	11.78	52.29
Bhima Shweta (C)	32.43	32.01	59.33	0.00	10.84	66.42
C.D. 5%	5.65	5.99	7.43	2.03	0.56	14.02

(TY: Total Yield; MY: Marketable Yield; MBW: Marketable Bulb Weight; TSS Total Soluble Solid; SL4M: Storage loss in 4 months)

Fig. 1.1 High yielding onion germplasm during *rabi* season

During *kharif* 2021, a total of fifteen white onion germplasm was multiplied and evaluated with check Bhima Shubhra. There was severe incidence of anthracnose and yield range was very less 0.45 to 6.68 t/ha and none of the germplasm were found to be superior to check Bhima Shubhra (marketable yield 14.91 t/ha). Total soluble solids ranged between 11.08 to 11.88%. There was severe incidence of anthracnose during *kharif* and late-*kharif* and trial were failed. Despite of this the observations were recorded for anthracnose incidence and selected bulbs were planted for further seed production which survived under huge disease pressure which would be helpful in development of anthracnose tolerant lines.

During late-*kharif* 2020-21, thirty-five white onion germplasm were evaluated with the check Bhima Shubhra. There was severe incidence of anthracnose disease and heavy rainfall at the time of harvesting which resulted in low yield among the germplasm. The marketable yield ranged between 2.43 to 12.75 t/ha. Bulbs from these lines were selected and being multiplied for further evaluation against anthracnose. Storage loss after 2 months ranged between 18.44 to 63.44%. Line W-177 recorded lowest storage loss (18.44%) followed by W-507 (20.43%) as compared to check Bhima Shubhra (52.64%).

1.1.2. Evaluation of yellow onion germplasm during *rabi*

Eleven lines of *kharif* yellow onion germplasm were evaluated where line Y-005 recorded highest marketable yield (26.93 t/ha) and total yield (27.16 t/ha), and were bolter free. Storage losses varied from 64.72 to 72.57% after 4 months of storage (Table-1.2).

Table 1.2 Evaluation of yellow onion germplasm during *rabi*

Lines	TY (t/ha)	MY (t/ha)	MBW (g)	Bolter (%)	TSS (°Brix)	SL4M (%)
Y-005	27.16	26.93	47.54	0.80	14.26	64.72
Y-027	17.23	16.88	33.66	0.00	12.01	72.57
Arka Pitamber (C)	29.72	29.60	53.73	0.00	11.64	66.25
C.D. 5%	5.65	5.99	7.43	2.03	0.56	14.02

(TY: Total Yield; MY: Marketable Yield; MBW: Marketable Bulb Weight; TSS Total Soluble Solid; SL4M: Storage loss in 4 months)

1.1.3. Evaluation of white onion breeding lines

During *rabi* 2020-21, a total of 62 white onion breeding lines were evaluated and compared with check Bhima Shweta. Three lines for total yield and marketable yield were found significantly superior as compared to check Bhima Shweta. Highest marketable yield was observed in W-398 AD-5 (46.93 t/ha) and total yield (48.81 t/ha), followed by line W-085 AD-6 and W-355 (43.10 t/ha for marketable yield and 45.06 t/ha for total yield) over check Bhima Shweta where marketable yield was 32.01 t/ha and total yield 32.43 t/ha. The line W-340 EL-8 recorded lowest storage loss (28.48%) after 4 months of storage (Table 1.3).

Table 1.3 Evaluation of white onion breeding lines during *rabi*

Lines	TY (t/ha)	MY (t/ha)	MBW (g)	Bolter (%)	TSS (oBrix)	SL4M (%)
W-398 AD-5	48.81	46.93	75.86	0.00	11.40	75.70
W-355	45.06	43.10	74.59	0.00	11.50	52.92
W-085 AD-6	45.06	43.10	76.12	1.44	11.08	53.73
Bhima Shweta (C)	32.43	32.01	59.33	0.00	10.84	66.42
C.D. 5%	8.13	8.43	6.60	0.16	0.55	15.82

(TY: Total Yield; MY: Marketable Yield; MBW: Marketable Bulb Weight; TSS Total Soluble Solid; SL4M: Storage loss in 4 months)

Fig 1.2 High yielding accessions of white onion breeding lines during *rabi* season

1.1.4. Evaluation of white onion high-TSS lines during different season

During late-*kharif* 2020-21, total 11 high TSS *rabi* lines were evaluated and compared with 3 checks. There was severe incidence of anthracnose hence yield was very less but TSS in these lines ranged between 15.75 to 20.62° Brix. All the lines recorded TSS above 15° Brix. Highest TSS was recorded in WHTS-7G-GT-15-MC-M-7 (20.62° Brix) followed by WHTB-GT-18-M-9-MC (17.54° Brix), WHTB-15-18-M-9-SC (17.27° Brix) and WHTB-3C-GT-18-MC-M-9 (17.14%) over check where TSS were less than 12%. Above 81% of bulbs in the population recorded average TSS above 15° Brix in WHTS-7G-GT-15-MC-M-7 (79.31%), WHTB-GT-18-M-9-MC (79.32%) and WHTB-15-18-M-9-SC (77.69%) with population TSS 20.62%, 17.54% and 17.27%, respectively.

Table 1.4 Five high-TSS lines of white onion during late *kharif* season

ENTRY	% bulbs having TSS above 15%	Average population TSS%
WHTS-7G-GT-15-MC-M-7	79.31	20.62
WHTB-GT-18-M-9-MC	79.32	17.54
WHTB-15-18-M-9-SC	77.69	17.27
WHTB-3C-GT-18-MC-M-9	87.30	17.14
WHTS-15-18-M-9-SC	80.00	16.92
Bhima Shweta	0.00	12.14
Bhima Shubhra	0.00	11.16
Bhima Safed	0.00	12.11

Table 1.5 Evaluation of white onion high-TSS lines during late-*kharif*

Lines	TY (t/ha)	MY (t/ha)	MBW (g)	Bolter (%)	TSS (°Brix)
WHTS-7G-GT-15-MC-M-7	0.39	0.34	40.24	0.00	20.62
WHTB-GT-18-M-9-MC	5.07	4.50	38.89	0.00	17.54
WHTB-15-18-M-9-SC	5.23	5.23	39.88	0.00	17.27
WHTB-3C-GT-18-MC-M-9	2.27	2.27	27.01	0.00	17.14
WHTS-15-18-M-9-SC	1.27	0.31	37.64	0.00	16.92
Bhima Shweta	25.85	20.70	42.61	1.45	12.14
Bhima Shubhra	21.02	19.53	44.50	0.00	11.16
Bhima Safed	21.76	19.69	42.31	0.49	12.11
C.D. 5%	1.55	1.31	3.99	0.51	1.03

(TY: Total Yield; MY: Marketable Yield; MBW: Marketable Bulb Weight; TSS Total Soluble Solid)

During *rabi* 2020-21, a total of 31 high TSS lines were evaluated for the performance and compared with nine varieties for TSS. Total 28 lines recorded average TSS of the bulb greater than 15.0 °Brix. TSS in these lines ranged between 14.35-18.61 °Brix. Whereas in all the 9 check varieties TSS was less than 12.5 °Brix (ranged between 11.36 to 12.36 °Brix). Five lines viz. HT-GR-1A-M-8-SC (SGT-18) (18.03 °Brix), WHT-23A-2 (18-20) (18.61 °Brix), WHT-23A-3 (18.38 °Brix), WHTB-15-18-M-9-SC (18.10 °Brix) and WHTS-GT-18-M-9-MC (18.03 °Brix) were with TSS above 18.0 °Brix. WHT-23A-2 (18-20 °Brix) recorded highest TSS. Better performing lines are advanced for seed production in current season (Fig-1.3). One high TSS line WHTS-15-18-M-8-SC (29.83 t/ha) was found at par with check Bhima Shweta (32.01 t/ha), whereas 14 lines viz. HT-GR-2B-SMC-M-7 (24.87 t/ha), WHT-23A (26.67 t/ha), WHT-23A-2 (18-20) (24.94 t/ha), WHT-23A-3 (24.94 t/ha), WHTB-15-18-M-8-MC (22.42 t/ha), WHTB-15-18-M-8-SC (20.51t/ha), WHTB-3C-GT-18-MC-M-8 (19.86 t/ha), WHTB-6F-GT-15-MC-M-7 (20.23t/ha), WHTB-GT-18-M-8-SC (22.66 t/ha), WHTB-GT-18-M-9-SC (21.25 t/ha), WHTS-15-18-M-9-MC (20.96 t/ha), WHTS-15-18-M-9-SC (23.31 t/ha) and WHTS-2B-GT-18-SC-M-7 (20.49 t/ha) were found at par and one line WHTS-15-18-M-8-SC (29.83 t/ha) was found significant over check Bhima Safed (24.47 t/ha) for the yield performance. Whereas, the varieties evaluated in the season viz. AFW (11.48 °Brix), GWO-1 (12.28 °Brix), P.K.V White (12.36 °Brix), Palampur White (11.73 °Brix), Pusa White Round (11.36 °Brix), Udaipur-102 (11.98 °Brix) recorded low in TSand and 15 lines were found with bulbs more than 75% for TSS above 15 °Brix.

Table 1.6 Percentage of bulbs in population having TSS more than 15% during *rabi*

ENTRIES	% bulbs having TSS >15° Brix	Average population TSS °Brix
HT-GR-1A-M-8-SC (SGT-18)	98.18	18.03
HT-GR-2A-M-8-SC	94.74	16.43
WHTB-GT-18-M-9-MC	89.57	17.23
WHTB-GT-18-M-9-SC	88.89	17.68
WHT-23A-2 (18-20)	88.36	18.61
WHTS-15-18-M-9-MC	85.61	16.84
WHTS-7G-GT-15-SC-M-8-SGT-18	85.29	15.82
HT-GR-2B-M-7-SGT-18	84.88	17.20
WHTS-GT-18-M-9-MC	84.86	18.03
WHTB-GT-18-M-8-MC	84.51	16.66
WHT-23A-3	83.08	18.38
WHTB-15-18-M-9-SC	81.76	18.10
9 Check varieties	0	<12.5

Table 1.7. Evaluation of white onion high-TSS lines during *rabi*

Lines	TY (t/ha)	MY (t/ha)	MBW (g)	Bolter (%)	TSS (°Brix)	SL4M (%)
WHTS-15-18-M-8-SC	29.83	29.63	53.80	0.00	17.07	54.68
WHT-23A-2 (18-20)	24.94	23.95	48.78	0.00	18.61	67.34
WHT-23A-1 (15-17.8)	23.42	23.22	48.03	0.00	16.92	80.69
WHTB-GT-18-M-9-SC	21.25	20.38	45.83	0.00	17.68	62.57
WHTS-2B-GT-18-SC-M-7	20.49	19.54	38.49	0.00	16.59	51.21
WHT-23A-3	20.31	19.78	44.45	0.00	18.38	53.24
Checks (9)	18.42-34.87	17.02-34.69	41.61-69.21	0.00-4.23	10.84-12.36	50.75-70.68
C.D. 5%	4.76	4.79	5.21	1.08	1.04	13.83

(TY: Total Yield; MY: Marketable Yield; MBW: Marketable Bulb Weight; TSS Total Soluble Solid; SL4M: Storage loss in 4 months)

Fig 1.3 High TSS accessions of white onion lines during *rabi* season

During *kharif*-2021, a total of 19 high TSS *rabi* onion lines were evaluated to see the performance and for selection of high-TTS lines. In most of the *rabi* high TSS lines, small knots were formed during *kharif* season in the nursery, hence its establishment was poor. Secondly, there was severe incidence of Anthracnose and trial was failed. The main purpose was to select the high TSS bulbs which were formed during *kharif* season which are being further utilized for the development of high TSS lines for *kharif* season. Six lines recorded more than 15 °Brix TSS (Table 1.8). Highest TSS was reported in WHTS-GT-18-M-10-MC (15.86°Brix), whereas, in all the three checks TSS was not found above 15°Brix and ranged between 11.40 to 11.66°Brix. Above 81% of bulbs in the population recorded average TSS above 15°Brix in WHTS-GT-18-M-10-MC (94.12%), WHTB-GT-18-M-9-MC (82.14%) and WHTB-GT-18-M10-MC (68.75%) with population TSS 15.86 °Brix, 15.76 °Brix and 15.40 °Brix, respectively. From the population evaluated, 6 lines were found with bulbs more than 60 % bulbs having TSS above 15°Brix.

Table 1.8. Five high TSS lines of white onion during *kharif* season

Lines	**% of bulbs having TSS Above 15** °Brix	**Average population TSS** °Brix
WHTS-GT-18-M-10-MC	94.12	15.86
WHTB-GT-18-M-9-MC	82.14	15.76
WHTB-GT-18-M10-MC	68.75	15.40
WHTB-GT-18-M-10-SC	74.36	15.20
WHTB-GT-18-M-8-SC	85.71	15.08
Bhima Shweta	0	11.40
Bhima Shubhra	0	11.42
Bhima Safed	0	11.66

Table 1.8 Evaluation of white onion high TSS lines during *kharif*

Lines	**TY (t/ha)**	**MY (t/ha)**	**MBW (g)**	**Bolter (%)**	**TSS (°Brix)**
WHTS-GT-18-M-10-MC	2.04	1.67	50.50	0.00	15.86
WHTB-GT-18-M-9-MC	0.62	0.00	0.00	0.00	15.76
WHTB-GT-18-M10-MC	3.78	2.52	54.66	0.00	15.40
WHTB-GT-18-M-10-SC	5.78	4.68	41.29	0.00	15.20
WHTB-GT-18-M-8-SC	2.62	4.19	58.75	0.00	15.08
Bhima Shweta	22.21	18.81	58.48	0.00	11.40
Bhima Shubhra	16.77	14.91	64.04	0.00	11.42
Bhima Safed	21.49	16.37	61.84	0.00	11.66
C.D. 5%	1.64	1.36	12.21	0.00	0.75

(TY: Total Yield; MY: Marketable Yield; MBW: Marketable Bulb Weight; TSS Total Soluble Solid)

1.1.5. Evaluation of white and yellow populations raised through crosses between long day and short-day onion in 6th generation during *rabi*

Twenty-two populations in 5th generation from the crosses between long day and short day white and yellow onion were multiplied and half the desirable selected bulbs were sent for seed production at CITH, Srinagar and received seeds of 6th generation. These are being evaluated with the aim to introgress the characters like shape, size and thin neck thickness of the bulbs with good storability in short day onion and being evaluated at ICAR-DOGR and simultaneously at CITH, Srinagar for further selection and evaluation at CITH.

Fig 1.4 White and Yellow lines raised from crossing of long & short-day onion genotypes

1.1.6. Evaluation of white onion advance/initial breeding lines

During *kharif* 2021, twenty-six advance and initial breeding lines were evaluated along with check Bhima Shubhra. Only one line was found at par for marketable yield and total yield compared with check Bhima Shubhra. Marketable yield was recorded for line W-439 M-8 (15.20 t/ha) and total yield (15.59 t/ha) compared with check Bhima Shubhra (marketable yield 14.91 t/ha and total yield 16.77 t/ha). Despite of heavy rainfall at the time of harvesting and incidence of anthracnose disease, marketable yield ranged from 0.52 to 15.20 t/ha in these lines.

Table 1.9. Evaluation of white onion advance/initial breeding lines during *kharif* 2021

Lines	TY (t/ha)	MY (t/ha)	MBW (g)	Bolter (%)	TSS (°Brix)
W-439 M-8	15.59	15.20	57.27	0.00	11.16
Bhima Shubhra (C)	16.77	14.91	64.04	0.00	11.88
C.D. 5%	2.87	2.39	6.94	1.53	0.51

(TY: Total Yield; MY: Marketable Yield; MBW: Marketable Bulb Weight; TSS Total Soluble Solid)

During late-*kharif* 2020-21, a total of 27 advance and initial breeding lines were evaluated and compared with check Bhima Shubhra. Two lines W-448 (marketable yield 24.45 t/ha and total yield 26.92 t/ha) and W-361 (marketable yield 20.98 t/ha and total yield 22.41 t/ha) recorded higher yield. The marketable yield ranged between 2.30 to 24.45 t/ha. Bolter was not problem during this year hence 25 lines were found to be bolter free. Storage losses ranged between 0.0 to 67.96% recorded after 2 months of storage as compared to check Bhima Shubhra (65.16%). W-396 AD-4 recorded least storage loss of 11.59% after 2 months of storage.

Table 1.10 Evaluation of white onion advance/initial breeding lines in late-*kharif*

Lines	TY (t/ha)	MY (t/ha)	MBW (g)	Bolter (%)	TSS (°Brix)	SL2M (%)
W-448	26.92	24.45	65.37	0.47	14.53	-
W-361	22.41	20.98	61.69	0.00	12.06	-
Bhima Shubhra (C)	30.38	28.37	57.77	0.91	12.10	65.16
C.D. 5%	3.07	2.10	8.07	0.55	0.41	3.11

(TY: Total Yield; MY: Marketable Yield; MBW: Marketable Bulb Weight; TSS Total Soluble Solid; SL2M: Storage loss in 2 months)

1.1.7 Evaluation of white onion bolting tolerant lines during late-*kharif*

Six bolting tolerant population being purified in 6th generation were evaluated and compared with check Bhima Shubhra. Two lines were at par for marketable yield as compared to check. This year there was very less bolter particularly during late-*kharif*, hence, all the lines including check were found to be bolter free. Two lines recorded at par performance for marketable yield compared with check. W. Genepool LG-107-6 recorded highest marketable yield 12.86 t/ha followed by W. EL. Comp LG-209-6 (11.25 t/ha) compared with check Bhima Shubhra (11.24 t/ha). Marketable yield ranged between 3.42 and 12.86 t/ha. Storage loss after 2 months ranged between 0.00 to 64.95%.

Table 1.11 Evaluation of white onion bolting tolerant lines during late *kharif*

Lines	TY (t/ha)	MY (t/ha)	MBW (g)	Bolter (%)	TSS (°Brix)
W. Genepool LG-107-6	13.12	12.86	40.45	0.00	11.68
W. EL. Comp LG-209-6	13.57	11.25	37.45	0.00	12.00
Bhima Shubhra (C)	12.27	11.24	44.50	0.00	11.94
C.D. 5%	1.40	1.32	3.94	0.54	0.50

(TY: Total Yield; MY: Marketable Yield; MBW: Marketable Bulb Weight; TSS Total Soluble Solid)

1.1.8. Evaluation of white onion hybrids

During *rabi*, 13 F1 hybrids were evaluated and compared with check Bhima Shweta. Three F1 hybrids recorded highly significantly superior performance compared with check. MS-100 × HT-GR-2A-M-6 Big bulb (15-17.8) (19.0, c-2) recorded highest marketable yield and total yield (50.87 t/ha), followed by MS-100 × B. Shweta F1 recorded 44.77 t/ha marketable yield and 45.41 t/ha total yield and MS-100 × W-355 F1 recorded 42.93 t/ha marketable yield and 43.44 t/ha total yield compared with check Bhima Shweta (32.01 t/ha). MS-100 × HT-GR-2A-M-6 Big bulb (15-17.8) (19.0, c-2) found superiority of heterosis for marketable and total yield (58.92%), followed by MS-100 × B. Shweta F1 (39.87%) for marketable yield and (41.87%) for total yield and MS-100 × W-355 F1 (34.11%) for marketable yield and (35.72%) for total yield over check Bhima Shweta. Six hybrids were statistically at par which the check. Four hybrids were found to be bolter free. MS-100 × HT-GR-1A-M-7 (>18.0) (21.0, C-2) recorded high TSS of 18.84% and MS-100 × HT-GR-2A-M-6 Big bulb (15-17.8) (19.0, C-2) recorded 15.60% TSS over check Bhima Shweta (10.84%).

Table 1.12 Evaluation of white onion Hybrid during *rabi*

Lines	TY t/ha	MY t/ha	MBW (g)	Bolter (%)	TSS (°Brix)	SL4M (%)
MS-100 X HT-GR-2A-M-6 Big bulb (15-17.8)	50.87	50.87	76.30	0.00	15.60	48.38
MS-100 X B. Shweta F1	45.41	44.77	69.67	0.39	10.82	55.17
MS-100 X W-355 F1	43.44	42.93	76.31	1.08	10.78	72.94
Bhima Shweta	32.43	32.01	59.33	0.00	10.84	66.42
C.D. 5%	5.07	5.09	7.86	1.70	0.55	11.40

(TY: Total Yield; MY: Marketable Yield; MBW: Marketable Bulb Weight; TSS Total Soluble Solid; SL4M: Storage loss in 4 months)

1.2 Maintenance and utilization of underutilized/wild *Allium*s

1.2.1. Conservation and popularization of wild and underutilized *Alliums* at ICAR-DOGR

A total of 89 wild and underutilized *Allium* lines of 17 different species are being maintained and evaluated for desirable traits and being utilized for breeding programs at ICAR-DOGR. The bank contains collections from in-country sources from the states like-Leh and Ladakh, Arunachal Pradesh, Assam, Sikkim, Manipur, Himachal Pradesh, Tamil Nadu etc, and also out of country sources such as, United States, Central Asia and the Netherlands through NBPGR. Also, some of the underutilized lines are being mass cultivated for the popularization. Keeping in mind the importance of flowering character for the further utilization in breeding; we are recording flowering trend of these lines in agro-climatic conditions of ICAR-DOGR.

Table 1.13 List of different *Allium* species available at ICAR-DOGR, Pune

A. altaicum Pall	*A. chinense*	*A. senescence*
A. cepa var. aggregatum	*A. hookerii*	*A. cepa* x *A. fistulosum* (Beltsville bunching)
A. fistulosum	*A. schoenoprasum*	*A. cepa* (Bulb onion)
A. tuberosum	*A. fragrance*	*A. ladeboramun*
A. macranthum	*A. ampeloprasum*	*A. ascalonicum*
A. prszewalskianum	*A. cariolinianum*	*A. sativum*

1.2.2. Flowering status of *Allium* species at ICAR-DOGR

All the identified 26 flowering lines from four *Allium* species recorded similar flowering trend in 2021 as observed in the year 2020. The January-May flowering of two identified lines of *A. altaicum* Pall was constant in January-May of the year 2021. All the 11 flowering lines identified from the *A. fistulosum* flowered in the month of March 2020, but an early flowering starting from February was recorded in 2021. For the two identified flowering lines of the *A. schoenoprasum* flowering in February 2020 was constant for the year 2021 and similarly in *A. tuberosum*, the January to May flowering in 2020 was constant in the year 2021.

Table 1.14 List of flowering *Allium* species at ICAR-DOGR, Pune

Allium species	Flowering lines	Flowering months observed in 2020	Flowering months observed in 2021
A. altaicum	2	January - May	January-May
A. fistulosum	11	March	February- March
A. schoenoprasum	2	February	February
A. tuberosum	11	January - May	January-May

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

Promising results for the foliage production trend in Pune condition based on two years of experiment were recorded in three identified *Allium* species viz. *A. tuberosum* Kazakhistan, All-1587, *A. tuberosum* CGN-16418 (NF) and *A. tuberosum* Rott /Ex-sprkucchai CGN-16373 for foliage purpose. All these lines showed character of multiple cuttings and an increase in the number of tillers with the successive harvest cuttings. These lines were mass multiplied for the further evaluation in 2021. The yield trend in the chives (foliage cuttings) was promising. For the year 2021, highest yield of 129.25 t/ha per annum was recorded in *A. tuberosum* Kazakhistan All-1587 which was higher than the previous year (73.57 t/ha). Both the annual yield and the season wise yields recorded for all three lines in the year 2021 were higher than yields recorded in previous year 2020. In summer 2021 the yield ranged between 32.45-39.54 t/ha and recorded highest (39.54 t/ha) in *A. tuberosum* Kazakhistan All-1587. Similarly yields for the rainy season of 2021 and for the winter 2021 ranged between 40.23-58.88 t/ha and 62.47-73.57 t/ha, respectively and too was recorded highest in *A. tuberosum* Kazakhistan All-1587. In June 2021, MOU was signed between ICAR-DOGR and 'Kisan Konnect', one of the leading digital platforms in the fresh vegetable supply chain. Platform was used for the popularization of the three identified lines for the table and culinary purpose consumption in the chive forms on pilot basis. A total of 641.2 kg demand was received and supplied during July 2021 to Jan 2022. The demand observed a slight decline in September to November but geared up a steep rise from the December. Secondary objective of the MOU was to study the scope and general trends in commercialization for chive cuttings. As rising trend in demand being observed; it indicated attainable scope of commercialization with current popularization efforts. Also, all three lines recorded nil disease and pest incidence, thus demanded no use of pesticides that depicts possible alternative to use residue free foliage for consumption.

Table 1.15 High yielding (t/ha) accessions of wild *Allium* species for foliage during summer, rainy and winter season

Wild *Allium* species	Summer (t/ha)		Rainy (t/ha)		Winter (t/ha)		Yield (t/ha)	
	2020	2021	2020	2021	2020	2021	2020	2021
A. tuberosum Kazakhistan All-1587	28.74	39.54	30.46	58.88	14.37	30.83	73.57	129.2
A. tuberosum CGN-16418	25.27	34.28	33.83	51.20	13.63	27.26	72.73	112.7
A. tuberosum Rott/Ex-sprkucchai CGN-16373	27.84	32.45	26.32	40.23	8.31	22.73	62.47	95.4

1.2.4. Extraction of phytochemicals and evaluation of antioxidant potentials of wild *Allium* species

Wild *Allium* species are reported to have reserves of phytochemicals attributing not only to pharmacogenic properties but also provide tolerance to various biotic and abiotic stresses. Extracts of various plant parts contains antimicrobial properties against fungi, bacteria and even viruses. Many pharmacogenic effects are directly or indirectly associated with antioxidant potentials of phytochemicals. Leaf extract of ten wild *Allium* species were used for total phenolic, anthocyanin, flavonoids and total thiosulfinates determination and evaluated for its total antioxidant's potentials. Total phenol content (TPC) was observed maximum of 50.26 ± 2.09 mg/g FW in *A. fragrance* followed by 49.43 ± 1.33 mg/g FW in *A. angulosum* and minimum in *A. altaicum* Pall (23.22 ± 0.47 mg/g FW). As presented in table, total flavonoid content (TFC) was also observed maximum in *A. fragrance* and *A. angulosum*. Antioxidant potential of leaf extract were evaluated with three popular methods viz. ABTS, DPPH and FRAP assay and expressed as percentage inhibition and micromole of Trolox equivalence. *A. angulosum* and *A. fragrance* exhibited maximum antioxidant potential in all three methods whereas it was observed lowest in *A. cepa*. aggr. 3 meithei. Thiosulfinates are relatively stable intermediates of produced in the course of breakdown of storable sulphur metabolites in *Allium* species. Total thiosulfinate content (TTC) was observed maximum in leaf extract of *A. tuberosum* (6.63 ± 0.04 µmol/g FW) and minimum in *A. ladebouramun* (0.53 ± 0.07 µmol/g FW).

1.2.5. Characterization of wild *Allium* species based on male gametophyte

Garlic chives (*Allium tuberosum* Rottler ex Sprengel) are an underutilized and neglected food crop of the *Allium* genus, reveal the morphological features of male gametophytes for the future genetic development of *Allium*s, phenotypically of anther was reticulate, conspicuous, folded surface with scaly plates, and pollen was found to be sub-ovoid morphologies with long regulate and striated sexine. These insights of male gametophytes traits and characteristics breeding behaviour could aid in the better understanding, characterization, identification and genetic improvement of *A. tuberosum* and insights could be the aid to breed the new garlic chives varieties.

1.2.6. Inter-specific crosses of onion and *In-vitro* regeneration of the progenies

Among 15 inter-specific hybrid lines developed (using different *A. fistulosum* and *A. tuberosum* lines) were selfed and 6268 enlarged ovaries were cultured *in-vitro*, from those 4 shoots were germinated. Now one plant is growing in field. In case of onion varieties B. Kiran and B. Raj, out of 5 inter-specific hybrid lines 134 enlarged ovaries were inoculated *in-vitro*, from those 4 shoots were germinated and one 1 plant is survived. Eight onion varieties (B. Super, B. Red, B. Raj, B. Kiran, B. Shakti, B. Dark Red, B. Shweta and B. Safed) were crossed with 3 wild spp. and 618 enlarged ovaries were cultured in-vitro, from those 26 shoots were germinated and 2 plants are survived being multiplied in the field. Further 6 inter-specific lines as female were crossed with 5 onion varieties (B. Shakti, B. Raj, B. Kiran, B. Safed and B. Dark Red) where 441 enlarged ovaries were inoculated *in-vitro* from that 1 shoot was germinated.

1.2.7. Evaluation of white onion lines against diseases in different seasons

During *rabi* 2021, among 18 white germplasm including checks evaluated, WHTS-7G-GT-15-SC-M-7, WHT-23A-2 (18-20), WHTS-8H-GT-15-MC-M-7, W-344, W-453, M-8, W-408, WHTB-3C-GT-18-MC-M-7 and W-358 were promising receiving less than 10 PDI (Pest and Disease Index). During *kharif* 2021, altogether, 30 white germplasm including checks were evaluated, among them, WHTS-8H-GT-15-MC-M-7 germplasm was free from anthracnose disease and W-344 shown 7 PDI. Four (W-358, W-143 GP, W-458 GP and W-125 GP) germplasm showed less anthracnose (<20 PDI). Remaining 21 germplasm showed higher disease ranging from 25-77 PDI. Whereas observations were also recorded for anthracnose in E-2 germplasm evaluation block, where 152 germplasm including check were transplanted. Among them, four germplasm (W-523-GP, W-414-EL-7, W-443-M-6, W-147-M-6 and MS-100 × WHT-23A F1M1) received ≤ 20 PDI. Rest all the germplasm received higher incidence of anthracnose ranging from 27-100 PDI. The intensity of disease was higher in E-2 plot.

1.2.8. Evaluation of white onion genotypes for resistance to thrips (*Thrips tabaci* Lindeman)

Thirty-two white onion genotypes were evaluated against onion thrips in *rabi*, 2021 under natural infestation conditions. Observations on thrips per plant were recorded at fort-night interval starting from 30 days after planting. The intensity of thrips damage or pest pressure was very low in all the genotypes therefore, the genotype reactions were scored based on mean thrips density as criteria, and categorized as resistant (R), moderately resistant (MR), susceptible (S) and highly susceptible (HS). For this classification, the mean value of an individual genotype ($\bar{X}i$) was compared to the mean value of all genotypes ($\bar{X}$) and standard deviation (SD) as described by Shaikh et al. (2014) with a minor modification. Twelve genotypes were categorized as resistant, four as moderately resistant and remaining were susceptible and highly susceptible. Although some of the genotypes are categorized as resistant and moderately resistant while considering thrips pressure, more testing under severe pest pressure conditions is required for further confirmation of their reactions.

Table 1.16 Evaluation of white onion genotypes to onion thrips under natural infestation condition

Category	Genotypes
Resistant	W-355, W-408 GP, W-500 GP, W-367 AD 5, W-147 m-6, W-340 m-8, W-353-m-4, W-414-m-4, W-441-m-9, W-500-m-1, AFW, Udaipur-10 2
Moderately resistant	WHT-23 A3 SB, W-125 GP, HT-GR-2A-m-7 SGT-18 and WHTB-6-F GT-mc-M 7
Susceptible	B. Shubhra, B. Shweta, B. Safed, W-344, WHTB 15-18 1M-9SC, PKV White, W-217 GP
Highly susceptible	W-361, W-448, W-340, W-504, WHTB GT-18 m-9SC and WHT-23 a2-18-20

1.2.9. *Allium* germplasm at ICAR-CITH, Srinagar & Introgression breeding

At present, 110 collections of long day (LD) onion are being maintained at ICAR-CITH, Srinagar out of which approximately 101 are red, 8 yellow and 1 brown. However, only 30 genotypes were evaluated during the reported period. The marketable bulb yield ranged from 30.96 to 67.04 t/ha and TSS was from 7.6 to 16.90 °Brix.

1.2.10 Conservation of other *Allium* species

Other *Allium* species including underutilized and exotic like Pran (17 collections), wild onion, Central Asian garlic and *Allium fistulosum* are also being conserved. Some of these have EC numbers (EC-862413 to EC-862418, EC-862424 to EC-862427, EC-862434 and 862435). All these species account for 34 genotypes altogether.

1.2.11. Introgression breeding between short day and long day onion at CITH, Srinagar

Four introgression breeding lines were selected from LD × SD introgression breeding programme shared by CITH and DOGR (since 2008-09) for suitability for cultivation in Kashmir with respect to storability, yield and bulb colour in 2021 and seed was produced. Further, introgression programme was started to introgress the storability trait into long day onion from short day onions of Bhima series at ICAR-CITH, Srinagar in collaboration with ICAR-DOGR, Pune. Nine short day varieties (Bhima Kiran, Bhima Safed, Bhima Shakti, Bhima Red, Bhima Shweta, Bhima Super, Bhima Raj, Bhima Shubhra and Bhima Dark Red) have been paired with Brown Spanish for crossing. Seed production and selections will be carried out at ICAR-CITH every year and further half of the seed produced will be sent to ICAR-DOGR every year for further selections under plains also.

1.2.12. Introgression breeding in *Allium* species

Use of wild Allium species for introgression purpose

For transfer of disease resistance trait from wild *Allium* to common onion, crosses were made between *A. cepa* x *A. fistulosum* using embryo rescue technique. The standardized protocol used for crossing, culturing and regeneration of putative hybrid plantlets. These hybrids will be screened for disease resistance in coming *kharif* season.

Table 1.17 Details of Interspecific hybrid development crossing program using *Allium* species

Female line	Male line	Ovaries inoculated *in-vitro* after hand pollination	No. of shoots germinated
IH lines (F_2)	15	6268	4
A. cepa (2 varieties)	IH Lines (5)	135	5
A. cepa (8 Varieties)	*Allium* spp. (3)	618	26
IH lines (6 No.)	*A. cepa* ICAR-DOGR Varieties (5)	441	1

*IH-Interspecific hybrid

In crossing program, a total of 15 interspecific hybrids were selfed for F_2 population development with *in-vitro* culturing of 6268 ovaries after pollination. Total 4 *in-vitro* shoots have been obtained from cultured ovaries. Five interspecific hybrid lines with almost 50% pollen fertility were used as a male parent with two onion (*A. cepa*) varieties.

Table 1.18 Pollen fertility of hybrid lines

Hybrids	Fertile pollen (%)	Hybrids	Fertile pollen (%)
IH301	39.74%	IH101	55.49%
IH207	60.61%	IH113	49.11%
IH204	51.57%	IH112	55.98%
IH110	46.49%	IH203	61.25%
IH109	49.00%	IH206	47.62%
IH102	28.08%	IH104	59.39%
IH205	63.25%	IH306	63.76%
IH105	59.84%	IH108	67.88%
IH107	80.20%	IH201	56.73%
IH211	26.35%		

After hand pollination, 135 ovaries were *in-vitro* inoculated in standardized medium where after one month of culturing five shoots were germinated from ovaries. Reciprocal cross of these set was also attempted with the addition of few available parents where a total 441 ovaries cultured *in-vitro*, after one month of culturing one shoot was obtained. Three accessions of *A. fistulosum* L. were used as a male parent with 8 onion varieties for development of interspecific hybrids. After crossing 618 ovaries cultured *in-vitro* in BDS medium and 26 shoots obtained from these set (Table 1.17). During *rabi* 2020-21 total of 25 field established interspecific hybrids showed induction of scape and flowering. Pollen fertility ranged between 26.35 to 80.20% (Table 1.18).

1.3 Genetic improvement of red onion

1.3.1 Collection, evaluation, conservation and documentation of red onion germplasm

Onion germplasm were evaluated during late-*kharif* (140 accessions), *rabi* (263 accessions) and *kharif* (160 accessions) along with checks. All the onion accessions were characterized for 24 important traits. Seeds of 642 red onion germplasm have been conserved in mid-term storage at ICAR-DOGR. During late-*kharif* 2020-21, Acc. 1319, 1321, 1650, 1279 and 1640 produced more than 59 t/ha marketable yield and found superior over best check Bhima Super (48.02 t/ha) (Table 1.19). These accessions also recorded with more than 94% marketable yield and were free from doubles and bolters except 1640 (5.19% bolters). Minimum days to harvesting was recorded in Acc. 1279 (102 days) followed by 1319, 1640 and 1650 (106 days). Minimum storage loss after four months of storage was recorded in Acc. 1339 (20.79%) followed by 1320 (23.70%), 1722 (25.00%) and 1771 (25.40%) whereas, in Bhima Shakti (40.73%).

Table 1.19 Best performing red onion accessions during late-*kharif* 2020-21

Entries	MY (t/ha)	Mrk. %	ABW (g)	Doubles (%)	Bolters (%)	DTH	E:P
1319	63.56	100.00	116.67	0.00	0.00	106.00	1.06
1321	61.14	100.00	114.64	0.00	0.00	115.00	1.11
1650	60.80	100.00	114.00	0.00	0.00	106.00	1.07
1279	59.73	100.00	112.00	0.00	0.00	102.00	1.16
1640	59.03	94.33	119.18	5.19	0.00	106.00	1.18
1309	56.13	100.00	105.25	0.00	0.00	115.00	1.09
1366	53.16	100.00	99.67	0.00	0.00	115.00	1.14
Bhima Super (C)	48.02	100.00	90.03	0.00	0.00	122.67	1.26
Bhima Kiran (C)	47.04	88.62	102.47	0.00	11.38	122.67	1.16
Bhima Shakti (C)	46.23	90.23	92.53	0.00	9.77	125.33	1.18
CV (%)	9.80	11.23	8.93	18.45	25.09	5.01	-
LSD (P=0.05)	4.55	12.26	6.81	10.41	9.11	7.10	-

(MY: Marketable Yield; Mrk: Marketable bulb percentage; ABW: Average Bulb Weight; DTH: Days to harvest; E: Equatorial diameter; P: Polar diameter)

During late-*kharif* 2020-21, under bolting free group, Bhima Shakti (LG-107-3) and DOGR-1133 (LG-107-3) produced more than 53 t/ha marketable yield and found superior over best check Bhima Super (47.01 t/ha) (Table 1.20). These accessions also recorded with 100% marketable yield and were free from doubles and bolters. Minimum days to harvesting (105 days) was recorded in DOGR-1168 (LG-107-3) whereas, in check Bhima

Super and Bhima Shakti (125 days). Minimum storage loss after four months of storage was recorded in Bhima Super (LG-107-3) (19.18%) followed by B-780-5-3-1 LR (LG-107-3) (22.99%) and Bhima Red (LG-107-3) (26.21%).

Table 1.20 Best performing red onion LG group during late-*kharif* 2020-21

Entries	MY (t/ha)	Mrk. %	ABW (g)	Double (%)	Bolter (%)	DTH	E:P
B. Shakti (LG-107-3)	61.60	100.0	115.5	0.00	0.00	113.0	1.24
DOGR-1133(LG-107-3)	53.60	100.0	100.5	0.00	0.00	113.0	1.17
B. Raj (LG-107-3)	42.69	94.83	87.53	1.28	3.33	110.3	1.21
DOGR-1168(LG-107-3)	42.13	100.0	79.00	0.00	0.00	105.0	1.24
RGO-53 (LG-107-3)	39.51	93.75	86.43	2.10	2.02	106.3	1.24
B. Red (LG-107-3)	39.20	91.91	89.67	5.14	0.58	109.0	1.24
DOGR-595 (LG-107-3)	34.59	89.03	83.89	10.97	0.00	109.0	1.21
B. Super (C)	47.01	96.54	96.21	2.48	0.00	125.7	1.19
B. Shakti (C)	42.67	100.0	80.00	0.00	0.00	125.7	1.26
Phule Samarth (C)	36.15	93.67	75.86	3.11	1.76	128.3	1.21
CV (%)	10.30	11.13	11.40	25.88	28.07	3.57	-
LSD (P=0.05)	5.48	11.86	8.52	6.94	5.58	7.00	-

(MY: Marketable Yield; Mrk: Marketable bulb percentage; ABW: Average Bulb Weight; DTH: Days to harvest; E: Equatorial diameter; P: Polar diameter)

During *rabi* 2020-21, Acc. 1671, 1665, 1754, 1662 and 1622 produced more than 50 t/ha marketable yield and found superior over best check Bhima Kiran (38.75 t/ha) (Table 1.21). These accessions also recorded more than 84% marketable yield and Acc. 1754 was free from doubles and bolters while Acc. 1665 was bolter free with 103 days to maturity. Minimum storage loss after four months of storage was recorded in Acc. 1463 (16.67%), 1769 (18.48%) and 1427 (19.87%) whereas, check Bhima Shakti (21.41%).

Table 1.21 Best performing red onion germplasm during *rabi* 2020-21

Entries	MY (t/ha)	Mrk. %	ABW (g)	Doubles (%)	Bolters (%)	TSS (%)	DTH	E:P
1671	54.92	96.69	115.53	1.17	1.81	11.81	107.67	1.09
1665	53.95	96.02	116.00	3.98	0.00	12.18	103.00	1.06
1754	53.17	100.00	124.63	0.00	0.00	11.08	114.00	1.23
1662	52.57	84.88	115.33	13.42	1.70	11.15	107.00	1.09
1622	50.90	95.02	107.67	3.71	1.27	11.09	106.33	1.11
1631	48.34	96.45	103.41	2.35	1.20	11.97	106.00	1.10
1651	48.17	95.28	99.95	0.00	2.77	11.71	107.00	1.14
Bhima Kiran (C)	38.75	94.13	81.61	5.67	0.00	11.49	107.67	1.09
Bhima Shakti (C)	38.54	98.75	88.39	0.00	0.00	11.72	107.67	1.09
BLR (C)	28.93	96.90	73.27	0.00	0.45	11.75	106.00	1.07
CV (%)	11.10	3.84	11.89	22.01	19.30	4.89	3.49	-
LSD (P=0.05)	4.60	6.00	13.89	4.10	2.22	0.91	6.14	-

(MY: Marketable Yield; Mrk: Marketable bulb percentage; ABW: Average Bulb Weight; DTH: Days to harvest; TSS; Total Soluble Solids; E: Equatorial diameter; P: Polar diameter)

Acc. 1622 **Acc. 1662** **Acc. 1754**

Fig 1.5 Best performing red onion germplasm during *rabi* 2020-21

During *kharif* 2021, Acc. 1615, 1397, 1250, 1221 and 1623 produced more than 30 t/ha marketable yield and found superior over best check Bhima Super (25.53 t/ha) (Table 1.22). These accessions also recorded with more than 82% marketable yield and were free from doubles and bolters. Minimum days to harvesting was recorded in Acc. 1379, 1369 and 1646 (77 days) whereas, in check Bhima Super (85 days).

Table 1.22 Best performing red onion germplasm during *kharif* 2021

Entries	MY (t/ha)	Mrk. %	ABW (g)	Doubles (%)	Bolters (%)	TSS (%)	DTH	E:P
1615	38.67	94.31	69.60	0.00	0.00	11.20	87.00	1.23
1397	36.82	94.10	65.27	0.00	0.00	10.40	77.00	1.14
1250	35.67	100.00	53.50	0.00	0.00	10.96	82.00	1.10
1221	30.27	92.84	56.75	0.00	0.00	10.96	82.00	1.08
1623	30.06	82.53	70.86	0.00	0.00	10.08	87.00	1.09
1369	30.00	70.16	90.00	0.00	7.82	11.12	77.00	1.12
1646	29.40	91.30	63.00	0.00	0.00	10.92	77.00	1.22
Bhima Super (C)	25.53	80.52	65.06	6.78	3.37	10.84	84.67	1.11
BDR (C)	19.35	75.21	60.39	2.46	10.64	10.59	86.33	1.14
Arka Kalyan (C)	21.13	83.86	70.44	16.14	0.00	10.76	83.00	1.14
CV (%)	8.65	9.47	6.35	11.37	17.13	3.90	4.32	-
LSD (P=0.05)	4.00	11.11	14.05	10.62	10.17	0.68	5.72	-

(MY: Marketable Yield; Mrk: Marketable bulb percentage; ABW: Average Bulb Weight; DTH: Days to harvest; TSS; Total Soluble Solids; E: Equatorial diameter; P: Polar diameter)

Acc. 1615 **Acc. 1623** **Acc. 1646**

Fig 1.6 Best performing red onion germplasm during *kharif* 2021

1.3.2 Breeding improved onion varieties for table purpose

Evaluation of red onion advance breeding lines in different season

Advance breeding lines were evaluated during late *kharif* (30 lines), *rabi* (31 lines) and *kharif* (33 lines) along with checks for 24 important traits.

During late-*kharif* 2020-21, five lines (DOGR-1614, KH-M-1, DOGR-1172-DR, RGP-5 and DOGR-1657) produced more than 51 t/ha marketable yield and found superior over best check Bhima Kiran (45.95 t/ha) and were free from bolters except DOGR-1614 and DOGR-1657. These lines also recorded more than 82% marketable yield with dark red, globe and big sized bulbs (118-153 g). Minimum days to harvesting was recorded in DOGR-1614 and KH-M-1 (109 days) whereas, in check Bhima Kiran (127 days). Minimum storage loss after four months of storage was recorded in DOGR-1611 (40.17%) followed by Agrifound Light Red (42.26%) and Bhima Kiran (42.71%).

Table 1.23 Best performing advance breeding lines during late-*kharif* 2020-21

Entries	MY (t/ha)	Mrk. %	ABW (g)	Double (%)	Bolters (%)	DTH	E:P
DOGR-1614	60.50	82.76	153.03	6.61	10.62	109.00	1.13
KH-M-1	60.47	97.95	134.58	2.05	0.00	109.00	1.22
DOGR-1172-DR	52.70	88.51	118.07	11.49	0.00	110.33	1.18
RGP-5	51.96	87.80	118.29	12.20	0.00	117.00	1.13
DOGR-1657	51.22	84.00	132.43	8.66	6.88	110.67	1.12
DOGR-1604	48.53	90.03	104.00	0.00	0.00	113.00	1.29
DOGR-1669	46.56	68.21	168.98	18.80	4.35	112.00	1.18
Bhima Kiran (C)	45.95	87.07	110.81	12.93	0.00	127.00	1.14
Bhima Super (C)	45.54	90.79	107.27	6.56	2.19	125.67	1.11
Bhima Shakti (C)	34.81	80.74	101.78	17.85	0.00	127.00	1.26
CV (%)	12.67	9.07	13.18	20.79	28.04	5.30	-
LSD (P=0.05)	4.82	9.28	10.35	4.11	9.55	10.00	-

(MY: Marketable Yield; Mrk: Marketable bulb percentage; ABW: Average Bulb Weight; DTH: Days to harvest; TSS; Total Soluble Solids; E: Equatorial diameter; P: Polar diameter)

During *rabi* 2020-21, DOGR-546-DR (56.07 t/ha), DOGR-1610 (53.47 t/ha), RGP-2 (50.92 t/ha), DOGR-1044-Sel (49.02 t/ha) and DOGR-1614 (47.87 t/ha) were found superior over best check Agrifound Light Red (37.59 t/ha) with dark red, globe and big sized bulbs (78-93 g) and more than 97% marketable yield (Table 1.24). All the lines were free from doubles and bolters except DOGR-1044-Sel (2.18% bolters) whereas, minimum days to harvesting was recorded in DOGR-546-DR (100 days). Minimum storage loss after four months of storage was recorded in Bhima Shakti (18.81%) followed by DOGR-1657 (23.38%) and RGP-3 (23.49%).

Table 1.24 Best performing advance breeding lines during *rabi* 2020-21

Entries	MY (t/ha)	Mrk. %	ABW (g)	Doubles (%)	Bolters (%)	TSS (%)	DTH	E:P
DOGR-546-DR	56.07	100.00	93.44	0.00	0.00	11.68	100.00	1.16
DOGR-1610	53.47	100.00	90.06	0.00	0.00	12.04	102.00	1.14
RGP-2	50.92	100.00	92.27	0.00	0.00	11.91	102.67	1.14
DOGR-1044-Sel	49.02	97.82	78.94	0.00	2.18	11.49	104.00	1.15
DOGR-1614	47.87	97.36	84.88	0.00	0.00	11.96	101.33	1.14
DOGR-1047-Sel	46.33	100.00	71.55	0.00	0.00	11.87	106.00	1.15
DOGR-1014-GDR	44.53	95.43	78.59	0.00	4.57	12.28	104.00	1.18
ALR (C)	37.59	97.96	67.45	0.00	0.00	11.63	107.67	1.15
Arka Niketan (C)	37.11	100.00	60.73	0.00	0.00	12.40	106.00	1.19
Bhima Shakti (C)	29.07	93.60	60.96	0.25	0.30	12.44	107.67	1.16
Bhima Kiran (C)	28.93	95.72	64.01	0.33	0.00	12.35	110.67	1.15
CV (%)	11.13	5.46	12.15	9.24	6.98	6.22	2.03	-
LSD (P=0.05)	4.88	8.32	9.52	1.17	1.67	1.19	3.43	-

(MY: Marketable Yield; Mrk: Marketable bulb percentage; ABW: Average Bulb Weight; DTH: Days to harvest; TSS; Total Soluble Solids; E: Equatorial diameter; P: Polar diameter)

During *kharif* 2021, DOGR-1614 (35.42 t/ha), DOGR-1048-Sel (33.07 t/ha), DOGR-1611 (32.58 t/ha) and DOGR-1014-GDR (29.33 t/ha) were found superior over best check Bhima Super (25.53 t/ha) with dark red, globe bulbs and more than 89% marketable yield (table 1.25). All the lines were free from bolters and doubles except DOGR-1048-Sel (4.32% doubles). Minimum days to harvesting was recorded in DOGR-1048-Sel (78 days) followed by RGP-5 and DOGR-1047-Sel (81 days).

Table 1.25 Seven best performing advance breeding lines during *kharif* 2021

Entries	MY (t/ha)	Mrk. %	ABW (g)	Doubles (%)	Bolters (%)	TSS (%)	DTH	E:P
DOGR-1614	35.42	100.00	65.38	0.00	0.00	10.44	83.00	1.26
DOGR-1048-Sel	33.07	89.37	66.13	4.32	0.00	10.76	78.00	1.14
DOGR-1611	32.58	100.00	60.15	0.00	0.00	10.56	83.00	1.09
DOGR-1014-GDR	29.33	100.00	70.40	0.00	0.00	11.12	83.00	1.02
RGP-5	28.98	74.39	78.63	9.99	7.99	10.92	81.33	1.14
DOGR-1627	23.88	76.86	68.56	11.40	3.35	10.41	83.00	1.13
DOGR-1047-Sel	22.87	84.10	58.30	0.00	4.71	10.32	81.33	1.12
Bhima Super (C)	25.53	80.52	65.06	6.78	3.37	10.84	84.67	1.11
BDR (C)	19.35	75.21	60.39	2.46	10.64	10.59	86.33	1.14
Arka Kalyan (C)	21.13	83.86	70.44	16.14	0.00	10.76	83.00	1.14
CV (%)	10.67	11.64	12.33	21.79	15.81	3.56	4.93	-
LSD (P=0.05)	3.76	8.58	12.37	12.13	10.13	0.62	6.67	-

(MY: Marketable Yield; Mrk: Marketable bulb percentage; ABW: Average Bulb Weight; DTH: Days to harvest; TSS; Total Soluble Solids; E: Equatorial diameter; P: Polar diameter)

Evaluation of red onion initial breeding lines

Thirty-eight breeding lines were evaluated during late *kharif*, 39 lines during *rabi* and 44 lines during *kharif* along with checks. During late *kharif*, LK-07-C2/LR-1 (63.50 t/ha), DOGR-671-Sel (59.46 t/ha), DOGR-1064-Sel (53.67 t/ha), Red Genepool-6 (52.54 t/ha) and LK-07-C2/DR-2 (48.38 t/ha) were found superior over best check Bhima Kiran (44.58 t/ha) with dark red, globe and big sized bulbs (101-152 g), more than 78% marketable yield. Minimum days to harvesting was recorded in LK-07-C2/LR-1, DOGR-1064-Sel and LK-07-C2/DR-2 (109 days) whereas, check Bhima Kiran (124 days). Minimum storage loss after four months of storage was recorded in DOGR-1603 (30.75%) followed by R-Rb-M-III (31.00%) and LK-07-C2/DR-4 (31.63%) whereas, in Bhima Shakti (34.79%).

Table 1.26 Best performing initial breeding lines during late-*kharif* 2020-21

Entries	MY (t/ha)	Mrk. %	ABW (g)	Doubles (%)	Bolters (%)	DTH	E:P
LK-07-C2/LR-1	63.50	100.00	127.00	0.00	0.00	109.00	1.23
DOGR-671-Sel	59.46	84.00	139.97	16.00	0.00	110.33	1.19
DOGR-1064-Sel	53.67	78.93	152.46	7.04	14.03	109.00	1.18
Red Genepool-6	52.54	100.00	105.08	0.00	0.00	111.00	1.21
LK-07-C2/DR-2	48.38	95.71	101.39	4.29	0.00	109.00	1.20
R-Rb-M-III	47.81	84.89	122.50	0.00	15.11	115.00	1.23
R-Rb-M-IV	45.98	77.89	127.21	11.75	10.36	110.33	1.20
Bhima Kiran (C)	44.58	100.00	89.17	0.00	0.00	124.00	1.27
Bhima Super (C)	41.03	76.31	101.86	8.18	15.51	128.33	1.21
Phule Samarth (C)	38.64	82.81	90.08	5.05	11.42	118.33	1.22
Bhima Shakti (C)	34.81	80.74	101.78	17.85	0.00	127.00	1.26
CV (%)	12.37	12.89	11.49	15.66	12.51	4.30	-
LSD (P=0.05)	4.67	8.57	6.23	13.98	18.85	7.87	-

(MY: Marketable Yield; Mrk: Marketable bulb percentage; ABW: Average Bulb Weight; DTH: Days to harvest; TSS; Total Soluble Solids; E: Equatorial diameter; P: Polar diameter)

During *rabi* 2020-21, LK-07-C2/DR-3 (55.07 t/ha), LK-07-C2/LR-3 (53.72 t/ha), DOGR-650-Sel (52.89 t/ha), DOGR-1603 (52.78 t/ha) and R-LK-M-I (51.92 t/ha) were found superior over best check Bhima Kiran (42.02 t/ha) with dark red, globe and big sized bulbs (89-103 g), more than 95% marketable yield (Table 1.27). All the lines were free from bolters while LK-07-C2/DR-3 was free from double bulbs also. Minimum storage loss after four months of storage was recorded in Bhima Shakti (29.27%) followed by LK-07-C2/LR-3 (29.57%) and RGP-2-LK-Sel (33.16%).

During *kharif* 2021, DOGR-1064-Sel (29.87 t/ha) and R-Rb-M-I (28.42 t/ha) were at par with best check Bhima Super (28.37 t/ha) with dark red, globe and medium sized bulbs (71-74 g), more than 97% marketable yield (Table 1.28). Line DOGR-1064-Sel was free from doubles and bolters. Minimum days to harvesting was recorded in C6-KM-2 (80 days) followed by DOGR-671-Sel (81days) and LK-07-C2/DR-3 (82 days).

Table 1.27 Best performing initial breeding lines during *rabi* 2020-21

Entries	MY (t/ha)	Mrk. %	ABW (g)	Doubles (%)	Bolters (%)	TSS (%)	DTH	E:P
LK-07-C2/DR-3	55.07	100.00	103.25	0.00	0.00	11.40	108.00	1.14
LK-07-C2/LR-3	53.72	95.99	98.90	3.64	0.00	11.37	106.67	1.13
DOGR-650-Sel	52.89	95.74	94.64	4.26	0.00	11.71	103.67	1.14
DOGR-1603	52.78	97.10	89.51	2.20	0.00	11.85	104.33	1.14
R-LK-M-I	51.92	98.86	93.21	1.14	0.00	11.76	105.33	1.13
DOGR-654-Sel	50.07	98.32	84.37	1.02	0.50	12.01	105.00	1.15
Red Comp-1 (KH-12)	49.20	100.00	100.64	0.00	0.00	12.56	103.00	1.08
Bhima Kiran (C)	42.02	98.01	89.34	1.46	0.00	11.92	108.67	1.09
ALR (C)	41.71	97.28	91.44	2.35	0.00	11.75	109.00	1.15
Bhima Shakti (C)	36.81	97.96	69.08	0.00	0.35	12.19	112.00	1.14
CV (%)	7.36	4.58	12.21	20.98	23.21	4.37	1.69	-
LSD (P=0.05)	4.52	7.17	6.57	5.30	4.04	0.83	2.88	-

(MY: Marketable Yield; Mrk: Marketable bulb percentage; ABW: Average Bulb Weight; DTH: Days to harvest; TSS; Total Soluble Solids; E: Equatorial diameter; P: Polar diameter)

Table 1.28 Best performing initial breeding lines during *kharif* 2021

Entries	MY (t/ha)	Mrk. %	ABW (g)	Doubles (%)	Bolters (%)	TSS (%)	DTH	E:P
DOGR-1064-Sel	29.87	100.00	74.67	0.00	0.00	10.40	89.00	1.15
R-Rb-M-I	28.42	97.53	71.16	2.47	0.00	10.88	83.50	1.12
C6-KM-2	26.84	84.07	80.18	3.61	0.00	10.80	80.00	1.13
RGP-1-LK-Sel	26.67	72.99	66.67	0.00	0.00	10.76	89.00	1.18
C6-KM-1	26.27	89.11	66.40	4.77	0.00	10.72	85.33	1.09
LK-07-C2/DR-3	26.22	95.16	78.67	0.00	0.00	10.87	82.00	1.15
DOGR-671-Sel	25.54	87.06	71.14	0.00	0.00	10.00	81.00	1.22
Bhima Super (C)	28.37	91.29	72.95	0.61	0.00	10.49	84.33	1.16
BDR (C)	25.58	90.87	69.40	0.91	0.00	11.21	86.00	1.09
Phule Samarth (C)	21.48	86.08	69.81	3.10	0.00	10.64	86.67	1.11
CV (%)	8.08	11.58	8.98	17.58	2.94	2.84	3.74	-
LSD (P=0.05)	3.12	8.13	11.77	8.82	0.00	0.50	5.07	-

(MY: Marketable Yield; Mrk: Marketable bulb percentage; ABW: Average Bulb Weight; DTH: Days to harvest; TSS; Total Soluble Solids; E: Equatorial diameter; P: Polar diameter)

Onion lines under AINRPOG

Three red onion lines viz.; DOGR-1606, DOGR-1654 and DOGR-1657 have been introduced in AINRPOG trials as IET during 2021-22. However, DOGR-1627, DOGR-1639 and DOGR-1203-DR being evaluated as AVT-II during 2021-22.

DOGR-1606 **DOGR-1654** **DOGR-1657**

Fig. 1.7 Three onion lines introduced in AINRPOG trails as IET

1.3.3 Development of F_1 hybrids in red onion

Evaluation of red onion F_1 hybrids developed through male sterile lines

Fifty F_1 hybrids along with their parents and checks were evaluated during late-*kharif* season. Five F_1 hybrids viz.; MS65A × 1630, MS1600A × 1604, MS1600A × 1607, MS1600A×KH-M-2, MS111A×RGP-1 and MS1600A × KH-M-1 recorded more than 30% heterosis for marketable yield over best check BSS-441 (43.83 t/ha) with uniform bulbs and were free from doubles and bolters except MS1600A × KH-M-2 (5.79% bolters). Minimum storage loss after four months of storage was recorded in MS65A × RGP-3 (30%) followed by MS111A × RGP-1 (30.55%) and MS1600A × RGP-5 (31.67%) whereas, in Bhima Shakti (41.53%) (Table 1.29).

Table 1.29 Best performing F_1 hybrids during late-*kharif* 2020-21

Entries	MY (t/ha)	Mrk. %	ABW (g)	Doubles (%)	Bolters (%)	DTH	E:P	HOBC
MS65A × 1630	65.83	94.96	103.25	0.00	0.00	108.50	1.19	50.19
MS1600A × 1604	63.69	100.00	95.54	0.00	0.00	106.00	1.17	45.31
MS1600A × 1607	63.14	100.00	94.71	0.00	0.00	108.50	1.20	44.04
MS1600A × KH-M-2	59.83	94.21	94.83	0.00	5.79	102.67	1.16	36.48
MS111A × RGP-1	57.33	100.00	86.00	0.00	0.00	100.00	1.14	30.80
MS1600A × KH-M-1	50.17	95.40	93.89	0.00	2.73	104.00	1.16	14.45
MS65A × 1666	48.57	94.02	83.21	3.63	0.00	110.33	1.14	10.81
BSS-441 (C)	43.83	100.00	65.75	0.00	0.00	113.00	1.20	-
Bhima Super (C)	40.19	88.48	68.17	2.69	7.64	118.67	1.21	-
BSS-133 (C)	39.36	86.90	94.62	4.05	0.00	107.00	1.18	-
CV (%)	11.26	11.54	7.52	28.68	21.95	4.91	-	-
LSD (P=0.05)	5.96	7.25	6.08	6.38	8.81	8.65	-	-

(MY: Marketable Yield; Mrk: Marketable bulb percentage; ABW: Average Bulb Weight; DTH: Days to harvest; TSS; Total Soluble Solids; E: Equatorial diameter; P: Polar diameter; HOBC; Heterosis over best check)

During *rabi* 2020-21, 71 F_1 hybrids were evaluated along with their parental lines and checks. Standard heterosis was recorded up to 59.64% (MS48A×1613) on marketable yield (Table 1.30). Five F_1 hybrids viz. MS48A×1613, MS111A×RGP-3, MS111A×1609, MS111A×1604 and MS65A×RGP-2 showed more than 41% heterosis on marketable yield over best check Bhima Kiran (38.75 t/ha). These hybrids showed >84% marketable yield and were free from doubles and bolters except MS48A×1613 (15.71% doubles). Minimum storage loss after four month of storage was recorded in MS111A×RGP-4 (26.36%) followed by MS48A×1606 (27.14%) and MS222A×571-LR (29.66%).

During *kharif* 2021, 49 F1 hybrids along with their parents and checks were evaluated. Standard heterosis was recorded up to 47.51% (MS65A×KH-M-2) on marketable yield (Table 1.30). Two F1 hybrids viz. MS65A×KH-M-2 and MS1600A×1657 showed >47% heterosis on marketable yield over best check Bhima Super (28.54 t/ha). These hybrids showed 100% marketable yield and were free from doubles and bolters. Minimum days to harvesting was recorded in MS1600A×1630 and MS111A×RGP-2 (77 days) whereas, check Bhima Super (87 days).

Table 1.30 Best performing F_1 hybrids during *rabi* 2020-21

Entries	MY (t/ha)	Mrk. %.	ABW (g)	Doubles (%)	Bolters (%)	TSS (%)	DTH	E:P	HOBC
MS48A × 1613	61.87	84.29	137.09	15.71	0.00	10.76	102.00	1.13	59.64
MS111A × RGP-3	58.19	100.00	121.22	0.00	0.00	11.12	104.00	1.11	50.99
MS111A × 1609	56.38	100.00	105.71	0.00	0.00	10.68	107.00	1.15	45.49
MS111A × 1604	55.25	100.00	103.60	0.00	0.00	10.64	107.00	1.12	42.58
MS65A × RGP-2	54.93	95.15	137.33	0.00	0.00	10.47	102.00	1.16	41.75
MS222A × 1657	54.63	89.51	119.50	10.49	0.00	10.24	102.00	1.15	40.97
MS1600A × 1608	54.27	100.00	101.75	0.00	0.00	10.72	107.00	1.10	40.03
Bhima Kiran (C)	38.75	94.13	81.61	5.67	0.00	11.49	107.67	1.09	-
Bhima Shakti (C)	38.54	98.75	88.39	0.00	0.00	11.72	107.67	1.09	-
BLR (C)	28.93	96.90	73.27	0.00	0.45	11.75	106.00	1.07	-
CV (%)	11.68	5.90	12.69	17.09	21.30	4.63	3.94	-	-
LSD (P=0.05)	4.53	9.11	16.59	7.87	5.63	0.82	6.81	-	-

(MY: Marketable Yield; Mrk: Marketable bulb percentage; ABW: Average Bulb Weight; DTH: Days to harvest; TSS; Total Soluble Solids; E: Equatorial diameter; P: Polar diameter; HOBC; Heterosis over best check)

Table 1.31 Best performing F_1 hybrids during *kharif* 2021

Entries	MY (t/ha)	Mrk. %	ABW (g)	Double (%)	Bolters (%)	TSS (%)	DTH	E:P	HOBC
MS65A × KH-M-2	42.10	100.00	78.00	0.00	0.00	11.13	82.00	1.05	47.51
MS1600A × 1657	42.00	100.00	75.60	0.00	0.00	11.00	82.00	1.13	47.16
MS1600A × 1630	30.67	100.00	69.00	0.00	0.00	10.70	77.00	1.18	7.46
MS65A × RGP-3	28.80	91.82	108.00	0.00	8.18	11.20	88.00	1.10	-
MS111A × RGP-2	24.17	96.03	72.50	0.00	0.00	11.88	77.00	1.11	-
MS222A × RGP-1	23.83	100.00	57.20	0.00	0.00	10.52	82.00	1.05	-
MS222A × 1605	23.36	78.59	63.93	0.00	0.00	11.05	81.67	1.11	-
Bhima Super (C)	28.54	88.23	63.78	0.00	0.00	11.04	87.33	1.12	-
Bhima Dark Red (C)	21.70	88.11	57.78	0.76	0.00	10.92	84.33	1.10	-
ADR (C)	11.30	46.62	54.62	6.73	0.00	10.73	84.00	1.10	-
CV (%)	10.45	11.38	12.18	19.69	18.68	4.02	4.43	-	-
LSD (P=0.05)	4.15	9.99	11.34	9.02	3.45	0.72	5.96	-	-

(MY: Marketable Yield; Mrk: Marketable bulb percentage; ABW: Average Bulb Weight; DTH: Days to harvest; TSS; Total Soluble Solids; E: Equatorial diameter; P: Polar diameter; HOBC; Heterosis over best check)

Further, 110 F1 hybrids of red onion were developed by crossing between five MS lines (MS 48A, MS 65A, MS 111A, MS 222A and MS 1600A) with selected 22 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 and 1666 and evaluation of these hybrids are in progress. Evaluation of 9 synthetic crosses made between selected six elite lines are in progress.

F_1 Hybrids under AINRPOG

Two red onion F_1 hybrids viz. DOGR Hy-156 and Hy-172 have been introduced in AINRPOG trials as IET (initial evaluation trial) during 2021-22. However, DOGR Hy-6, Hy-73, Hy-173 and Hy-179 being evaluated as AVT-II (Advance varietal trial) during 2021-22.

DOGR Hy-156 **DOGR Hy-172**

Fig. 1.8 F_1 hybrids of red onion varieties introduced as IET in AINRPOG in 2021.

Development of male sterile lines and inbred in red onion

Purification and multiplication of five red onion male sterile lines were continued with the selected bulbs. Six combinations 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). Development of inbred lines from single bulb of selected parents (34 inbreds in I1, 22 inbreds in I2, 8 inbreds in I3 and 5 inbred in I4 stage) are in progress.

1.3.4 Performance of red onion genotypes against onion thrips

Thirty-two red onion genotypes were evaluated against onion thrips during *rabi* 2020-21 under natural infestation conditions. Observations on thrips per plant were recorded at fort-night interval starting from 30 days after transplanting. The intensity of thrips damage or pest pressure was very low in all the genotypes; therefore, the genotype reactions were scored based on mean thrips density as criteria, and categorized as resistant (R), moderately resistant (MR), susceptible (S) and highly susceptible (HS). For this classification, the mean value of an individual genotype ($\bar{X}i$) was compared with mean value of all genotypes ($\bar{X}$) and standard deviation (SD). Ten genotypes were categorized as resistant, nine as moderately resistant and remaining were susceptible and highly susceptible (Table 1.32). Though there are many genotypes categorized as resistant and moderately resistant, while considering pest pressure, more testing under severe pest pressure condition is required for further confirmations.

Table 1.32 Reactions of red onion genotypes to onion thrips under natural infestation

Category of resistance	Scale for resistance	Genotype
Resistant	$\bar{X}i < \bar{X} - sd$	RGP-5, 1629, 1671, 1634, 1735, 1738, 1742, 1751, 1770, 1773
Moderately resistant	$\bar{X}i > \bar{X} - sd < X$	Bhima Kiran, KH-M-3, 1623, 1630, 1649, 1708, 1741, 1747, 1755
Susceptible	$\bar{X}i > \bar{X} < (\bar{X} + sd)$	1203, Bhima Shakti, Bhima Light Red, DOGR Hy-8, DOGR Hy-56, DOGR Hy-50, DOGR Hy-7, DOGR Hy-6, 1622
Highly susceptible	$\bar{X}i > (\bar{X} + sd) < (\bar{X} + 2sd)$	Bhima Raj, 1613, 1618, 1621

1.3.5 ICAR-DOGR varieties registered with PPV & FRA

Three extant onion varieties (Bhima Shakti, Bhima Dark Red and Bhima Super) have been registered with PPV&FRA, New Delhi for its protection. One onion variety Bhima Shweta and one garlic variety Bhima Purple are under registration with PPV&FRA.

Bhima Shakti

Bhima Dark Red

Bhima Super

Fig. 1.9 Three onion varieties registered with PPV&FRA

1.4. Genetic improvement of garlic through conventional and biotechnological approaches

1.4.1. Garlic maintenance at ICAR-DOGR

ICAR-DOGR is being acting as National Active Germplasm Site for Garlic. The following table represents the different categories under which garlic accessions are being maintained at ICAR-DOGR in field gene bank (Table 1.33). During *rabi* 2021-22 all the germplasm were planted at B-4 plot at main campus of ICAR-DOGR with recommended agronomic package of practices. Almost 700 garlic lines including germplasm, landraces and varieties are under maintenance and breeding activities.

Table 1.33 Garlic germplasm collection at ICAR-DOGR, Pune

Particulars	No. of Accessions
Selection lines	18
Trait specific identified line	22
Garlic elite lines	28
Core garlic germplasm	22
Garlic with distinct clove skin colour	15
Kharif season suitable lines	11
GS number	15
Germplasm	483
Radiation M_2	6
EMS treated lines	7
Radiation M3	20
NHRDF varieties	8
GA_3 Spray treated lines	35
Heat treated lines	4
Mutated lines	450
Varieties	29

In-vitro maintenance of garlic germplasm

Presently core set collection (32 accessions), manually developed core set collection (49 accessions) and six trait specific garlic germplasm are under in vitro gene bank conservation. Besides this 17 core set collections were also deposited to NBPGR, New Delhi for long term conservation in cryo-banking.

1.4.2. Evaluation of high yielding garlic lines during *rabi* 2020-21

Total seven high yielding garlic lines were evaluated for yield and other yield contributing traits (21 traits), characterized for quantitative and qualitative traits (Table 1.34). Here all the lines were planted in 50 m^2 area with 10 cm plant to plant distance and 15 cm row to row distance. Marketable yield ranged between 5.59 to 6.82 t/ha. Average weight of single bulb ranged between 14.6 to 19.1 g. TSS of all the lines ranged between 41 to 43 °Brix. Suffice variation was recorded in quantitative traits among the entries. Entry 493 recorded superior marketable yield (6.82 t/ha) over check Bhima Purple.

Table 1.34 Characterization of high yielding garlic lines for yield and other traits

Entry	PH (cm)	NL	LL (cm)	LW (cm)	PL (cm)	PW (mm)	TSS (°Brix)
513	56.90	7.6	33.12	1.62	6.02	10.40	40.62
709	62.50	8.0	33.92	2.06	6.52	13.26	40.78
569	51.30	6.6	30.30	1.62	5.06	07.30	43.34
493	65.08	8.6	35.68	2.02	7.96	12.44	41.78
48-W	55.92	9.4	30.50	1.56	6.08	10.10	40.76
793	51.06	8.4	28.92	1.92	6.18	10.91	39.16
746	54.88	7.6	31.56	1.52	6.64	10.05	42.21
BP	43.23	7.4	31.21	1.65	6.20	10.11	43.11
CD at 5%	4.22	3.06	2.35	2.16	2.12	3.12	3.07
CV%	9.56	8.45	9.11	5.23	9.23	8.13	7.12
Entry	**DTH**	**MY (t/ha)**	**PD (mm)**	**ED (mm)**	**SBW**	**C/B**	**W50C (g)**
513	124	5.98	30.84	36.09	18.5	24.4	48.2
709	132	6.35	28.31	39.30	14.9	18.6	48.5
569	124	6.24	30.59	35.29	14.6	12.0	44.3
493	132	6.82	29.73	39.84	18.9	25.6	36.5
48-W	132	5.59	29.92	42.50	19.1	24.6	36.0
793	124	5.53	30.86	39.95	15.8	14.4	48.2
746	123	5.44	32.51	40.90	16.8	14.4	47.2
BP	129	5.51	31.13	42.11	16.11	13.7	43.2
CD at 5%	2.47	1.23	2.56	3.22	3.01	2.11	3.11
CV%	7.35	12.54	6.12	8.11	9.11	6.34	9.67

(PH: Plant Height; LP: Number of Leaves per Plant; LL: 4th Leaf Length; LW: 4th Leaf width; PL: Pseudostem Length; PW: Pseudostem width; DM: Days to harvest; MY: Marketable Yield; PD: Polar diameter; ED: Equatorial Diameter; SBW: Single bulb Weight; C/B: Number of cloves per bulb; W50C: Weight of 50 Cloves; TSS: Total Soluble Solids)

1.4.3. Evaluation of garlic for red clove skin color

Considering public preference for red clove colour as well as process industries clonal selection breeding method has been subjected to garlic promising lines. Total 17 garlic lines along with two check varieties Phule Baswant and Godavari were evaluated for clove red colour with yield and other yield attributing traits. All the entries were planted in 20 sq m area with recommended agronomic practices. The marketable yield was ranged between 1.50 to 13.98 t/ha. Entries 63 and 303 recorded superior marketable yield than check varieties. Average bulb weight ranged between 7.6 to 14.7 g and TSS varying between 39.6-44.5 °Brix (Table 1.35).

Table 1.35 Evaluation of red garlic for yield and related traits

Entry	DTH	MY (t/ha)	ABW (g)	C/B	W50C (g)	TSS (°Brix)
63-P	132	11.98	17.7	29.41	32.11	42.36
756-P	129	5.75	12.22	24.23	38.51	41.52
353-P	131	9.35	9.41	12.84	36.11	43.36
303-P	131	11.10	11.53	12.65	40.23	43.56
224-P	132	7.54	13.34	24.23	35.21	42.22
338-P	132	5.39	14.73	15.42	50.23	42.21
373-P	133	4.83	13.25	12.42	38.53	42.18
534-P	133	5.20	13.14	19.82	37.51	43.22
419-P	130	2.74	8.25	11.45	29.12	42.41
301-P	119	5.39	7.65	14.22	26.34	39.26
444-P	132	9.54	12.13	11.43	34.22	41.34
258-P	132	7.60	14.83	14.23	43.52	42.83
787-P	141	4.70	17.45	16.81	54.35	43.41
37-P	129	3.65	10.96	13.23	43.23	42.61
266-P	132	4.65	13.93	18.61	50.53	41.31
282-p	132	5.54	15.54	12.62	60.23	42.76
662-p	132	1.50	14.13	22.82	39.23	43.02
Phule Baswant ©	132	8.31	11.43	21.23	32.11	44.54
Godavari ©	128	2.20	7.64	12.22	37.23	39.34
CD at 5%	2.13	5.28	4.65	4.79	8.24	4.23
CV%	9.27	13.45	14.23	15.76	14.23	7.49

(DM: Days to harvest; MY: Marketable Yield; ABW: Average bulb weight; bulb Weight; C/B: Number of cloves per bulb; W50C: Weight of 50 Cloves; TSS: Total Soluble Solids)

1.4.4. Evaluation of garlic for *kharif* season suitability

Total eight garlic elite lines were evaluated along with three check varieties i.e. Bhima Purple, G-41 and G-282 for *kharif* season suitability. All the lines were planted in 15 sq. mt. area at 10 cm plant to plant distance and 15 cm as row-to-row distance. These lines were characterized for 22 agronomic traits however important traits as mentioned in below Table 1.36. No entry recorded highest yield (line 282 1.88 t/ha) higher than check G-282

(3.08 t/ha). The highest weight of single bulb was recorded in line 23 and G-282 (13 g) and highest TSS was noted in line 555 (44.70%).

Kharif produced bulbs were planted in *rabi* after one month of resting period to see the possibilities of growth pattern and yield. A total of 16 traits has been recorded alike in *kharif* season (Table 1.37). The average value of all the growth parameters has been increased during *kharif* including marketable yield.

Table 1.36 Evaluation of *kharif* garlic elite lines for yield and related traits

Entry	PH (cm)	LP	LL (cm)	LW (cm)	PL (cm)	PW (mm)	DTH	BC
555	57.90	6.63	39.36	1.00	8.34	7.68	136	W
324	51.44	7.63	34.98	0.88	6.48	6.81	122	W
23	56.74	8.25	38.52	1.12	8.28	7.08	123	W
296	43.28	6.21	30.00	0.98	6.12	5.33	136	P
282	49.94	6.23	36.38	1.42	6.66	7.30	136	P
100	58.10	7.60	40.60	1.12	7.22	7.23	136	P
26	51.80	7.32	36.80	1.04	6.78	7.02	136	W
27-W	56.66	7.43	39.54	1.14	8.02	7.05	136	W
BP	51.38	6.22	38.92	1.30	4.90	7.50	135	P
G-282	61.60	7.62	44.10	1.32	7.46	8.14	123	W
G-41	54.60	8.84	36.76	1.52	5.90	9.11	136	W
CD@5%	4.31	3.54	3.24	2.21	3.21	4.11	2.23	-
CV	11.13	15.67	8.11	8.97	8.32	6.14	5.11	-

Entry	TY (t/ha)	MY (t/ha)	PD (mm)	ED (mm)	SBW	C/B	W50C	TSS (°Brix)
555	1.96	1.54	25.49	30.76	9.34	11.15	40.23	44.70
324	1.26	0.33	18.55	19.03	4.10	7.00	21.13	36.64
23	1.91	1.59	27.20	31.68	13.50	6.22	42.32	36.10
296	0.55	0.11	22.09	18.26	4.43	6.83	25.12	34.50
282	2.96	1.88	23.41	28.94	4.73	7.40	26.32	33.90
100	1.92	1.37	23.28	28.96	7.33	11.23	34.21	40.74
26	1.59	0.99	24.17	31.52	8.34	12.02	42.43	42.36
27-W	1.73	1.23	24.25	30.70	8.92	12.45	41.32	42.92
BP	1.55	0.86	23.66	28.06	6.32	5.63	35.12	41.38
G-282	3.91	3.08	28.13	35.60	13.10	11.23	52.01	39.32
G-41	1.37	1.04	22.95	23.44	7.70	8.43	35.43	38.34
CD at 5%	1.22	1.03	4.56	6.89	5.34	4.72	5.23	4.41
CV	15.89	13.56	10.11	9.02	8.09	10.07	8.90	7.03

(PH: Plant Height; LP: Number of leaves per plant; LL: 4th Leaf Length; LW: 4th Leaf width; PL: Pseudostem Length; PW: Pseudostem width; DH: Days to harvest; BC: Bulb colour; TY: Total Yoied; MY: Marketable Yield; PD: Polar diameter; ED: Equatorial Diameter; SBW: Single bulb Weight; C/B: Number of cloves per bulb; W50C: Weight of 50 Cloves; TSS: Total Soluble Solids; P: Purple; W: White)

Table 1.37 Characterization of *kharif* garlic elite lines bulbs during *rabi* season for yield and related traits

Entry	PH (cm)	LP	LL	LW	PL	PW	TSS (°Brix)
27	59.70	9.20	33.44	1.54	6.68	9.51	41.50
26	51.60	9.40	29.96	1.08	5.64	6.32	42.58
100	58.38	9.60	34.68	1.64	6.44	10.24	41.18
23	60.40	10.0	34.28	1.64	7.24	10.70	40.16
G-324	65.14	11.2	43.92	1.98	7.62	12.67	38.32
282	52.36	8.20	29.18	1.76	7.04	9.75	41.36
24	51.86	7.60	32.90	1.44	5.90	10.70	37.72
BP	56.04	8.20	36.28	1.62	6.92	10.68	41.46
G-282	60.50	10.00	37.96	1.40	8.04	10.50	40.78
G-41	51.56	9.80	30.72	1.22	7.10	10.35	43.94
CD at 5%	4.23	3.21	3.23	2.12	2.21	3.21	3.08
CV%	13.11	14.12	11.09	10.93	11.56	12.11	5.76
Entry	**MY (t/ha)**	**PD (mm)**	**ED (mm)**	**SBW**	**C/B**	**W50C**	**BC**
27	3.20	26.55	32.82	12.00	13.80	47.00	Purple
26	1.41	22.50	27.45	7.30	16.40	19.5	White
100	2.92	27.94	35.86	15.10	22.00	37.00	Purple
23	3.19	26.09	32.04	12.50	13.40	44.00	White
G-324	2.72	31.92	35.45	8.50	6.20	32.00	White
282	6.77	27.56	36.14	12.00	13.00	45.10	Purple
24	2.69	23.32	30.74	9.30	14.40	39.00	White
BP	5.04	24.50	34.68	11.50	12.20	42.50	Purple
G-282	5.80	26.85	33.43	13.90	17.00	48.50	Purple
G-41	4.39	30.29	38.72	17.30	16.00	63.00	White
CD at 5%	2.03	3.98	3.56	2.11	2.23	4.45	-
CV%	14.21	10.76	12.11	12.13	11.23	10.21	-

(PH: Plant Height; LP: Number of leaves per plant; LL: 4th Leaf Length; LW: 4th Leaf width; PL: Pseudostem Length; PW: Pseudostem width; BC; Bulb colour; MY: Marketable Yield; PD: Polar diameter; ED: Equatorial Diameter; SBW: Single bulb Weight; C/B: Number of cloves per bulb; W50C: Weight of 50 Cloves; TSS: Total Soluble Solids)

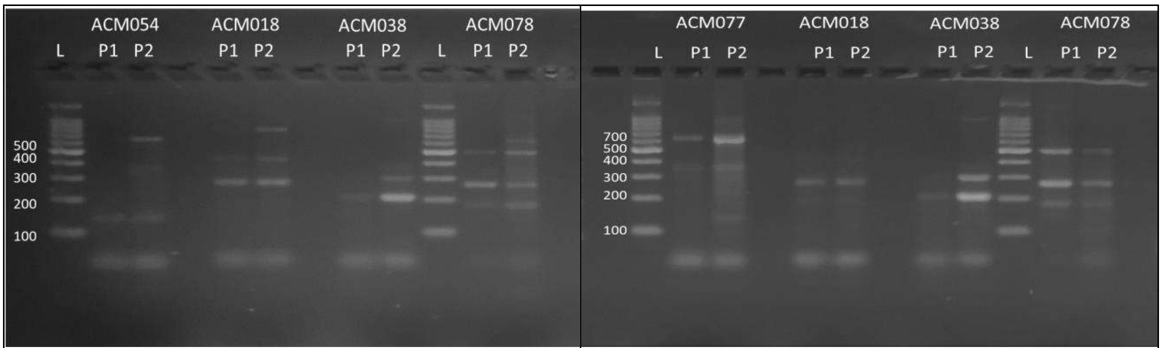
1.5 Breeding for abiotic stress tolerance in *Allium* species

1.5.1 Genetic architecture of waterlogging tolerance in onion

To develop mapping population, waterlogging tolerant line Acc. 1666 was crossed with waterlogging susceptible line Acc. 1639. Similarly, waterlogging tolerant line Acc. 1630 was crossed with waterlogging susceptible variety Bhima Super in the *rabi*-21. Among white onion line, tolerant line W-355 was crossed with waterlogging susceptible line W-085 to develop F1 hybrid population. These F1 plants were raised in *kharif* 2021 for the bulb production and their bulbs were planted in *rabi* 2021-22 for the back cross and F2 population development.

1.5.2 Identification of polymorphic SSR markers for waterlogging tolerance in onion

For the cross between, Acc. 1639 and Acc. 1666, both parents were screened with 172 SSR primers for polymorphism. Among them, only four primers i.e. ACM054, ACM018, ACM038 and ACM078 showed polymorphism in Figure 1. In another cross between Bhima Super and Acc. 1666, four primers i.e. ACM077, ACM018, ACM038 and ACM078 showed polymorphism in Figure 2. Among white onion, selected parents were screened with SSR primers and six primers i.e. ACM077, ACM018, ACM038, ACM078, ACM154 and ACM004 were found polymorphic (Figure 1.10). These primers can be used for genotyping of F2 population and thereby developing linkage map.



L: Ladder, P1: Acc. 1639 and P2: Acc 1666	L: Ladder, P1: Bhima Super and P2: Acc 1630

Fig. 1.10 L: Ladder, P1: W-085 and P2: W-355

1.5.3 Genetic architecture and identification of polymorphism for drought tolerance in onion

The drought tolerant line Acc. 1656 and drought susceptible line Acc. 1627 were crossed in the *rabi* 2020-21 to develop F1 hybrid population. These F1 plants were raised in *kharif* 2021 for the bulb production and their bulbs were planted in *rabi* 2021-22 for the back cross and F2 population development. These parents also screened with 160 SSR primers, among them ACM018, ACM038 and ACM078 showed polymorphism (Figure 1.11). These primers were also used for genotyping of F2 population and thereby developing linkage map.

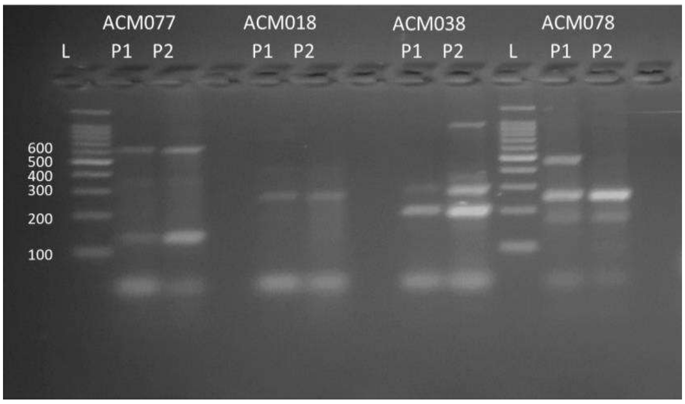


Fig. 1.11 L: Ladder, P1: Acc. 1627 and P2: Acc. 1656

1.6 Genetic analysis of bolting in onion (*Allium cepa* L.)

For the generation of mapping population, two onion cultivars, Agrifound Dark Red (ADR) with late flowering phenotype and Agrifound Rose (AFR) with very early flowering phenotype, were used in this study. The F1 plants produced from crosses between ADR and AFR were free from bolters. These F1 bulbs were planted in *rabi* 2021-22 for further population development.

1.7 Identification and cloning of *AcLEAFY* gene from *Allium* cepa

A single copy of the inflorescence meristem specific LEAFY gene (1122bp) was amplified from the cDNA encoding protein of 373 amino acids and a 1266 bp fragment was amplified from the genomic DNA of *Allium* cepa cv Bhima Super. The amplified products were cloned into the pJET1.2 sequencing vector and sequenced. The sequence was submitted to the Gene Bank, NCBI database with the accession number, OM280048.

1.8 Biotechnological approaches for improvement of onion

1.8.1 Agrobacterium-mediated transformation of *DREB1A* gene in onion

The calli of onion (*Allium* cepa L.) cv. B. super induced from seedling radicle were co-cultivated with *Agrobacterium* strain LBA4404 carrying *AtDREB1A* gene under the control of rd29A promoter and tNOS terminator in binary vector pCAMBIA1305.1. Putative transformed calli were selected consecutively in 3 rounds (15 days each) on selection media containing 50 µg/L Hygromycin B. The survived (non-brown and light yellowish) calli were selected and transferred to shooting media containing 50 µg/L Hygromycin B. So far, 3 batches were co-cultivated with *DREB1A* construct, 2 batches are in shooting stage, 1 batch is in selection stage.

1.8.2 *In-vitro* haploid induction in onion through gynogenesis

For haploid induction in onion through gynogenesis, an unopened flower buds from 3 different cultivars and their inbred lines were inoculated on a shoot medium. The details of number of flowers inoculated and shoots regenerated is given in following Table 1.38.

Table 1.38 Details of haploid induction in onion through gynogenesis

Cultivar	Inbred/variety	No. of flowers inoculated	No. of shoots germinated
B. Shweta	I1	1137	74
	I2	1250	175
	I3	1098	29
	Variety	1190	37
B. super	I1	1182	135
	I2	1246	57
	I3	1289	132
	Variety	1174	17
B. Dark Red	I1	1381	68
	I2	1204	42
	I3	1181	141
	Variety	1816	129

1.9 Physiological, biochemical, microscopic analyses of glossy mutant of onion

M3 generation EMS-mutagenized *Allium* cepa plants (glossy type) and its non-mutagenized counterpart (wild type (WT)/ waxy) were analyzed for their phenotypic, biochemical, microscopic and transcriptome analyses. Foliage of the mutant glossy onion was shiny green in appearance, whereas leaves of WT were greenish-grey (Fig. 4.9). The number of stomata and the stomatal index were higher in mutant leaves as compared to WT. SEM analysis revealed large quantities of the spiky, needle-like crystals were uniformly covered the entire leaf in WT type, whereas in mutant type, relatively few wax crystals were scattered around the stomatal region alone (Fig. 1.12).

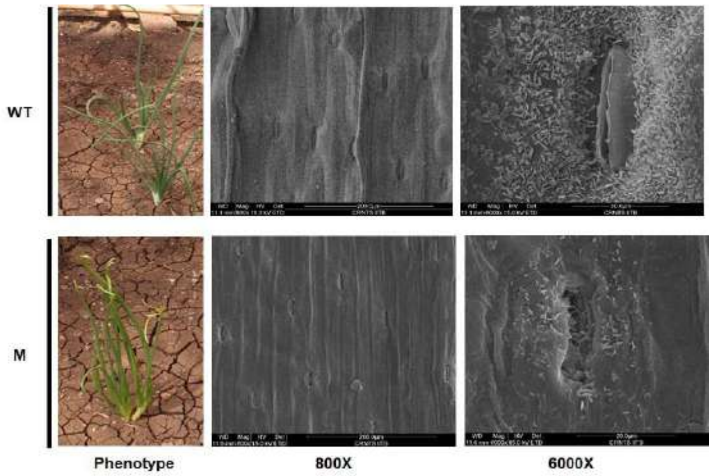


Fig. 1.12 Comparative SEM photographs of wild type and glossy mutant of onion

1.10 Screening of garlic genotypes under water deficit condition

During *Rabi* 2019-20, a total of 20 garlic core germplasm group has been evaluated under water deficit condition (Table 1.39). This experiment was conducted in open field condition. The purpose of experiment was to identify the genotype performing better under limited water condition during crucial growth period. In case of garlic, after 30 to 35 days after planting i.e. at the time of five to six leaves condition, bulb initiation starts which vary with genotypes up to 40 days of planting. Later bulb enlargement and simultaneously clove dividation takes place in the next 40-50 days. The overall vegetative growth of garlic occurs during first 70 days after planting. Therefore, in treated plot irrigation was stopped for total 25 days during bulb initiation and enlargement stage i.e. after 40 days of planting to 65 days of planting. Afterwards routine agronomical practices have been carried out for both controlled and irrigated plots. Before and after subjecting this water stress, physiochemical parameter as well as root anatomical observations were noted. Among the 20 core group garlic entries alike 2018-19 data results, based on physiochemical and root anatomical studies, accession DOGR-28 and DOGR-24 found to be susceptible and resistant respectively for water deficit condition. Here, the results of root anatomical observations (Figure 1.13) support and justify the agro-physiological performance of contrasting lines under water deficit condition.

Table 1.39 Performance of garlic entries under water deficit condition for yield and contributing traits

Particulars	Control	Treated	Control	Treated
Entry	28		24	
	Susceptible		Resistance	
Plant height (cm)	50.58	51.25	49.78	47.80
Number of leaves plant^{-1}	7	7	8	8
4th Leaf length (cm)	34.95	37.23	37.48	32.55
4 th Leaf width (cm)	1.78	2.08	1.90	1.83
Pseudostem length (cm)	5.58	7.03	5.30	6.25
Pseudostem width (mm)	8.90	10.09	9.29	9.11
Stem pigment (Green/Yellow/Red/White)	White	White	Green	Green
Foliage attitude (Erect/Semi Erect/Drooping)	Erect	Erect	Erect	Erect
Leaf Greenness (Light/Medium/Dark)	G	G	G	G
Leaf waxiness (Absent/Present)	Absent	Absent	Absent	Absent
Bulb Polar Diameter (mm)	26.90	24.50	26.27	26.14
Bulb Equatorial diameter (mm)	30.69	26.68	26.58	27.03
Single bulb weight (g)	16.00	8.05	14.90	13.70
Avg no. of clove/ bulb	14	10	15	13
Weight of 50 cloves (g)	51.25	30.85	45.00	45.25
Total Soluble Solids (°Brix)	44.6	38.4	41.2	44.0
Shape of bulb (OB-Oblong)	OB	OB	OB	OB
Bulb skin colour (P-Purple, W-White)	P	P	W	W
Clove Skin Colour (P-Purple, W-White)	P	P	W	W
Marketable yield (q/ha)	37.2	12.21	29.34	21.35
% Yield reduction compare to control	67.18		27.24	

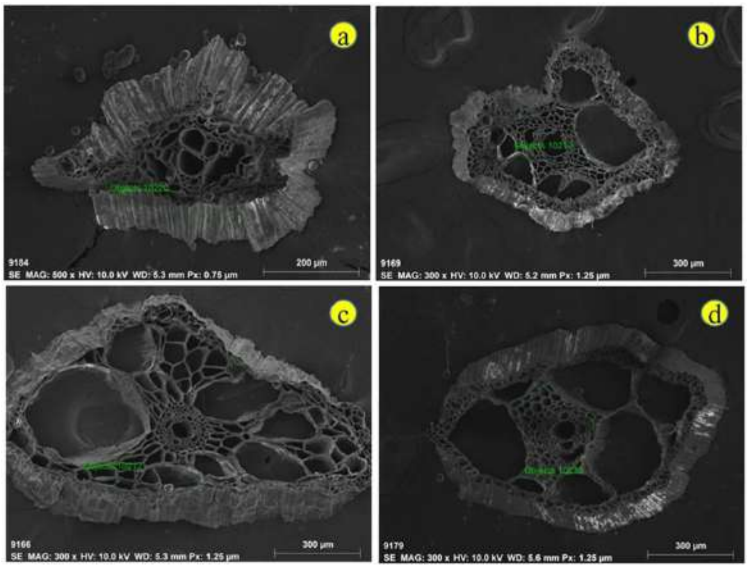


Fig. 1.13 Root anatomy under control condition
(a) and water deficit condition (b) of genotype DOGR-24, and genotype DOGR-28 roots revealed under control condition (c) and water deficit condition (d)

Externally Funded Project: ICAR-National Fellow

1.11 Haploid induction in onion through genome elimination

1.11.1 Segregation analysis of T_1 seeds expressing GFP tailswap

T_0 bulbs of 6 events of transgenic plants expressing GFP tailswap were planted in r*abi* 2020. TAIL PCR analysis was done for all the events and sites of insertion were mapped. The flowers of T_0 bulbs were selfed to get T_1 seeds (Table 1.40). These T_1 seeds were planted in *Kharif* 2021 and analyzed for the presence of GFP tailswap by PCR analysis (Figure 1.14). T_1 plants were found to be segregating as per the mendelian fashion.

Table 1.40 Seed set in T_1 GFP tailswap transgenic plants and segregation analysis of T1 plants

Sl. No.	Transgenic event ID	No. of seeds obtained	No. of seeds sown	No. of seeds germinated	PCR positive
1	GFP 1	23	20	17	12
2	GFP2	37	34	25	19
3	GFP 3	31	27	23	15
4	GFP 4	15	13	8	4
5	GFP 5	24	21	18	13
6	GFP 6	19	17	15	11

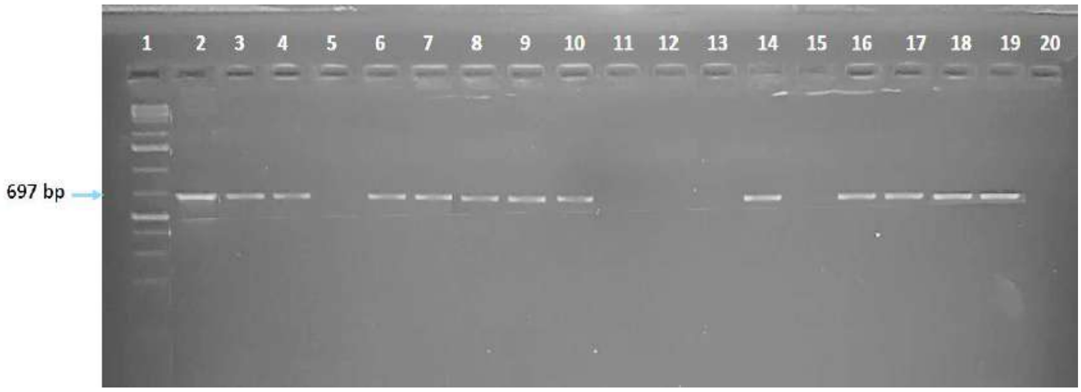


Fig. 1.14 Segregation analysis of T_1 transgenic plants: PCR analysis of T_1 transgenic plants to confirm presence & segregation of GFP tailswap in T_1 population

Where; [1: 1 KB plus ladder, 2: pC1305.1-GFP tailswap plasmid, 3: GFP1-1, 4: GFP1-2, 5: GFP1-3, 6: GFP1-4, 7: GFP1-5, 8: GFP1-6, 9: GFP1-7, 10: GFP1-8, 11: GFP1-9, 12: GFP1-10, 13: GFP1-11, 14: GFP1-12, 15: GFP1-13, 16: GFP1-14, 17: GFP1-15, 18: GFP1-16, 19: GFP1-17, 20: B. super]

1.11.2 *Agrobacterium*-mediated transformation of pCAMBIA1305.1-*AcCENH*3 RNAi construct in onion

Eight weeks old embryogenic calli induced from seedling radicle of the onion cv. B. super were transformed by *Agrobacterium*-mediated transformation with *Agrobacterium* strain LBA4404 harboring pCAMBIA1305.1-*AcCENH*3-RNAi construct. Putative transformed calli were selected on hygromycin containing selection and shooting media. The regenerated plants were rooted in rooting medium and hardened in green house. So far, total 5 independent events were generated and evaluated by PCR using sense-strand specific primer set. PCR analysis resulted in amplification of 793 bp sense strand in positive control plasmid and putative transgenic plants, whereas no amplification was found in wild-type B. super plant (Fig. 2). This confirmed the presence of *AcCENH*3 RNAi construct in all the 5 independent events.

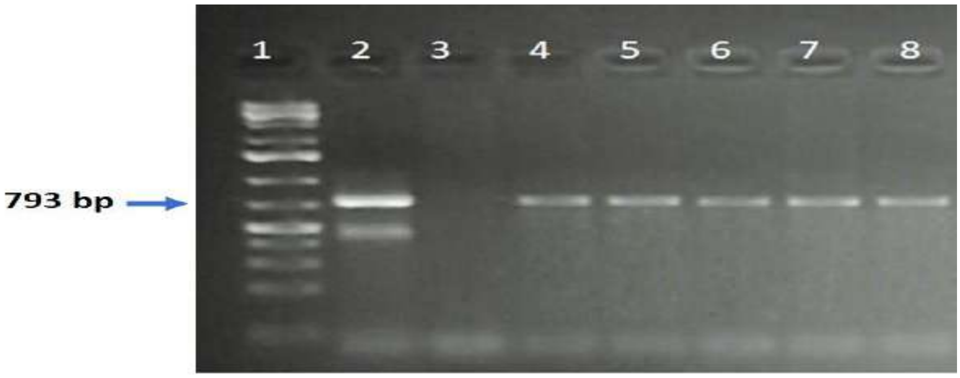


Fig. 1.15 PCR analysis of putative transgenic plants to confirm the presence of *AcCENH*3 *RNAi* construct

Where; [1: 1 KB plus ladder, 2: pC1305.1-AcCENH3 RNAi plasmid, 3: Wild type B. super DNA, 4: RNAi event 1, 5: RNAi event 2, 6: RNAi event 3, 7: RNAi event 4 8: RNAi event 5]

1.11.3 *Agrobacterium*-mediated transformation of CRISPR/cas9 construct in onion for haploid induction

Agrobacterium strain LBA4404 harboring binary vectors pCAMBIA1305.1-mis*AcCENH*3-*AcCENH*3 sgRNA were used for Agrobacterium-mediated transformation of 8-weeks-old embryogenic calli induced from seedling radicle of onion cv. B. super. After resting period of 15 days, putative transformed calli were screened in 3 rounds (15 days each) on 50 µg/L Hygromycin B containing selection media. The survived calli were transferred to shooting media containing 50 µg/L Hygromycin B. So far, 7 batches were transformed, 2 batches are in shooting stage, 3 batches are in selection stage, 2 batches are in resting stage.

Externally Funded Project: DST-SERB

1.12 Development of cytoplasmic male sterile lines in onion through targeted mutagenesis

Agrobacterium-mediated transformation of CRISPR/cas9-*AcMSH*1 construct in onion

CRISPR/cas9 construct targeting exon 2 and exon 3 of *AcMSH*1 gene was cloned separately in pRGEB31 vector under OSU3 promoter and mobilized into *Agrobacterium* strain LBA4404. These Agrobacterium strains harboring exon 2 and exon 3 target sequence of *AcMSH*1 gene were used for Agrobacterium-mediated co-transformation of 8-weeks-oldembryogenic calli of the onion cv. B. super. After co-cultivation, calli were rested for 15 days and screened on selection medium containing 50 µg/L Hygromycin B for 3 times (15 days each). The survived calli were transferred to shooting media containing 50 µg/L Hygromycin B. So far, 10 batches were co-cultivated. Among them, 4 batches are in shooting stage, 4 batches are in selection stage, 2 batches are in resting stage.

Quantification of AcMSH1 protein in different developing tissues of onion plant

The quantitative immunoassay was performed for the selective detection of *AcMSH*1 protein in the different developing tissues (Root tip, Shoot tip, first true leaf, 8-weeks-old embryogenic calli induced from seedling radicle, Unopened umbel and flower bud) of field-grown onion plant cv. Bhima super. An indirect assay was performed in 96-well ELISA plate coated with *AcMSH*1 protein as an antigen. ELISA results revealed that the concentration of *AcMSH*1 protein was highest in shoot tip whereas it was lowest in 8-week-old embryogenic calli (Fig. 1.16).

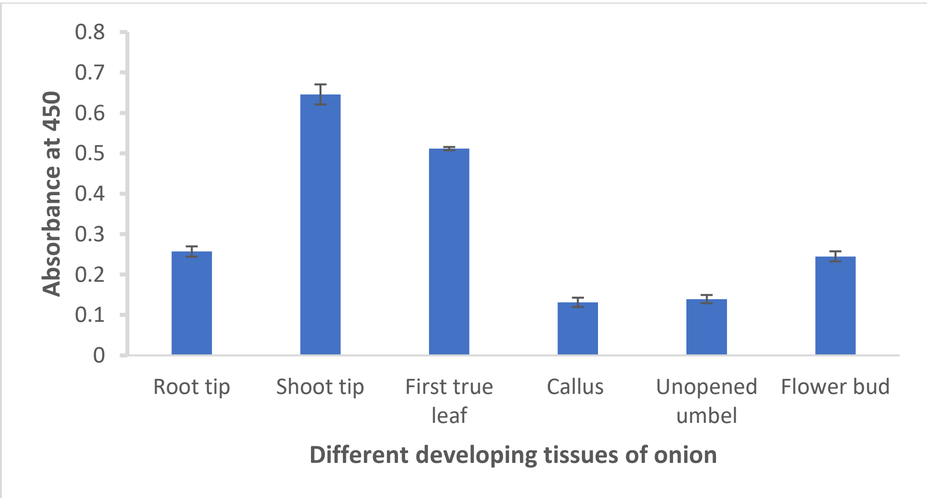


Fig. 1.16 Quantification of *AcMSH1* protein in different developing tissues of onion

2. Crop Production

2.1 Development of improved nutrient management practices for onion and garlic

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

Permanent manurial experiment was initiated during *rabi* 2013-14 with eight treatments. Each block was assigned for specific fertilizer treatment and care was taken to avoid mixing of soil from one block to another. Vermicompost (VC) @ 10 t/ha was included as ninth treatment during 2015-16. Field experiment was carried out to monitor the effect of soybean and maize (*Kharif*) - onion (*Rabi*) cropping system and four fertilizer treatments on onion production, plant nutrient uptake and soil health. Inclusion of maize as preceding crop and application of inorganic fertilizers alone produced significantly higher bulb yield compared to other fertilizer treatments. Among the fertilizer treatments, treatment plots receiving 75% RDF produced bulb yield similar to that of 100% RDF (Figure 2.1).

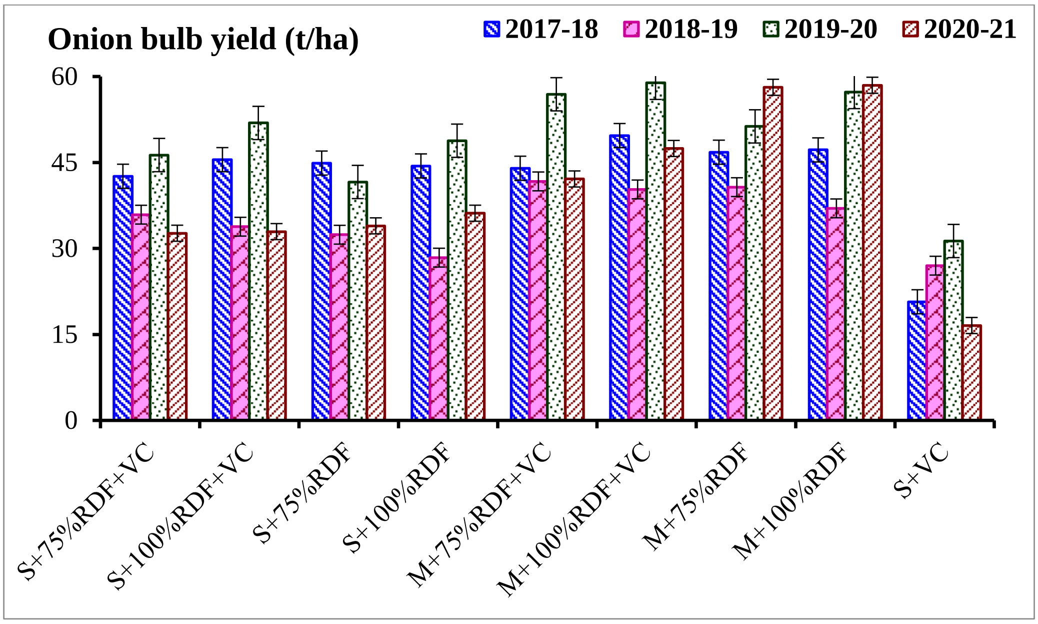


Fig. 2.1 Effect of continuous use of fertilizers and manures on onion bulb yield
RDF: Recommended dose of fertilizer; VC: Vermicompost

Furthermore, application of 10 tons vermicompost/ha alone produced 16.6 t/ha onion yield which was significantly lower than other fertilizer treatments. Onion yield trend from 2017-18 to 2020-21 showed that INM treatments showed higher yield in 2017-18 compared to the treatments received chemical fertilizers alone. From 2018-19 to 2020-21, the onion yield in INM treatments and chemical fertilizer treatments of soybean block were decreased significantly in comparison to maize block. This lower yield recorded in soybean block was due to high incidence of *Stemphyllium* incidence recorded during the last three years. Higher nitrogen uptake was recorded in soybean block, whereas PKS uptakes were higher in maize block (Figure 2.2). Combined application of mineral fertilizers and vermicompost showed higher soil organic carbon and soil available N compared to mineral fertilizer alone applied treatments (Table 2.1). Furthermore, soil organic carbon and soil available nutrients were higher in soybean block compared to the maize block. Initial soil fertility status was maintained in all the fertilizer treatments.

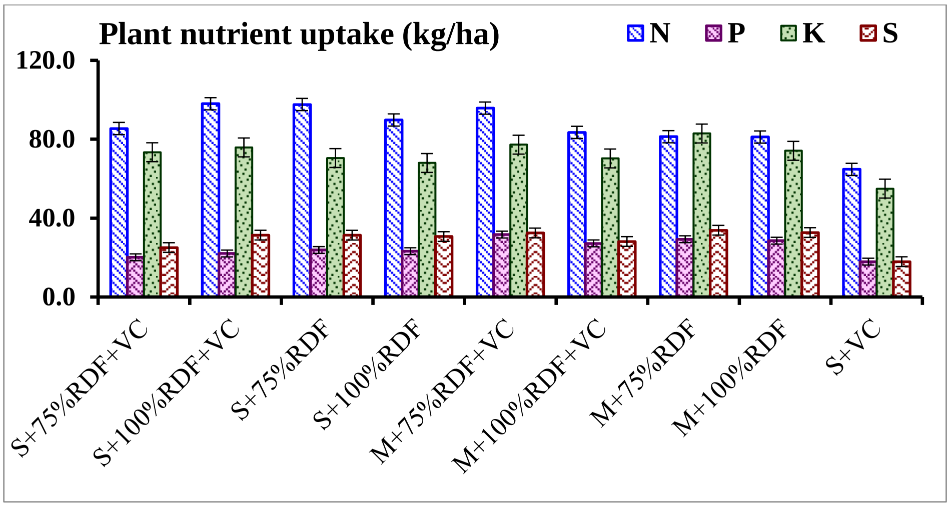


Fig. 2.2 Effect of continuous use of fertilizers and manures on NPKS uptake
RDF: Recommended dose of fertilizer; VC: Vermicompost

Table 2.1 Effect of continuous use of fertilizers and manures on soil properties

	Treatments	Soil pH	EC (dS/m)	SOC (%)	Soil available nutrients (mg/kg soil)			
					N	P	K	S
Soybean	75 % RDF + FYM	7.69	0.11	0.72	74.0	15.3	164.3	9.97
	100 % RDF + FYM	7.56	0.12	0.73	75.9	17.6	175.3	12.5
	75 % RDF	7.69	0.10	0.66	70.3	14.6	174.3	9.3
	100 % RDF	7.72	0.10	0.68	70.3	14.4	184.5	11.8
Maize	75 % RDF + FYM	8.06	0.12	0.73	74.0	13.9	202.3	13.0
	100 % RDF + FYM	8.11	0.13	0.73	70.3	13.6	202.9	11.1
	75 % RDF	8.23	0.11	0.63	66.6	09.2	194.6	14.8
	100 % RDF	8.24	0.13	0.63	70.3	10.3	203.6	13.5
Soybean	VC	7.99	0.08	0.57	68.5	17.0	148.7	12.5

RDF: Recommended dose of fertilizer; VC: Vermicompost

2.1.2 Faunal diversity of insect pests and their natural enemies in different onion-based agroecosystem (organic & inorganic fields)

Observations on pest and natural enemy population were recorded on 30, 45, 60 and 90 DAT in both organic and inorganic trials. Visual inspection for thrips population was done in a sample size of Quadrat of 1 sq. m area from each plot. Aerial insects were caught using sticky traps. Among the different orders of insects, *Coleoptera* (representing beetles and weevils) dominated the onion ecosystem in terms of species diversity, irrespective of the treatments. With respect to the maximum number of individuals caught, order *Thysanoptera* dominated in both organic and inorganic treatments. Maximum thrips population was found in organic trials in comparison to inorganic treatments. Peak thrips population was observed during January in all treatment plots. Apart from thrips, incidence of defoliator pest *Spodoptera frugiperda* was recorded for the first time in onion where maize was planted as border crop. The present study revealed that maximum species diversity was found in organic treatments in comparison to inorganic treatments; thereby making them a more stable agro-ecosystem.

2.1.3 Effect of organic farming on onion production compared to conventional farming

The field experiment was conducted to study the effect of organic farming on onion production and nutritional quality in comparison to mineral fertilizer application. The experiment was laid out in split plot design with 14 replications. The main plot consisted of six treatments including mineral fertilizer application (150:50:80:30 NPKS/ha) and sub-plots consisted inorganic and organic plant protection system. The experimental results showed that organic farming treatments produced 42.3-51.0% lower bulb yield compared to mineral fertilizer application (CF) and integrated nutrient management (INM) plots (Figure 2.3). No significant difference was observed between INM and mineral fertilizer alone applied treatments. Among the organic treatments, combined application of FYM (10t/ha), vermicompost (2.0 t/ha), neem cake (1 t/ha), phosphorus solubilizing bacteria and *Azotobacter* @ 5 kg each/ha with organic pest and disease management practices (OM2) produced significantly higher bulb yield compared to other organic treatments. Furthermore, organic nutrient management practices with chemical plant protection measures produced 10.84% higher yield compared to organic nutrient management practices with organic pest and disease management practices. No significant difference was observed between the treatments for total storage losses after 5 months of storage (Figure 2.4). N, P, K and S uptake were significantly higher in mineral fertilizer applied and INM plots compared to organic treatments. Soil analysis showed that soil organic carbon and soil available N concentration were higher in organic treatment compared to INM and mineral fertilizer treatments (Figure 2.5 and 2.6). The lowest soil organic carbon and soil available N was recorded in INM and conventional treatments. Thrips population was the highest in plots received organic plant protection measures.

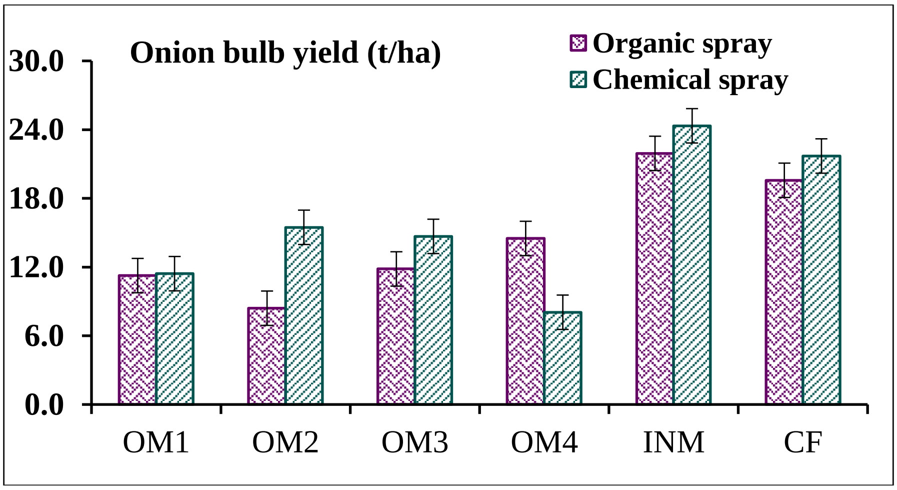


Fig. 2.3 Effect of organic farming practices on onion yield
OM: Organic Module; INM: Integrated Nutrient Management

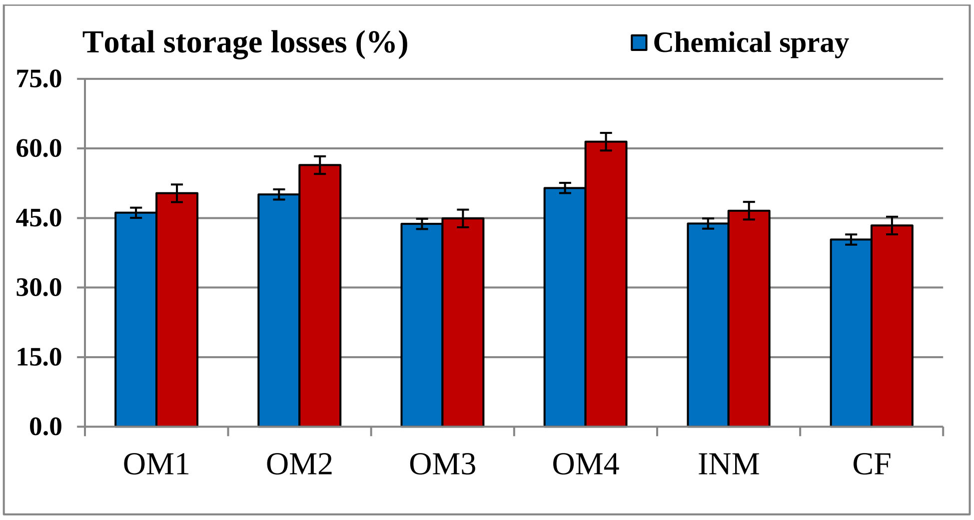


Fig. 2.4 Effect of organic farming practices on total storage losses

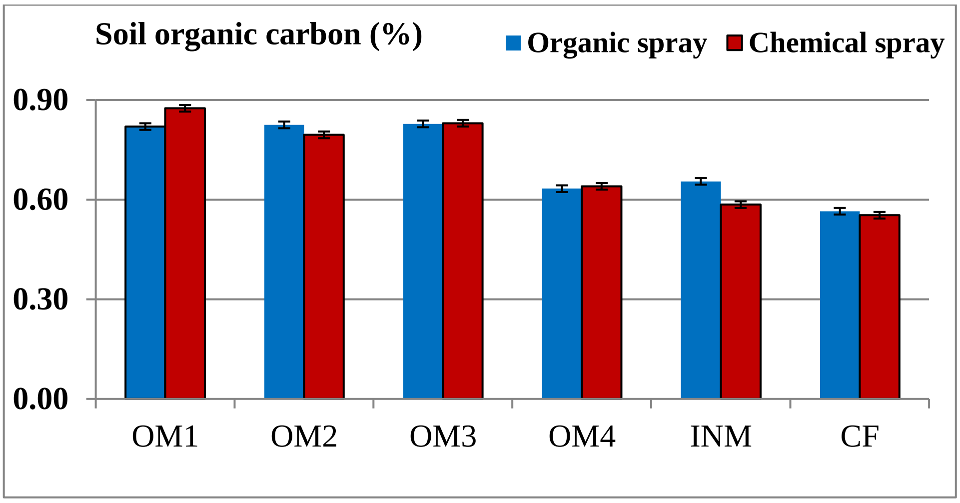


Fig. 2.5 Effect of organic farming practices on soil organic carbon

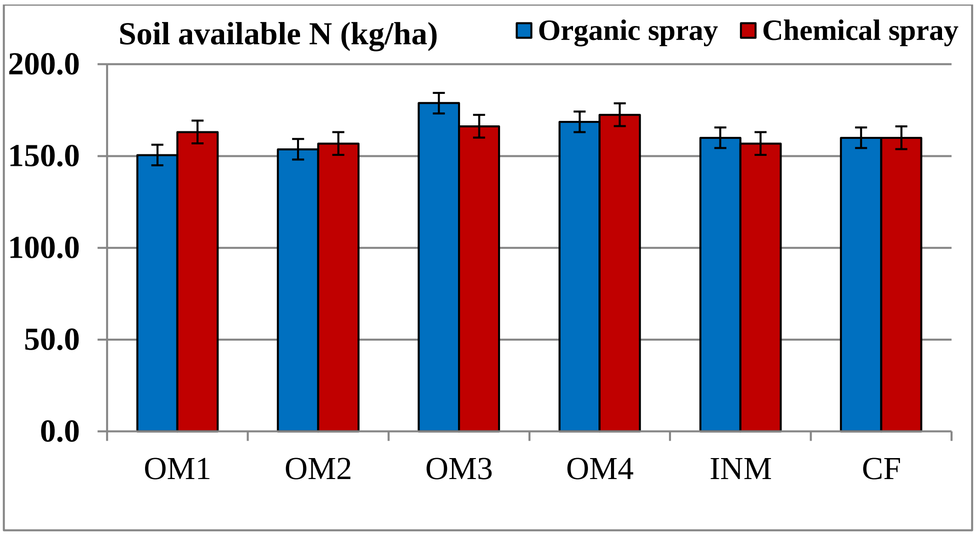


Fig. 2.6 Effect of organic farming practices on soil available nitrogen

2.1.4 Effect of PSB and Mycorrhizal inoculation on onion yield, nutrient concentration and bulb quality

A field experiment was conducted to study the effect of microbial inoculation on onion yield and nutrient concentration with 8 treatments in three replications during 2020-21. The results revealed that fertilizer treatments had significantly increased onion bulb yield compared to the control. Inoculation of PSB and *Piriformospora indica* increased onion bulb yield by 9.4% and 13.9% compared to the control, respectively (Figure 2.7). VAM inoculation did not increase onion yield significantly. In addition, PSB and *Piriformospora indica* also increased NPKS uptake significantly compared to the control (Figure 2.8).

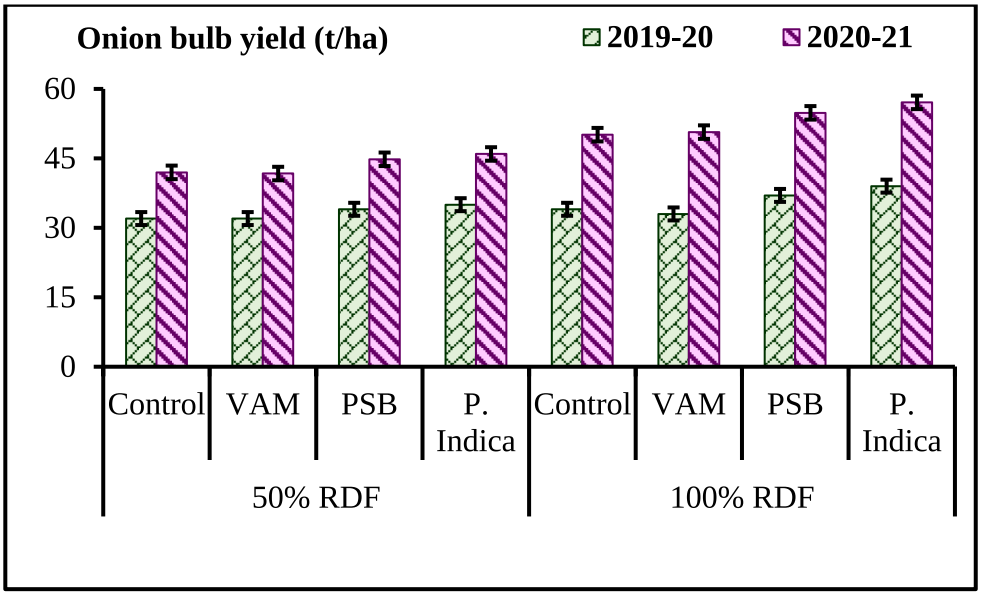


Fig. 2.7 Effect of biofertilizers applications on onion yield

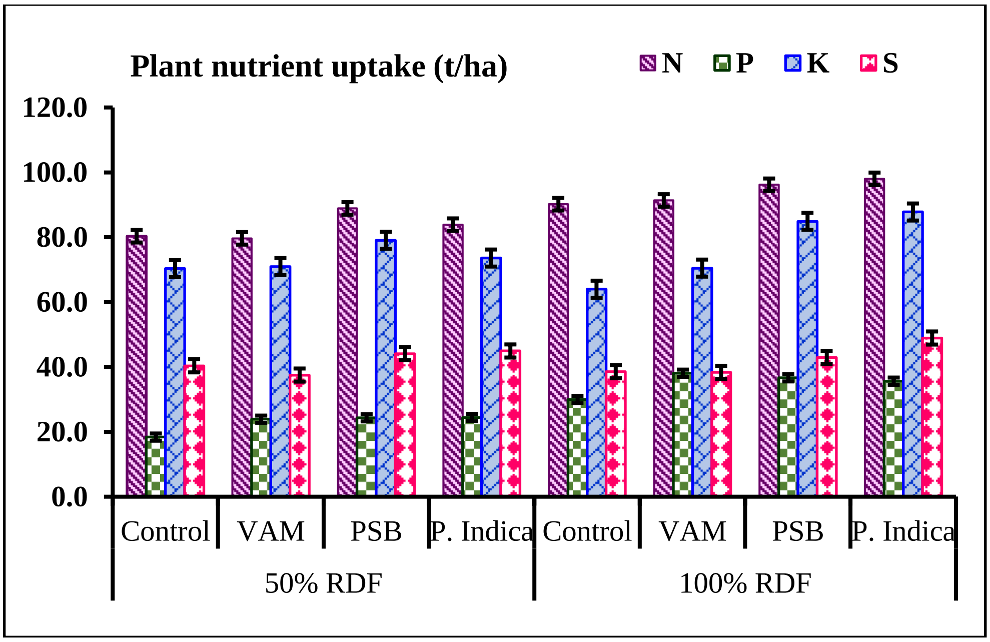


Fig. 2.8 Effect of biofertilizers applications on NPKS uptake

2.1.5 Fertilizer scheduling through drip system

Onion

The field experiment was carried out to study the effect of split application of fertilizers as per crop requirement through drip irrigation system in onion during 2020-21. The experiment consisted of nine treatments and each treatment replicated five times. The experiment was laid out in randomized block design. The results showed that application of fertilizer nutrients (NPKS) through drip irrigation system increased marketable and total yield significantly in comparison to flood irrigation with broadcasting method of fertilizer application. Application of 100% RDF (110:40:60:30 kg NPKS/ha) through drip at 6 days interval increased marketable bulb yield by 24.2% compared flood irrigation system and broadcasting method. This also increased onion yield by 12.5% compared to 100% N alone applied through drip (Figure 2.9). Application of fertilizers through drip system reduced bolters and double bulbs compared to control. Application of 100% RDF (110:40:60:30 kg NPKS/ha) through drip at 6 days interval showed higher NPKS uptake and benefit cost ratio compared to remaining treatments. However, we did not find much difference in soil available nutrient concentration between pre and post-harvest soil analysis. Application of NPKS through drip increased agronomic NPKS use efficiency significantly in comparison to broadcasting method.

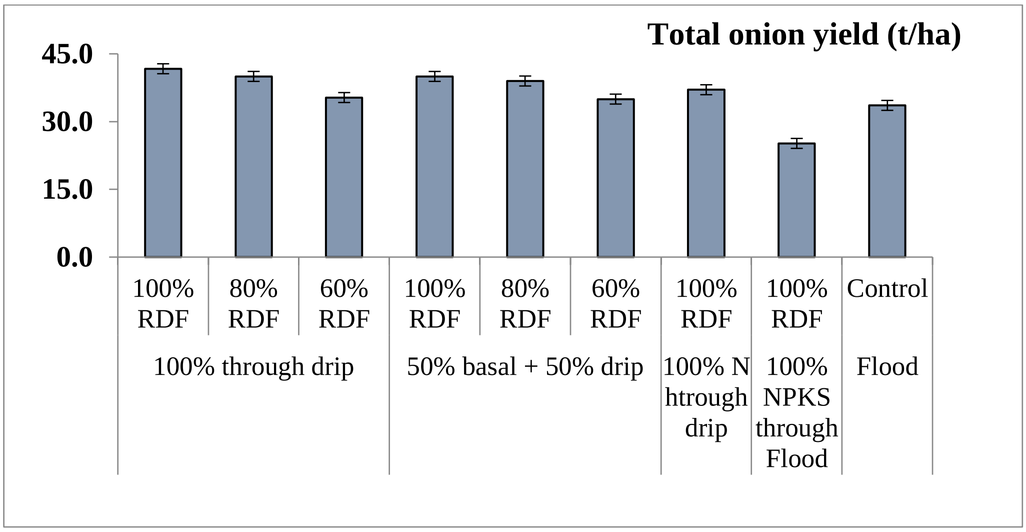


Fig. 2.9 Effect of drip fertigation on onion yield

Garlic

The field experiment was carried out to study the effect of split application of fertilizers as per crop requirement through drip irrigation system in onion during 2020-21. This experiment consisted of nine fertilizer treatments. The experiment was laid out in randomized block design with 5 replications. The results showed that application of fertilizer nutrients through drip irrigation system increased marketable and total bulb yield significantly compared to application of 100% RDF through broadcasting under flood irrigation system. Application of 100% (100:50:50:30 kg NPKS/ha) at 6 days interval + 5 t compost /ha increased marketable yield by 79.3% compared to the control. Furthermore, this treatment increased garlic yield by 25.7% compared to 100% N alone applied through drip. In addition, higher nutrient uptake and benefit cost ratio were recorded in plot received

100% RDF (100:50:50:30 kg NPKS/ha) at 6 days interval + 5 t compost /ha followed by 80 and 60% RDF.

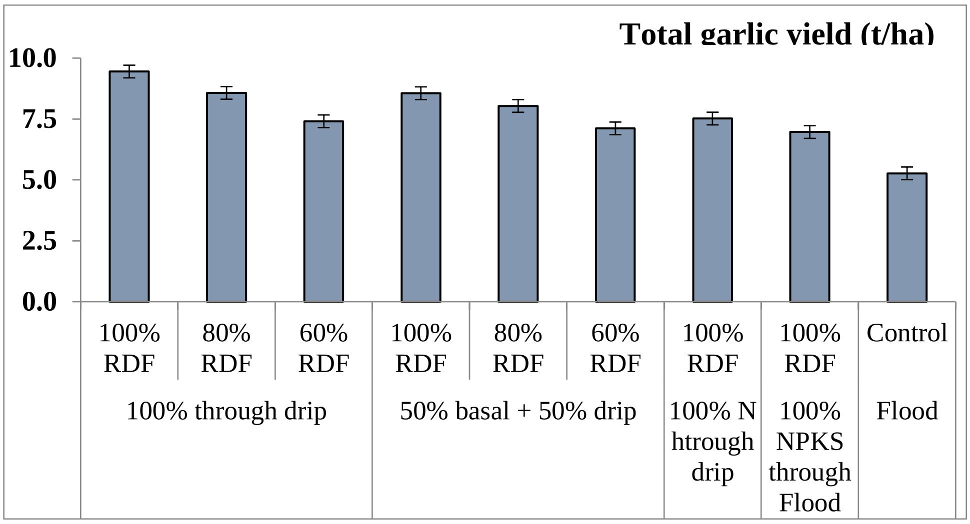


Fig. 2.10 Effect of drip fertigation on garlic yield

2.2 Weed management in onion crop

Transplanted onion

Field experiment was conducted during 2020-21 to develop weed management strategy in onion with special reference to purple nutsedge (*Cyperus rotundus*). Based on preliminary studies of previous year, integrated weed management modules were developed combining the stale seed beds (SSB) with sequential application of pre and post emergence herbicides and were evaluated against the standard herbicide check (Oxyfluorfen 250 g/ha + 1 hand weeding) and weedy and weed free checks. The experiment was laid out in randomized block design having 9 treatments and three replications. For stale seed beds, raised beds were prepared 20 days before optimum sowing date, and irrigated to stimulate weed emergence. After 12-15 days, the initial flush of weeds was killed using glyphosate 41% SL 2 kg a.i./ha + 2% (20 g/litre) urea. Onion was transplanted 3-5 days following glyphosate application. Pre-emergence herbicides were sprayed in moist soil one day before transplanting, while post-emergence herbicides at 25 DAT. Stale seed bed treatments successfully controlled the problematic weed *Cyperus rotundus* with glyphosate application, and led to its lower emergence especially during the critical stages of crop–weed competition period leading to better crop growth (Table 2.2). Treatment combination, SSB + oxadiargyl 120 g a.i/ha followed by fluazifop 200 g a.i/ha + oxyfluorfen 200 g a.i/ha showed yield and weed control efficiency on par with the recommended practice oxyfluorfen 250 g/ha + one hand weeding (Table 2.3). Although, SSB + polythene mulch was superior in terms of weed control, excessive heat under polythene sheets during bulb maturity led to bulb rotting (10-15%) and lower yield.

Table 2.2 Weed density (No/m^2) in onion as influenced by weed control treatments

Treatments	Weed density (No./m^2) at 60 DAT				Weed density (No./m^2) at 90 DAT			
	Grass	Broad leafed	*C. rotundus*	Total	Grass	Broad leafed	*C. rotundus*	Total
T1	3.0^{b}	3.5^{b}	1.9^{b}	4.9^{b}	3.2^{b}	3.7^{b}	2.9^{abc}	5.5^{b}
T2	2.9^{b}	3.3^{b}	2.2^{b}	4.8^{b}	2.8^{bc}	3.7^{b}	2.9^{ab}	5.5^{b}
T3	2.5^{b}	2.9^{bc}	1.7^{b}	4.0^{bc}	3.3^{b}	2.9^{bc}	2.5^{bc}	5.0^{bc}
T4	2.3^{b}	2.2^{cd}	1.9^{b}	3.6^{c}	1.9^{cd}	2.5^{c}	2.4^{bc}	3.9^{c}
T5	2.5^{b}	2.1^{cd}	2.0^{b}	3.7^{c}	1.8^{cde}	2.1^{c}	2.9^{ab}	3.9^{c}
T6	1.2^{c}	0.7^{e}	0.9^{c}	1.3^{d}	1.2^{de}	0.7^{d}	2.1^{c}	2.3^{d}
T7	2.4^{b}	1.8^{d}	2.2^{b}	3.6^{c}	2.3^{bcd}	2.2^{c}	2.7^{abc}	4.1^{c}
T8	7.5^{a}	8.3^{a}	3.1^{a}	11.6^{a}	7.6^{a}	8.7^{a}	3.4^{a}	12.0^{a}
T9	0.71^{c}	0.71^{e}	0.71^{c}	0.71^{d}	0.71^{e}	0.71^{d}	0.71^{d}	0.71^{e}

Table 2.3 Weed control efficiency, weed index & onion yield as influenced by weed control treatments

Treatments	Weed control efficiency (%)		Weed index	Yield (t/ha)
	60 DAT	90 DAT		
T1	81.8^{c}	77.4^{d}	20.6^{b}	31.0^{d}
T2	82.2^{c}	78.3^{d}	9.5^{cd}	35.2^{bc}
T3	87.8^{b}	82.6^{cd}	23.5^{b}	29.8^{d}
T4	90.4^{b}	88.6^{bc}	7.0^{de}	36.3^{ab}
T5	89.0^{b}	89.6^{bc}	7.9^{cde}	35.9^{abc}
T6	98.9^{a}	96.4^{ab}	15.9^{bc}	32.7^{cd}
T7	90.5^{b}	88.2b^{c}	7.5cd^{e}	36.0^{abc}
T8	0.0^{d}	0.0^{e}	42.3^{a}	22.4^{e}
T9	100.0^{a}	100.0^{a}	0.0^{d}	39.0^{a}

Where;

T1: SSB+ Oxadiargyl 120 g a.i./ha (PE) fb Propaquizafop 90 g a.i./ha + Oxyfluorfen 150 g a.i./ha (POE); **T2:** SSB+ Oxadiargyl 120 g a.i./ha (PE) fb Fluazifop-p-butyl 150 g a.i./ha + Oxyfluorfen 150 g a.i./ha (POE); **T3:** SSB+ Oxadiargyl 120 g a.i./ha (PE) fb Propaquizafop 120 g a.i./ha + Oxyfluorfen 200 g a.i./ha (POE); **T4:** SSB+ Oxadiargyl 120 g a.i./ha (PE) fb Fluazifop-p-butyl 200 g a.i./ha + Oxyfluorfen 200 g a.i./ha (POE); **T5:** SSB+ Pendimethalin 1500 g a.i./ha (PE) fb Quizalofop 75 g a.i./ha + Oxyfluorfen 150 g a.i./ha (POE); **T6:** SSB fb Polythene mulching; **T7:** Oxyfluorfen 250 g a.i./ha (PE) + 1 Hand weeding at 40 DAT; **T8:** Weedy check**; T9:** Weed free check. *SSB: Stale seed bed with Glyphosate 1.2 kg a.i./ha + 2% (NH4)2SO4; PE- Pre-emergence, POE- Post emergence; Weed count data have been transformed through square root (X+0.5)1/2 transformation*

Onion nursery during kharif

Field experiment was conducted during *kharif* 2021 to develop weed management strategy in onion nursery. The experiment evaluated oxadiargyl 75 g/ha as pre-emergence herbicide for onion nursery. Higher seedling stand and minimal seedling mortality was observed in Oxadiargyl 75 g/ha treated plots which was comparable with Pendimethalin 500 g/ha. Like pendimethalin 500 g/ha + one hand weeding, treatment combination, SSB+ Oxadiargyl 75 g/ha +one hand weeding also showed lower weed density, higher seedling dry weight, and better root growth (Table 2.4, 2.5). However, this needs to be confirmed with more trials in subsequent seasons. Among post emergence herbicides, propaquizafop 60 g/ha and quizalofop 25 g/ha in combination with oxyfluorfen 125 g/ha caused slight to moderate seedling stunting and leaf tip burning symptoms which recovered subsequently.

Table 2.4 Seedling height, root length and dry weight of seedling in onion nursery as influenced by weed control treatments.

Treatments (T)	Plant height (cm)		Root length (cm)		Dry weight (mg/plant)	
	20 DAS	35 DAS	20 DAS	35 DAS	20 DAS	35 DAS
T1	19.0[ab]	31.7[abc]	2.5[ab]	5.5[ab]	40.0[a]	256.7[ab]
T2	18.4[abc]	29.0[bcd]	2.6[ab]	5.1[bc]	39.0[a]	236.7[b]
T3	18.6[abc]	28.6[cd]	2.6[ab]	4.6[cd]	39.3[a]	195.7[c]
T4	21.0[a]	32.4[ab]	2.6[ab]	5.6[ab]	40.0[a]	254.0[ab]
T5	17.8[bc]	28.0[d]	2.4[bc]	4.8[cd]	39.0[a]	194.0[c]
T6	19.9[ab]	33.5[a]	2.7[ab]	5.8[a]	42.7[a]	272.3[a]
T7	20.9[a]	31.8[abc]	2.8[a]	5.6[ab]	42.3[a]	257.0[ab]
T8	16.3[c]	23.9[e]	2.1[c]	4.2[d]	32.0[b]	121.3[d]

Table 2.5 Weed density and weed control efficiency in onion nursery at 35 DAS as influenced by weed control treatments.

Treatments	Weed density (no./m2) at 35 DAS				WCE at 35 DAS (%)
	Grass	BLW	Sedge	Total	
T1	2.4[b]	1.6[b]	0.9[c]	2.9[b]	89.7[d]
T2	2.1[bc]	1.6[b]	0.7[c]	2.5[bc]	93.1[bcd]
T3	1.6[cd]	1.3[bc]	0.7[c]	2.0[cd]	96.1[ab]
T4	1.6[bcd]	1.3[bc]	0.7[c]	2.0[cd]	95.5[abc]
T5	1.9[bcd]	1.2[bc]	0.7[c]	2.2[bcd]	95.1[abc]
T6	1.2[d]	0.7[c]	1.1[c]	1.4[d]	98.2[a]
T7	1.6c[d]	0.7[c]	2.5[b]	2.9[bc]	91.0[cd]
T8	6.9[a]	4.5[a]	4.4[a]	9.2[a]	0.0[e]

Where;

T1:SSB+ Oxadiargyl 75 g a.i./ha (PE) fb Oxyfluorfen 125 g a.i./ha (POE); **T2**:SSB+ Oxadiargyl 75 g a.i./ha (PE) fb Oxyfluorfen 180 g a.i./ha (POE); **T3:**SSB+ Oxadiargyl 75 g a.i./ha (PE) fbPropaquizafop 60 g a.i./ha + Oxyfluorfen 125 g a.i./ha (POE); **T4**:SSB+ Oxadiargyl 75 g a.i./ha (PE) fbFluazifop-p-butyl 135 g a.i./ha + Oxyfluorfen 125 g a.i./ha (POE); **T5**:SSB+ Oxadiargyl 75 g a.i./ha (PE) fbQuizalofop 5 EC 25 g a.i/ha + Oxyfluorfen 125 g a.i./ha (POE); **T6**:SSB+ Oxadiargyl 75 g a.i./ha (PE) fb1 HW; **T7**:Pendimethalin 500 g a.i./ha (PE) fb 1 HW; **T8**:Weedy check. *SSB: Stale seed bed with Glyphosate 1.2 kg a.i./ha + 2% (NH4)2SO4; PE- Pre-emergence, POE- Post emergence; fb: followed by. Weed count data have been transformed through square root (X+0.5)1/2 transformation*

2.3 Abiotic stress management in onion and garlic

2.3.1 Morphological, histochemical and phytohormonal root studies in onion entries under water logging stress

An experiment was conducted to study the alterations in root architecture patterns under water logging condition. Seedlings of sixteen onion genotypes were transplanted in root trainers of size 1200cc in two sets and allowed them to grow for 30 days under normal condition. Thereafter, water logging treatment was imposed in one set for 8 days by creating an artificial condition in tank. After completion of treatment, the roots were washed properly without damaging and used it for microtome, and scanning electron microscopy/energy dispersive spectroscopy (SEM/EDS) analyses. Anatomical and histological study by using transverses sectioning of roots showed that Acc. 1630 and RGP 2 onion entries performed better under water-logging condition due to induction of root aerenchyma formation, and higher ethylene concentration in their root zones (Figure 2.11 and 2.12). These aerenchymatic cells help to supply required oxygen to the plant under water logging condition. In contrast, onion genotypes accession W-344 showed more root structural damages and the development of aerenchymatic cells were also lesser. Further, biochemical analyses result also revealed that Acc.1630 and RGP-2 onion entries performed better and hence, are tolerant to water logging condition, whereas accession W-344 performed poorly under water logging condition.

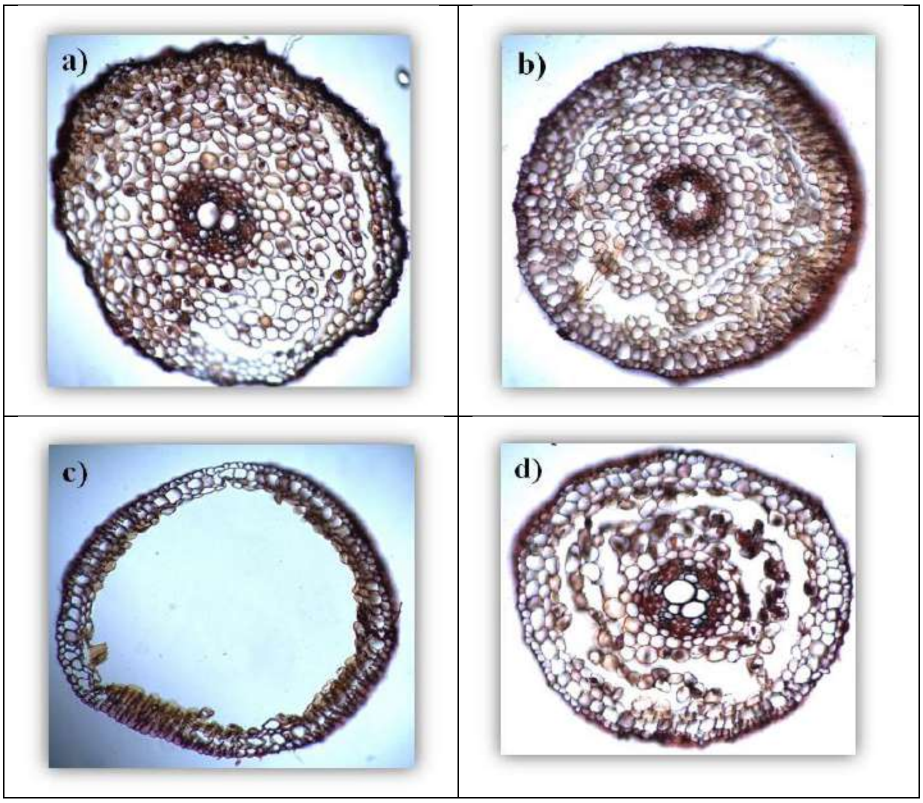


Fig. 2.11 Transverse sections of roots through microtome

a) Bhima Shubhra b) Acc. 1630 under normal condition

c) Bhima Shubhra d) Acc. 1630 under water-logging condition

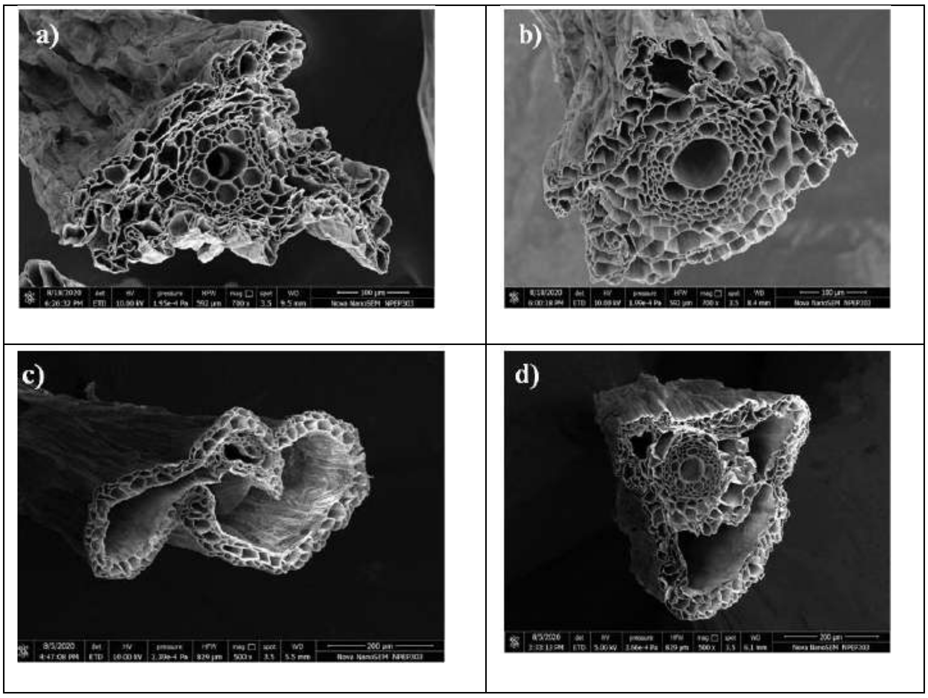


Fig. 2.12 Transverse sections of roots through FESEM
a) Bhima Shubhra b) Acc. 1630 under normal condition
c) Bhima Shubhra d) Acc. 1630 under water-logging condition

2.3.2 Root studies in onion entries under drought stress condition

An experiment was conducted to study the alterations in root architecture patterns under drought condition. Seedling of sixteen onion genotypes were transplanted in root trainers of size 1200cc in two sets and allowed them to grow for 30 days under normal condition. Thereafter, drought treatment was imposed in one set for 25 days by withholding irrigation water. After completion of treatment, the roots were washed properly without damaging and used it for microtome, SEM and EDS analyses. After completion of treatment, the roots were washed properly without damaging and used it for microtome, SEM and EDS analyses. The results of anatomical and histological study by using transverses sectioning of roots showed that W 344 and W 448 showed lesser anatomical damages in their root structures. In addition, these two genotypes showed lack of lignin in sclerenchyma layer and the cortical tissue between aerenchyma which indicated the tolerance pattern against drought condition. In contrast, Bhima Dark Red and DOGR HY-7 showed higher root anatomical damages under drought stress condition. The histochemical study showed that lesser amount of reduction in auto-fluorescence of the epidermis, exodermis, and sclerenchyma in roots of these two genotypes. Furthermore, the abscisic acid (ABA) concentration was significant higher in W-344 and W-448 which helps in regulating the stomata conductance to manage transpiration rate during drought stress condition (Figure 2.13). The ABA also helps to regulate osmosis and turgidity under drought stress condition, and hence, this parameter is used as an indicator of tolerance behavior under drought condition. However, the ABA concentration was lower in Bhima Dark Red and DOGR HY-7. Thus, the experimental results revealed that W-344 and W-448 performed better under drought stress condition and hence, classified as tolerant, whereas Bhima Dark Red and DOGR HY-7 found susceptible to drought stress condition.

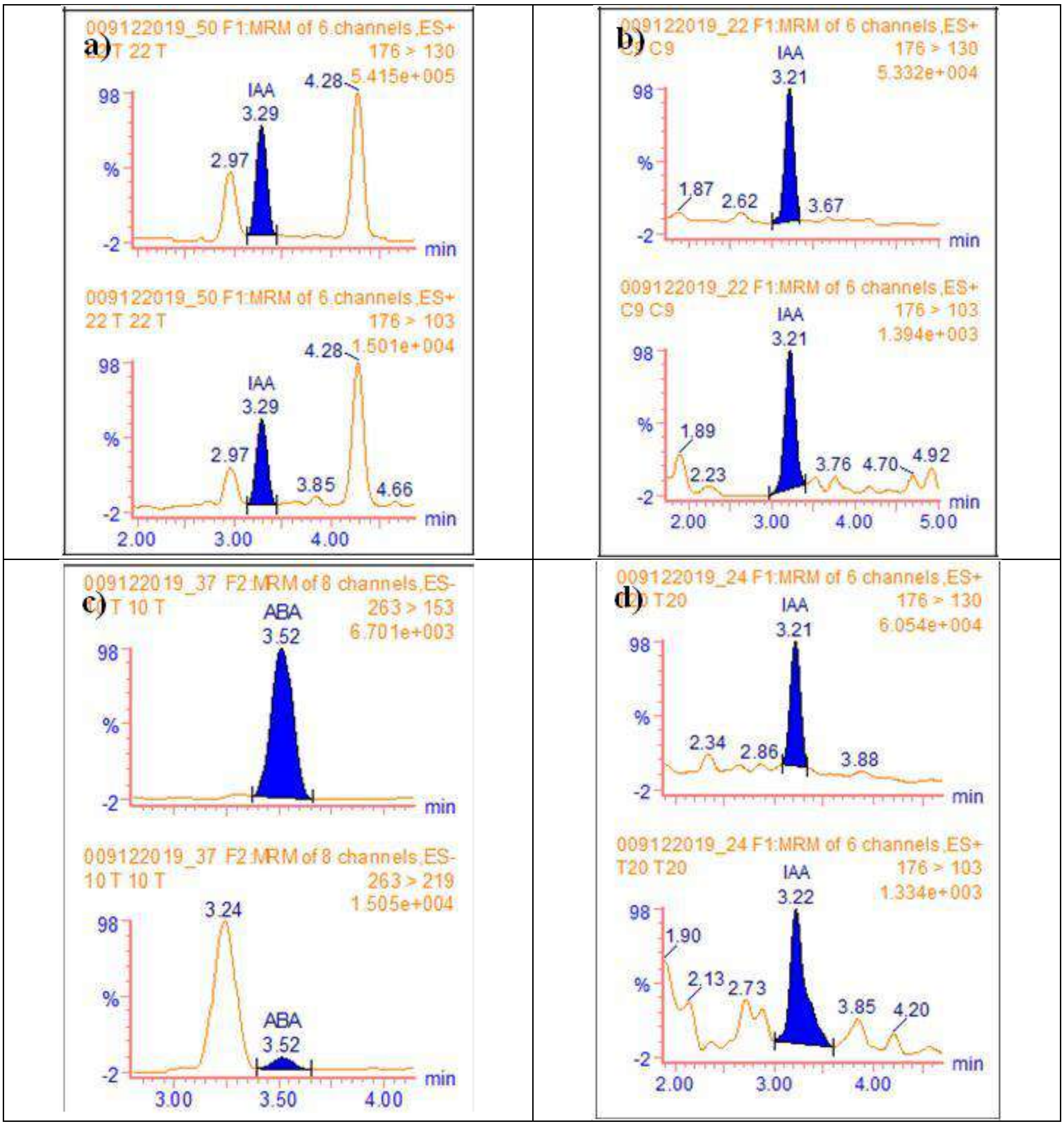


Fig. 2.13 Detection of abscisic acid in roots
a) Bhima Dark Red b) W-344 under normal condition
c) Bhima Dark Red d) W-344 under drought stress condition

2.3.3 Effect of *Piriformispora indica* and VAM under waterlogging stress

A field experiment was conducted to evaluate the effect of *Piriformispora indica* and VAM inoculation in onion cv. Bhima Super. The 45 days old seedlings were treated with the above-mentioned growth promoting microbes by dipping the roots in the microbial culture for two hours before transplanting during *kharif* 2021. Waterlogging treatment was imposed for continuous ten days from 40 to 50 DAT by maintaining the water level through sprinkler and flood irrigation. *Piriformispora indica* and VAM treated seedlings performed better compared to the control plants with respect to survival and recovery after stress period (Figure 2.14). Plants without microbial inoculation recorded with poor plant stand and survival after stress treatment. The bulb yield loss was also highest in seedlings without microbial inoculation (68-70% losses) compared to *Piriformispora indica* and VAM treated seedlings. Yield loss was less with VAM inoculation (25% losses) compared to

Piriformispora indica treatment (50% losses) (Figure 2.15). The result thus indicate that VAM inoculation is more benefical compared to *Piriformispora indica* in onion crop. Overall, microbial treatment improved plant growth and reduced onion yield losses under water logging condition.

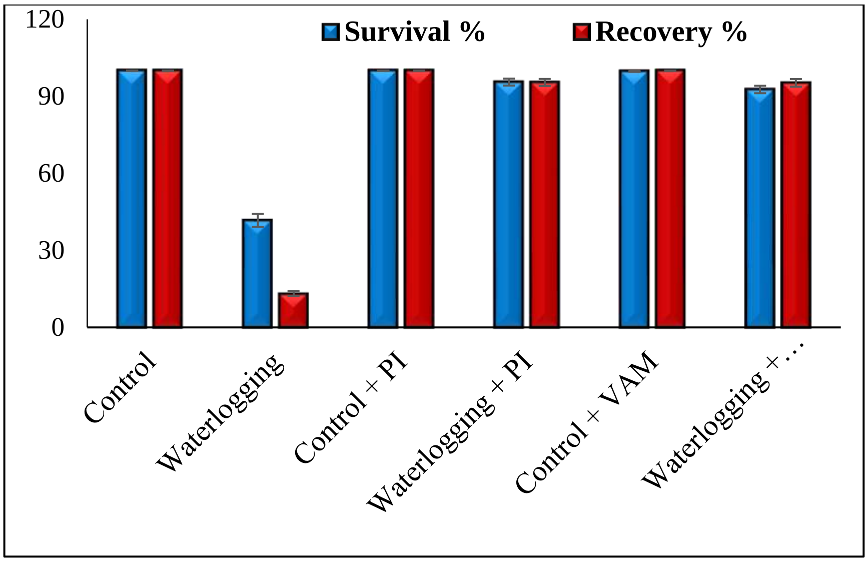


Fig. 2.14 Effect of VAM and PI treatment on plant survival and stress recovery in onion crop under waterlogging stress

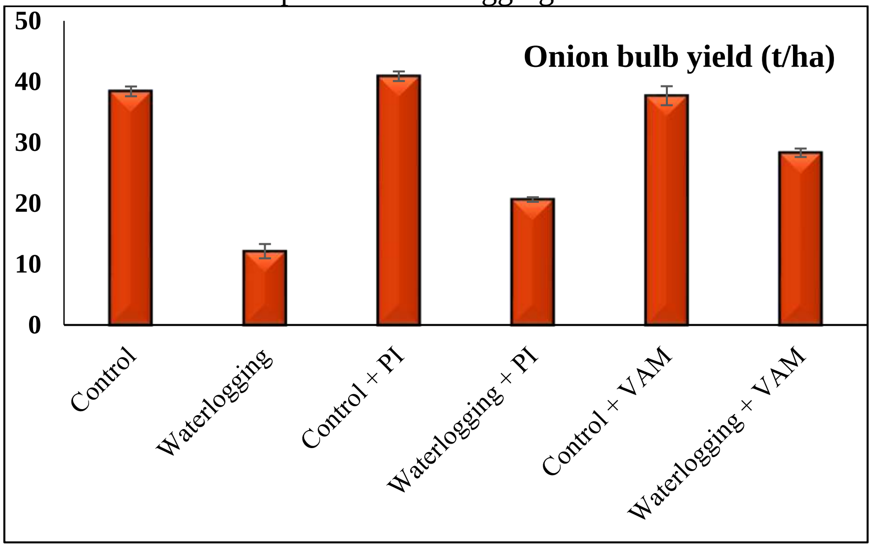


Fig. 2.15 Effect of VAM and PI treatment on onion bulb yield under waterlogging stress

2.3.4 Effect of plant growth regulators in onion crop subjected to drought stress

The field experiment was conducted to evaluate the effect of plant growth regulators (Salicylic acid 100 and 500 ppm, Thiourea 100 and 250 ppm, Potassium Nitrate 2 and 3%, 6-BAP 20 and 50 ppm, and IAA 10 ppm) in onion cv. Bhima Shakti under drought stress during *rabi* 2020-21. Drought stress was imposed by withholding irrigation during 50-75 DAT. Foliar application of plant growth regulators significantly improved plant growth parameters and reduced bulb yield losses compared to the control plants without plant growth regulator treatments (Figure 6.16). Foliar spray of Thiourea (100 ppm), 6-BAP (50 ppm), and Potassium nitrate (2%) were recorded with the lowest bulb yield loss (less than 20%) compared to other treatments. The findings thus suggest that foliar application of thiourea (100 ppm), 6-BAP (50 ppm), and potassium nitrate (2%) is beneficial to onion crop under drought stress.

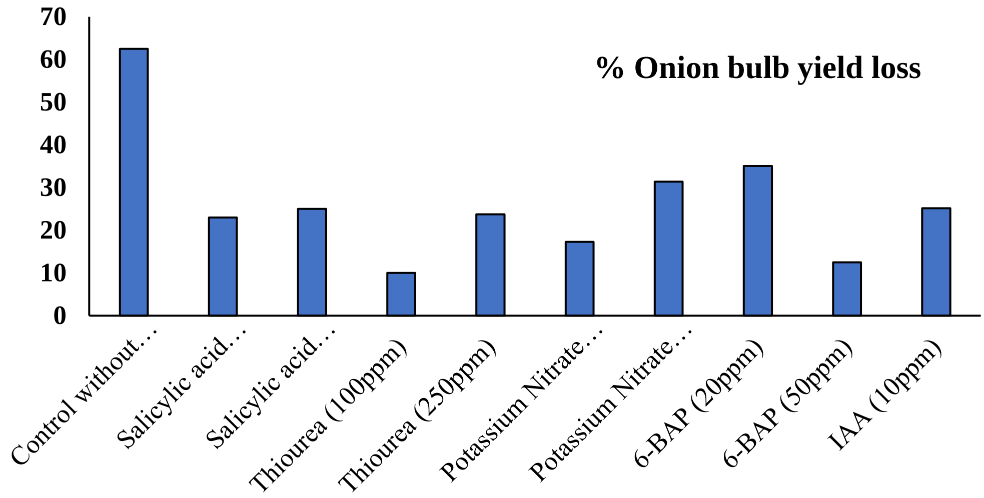


Fig. 2.16: Effect of plant growth regulators on onion bulb yield loss under drought stress

2.3.5 Effect of *Piriformispora indica* and VAM under drought stress

A field experiment was conducted to evaluate the effect of *Piriformispora indica* and VAM inoculation in onion variety Bhima Shakti. The 45 days old seedlings were treated with the growth promoting microbes by dipping the roots in the microbial culture for two hours before transplanting in *rabi* 2020-21. Drought stress was imposed for continuous twenty-five days from 50 to 75 DAT by with-holding the irrigation. *Piriformispora indica* and VAM treated seedlings performed better with respect to morphological and physiological traits in comparison to the control plants under drought condition. The bulb yield in response to both the microbes was found to be higher compared to non-inoculated seedlings under drought stress. The yield loss was highest in seedlings without microbial inoculation (54%) compared to *Piriformispora indica* (32%) and VAM (38%) treated seedlings (Figure 2.17). Overall, microbial treatment increased plant growth and marketable bulb yield under drought condition.

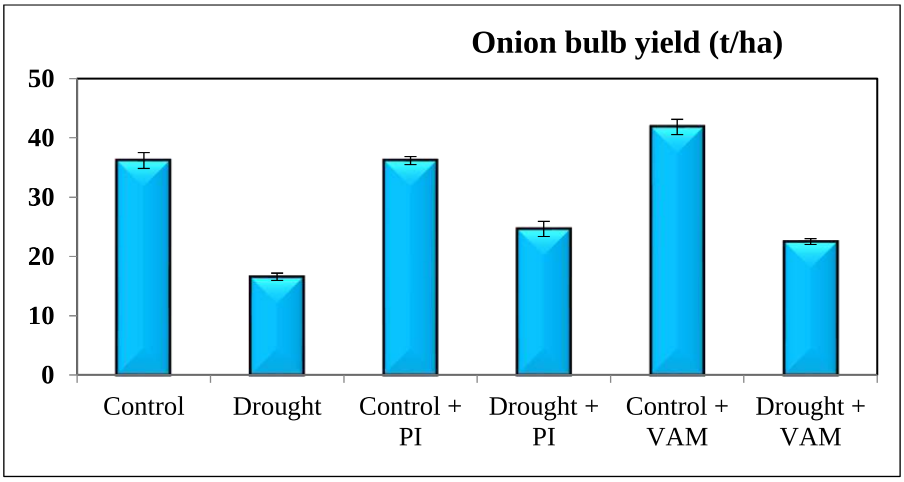


Fig. 2.17: Effect of VAM and PI treatment on onion bulb yield under drought stress

2.3.6 Performance of onion varieties on different dates of planting

A field experiment was conducted to evaluate the effect of dates of planting (1st December, 15th December, 1st January, 15th January, 1st February and 15th February) on plant growth and yield of onion. Five different onion varieties (Bhima Kiran, Bhima Red, Bhima Shakti, Bhima Dark Red, and Bhima Shweta) were used for the present study during *rabi* 2020-21. The seedling transplantation on 1stJanuary recorded significantly higher bulb yield (30-36 t/ha) followed by 15th December (28-32 t/ha) and 1st December (26-30 t/ha) in all the studied varieties (Figure 2.18). Delayed transplantation negatively affected bulb size and bulb yield (15th January 16-25 t/ha; 15th February 3-8 t/ha). The findings thus suggest that seedling transplantation beyond 1st January significantly reduces the bulb yield in onion crop.

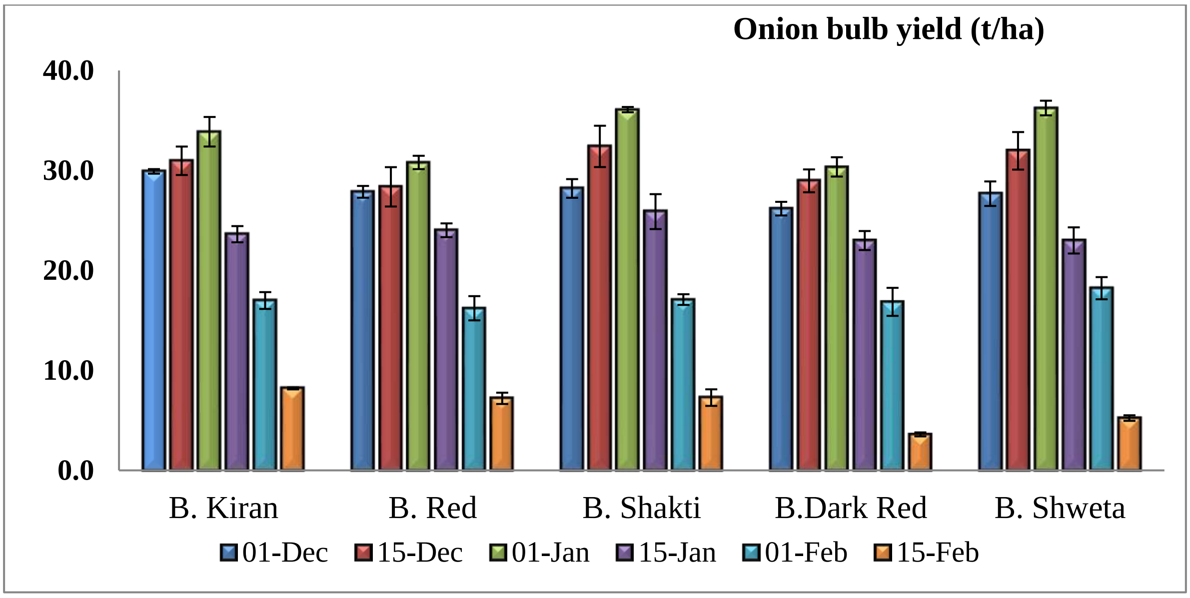


Fig. 2.18: Performance of onion varieties on different dates of planting

3. Crop Protection

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

Seven *Trichoderma* spp./isolates were evaluated against fungal disease pathogens of onion under net house conditions. Observations on crop growth, including plant height and pseudostem diameter etc., were recorded. Among seven *Trichoderma* spp./isolates, T-354 performed well against pathogens, enhancing almost all the parameters, including yield. This preliminary study continued under field conditions from *Rabi*-2020-21 with the variety Bhima shakti and Bhima super for *Rabi* and *Kharif* seasons, respectively.

3.1.1 Collection, isolation and identification of diseases pathogens

A total of 22 onion and garlic diseases (viz. Anthracnose, Purple blotch, Stemphylium blight, White rot, Damping-off, and Basal rot) samples were collected from the DOGR field and adjoining places. Pathogens were isolated, and ten cultures were identified from *Colletotrichum* spp., *Fusarium* spp., *Alternaria* spp., *Stemphylium* spp. etc., based on morphological characters, and are maintained. In addition to that, few potential endophytes were also isolated. The *in-vitro* bio-efficacy (Figure 3.1) of this endophyte was tested against Anthracnose pathogen.

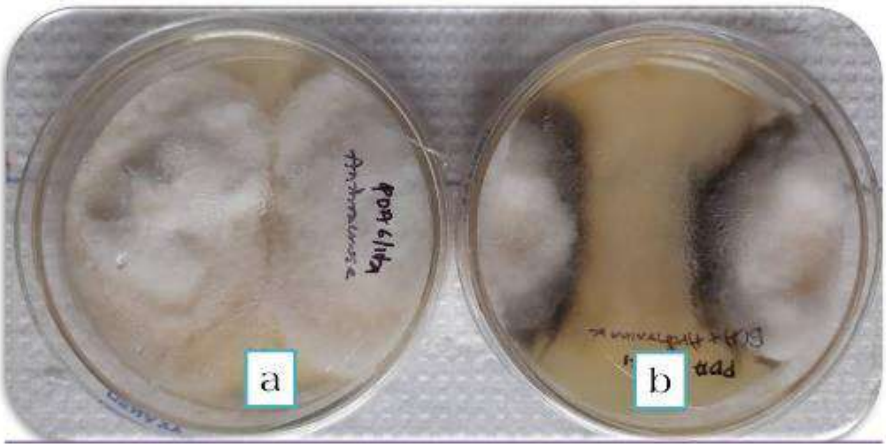


Fig. 3.1. In-vitro efficacy of isolated endophyte against *Colletotrichum* spp.
a. Control; b. Dual culture plate at 12 DAI.

3.1.2 Evaluation of *Trichoderma* species/isolates on crop growth and disease management in onion under field conditions during *rabi* 2020-21 and *kharif*-2021

Crop growth

Fourteen *Trichoderma* spp./isolates were evaluated and observations on growth parameters were recorded. All *Trichoderma* spp./isolates enhanced the growth, viz. plant height (21-24%) and pseudostem diameter (31-35%) in *rabi*-2021. During *kharif* 2021, most of the *Trichoderma* spp./isolates enhanced the plant height (ranging from 0-10%), and all the spp./isolates increased the pseudostem diameter (range, 2-19%) over control.

Effect on anthracnose disease

Fourteen *Trichoderma* spp./isolates evaluated against anthracnose during *kharif* 2021, and the disease inhibition rate was ranged from 13-49% over control. The maximum (49%) inhibition was recorded with *Trichoderma* isolate, T-4R, minimum (13%) from *Trichoderma koningiopsis*. Negligible diseases were observed during the *rabi*-2021, hence not reported.

Bulb yield

Among the above 14 *Trichoderma* spp./isolates evaluated, all the spp./isolates enhanced the yield in the range of 3-28%. The maximum (28%) increase was supported by *Trichoderma* T-354 (34 t/ha) over control (26 t/ha) in *rabi*. Whereas during *kharif*, among the above 14 *Trichoderma* spp./isolates, eleven spp./isolates enhanced the yield in the range of 1 to 21%. The maximum (21%) increase was supported by *Trichoderma* T-4R (21t/ha) against control yield (17 t/ha).

Total biomass

Among the different *Trichoderma* strains, *Trichoderma*- 354 recorded significantly higher (65%) total biomass followed by *T. koningiopsis* (62%) compared to control during *rabi*-2021. Whereas, during *kharif* -2021 strain, *Trichoderma*-4R recorded significantly higher (65%) total biomass followed by *T. koningiopsis* (58%) over control to accelerate the physiological activities for the betterment of growth and development.

Storage

The produce of *rabi*-2021 was kept in storage, and it was noted that *Trichoderma* T-354 had some effect on storage over control, reducing storage losses by 18%. The *Trichoderma* T-354 samples received storage losses of 37% against 45% in control.

3.1.3 Evaluation of IPDM modules 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 *kharif* 2021. All the modules inhibited the Anthracnose disease, ranging from 7-61% over FP and 33-51% over EP. The maximum (61%) inhibition was recorded with M1 (Intensive management) followed by M2 (46%) over FP. While compared with EP, M1 and M2 inhibited 51% and 33% of anthracnose, respectively. The *Stemphylium blight* was not recorded in M1, M2 and M3 treatments. However, it was observed in M4, EP, FP and AC treatments. When compared with EP and FP, 40% and 41% inhibition of Stemphylium was recorded in M4. There were negligible diseases during *rabi*-2021; hence not reported.

Bulb yield

Among the above four modules (M1, M2, M3, M4), M1 supported 32% and 44% higher yield over FP (26 t/ha) and EP (24 t/ha), followed by M2, which supported 18% and 23% higher yield over FP and EP during *rabi* 2021. During *kharif*-2021, the pattern was same, where M1 supported 20% and 31% higher yield over FP (18 t/ha) and EP (17 t/ha), followed by M2, which supported 14% and 24% higher yield over FP and EP.

3.1.4 Evaluation of organic formulations against onion disease

Effect on diseases

During *kharif* 2021, four organic formulations were evaluated against onion disease. The maximum (79%) anthracnose inhibition was supported by DOGROF3 (Bajra flour, Calotropis leaves, Karanj leaves, Ginger powder, Turmeric powder, Hing powder to Water), followed by DOGROF1 (58%) being at par with DOGROF2 and DOGROF4. The maximum 61 PDI (for anthracnose) was recorded, with control and minimum with DOGROF3 (13 PDI). Further, DOGROF3 supported maximum (33%) inhibition of *Stemphylium blight*, followed by DOGROF4 (21%). The other two formulations were not adequate for *Stemphylium blight*. A maximum of 51 PDI (*Stemphylium blight*) was recorded in control and minimum with DOGROF3 (34 PDI). There were negligible diseases during *rabi*-2021; hence not reported.

Bulb yield

DOGROF3 recorded with 15% and 60% higher yields than the farmers' practice (25.85 t/ha) and control (18.55 t/ha), respectively, during *rabi* 2021. During *kharif* 2021, DOGROF3 supported a maximum 10% and 54% higher yield than the farmers' practice (18.40 t/ha) and control (13.10 t/ha), respectively.

3.1.5 Evaluation of onion germplasm for diseases

During *rabi* 2021, 19 red onion germplasm including checks were evaluated. DOGR-HY-8, 1630, 1708, and 1621 were promising germplasm receiving less than 10 PDI. Among 18 white germplasm including checks evaluated, WHTS-7G-GT-15-SC-M-7, WHT-23A-2(18-20), WHTS-8H-GT-15-MC-M-7, W-344, W-453, M-8, W-408, WHTB-3C-GT-18-MC-M-7 and W-358 were promising with less than 10 PDI.

During *kharif* 2021, 13 red onion germplasm (1609, DOGR-HY-56, DOGR-HY-8, KH-M-3, 1622, 1623, DOGR-HY-6, 1613, 1628, 1621, 1629, 1618, 1630) were evaluated. All germplasm received higher anthracnose disease ranging from 67-91 PDI. Thirty, white germplasm, including checks, were evaluated. WHTS-8H-GT-15-MC-M-7 germplasm was free from anthracnose disease, and W-344 showed 7 PDI. Four entries (W-358, W-143 GP, W-458, GP, W-125 GP) had lesser incidence of anthracnose (<20 PDI). The remaining 21 germplasms showed higher disease ranging from 25-77 PDI.
During *kharif* 2021, observations were also recorded for anthracnose in the E2 germplasm evaluation block, where 152 germplasm, including checks, were transplanted. Four germplasm (W-523-GP, W-414-EL-7, W-443-M-6, W-147-M-6, MS-100 X WHT-23A F1M1) received ≤ 20 PDI. Rest all the germplasm received a higher incidence of anthracnose ranging from 27-100 PDI.

3.1.6 Genetic analyses of purple blotch tolerance in onion

The present investigation was performed to study the inheritance of purple blotch tolerance in onions using Arka Kalyan (Tolerant variety) and Bhima Super (Susceptible variety). The F1 plants developed by crossing tolerant and susceptible varieties were planted in *kharif* 2021. Further, the F1 bulbs were planted in *rabi*-2022 to develop the back cross and F2 population.

3.2 Biotechnological approaches for biotic stress management

3.2.1 Comparative transcriptome analysis of onion in response to infection by *Alternaria porri* (Ellis) Cifferi

Purple blotch (PB) is one of the most destructive foliar diseases of onion and other *Allium*s, caused by a necrotrophic fungal pathogen *Alternaria porri* (Figure 3.2). There are no reports on the molecular response of onion to purple blotch infection. In order to elucidate the response of onion to *A. porri* infection, we consequently carried out an *RNAseq*. analysis of the resistant (Arka Kalyan; AK) and susceptible (Agri-found Rose; AFR) genotype after an artificial infection. The mega-assembly of the transcriptome comprised of 122660 transcripts with N50 value of 1685bp and a GC content of 42.9%. After differential expression analyses between control and pathogen-treated plants, we identified 8064 up regulated and 248 down regulated genes in AFR, while 832 up regulated and 564 down regulated genes were identified in AK. A further significant reprogramming in the gene expression profile was also demonstrated by a functional annotation analysis. GO terms, which are particularly involved in defense responses and signaling, are overrepresented in current analyses such as 'oxidoreductase activity', 'chitin catabolic processes, 'defense response' etc. Several plant defense genes were differentially expressed upon *A. porri* infection which includes PR proteins, receptor like kinases, phytohormones signaling, cell-wall integrity, cytochrome P450 monooxygenases, transcription factors etc (Figure 3.3). Some of the genes were exclusively overexpressed in resistant genotype; GABA transporter1, ankyrin repeat domain-containing protein, xyloglucan endotransglucosylase/hydrolase, PR-5 (Thaumatin-like) etc. Several transcripts were also showed homology with the reference pathogen receptor genes in the Plant Resistance Genes database (PRGdb) (Figure 3.4). Antioxidant enzyme activities were observed to be increased after infection in both genotype but higher activity was found in resistant genotype, AK. This is the first report of transcriptome profiling in onion in response to PB infection and will serve as a resource for future studies to elucidate the molecular mechanism of onion-*A. porri* interaction and to improve PB resistance in onion.

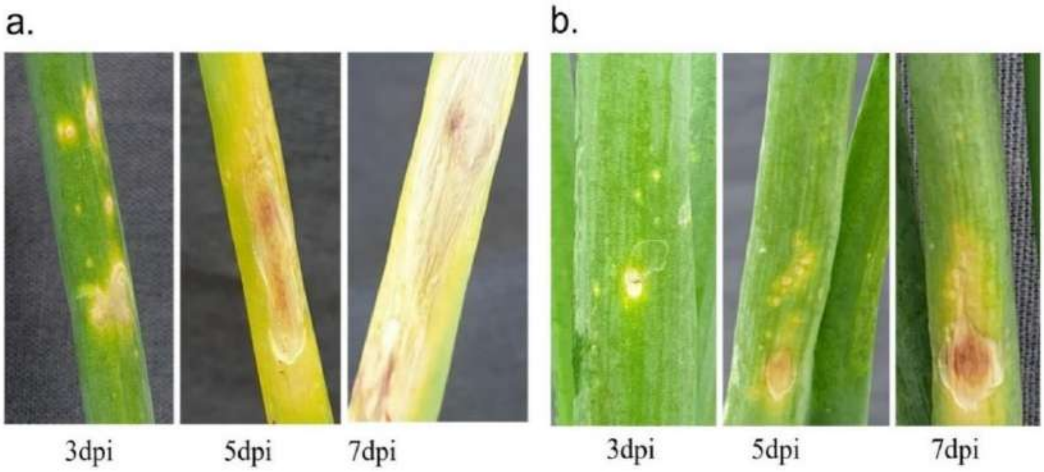


Fig. 3.2 Purple blotch symptom development in onion after pathogen inoculation (a. AFR b. AK)

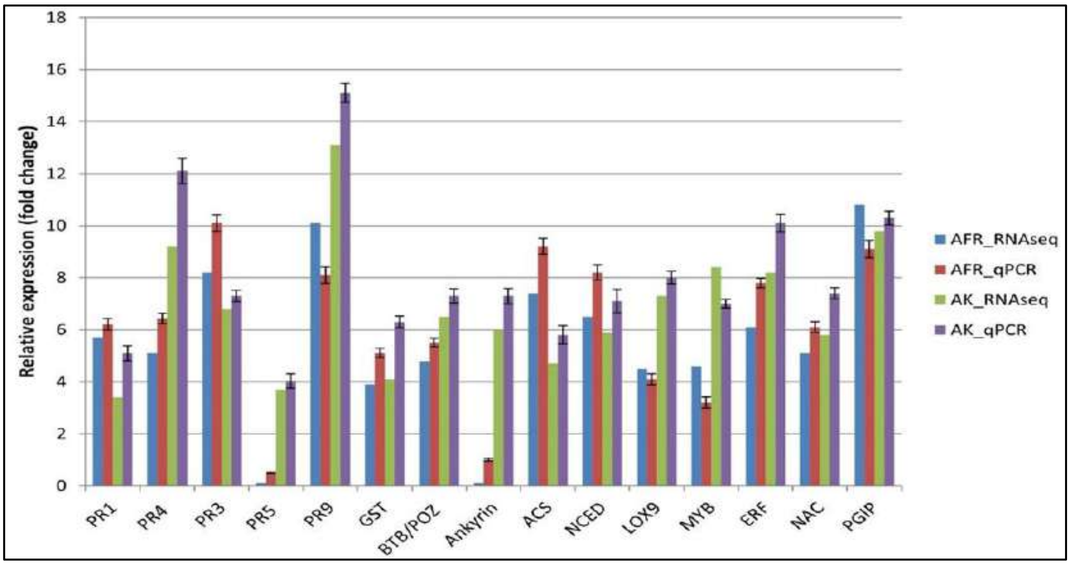


Fig. 3.3 Validation of selected differentially expressed genes by qPCR in AK and AFR
Error bars showing standard error of the mean

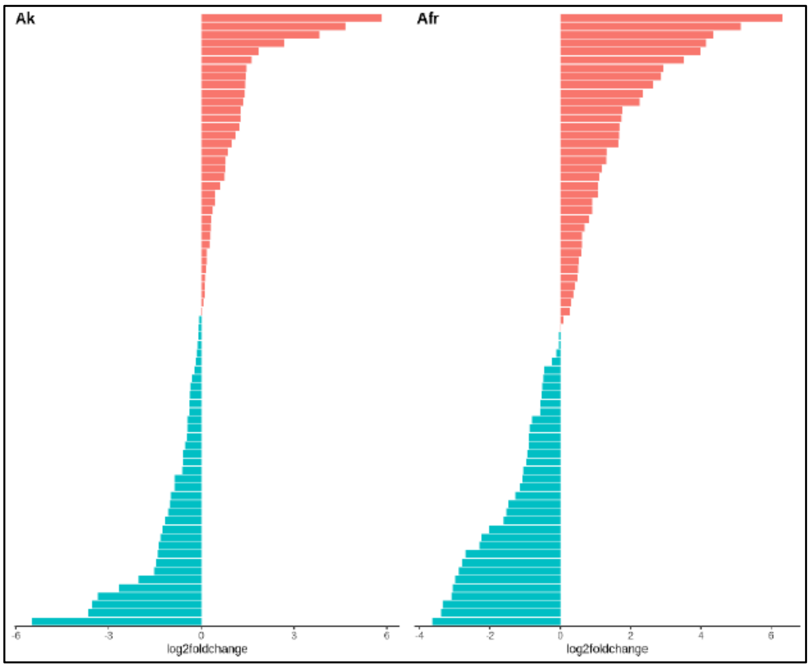


Fig 3.4. PRGdb analyses of transcripts in Arka Kalyan and Agrifound rose after *A. porri* infection

3.2.2 Screening of onion genotypes for anthracnose resistance

Anthracnose/twister is one the major and devastating disease of *kharif* onion. We have screened 29 genotypes for resistance to Anthracnose/twister (*Colletotrichum gleosporoides*) disease. Four genotypes viz., W-322, 1674, 1619, 165 were found moderately resistant (Figure 3.5) to the *C. gleosporoides*. Further, we have estimated salicylic acid (SA) and auxin-IAA content of genotype W-322, higher content of SA and IAA content was observed in this genotype (Figure 3.6).

Fig. 3.5 Moderately resistant onion genotypes

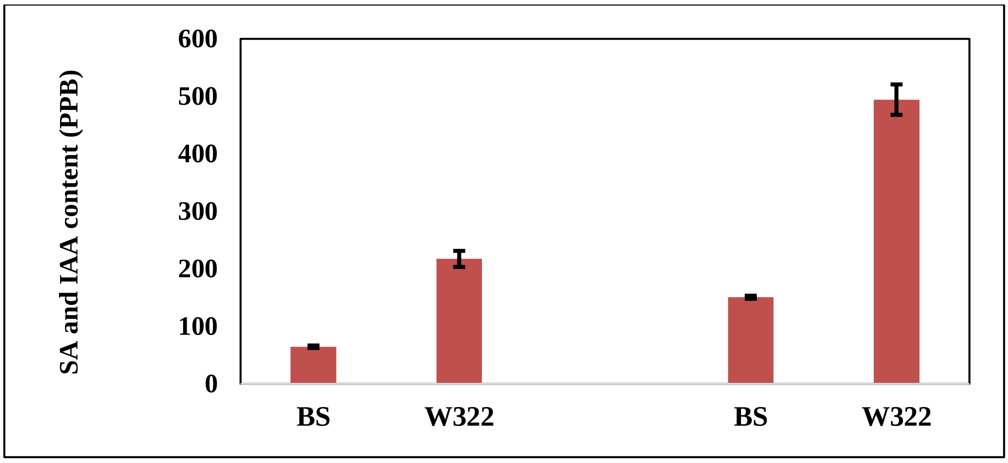


Fig. 3.6 Salicylic acid (SA) and Auxin-IAA content in MR genotypes

3.2.3 Screening of garlic core germplasm collection for presence of multiple viruses

Through RT-PCR, we have screened 46 accessions representing garlic core collection for presence of 10 garlic viruses viz. Onion yellow dwarf virus (OYDV), Leek yellow stripe virus (LYSV), Garlic common latent virus (GarCLV), Iris yellow spot virus (IYSV), Garlic virus-A (GarV-A), Garlic virus-A (GarV-B), Garlic virus-C (GarV-C), Garlic virus-D (GarV-D), Garlic virus-E (GarV-E). OYDV was found to be pre-dominant virus, detected in 45 accessions. Only OYDV was detected in Accession 18 and Accession 134 which was infected by 2 viruses (GarV-B and OYDV) (Table 3.1).

Table 3.1 Distribution of viruses among representatives of garlic core collection

Viruses	No. of infected accessions	Infected accessions names/codes
GarV-A	1	161
GarV-B	36	134, 161, 355, 266, 214, 418, 488, 534P, 436, 559, 282, 282G, 458, 493, 503, 593, 413, 357, 318W, 448, 426, 432, 258, 267, 570, B.O, 18-P, 600, 543, 23, 24, 28, 532, 294, 425, 437
GarV-C	14	266, 534P, 48P, 593, 570, 18P, 543, 415, 24, 532, 294, 425, 437, 283
GarV-D	12	161, 266, 481, 534P, 436, 559, 282, 282G, 458, 357, 27W
GarV-X	20	355, 266, 481, 418, 436, 48P, 426, 432, 258, B.O,18P, 543, 415, 23, 24, 28, 532, 294,425, 437
OYDV	45	134, 161, 355, 294, 266, 214, 32, 481, 418, 488, 534P, 436, 559, 282, 282, 282G, 48P, 458, 493, 503, 593, 413, 357, 18, 318W, 27W, 448, 426, 571, 432, 258, 267, 570, B.O,18P, 600, 543, 415, 23, 24 ,28, 532, 294, 425, 437, 283
LYSV	29	355, 294, 266, 214, 32, 481, 534P, 436, 559, 282, 48P, 413, 357, 318W, 27W, 426, 267, B.O, 18P, 543, 415, 23, 24, 28, 532, 294, 425, 437, 283
GCLV	41	161, 294, 266, 214, 32, 481, 488, 534P436, 559, 282, 282G, 48P, 458, 493, 503, 593, 413, 357, 318W, 27W, 448, 426, 571, 432, 258, 267, 570, 18P, 600, 543, 415, 23, 24, 28, 532, 294, 425, 437, 283
SLV	08	266, 214, 32, 282G, 571, 258, 415, 23
IYSV	0	-

3.3 Biointensive IPM strategies for insect, pests of onion and garlic

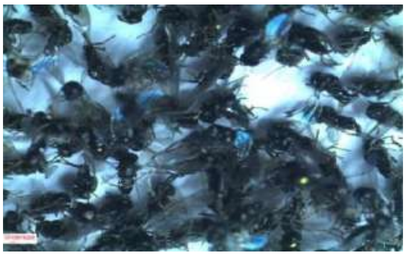
3.3.1 Documentation of natural enemies of onion and garlic pests

Periodical observation has been made to document the potential predators and parasitoid species in the onion and garlic ecosystem to document the prevailing natural enemies (NEs) of various insect pests of onion and garlic. The prevalence of Chalid parasitoid on the Green looper *Chrysodeixis acuta* (Lepidoptera: Noctuidae) larvae was recorded in *kharif*, 2021 (Figure 3.7). Field collected *C. acuta* were kept in the laboratory for observations and documented up to 40% parasitization under natural conditions (Figure 3.8). Based on the morphology, the species was documented as polyembryonic *Capidosoma* which belongs to the insect family Encytridae of the Hymenoptera order. The parasitized early instar larvae become sluggish at first, while later instars get a whitish translucent appearance, showing the development of a large number of wasp progeny internally. From a single larva, more than 300 hundred adult wasps emerged. The species confirmation using cytochrome c oxidase subunit I (COI) has yet to complete.

a. *Capidosoma* parasitization in *C. acuta*

b. Early stage of parasitized larvae

Final stage of parasitized *C. acuta* larva



c. Adult parasitoid

Figure 3.7 (a-d). Green looper, *Chrysodeixis acuta* parasitization by *Encytrid Capidosoma* sp.

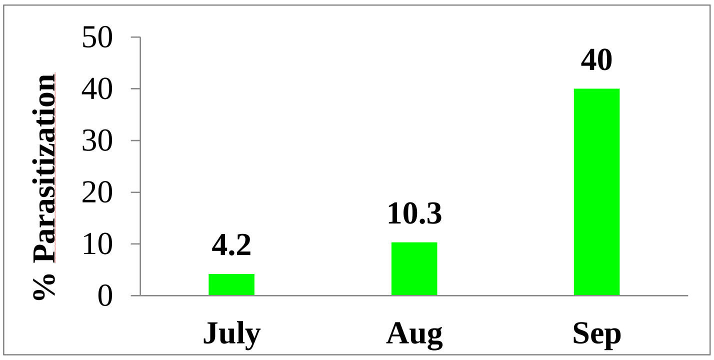


Fig. 3.8 Natural parasitism by *Capidosoma* sp on *Chrysodeixis acuta* infesting onion

The prevalence of predatory coccinellid has been recorded on thrips and aphids-infested garlic field. The activity of the beetle was recorded in early-January, 2022, and there were two colour morphs: a yellow adult one with a zigzag band on the elytra and an orange one with a similar band. The specimens were collected and identified morphologically as *Cheilnomenes sexmaculata* (Fabricius) (Figure 3.9 & Figure 3.10).

Fig. 3.9 Adult *Cheilnomenes sexmaculata* (Fabricius)

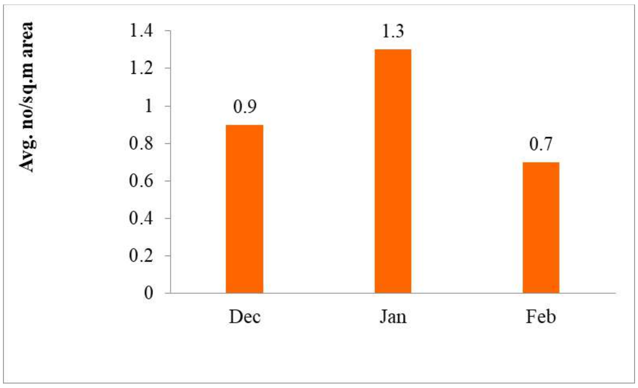


Fig. 3.10 Density of ladybird beetle *Cheilnomenes sexmaculata* in garlic ecosystem

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

Entomopathogenic fungi (EPF) are cosmopolitan microbial pathogens that cause fungal diseases in a wide range of insects via spore infection. Various EPFs are known as important bio control agents worldwide. Due to their natural enemy status, they have tremendous potential for use as microbial control agents against different agricultural pests and diseases.The bio-efficacy of various entomopathogenic fungi, including *Beauveria bassiana*, *Metarhizium anisopliae*, *Lecanicillium lecanii*, and the botanical pesticide neem oil, alone and in combination, was tested against onion thrips. Spinosad was taken as positive control. All three insect pathogens treatments significantly reduced thrips population (Nymph + Adults) compared to the untreated control. Adult thrips population was reduced by 24.1 to 53.7% in insect pathogen treated plots. Among the insect pathogens, *L. lecanii* treatment results maximum reduction of adult thrips, followed by neem oil + *L. lecanii* combination. Likewise, the reduction of thrips nymphs after application of insect pathogens ranged from 39.3 to 57.5% where *M. anisopliae* application resulted maximum of 57.5% reduction of nymphs followed by *B. bassiana* (49.6%) and *L. Lecanii* (39.9%). The tank mix combination of neem oil and the insect pathogen *L. lecanii* showed better efficacy against both adult and nymphs. Spinosad was most effective and it reduced the adults and nymphs up to 68.5% and 93.4%, respectively (Fig 9.4). The order of efficacy among the treatments was spinosad> neem oil > neem oil plus *L. lecanii*>*M. anisopliae*>*B. bassiana*>*L. lecanii*> neem oil plus *M. anisopliae*> neem oil plus *B. bassiana* (Figure 3.11).

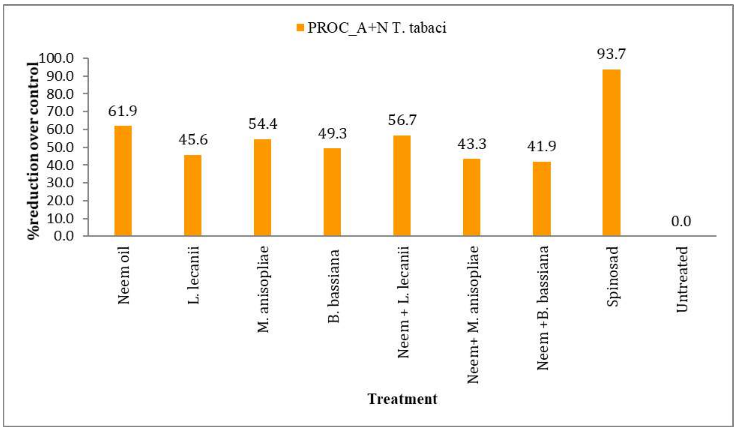


Fig. 3.11 Bio-efficacy of insect pathogens, botanical & biological pesticide against onion thrips

3.3.3 Isolation of native insect pathogens: Entomopathogenic fungi

An attempt was made to search for potent indigenous bioactive pathogens suitable for biological control. Native strains of entomopathogenic fungi as an alternative to chemical insecticides have to be evaluated against these onion insect pests. Therefore, naturally infested insect larvae were collected from the fields. About 3 isolates were obtained from *S. exigua*, 2 from *S. frugiperda* and *S. litura* each, and 5 from *C. acuta*. These EPF strains were isolated, and sub-cultured. Morphological and molecular characterizations of these entomopathogenic fungi are on-going.

3.3.4 Integrating reduced-risk insecticides in onion IPM

Management of onion thrips through seedling treatment

Cyantraniliprole, reduced risk insecticide was used in this study with objective of developing seedling root dipping strategy for protection of transplanted onion from onion thrips in the main field Treatment consisted of five different doses (0.4, 0.8, 1.2, 1.6 and 2.4 ml/lit), as well as carbosulfan 2 ml/lit as a positive control and an untreated control. The newly uprooted nursery was root dipped (cv. Bhima Kiran) for 2 hours and transplanted. The treated plants were monitored thrips infestation up to 35 days after transplanting, and population was recorded. The results revealed that all cyantraniliprole treated seedlings recorded had a significantly lower number of thrips than the control (Figure 3.12).

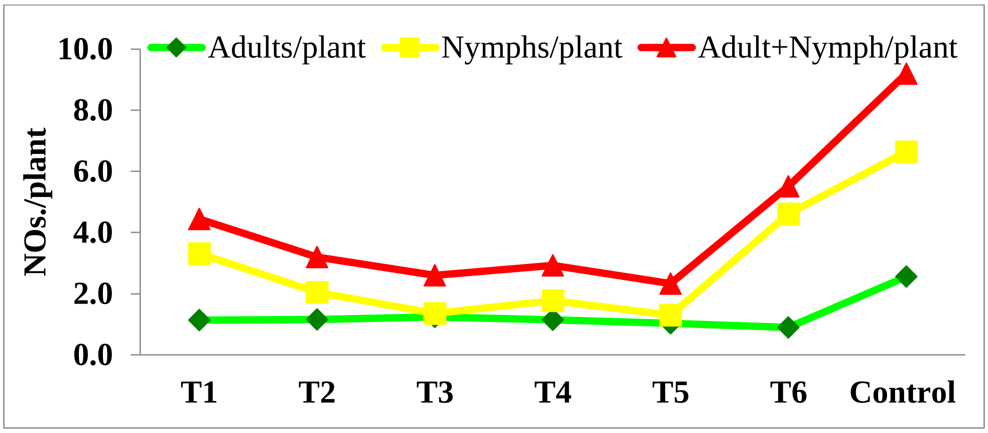


Fig. 3.12 Effect of cyantraniliprole root dipping on thrips infestation in onion

Effect of rotational application of reduced-risk insecticides on onion thrips management

The effect of sequential application of insecticides on thrips density and bulb yield in onion was assessed to develop a safer IPM/IRM strategy. Experiments were carried out in *kharif* as well as late-*kharif*) where insecticides, namely spinosad, spinetoram, fipronil, and profenofos were used in different treatments. Four sprays were taken in a season with 15 days intervals between the spray. Four of treatments used only one insecticide while other four treatments had sequential application. Thrips population in each treatment and bulb yield were recorded. The spray sequence consists of, spinetoram-fipronil-profenofos-spinosad was most effective in minimizing thrips population and produced higher bulb yield (15.7 t/ha) compared to other sequential applications and sole chemical application (Figure 3.13 & Figure 3.14).

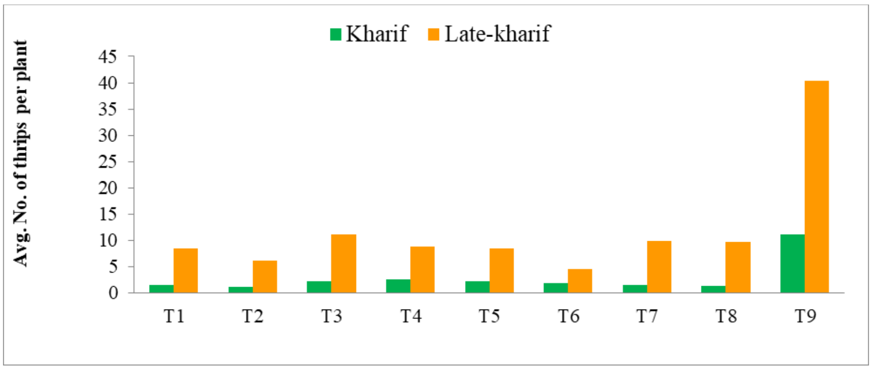


Fig. 3.13 Effect of insecticide rotational spray on thrips infestation in onion

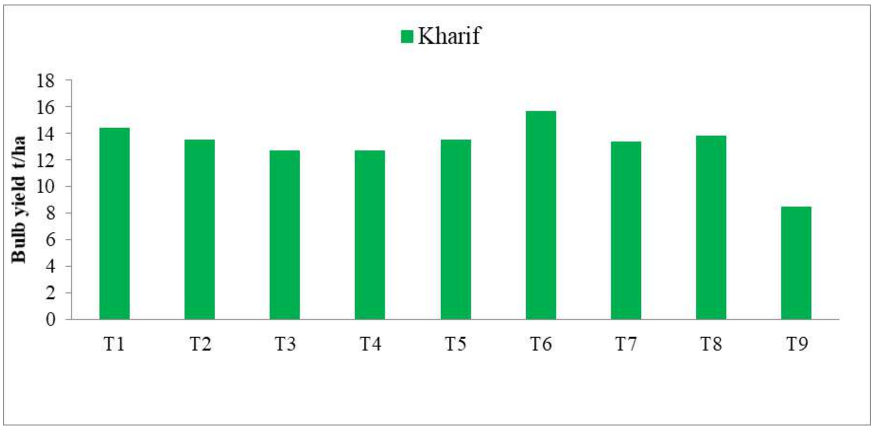


Fig. 3.14 Effect of insecticide rotational spray on onion bulb yield

3.3.5 Characterization of new emerging pests of onion and garlic

Sequencing and characterization of the complete mitochondrial genome of Green Semilooper (Chrysodeixis acuta)

The green semilooper (*Chrysodeixis acuta* Walker) is an emerging pest of the onion crop in India. *Chrysodeixis* is a genus of moths in the subfamily Plusiinae, and family Noctuidae. This subfamily is moderately large and taxonomically compact. Morphological techniques cannot reliably distinguish these pests. Taxonomic identification of the particular pest species is the fundamental step to device a suitable management strategy. Therefore, complete mitochondrial genome of Green Semilooper was sequenced. The circle genome of the Semilooper is 15,743 bp in length. There are 37 sequence elements including13 protein-coding genes, 22 tRNA genes, 2 rRNA genes, and a control region. With average gene length 395bp, the maximum and minimum gene length was 1749bp and 63bp respectively (Figure 3.15). Out of 13 PCGs 9 contains the ATN as stop codon and other 4 contains single T stop codon. All the tRNA a produced typical clover leaf structure expects trnS1. The conserved motif ATAGA and poly-T stretch was detected at start of control region. Total 6 overlapping regions and 18 intergenic spacer regions was identified, size ranging from 1 to 20 and 1 to 111 base pairs respectively. The phylogenetic analysis revealed the *C. acuta* is belongs to the Plusiinae sub-family of the noctuidae super-family and closely related to *Trichoplusia* ni species from the same subfamily. From outer to inner, the 1st circle shows the gene map (PCGs, rRNA, tRNAs & CR) and tRNA genes are abbreviated by one letter symbols according to the IUPAC-IUB single-letter amino acid codes. The 2nd circle shows the GC content and the 3rd shows GC skew calculated as (G-C)/ (G+C). GC content and GC skew are plotted as the deviation from the average value of the entire sequence

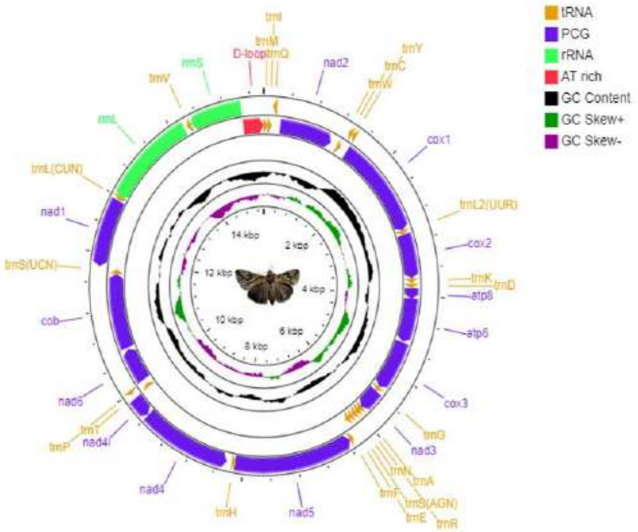


Fig. 3.15 Mitochondrial genome map of *Chrysodeixis acuta*

3.3.6 Damage intensity of *Chrysodeixis acuta* in *Alliums*

The occurrence of *C. acuta* in wild as well as cultivated *Allium*s has been recorded in the germplasm block during *Kharif*, 2021. The data on larval population and foliage damage was recorded. The data revealed that the highest foliage (leaf) damage (14%) in *Allium fistulosum* L. Georgien followed by *A. fistulosum* EC324643-1 and *A. fistulosum* NIC20221. The higher larval density recorded in *A. fistulosum* EC324643-1 (Figure 3.16).

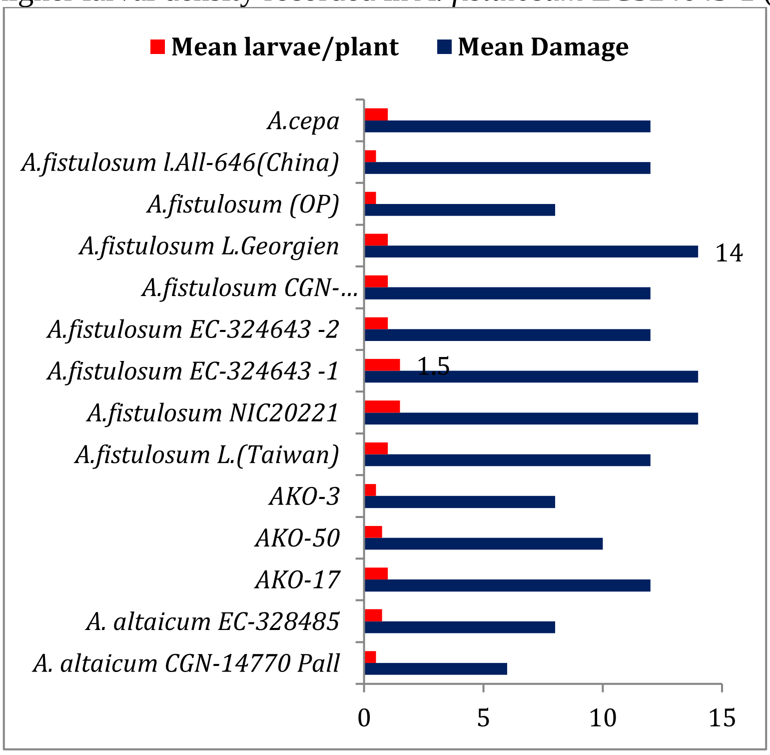


Fig. 3.16 *Chrysodeixis acuta* infestation in *Allium*s species

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

Initial survey was conducted to monitor the different storage structures and various pest and diseases associated with stored onion from major onion storage areas of Maharashtra namely Pune, Solapur, Nasik, Ahmednagar, Dhule, Jalgoan, Amravati and Akola. Usually, onion is either stored in ventilated structures or in house hold stores. To understand the common pesticides/ agrochemicals used in onion-based agroecosystem and to monitor the pesticide residue levels in the soil as well as onion bulbs, cropping pattern was observed. Usually farmers followed onion- maize cropping pattern. Various chemical pesticides were sprayed at different intervals, like 1-3 times or 4-6 times of spraying frequency in each season. Some of the farmers do used simple personal protective equipment's while spraying, while others don't. Likewise, in storage, most of the farmers either sprayed chlorpyriphos, malathion or used elemental Sulphur to manage pest (Figure 3.17). About 25-40% damage in storage was witnessed from these regions. From the collected samples, various diseases like bacterial soft rot, black mold rot (*Aspergillus niger*), Fusarium bulb rot and neck rot were observed. In some pockets, bulbs with secondary infestation caused by maggots were also obtained. Both pathogens and insect specimens are isolated and are kept for molecular characterization. Further, initial soil samples before the crop transplanting and stored onion bulbs are sent for pesticide residue analysis.

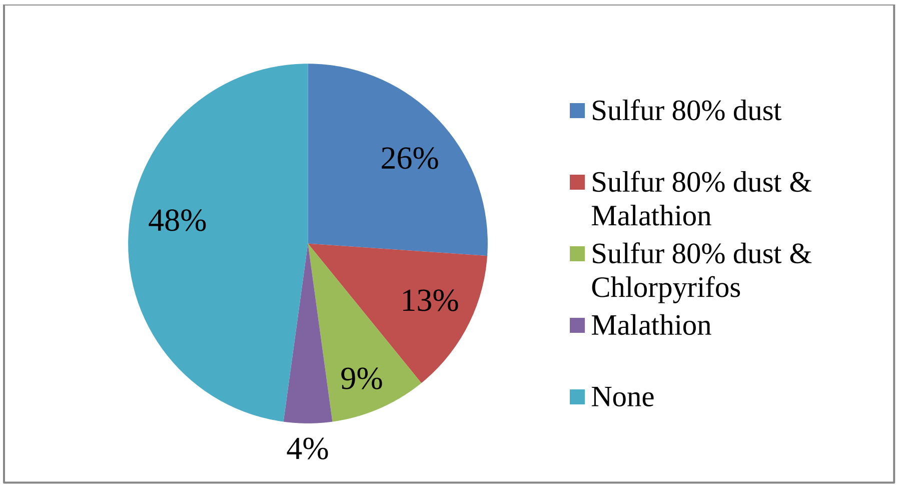


Fig. 3.17 Pesticide usage pattern in onion storage

3.5 Epidemiology and Bio-management of major fungal diseases of onion and garlic

Collection of major fungal diseases from major onion-garlic growing areas:

Major fungal diseases (Stemphylium blight, Purple blotch, and Anthracnose) samples of onion and garlic were collected from NHRDF Nashik, Solapur, Rajgurunagar, Junagadh and IARI New Delhi. The Stemphylium blight severity ranged from 13.33 to 28.67% (Junagadh), and purple blotch severity of 10% in garlic and 2.4% in onion was recorded at NHRDF Nashik.

Isolation of fungal pathogens

Collected samples were isolated and characterized as *Alternaria* sp., *Stemphylium* sp., *Colletotrichum gloeosporioides*, *Fusarium* sp. and *Exerohilum* sp. (Figure 3.18).

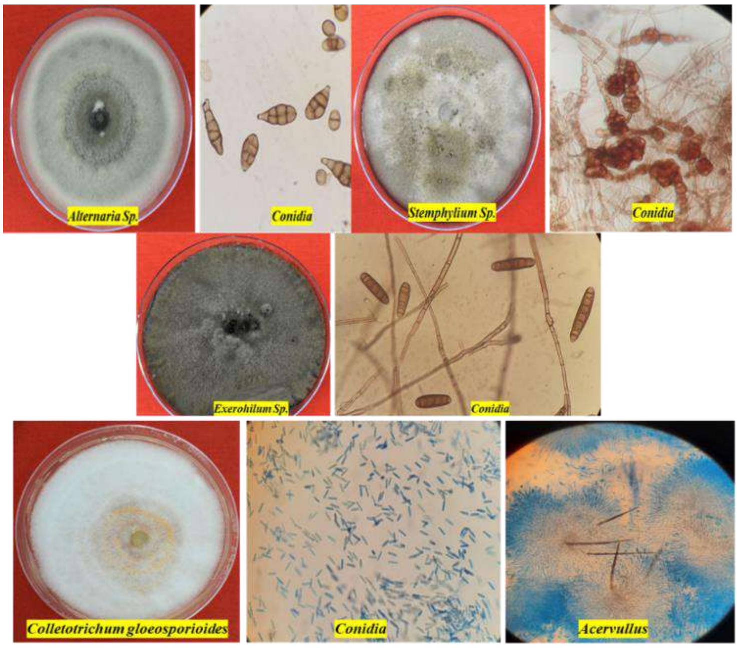


Fig. 3.18 Morphology of fungal pathogens and conidia

Screening of garlic and onion germplasms against fungal diseases

26 garlic and 30 red onion germplasms were screened against fungal diseases under field conditions during *rabi* 2021-22. Among 26 garlic germplasms, eleven were found resistant to Stemphylium blight, and none showed purple blotch incidence. And among 30 red onion germplasms, eight germplasms showed moderately susceptible reaction to Stemphylium blight, and there is no purple blotch and anthracnose incidence.

Screening of Trichoderma strains against fungal pathogens of onion

Eleven native *Trichoderma* isolates were evaluated against *Alternaria sp.*, *Stemphylium sp.*, *Colletotrichum gleosporioides*, and *Exerohilum* sp. using the dual culture technique. Most strains showed good efficiency against all the tested pathogens under in vitro conditions. Per cent growth inhibition of *Alternaria* sp. was significantly higher in T -29 (60.00%) followed by T-R (56.47 %) and *T. viride* (55.88 %), respectively (Figure 3.19).

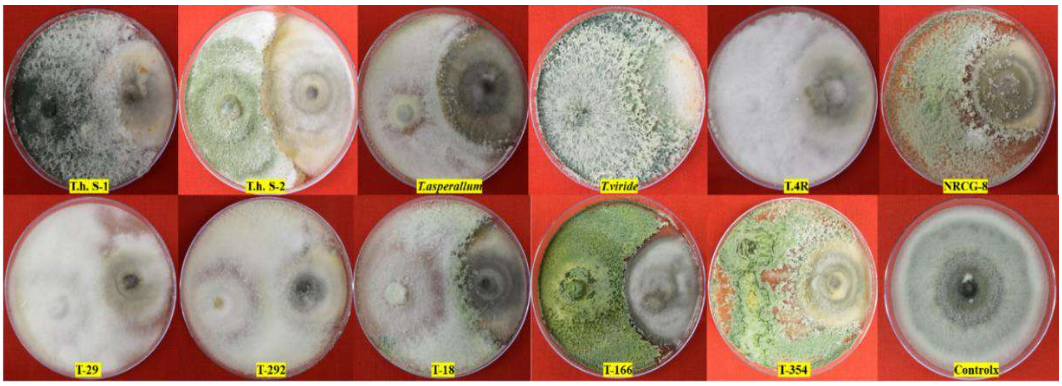


Fig. 3.19 *In-vitro* evaluation of *Trichoderma* stains against *Alternaria* sp.

Among 11 *Trichoderma* isolates screened against *Stemphylium* sp., T.292 showed highest inhibition of 48.28% and which is on par with *T. asperullum* and T-354 strain showed 47.65% inhibition (Figure 3.20).

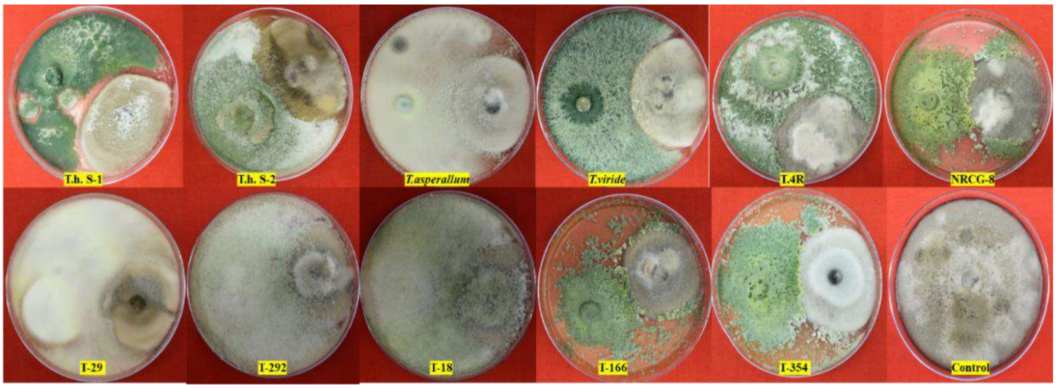


Fig. 3.20 *In-vitro* evaluation of *Trichoderma* strains against *Stemphylium* sp.

Trichoderma strain T-18 showed maximum inhibition of 42.94% against *C. gloeosporioides* followed by T-4R and *T. asperllum* (41.18%) inhibition (Figure 3.21).

Fig. 3.21 *In vitro* evaluation of *Trichoderma* strains against *Colletotrichum gloeosporioides*

The per cent growth inhibition of *Exerohilum* sp was maximum in T. *asperullum* (41.18%) followed by *T. viride* (40.00 %), T-354 (38.82 %) and NRCG-8 (38.24%) respectively (Figure 3.22).

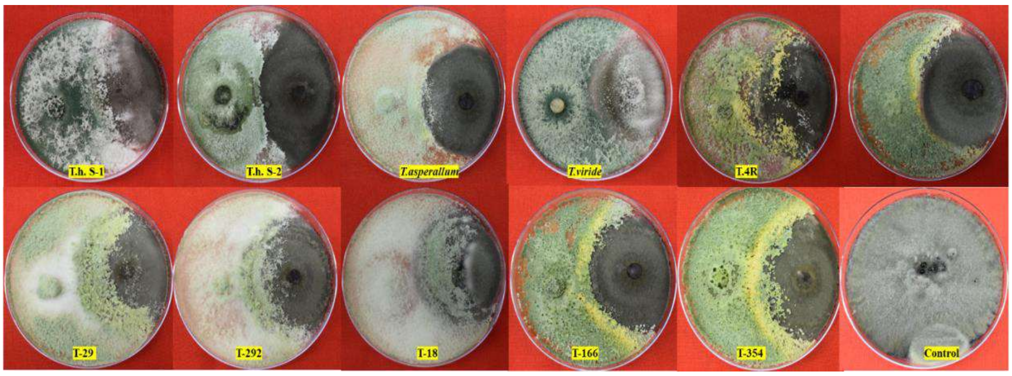


Fig. 3.22 *In vitro* evaluation of *Trichoderma* strains against *Exerohilum* sp.

4. Post-harvest Technology

4.1 Processing and value addition in onion and garlic

Optimisation of process protocol for red onion dehydration

Onion is one of major bulb crop grown in India. The onions are perishable commodity and cannot be stored for a long time after harvest in an ordinary condition. Dehydration is simply, effective and economical for preserving the onions during seasons of abundance and using them during off seasons. Dried onions can be easily reconstituted either by adding them to dishes with lots of cooking liquid like soup, stew, chili, etc. At a commercial level the convective drying of onion is used mainly however this convective drying method has some adverse effect on the finished product. Moreover, due to browning activities of red onions during the drying process or during storage of dehydrated flakes leads to the need of process optimization for red onion dehydration. Hence, Bhima shakti and Bhima Kiran, r*abi* cultivars were selected for the optimization of red onion slices (3mm thick) dehydration process using hot air-drying method at 50, 60 and 70°C. The biochemical analysis (Total pyruvic acid (PA) content, total thiosulfinates (TT), total flavonoid content, total sugar, reducing sugar, and antioxidant activity) of the selected cultivars was carried out to access the quality of final products. For preliminary experiments preservatives such as ascorbic acid (AA) at 0.5, 1, 2 % concentrations, citric acid (CA) 0.5, 1, 2%, KMS solution @ 0.25, 0.5 and 1.0% and NaCl @ 10,15 and 20 °Brix were used as pretreatments. The preliminary results indicated the use of 0.25%, 0.50% KMS, 1% CA @ 60°C that to be explored further in combination with brine solutions to optimize the drying and storage process of dried flakes.

4.2 Design and evaluation of 2000 MT capacity-controlled onion storage structure

Observations, Analysis & Feedback of 200MT storage from various Government Agencies, Stake Holders, Traders & Farmers, was taken following points emerged.

- ✓ The structure was capable of reducing the losses significantly. However due to high cost of the structure, it was felt that it may not be economically feasible to store only onion for the large capacity structures. Hence following changes were made to construct 2000MT capacity storage structure.
- ✓ Temperature ranges from 0˚C to 40˚C & RH 85 to 95% for Multi product Storage to utilize the facility round the year.
- ✓ Additional Chambers including Temperature, Humidity & Gaseous Parameter controls to provide maximum flexibility in storage of various commodities.
- ✓ Controlled Atmosphere facilities with Nitrogen Generator, CO2 Scrubber & Ethylene Scrubber to store precious horticulture commodities.
- ✓ Integrated pack house facilities including Grading, Sorting, Packing and Conveyorised Material Handling Facility to reduce the labor requirement significantly.
- ✓ Pre cooling chambers, Ripening Chambers.

For onion storage following conditions were maintained;

Temperature 27˚C ± 2˚C & RH 50% to 60%

Individual rack wise multi stage Ventilation system

Drying facility with Temperature 30˚C to 35˚C

Fig. 4.1 Controlled onion storage structure (2000 MT capacity)

During *rabi* 2021, 341 MT Onion was stored in two chambers of newly constructed 2000MT 'Controlled Atmosphere Onion and Multi Product Cold Storage Facility' which was having 9 chambers. in each chamber 4 racks were designed & erected. Onions were stored under price stabilization scheme, 2021 of NAFED. For observations on the losses, representative bags with approximately 2 kg onion were hanged for each bin on all the sides as shown in the Figure 4.1. The temperature and relative humidity were maintained as per the required parameters. The data on the temperature and relative humidity in the storage structure during the storage period is given in figure 4.2 and 4.3. Total loss of 9.97% was observed in 191 days of storage. Rotting and sprouting loss percentage was 0.37 and 0.03% respectively. Physiological weight loss was 7.63%. Apart from taking observations on representative samples the total onion stored and the total onion taken out from the storage was measured and losses were depicted in the table along with representative samples. The energy consumption during the storage period was calculated which was approximately Rs 0.31/ kg/ month. Apart from onion, in one chamber "Apple" was also stored during the same period which was successfully stored up to 3 months without any loss. Hence the structure was found feasible for other commodities also.

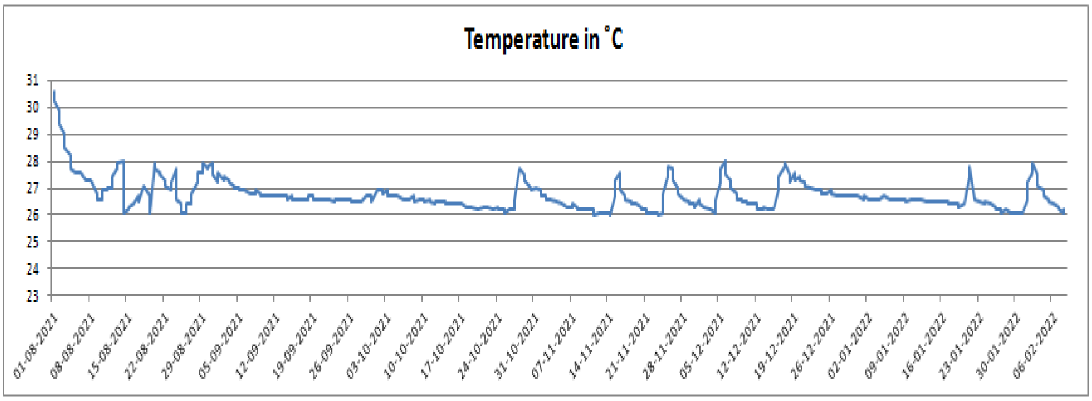


Fig. 4.2 Temperature in storage facility during storage period

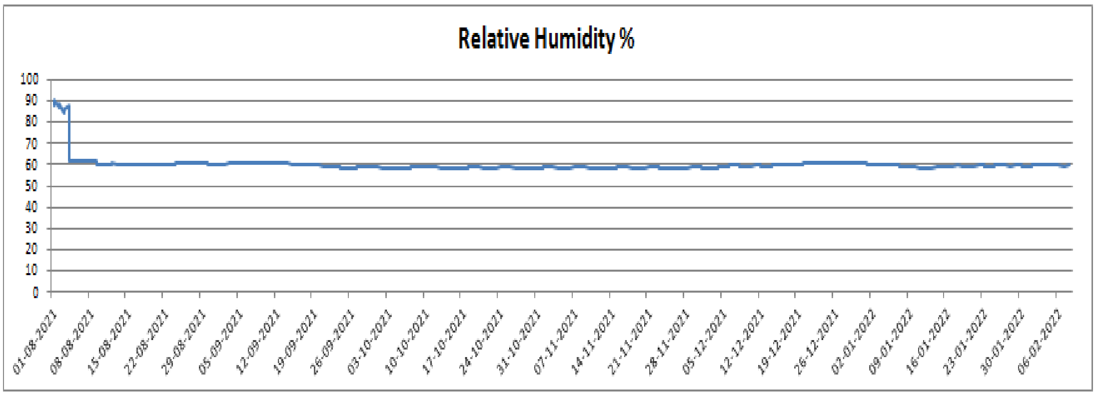


Fig. 4.3 Relative humidity in storage facility during storage period

5. Extension

5.1 Transfer of improved onion and garlic technologies and impact assessment

ICAR-DOGR carried out 381 demonstrations in different states viz., Maharashtra, Uttar Pradesh, Sikkim, Arunachal Pradesh, Manipur and Tripura during *kharif* (164), late-*kharif* (125) and *rabi* (92) seasons through SCSP, TSP, TSP-NEH and NEH Plan.

5.1.1 Demonstrations in *kharif* season

Onion varieties; Bhima Super, Bhima Red, Bhima Dark Red, and Bhima Safed were selected for *kharif* demonstrations under different schemes viz., SCSP, TSP and NEH plan in the states viz., Maharashtra, Uttar Pradesh and Sikkim. Total 164 *kharif* demonstrations were carried out in these states (Maharashtra: 80, Uttar Pradesh: 77 and Sikkim: 7). For the purpose, 216 kg onion seed of Bhima Super provided under SCSP to the farmers belongs to scheduled caste in Western Maharashtra and 25 kg onion seed of Bhima Safed in Vidarbha region of Maharashtra, 160 kg onion seed of Bhima Super, 40 kg onion seed of Bhima Red and 30 kg onion seed of Bhima Dark Red provided under TSP to the farmers belongs to scheduled tribe in Eastern Uttar Pradesh and 20 kg onion seed of Bhima Super provided under NEH Plan to the farmers in Sikkim. For demonstration purpose, mostly 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.

5.1.2 Demonstrations in late-*kharif* season

Onion varieties; Bhima Super, Bhima Light Red and Bhima Safed were selected for late *kharif* demonstrations under different schemes viz., SCSP, TSP, TSP-NEH and NEH plan in the states viz., Maharashtra, Uttar Pradesh, Manipur, Arunachal Pradesh and Tripura. Total 125 late *kharif* demonstrations were carried out in these states (Maharashtra: 40, Uttar Pradesh: 13, Manipur: 50, Arunachal Pradesh: 20 and Tripura: 2). For the purpose, 10 kg onion seed of Bhima Super provided under SCSP to the farmers belongs to scheduled caste in Western Maharashtra and 110 kg onion seed of Bhima Safed in Vidarbha region of Maharashtra, 40 kg onion seed of Bhima Light Red provided under TSP to the farmers belongs to scheduled tribe in Eastern Uttar Pradesh, 150 kg onion seed of Bhima Super provided under TSP-NEH to the farmers in Manipur, 60 kg onion seed of Bhima Super and 5 kg onion seed of Bhima Super provided under NEH Plan to the farmers of Arunachal Pradesh and Tripura, respectively. For demonstration purpose, mostly 3 kg onion seed 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.

5.1.3 Demonstrations in *rabi* season

Onion varieties; Bhima Shakti, Bhima Kiran, Bhima Light Red and Bhima Safed were selected for *rabi* demonstrations under SCSP and TSP schemes in the states viz., Maharashtra and Uttar Pradesh. Total 92 *rabi* demonstrations were carried out in these states (Maharashtra: 26 and Uttar Pradesh: 67). For the purpose, 77 kg onion seed of Bhima Safed provided under SCSP to the farmers belongs to scheduled caste in Vidarbha region of Maharashtra and 61 kg onion seed of Bhima Shakti, 35 kg onion seed of Bhima Kiran, 5kg onion seed of Bhima Light Red and 100 kg garlic provided under TSP to the farmers belongs to scheduled tribe in Eastern Uttar Pradesh. For demonstration purpose, mostly 3 kg onion seed and 3 kg garlic were provided for each *rabi* onion and garlic demonstration by the Directorate.

5.1.4 Performance of frontline demonstrations

The demonstrations in *kharif* season revealed that the germination percentage (98), average bulb weight (84g) and yield (265 q/ha) of Bhima Super was the highest. Bhima Dark Red (260 q/ha), Bhima Red (245 q/ha) and Bhima Safed (238 q/ha) also yielded more than local variety (185 q/ha). In varietal demonstration trials; Bhima Super variety yielded more as compared to other varieties regardless of torrential downpour. Hence, under changing climatic conditions, *kharif* onion production technology of raised bed planting and planting of *kharif* specific variety Bhima Super recommended by ICAR- DOGR. The germination percentage (95), average bulb weight (85 g) and the yield (420 q/ha) of Bhima Light Red were the highest in late *kharif* demonstrations. Bhima Super (400 q/ha and Bhima Safed (385 q/ha) also yielded more than local variety (250 q/ha) in late *kharif* demonstrations. The demonstrations conducted in *rabi* in Maharashtra and Uttar Pradesh revealed that the germination percentage (94), average bulb weight (82 g) and marketable yield (345 q/ha) of Bhima Shakti were the highest and Bhima Kiran (340 q/ha) also yielded more than local variety (290 q/ha). Bhima Safed (320 q/ha) yielded more than the local variety (275 q/ha) in Vidarbha region of Maharashtra. The varieties developed by ICAR-DOGR were found superior over the local cultivars in all the demonstrations.

5.2 Novel approaches for transfer of onion and garlic technologies

5.2.1 Development of ICT Tools for dissemination of technological information

To disseminate the information on the improved package of practices among the farmers and to address the information need of the farmers at critical stages of the crop cultivation, small videos showcasing the improved technologies application were developed in onion crop and uploaded on the ICAR-DOGR YouTube channel.

The list of developed videos:

- Improved varieties of onion and garlic
- Nursery Management-I: Seed treatment
- Nursery Management-II: Land preparation and crop husbandry
- Transplanting of onion seedlings in *rabi* season
- Onion transplanting and weed management
- Fertigation management in onion

ICAR-DOGR also signed MoU with ESDS Software Ltd for development of Decision Support System for pest and disease management, Varietal selection, Nutrient management development of the Knowledge Portal.

5.2.2 Farmer Producer Organization (FPO) based on value chain of onion in Maharashtra

To study the FPO-based Value chain of Onion in Maharashtra a case study of MAHAFPC: a state-level Consortium of Farmer Producer Companies was carried out. MAHAFPC is facilitating the member FPOs in the state of Maharashtra through business facilitation for backward as well as forward linkages to strengthen onion value chain. MAHAFPC has strong reach across the 28 districts of Maharashtra through 541 share-holder farmer producer organizations under the Company Act having registered shareholder base of more than 2.0 Lakh small and marginal farmers. MAHAONION is joint venture between the National Agricultural Marketing Federation of India (NAFED) and MahaFPC. Maha-Onion, has created India's first onion storage and marketing infrastructure through the public-private-partnership (PPP) model. MAHAFPC supported for backward linkage through creation of infrastructure for storage and market at village level, FARM ERP for farmers database, Capacity building of the farmers, input supply through IFFCO dealership, Tie-up with private agro-industries for quality input and developing SOPs, Linkages with govt. agencies for various schemes, and Grassroots level reach. It also support for forward linkage through decentralized government procurement, Interstate trade, e-Krishi Mandi, Linkages with processor, retailers, private players, Processing and retailing, Producer to government, Producer to processor/ retailer, Producer to consumer models, Farm to Fork model. MAHAFPC has partnered with NAFED for the purpose of handling the procurement operations. To promote direct purchase from farmers through FPCs at the farm gate level; MAHAFPC has engaged 40 FPCs in the procurement channel. Due to constraint of the centralized storage system, MAHAFPC explored decentralized storage structure at the farmer-owned Open Ventilated Storage Structures. Large-scale storage infrastructures are also being created under PPP mode.

5.2.3 Documentation and validation ITKs used in onion and garlic

The data has been collected on ITKs used in the cultivation of the onion by the farmers from Khed and Ambegaon tehsil of Pune District. The important ITKs such as water stress before harvesting, Ash application during fog and adverse climate, Irrigation in the morning during fog, planting mustard, radish, marigold to attract honey bee in seed plot, mixing of ash with the seed of onion and keeping in gunny bag /earthen pot/tin containers, use of the rotten cow dung compost, ash application in farm before Sowing, onion storage structure made from bamboo and kadba (Stover), Hanging of onion in open air inside the house for storage were practiced by the farmers.

5.2.4 Value chain model of underutilized *Allium*s (*Allium tuberosum* and other species)

To popularize and develop a value chain model of underutilized *Allium*s (*Allium tuberosum* and other species) MoU has been signed between ICAR-DOGR and KisanKonnect Farmer Producer Company Limited. Production plot of the *Allium tuberosum* (underutilized wild *Allium* species) has been maintained and foliage cuttings as per their requirement to the firm is regularly supplied for marketing. KisanKonnect Farmer Producer Company Limited is grading, sorting, and packaging for value addition to enhance the shelf life of *Allium* tuberosum. The material is being sold at average wholesale price Rs. 80/- per kg. The maximum retail price is Rs. 200/- per kg. ICAR-DOGR has earned revenue of Rs. 56710/- from the produce.

C. All India Network Research Project on Onion and Garlic

Onion Varietal

During *kharif*, white onion AVT-I (6), in red onion AVT-I (6) and AVT-II (2) entries, in late-*kharif*, white onion AVT-II (2), red onion variety AVT-II (2) and varietal performance AVT-II (9) entries, in *rabi*, white onion AVT-I (2) and AVT-II (2) and white onion Hi-TSS AVT-I (4), in red onion IET (5), AVT-I (6) and AVT-II (2), in early maturity trial, AVT-I (2) entries were tested along with check. In long day *rabi* white onion AVT-I (2) and AVT-II (2) and white onion Hi-TSS AVT-I (4), in red onion IET (5), AVT-I (6) and AVT-II (4) entries were tested along with check.

Onion Hybrid

In short day AVT-I *kharif*, two red onion entries and in AVT-I late *kharif*, two red onion entries were tested along with check. In AVT-I short day and long day *rabi*, four red onion entries were tested along with check.

Garlic Varietal Evaluation

In *rabi*, short day and long day garlic, IET (4), AVT-I (3) and AVT-II (9) entries were tested along with check.

Crop Production

Fertilizer scheduling through drip irrigation system in onion seed crop

The results of the trial conducted at seven locations during *rabi* in onion showed that application of fertilizer nutrients through drip irrigation system significantly increased onion seed yield compared to the plots received 100% RDF through broadcasting under flood irrigation system (T_1-control) in all the locations. Application of 100% (100:50:50:30 kg NPKS/ha) at 6 days interval + 5 tons compost /ha (T_2) increased seed yield by 7.26-35.4% compared to control (T_1). However, application of 80% RDF at 6 days interval + 5 t compost /ha (T_3) produced seed yield at par with 100% RDF at 6 days interval through drip + 5 tons compost/ha in all the locations except Nasik. Higher benefit cost ratio was recorded in treatment received 100% RDF (100:50:50:30 kg NPKS/ha) at 6 days interval + 5 tons compost /ha followed by 80 and 60% RDF in all the locations except Rajgurunagar. In Rajgurunagar, the highest cost benefit ratio was recorded in treatments received 80% (100:50:50:30 kg NPKS/ha) at 6 days interval + 5 tons compost /ha.

Effect of direct sowing using Jain onion seed drill on onion production

Direct sowing method of onion cultivation showed significant reduction in marketable and total onion yield compared to transplanting method at Dharwad, Tripura, Jobner, Nasik and Rajgurunagar. The reduction in yield with direct sowing method ranged from 16.6 to 51.82% compared to transplanting method. Whereas, direct sowing method showed significantly higher marketable and total bulb yield compared to transplanting method at Ludhiana. The yield increase by direct sowing method was 10.7% in comparison to transplanting method.

Weed management studies in onion seed crop

All herbicide treatments significantly increased onion seed yield compared to weedy check. Among the treatments, Oxyflurofen 250 g a.i./ha +1 hand weeding at 40 DAS recorded the highest onion seed yield in all the locations except Ludhiana, Jobner and Jabalpur. In

Ludhiana and Jobner, stale seedbed + Oxadiargyl 120 g a.i./ha (PE) followed by Propaquizafop 100 g a.i./ha (POE) recorded significantly higher yield compared to other treatments. The lowest yield was obtained under weedy check in all the locations. The highest average weed control efficiency across locations was observed in treatments Oxyflurofen 250 g a.i./ha (PE) + 1 hand weeding followed by Stale seed bed (SSB) + Oxadiargyl 120 g a.i./ha (PE) followed by Fluazifop-p-butyl 250 g a.i./ha and Stale seed bed (SSB) + Oxadiargyl 120 g a.i./ha (PE) followed by Propaquizafop 100 g a.i./ha.

Effect of zinc and boron application on onion seed crop

Onion seed yield was significantly affected by zinc and boron treatments in all the experimental locations. Seed yield was significantly increased with combined application of organic manures and foliar application of micronutrient mixture @ 0.5 % @ 30, 45 and 60 DAP (T_5) compared to the control plots in all the locations. Yield contributing parameters were higher in T5 compared to other treatments. Furthermore, benefit cost ratio was also the highest in T_5 at all the location.

Determination of optimum fertilizer regime for long day onion cultivation in Kashmir

Marketable yield and related parameters were significantly affected by fertilizer level, genotypes and their interaction. In both brown Spanish and Yellow Globe cultivars, application 15 tons FYM along with mineral fertilizers at 220:80:120 kg NPK/ha produced significantly higher yield compared to the remaining fertilizer treatments. In addition, this treatment showed the lowest total storage losses compared to the remaining treatments.

Determination of optimum fertilizer regime for long day garlic cultivation in Kashmir

Marketable yield was not affected by different fertilizer, genotype and their interaction. However, total storage losses were significantly affected by different fertilizer doses. The lowest total storage losses were observed in T_5 (FYM: 15, N: 180, P: 90, K: 90).

Crop Protection

Disease management *in onion and garlic*

This year all allotted centers conducted survey and monitoring for major diseases of onion and garlic except two centers could not conduct survey due to the pandemic of covid-19. Among the centers which conducted the survey major diseases found were Stemphylium blight, Purple Blotch and Anthracnose. The other fungal disease recorded at various centers includes basal rot, black mold and downy mildew whereas viral diseases such as Garlic Mosaic were recorded at some centers. Bacterial soft rots were also noticed at few centers.

Management of pests and diseases in garlic

Combination of fungicides viz., CabrioTop (Metiram + Pyraclostrobin), AmistarTop (azoxystrobin + difenconazole), CabrioTop + Cyantraniliprole, Amister Top + Cyantraniliprole with positive control propiconazole were evaluated against major fungal diseases during *rabi* 2020-21 at six main centers. The treatment, azoxystrobin 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.

Pest management in onion and garlic

Management of pest and diseases in garlic: Pesticide molecules Cyantranliprole 10.26 OD alone and in combination with CabrioTop (Metiram 55% plus Pyraclostrobin 5%) and AmistarTop (azoxystrobin + difenconazole) were evaluated for pests (Thrips). Trials were conducted at six main centers. Treatment, cyantraniliprole alone and its combinations were effective in suppressing thrips population over control at many locations and on with positive control insecticide Fipronil 5% SC in few locations.

Survey and *monitoring of insect pests of onion and garlic*

A survey on onion and garlic insect pests was conducted at eight locations during 2020-21. Among the various insect pests infesting onion and garlic, Onion thrips, *Thrips tabaci* was the major pest recorded in all surveyed locations. The incidence of cutworm, Spodoptera species, and red spider mite, Tetranychus species were recorded at Rajgurunagar. The Eriophyid mite infestation on garlic was recorded in Kanpur, Junagadh, Rajgurunagar and Sikkim. Green looper, *Chrysodeixis sp* damage reported at Rajgurunagar, and Sikkim as well as Tripura centers. Besides, *Helicoverpa armigera* was reported at Tripura, and onion maggot was recorded at Ludhiana. Coccinellids populations were reported at Ludhiana and Rajgurunagar centers.

Evaluation insecticide/miticide against sucking pests and mites of garlic

Four insecticides, including Fenpyroximate 5% EC, Propargite 57% EC, Spinetoram 11.7 SC and Spinosad 45% SC tested against garlic insect pests at five locations. All the treatments were superior in minimizing thrips and mites population in garlic. Spinetoram and Spinosad were effective against thrips, and Fenpyroximate and Propargite were effective against mites in all locations.

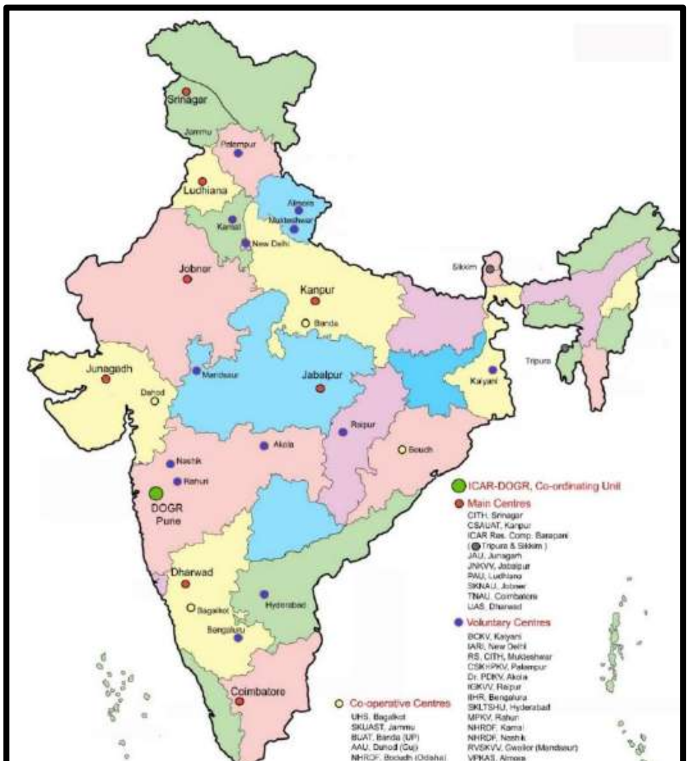


Fig. 1 Location of AINRPOG Centers

D. Scheduled Caste Sub-Plan (SCSP)

The main objective of this scheme is economic development of schedule caste farmers by providing them with resources for filling up the critical gaps and providing them with important and valuable inputs. During *kharif* season, 216 kg onion seed of Bhima Super and 25 kg onion seed of Bhima Safed were distributed among scheduled caste farmers of Western Maharashtra and Vidarbha region of Maharashtra, respectively. During late-*kharif* season, 10 kg onion seed of Bhima Super and 110 kg onion seed of Bhima Safed were distributed among scheduled caste farmers of Western Maharashtra and Vidarbha region of Maharashtra, respectively. During *rabi* season, 77 kg onion seed of Bhima Safed distributed among scheduled caste farmers of Vidarbha region of Maharashtra. Technical bulletins, fertilizers, pesticides, weedicides, and agricultural implements (sickle, shovel, spade, etc.), sewing machines, flour mill, motorized chaff cutter was also distributed to scheduled caste farmers.

The following training programmes were organized under SCSP.

- Training programme on "*Kharif* Onion Production Technology" attended by 25 farmers from District Pune on 14 June 2021 at KVK, Narayangaon, District Pune.
- Training programme on "*Kharif* Onion Production Technology" attended by 19 farmers from District Pune on 19 June 2021 at Taleghar, District Pune.
- Training programme on "*Kharif* Onion Production Technology" attended by 28 farmers from District Solapur on 21 June 2021 at ICAR-DOGR, Pune.
- Training programme on "Azadi Ka Amrut Mahotsav: Late-*kharif* Onion Production Technology" attended by 25 farmers from District Pune on 22 September 2021 at ICAR-DOGR, Pune.
- Farmers-Scientists Interaction cum Training programme on "Azadi Ka Amrut Mahotsav: Climate Resilient Technologies and Practices" attended by 43 farmers from Tal. Karjat, District Pune on 28 September 2021 at ICAR-DOGR, Pune.
- Training programme on "Azadi Ka Amrut Mahotsav: *Rabi* Onion Production Technology" attended by 50 farmers from District Pune on 14 October 2021 at KVK, Baramati.
- Training programme on "Azadi Ka Amrut Mahotsav: *Rabi* Onion Production Technology" attended by 33 farmers from District Pune on 27-29 October 2021 at ICAR-DOGR, Pune.
- Training programme on "Azadi Ka Amrut Mahotsav: Commercialization of Onion Production Technology" attended by 108 farmers from District Mirzapur on 16 December 2021 at Mirzapur (UP)
- Training programme on "Onion Production Technology" under TSP and SCSP attended by 75 farmers from District Pune on 3 August 2021 at Terungan, Tal. Ambegaon, District Pune.

A total of two Kisan Sangoshthi was organized in Mirzapur (UP) on 12th March, 2021 and 16th Dec, 2021 to promote *kharif* onion production in eastern parts of Uttar Pradesh and about 463 progressive farmers from different parts of Mirzapur, Varanasi, Sonbhadra, Ballia and Vindhyachal participated in both programs.

E. Tribal Sub-Plan (TSP)

Total 381 demonstrations in different states viz., Maharashtra, Uttar Pradesh, Sikkim, Arunachal Pradesh, Manipur and Tripura during *kharif* (164), late *kharif* (125) and *rabi* (92) seasons through TSP for development of remote, tribal, under privileged areas and communities.

1. TSP in Tribal belts of Nandurbar

TSP activities by ICAR-DOGR plays a vital role in food and nutritional security of tribal farmers. The systematic efforts were undertaken to improve the area and production of onion and garlic by careful application of improved technologies. Thus, focus was given to conduct field demonstrations of improved technologies at farmer's fields through improved seed/ bulb distribution, knowledge dissemination, capacity building and entrepreneurship building. About 970 tribal farmers were selected from 97 farmers' groups in Nandurbar (Navapur, Akalkua and Dhadgoan Talukas) and about 300 tribal farmers were selected from 30 farmers' groups in Pune (Khed and Ambegaon talukas) in Maharashtra.

Field Demonstrations: A total of 64 demonstrations in *kharif* and 36 demonstrations in *rabi* were conducted under TSP during 2020-21. The kit of fertilizers, fungicides, insecticides, weedicides, spray pump 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 four trainings/ field day (s) were organized under TSP in Maharashtra in which 289 tribal farmers participated. Field day program on "Quality seed production of onion and garlic" for tribal farmers of Nandurbar in collaboration with KVK, Nandurbar was organized on 23-24th March, 2021 to promote entrepreneurship and improve the livelihood of tribal farmers in Navapur taluka of Nandurbar. About 40 tribal farmers from various villages of Nandurbar attended the program.




Training program on “Onion Production Technology” was organized at Terungan, Pune on 3rd August, 2021 under TSP. About 75 farmers from Ambegaon region participated in the program. On the occasion, ICAR-DOGR distributed agricultural inputs like fertilizers, weedicides, fungicides, insecticides, sprayers etc. to selected 28 groups of tribal farmers.




Training-cum-awareness program on “Commercial cultivation of onion and garlic” for tribal farmers from Ambegaon and Khed talukas of Pune (Maharashtra) was organized by ICAR-DOGR under TSP on 1-3rd Nov, 2021 at ICAR-DOGR, Pune. A total of 39 selected tribal farmers participated in the program.




Training program on "Commercial cultivation of onion and garlic" was organized under TSP in collaboration with KVK, Nandurbar on 28-30th Oct, 2021. About 135 tribal farmers from various villages of Nandurbar attended the program. These were organized for one day each at Navyuvak Purush Bachat Gat, Nimboni; Arpit Shetkari Purush Bachat Gat, Raigan; and Saraswati MahilaBachat Gat, Palipada**.**




2. TSP in Eastern Uttar Pradesh

During *kharif* season, 160 kg onion seed of Bhima Super, 40 kg of Bhima Red and 30 kg of Bhima Dark Red, during late-*kharif* season, 40 kg onion seed of Bhima Light Red and during *rabi* season, 61 kg onion seed of Bhima Shakti, 35 kg of Bhima Kiran, 5 kg onion seed of Bhima Light Red and 100 kg garlic seed of Bhima Purple were distributed among the farmers of Eastern Uttar Pradesh. Training programme on "Azadi ka Amrut Mahotsav: Commercialization of onion and garlic technology" attended by 25 farmers on 18th September 2021 at Chunar (UP).

3. Activities in NEH Region

During late-*kharif* season, 150 kg onion seed of Bhima Super distributed among tribal farmers of Manipur under TSP-NEH. During *kharif* season, 20 kg onion seed of Bhima Super in Sikkim, 60 kg onion seed of Bhima Super in Arunachal Pradesh and 5 kg onion seed of Bhima Super in Tripura distributed among tribal farmers under NEH Plan.

F. Distinctness, Uniformity & Stability

ICAR-DOGR working as Nodal Centre for conducting DUS test for onion and garlic and is maintaining 63 onion and 35 garlic varieties under this project. These varieties of onion and garlic are treated as extant varieties. In case of onion, 44 *rabi* varieties and 10 *kharif* varieties and 31 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 Onion Varieties

Rabi 2020-21

Forty-four *rabi* onion varieties viz., Agri-found White, Agri-found Light Red, Arka Bheem, Arka Niketan, Arka Pitamber, Arka Pragati, Balwan Piaz, Bhima Kiran, Bhima Raj, Bhima Red, Bhima Shakti, Bhima Shweta, Bhima Light Red, GWO-3, GJRO-11, JWOL-85, Kalyanpur Red Round, N-2-4-1, NHRDF Red (L-28), NHRDF Red-2 (L-355), NHRDF Fursungi (L-819), PKV White, Phule Safed, Phule Samarth, Pilipatti Junagadh, Punjab Naroya, Punjab White, Pusa Madhavi, Pusa Red, Pusa Sona, POH-1, PRO-6, PRO-7, PYO-1, PWO-2, Rashidpura, Sanjivani Kala, Sona-40-2, Sukhsagar, Sukhsagar (Ballia),VL Piaz-3 and Udaipur-102 along with two famer varieties viz. Sandip Pyaz and Sona-40 were sown on 7^{th} Nov, 2020 and transplanted on 30th Dec, 2020 in 3 replications with the plot size of 2 × 3 sq. m. Crop were harvested in the month of April-May 2021 and all the observations were recorded as per DUS test guidelines.

***Kharif* 2021**

Ten *kharif* onion varieties viz., Agri-found Dark Red, Arka Kalyan, B-780, Bhima Raj, Bhima Red, Bhima Shubhra, Bhima Shweta, Bhima Super, Bhima Dark Red and Bhima Safed were sown on 10^{th} June, 2021 and transplanted on 29th July, 2021 in 3 replications with the plot size of 1 × 6 sq. m on raised beds. Crop were harvested in the month of November 2021 and all the observations were recorded as per DUS test guidelines.

Evaluation of DUS Garlic Varieties (2020-21)

Thirty-one garlic varieties viz., Bhima Omkar, Bhima Purple, Chunar Local-1, Chunar Local-2, DWDG-1, DWDG-2, G-1, G-41, G-50, G-282, G-323, G-386, G-404 (YP-10), GAG-5, GAG-6, GAG-7, GG-2, GG-3, GG-4, G-189 (YS-5), 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 along with one candidate variety Anta Garlic-1 as well as five farmers' varieties 2879/3457, 2879/3458, 2879/3459, Brij Lahsun (Reg/2018/688) and Pras Lahsun (Reg/2018/685) were planted on 27^{th} Oct, 2020 in 3 replications with the plot size of 3 × 2 sq. m. Crops were harvested in the month of March 2021 and all the observations were recorded as per DUS test guidelines.

Varieties under DUS Test

During 2020-21, DUS testing was conducted for one garlic variety i.e. Anta Garlic-1 as well as two onion farmers varieties i.e. Sona-40 and Sandip Pyaz for field screening test for genetic purity and uniformity. Dr. Major Singh (Director, ICAR-DOGR) Chairman, Monitoring Committee along with Dr. S. B. Chaudhary (PPV & FRA Representative) and Dr. Amar Jeet Gupta, Principal Scientist (Hort.)/ PI (DUS), monitored DUS Onion and Garlic trials at ICAR-DOGR, Pune on 8th March, 2021.

Varieties Registered with PPV & FRA

Four extant onion varieties (Bhima Shakti, Bhima Light Red, Bhima Dark Red and Bhima Super) have been registered with PPV & FRA, New Delhi for its protection. Five onion varieties (Bhima Kiran, Bhima Red, Bhima Raj, Bhima Shubhra and Bhima Safed as well as one garlic variety Bhima Omkar have already registered with PPV&FRA. One onion variety Bhima Shweta and one garlic variety Bhima Purple are under registration by PPV&FRA.

Fig. 1 DUS testing of onion and garlic varieties

G. Agri-Business Incubation

Under agri-business incubation project, Agri-Business Incubation Centre has been established with the work space for incubates. A pilot agri- processing plant is established for capacity building and consultancy to the incubates and start-ups. A technology demonstration on 'controlled onion storage structure' was organized for various Stakeholders from NABARD, Agricultural departments, ATMA, at Kala Genset Pvt Ltd. Chakan Talegaon on 20 October 2020.

Establishment of ABI Pilot Agro-processing facilities (APC) for Onion and garlic processing and value addition

Various machines and equipment needed for processing of onion and garlic (as enlisted below) are procured and installed in the institute. The facility is being used for various unit operations in processing and value addition of onion. The facility is also useful for training and demonstrations to farmers, SHGs etc. during visits and trainings.

- Onion Chopping Machine / Cutter Machine
- Working table (Chopping/Cutting/ Product display etc)
- Pretreatment unit and bucket centrifuge
- Hot air dryer
- Dry grinding machine/ Paste making machine
- Packaging machine

Fig. 1 Pilot processing plant for onion and garlic

H. Institute Technology Management Unit

The Institute Technology Management Unit (ITMU) adheres to ICAR guidelines to actively support Intellectual Property Management, Technology Transfer, and Commercialization initiatives. ITMU's primary focus lies in engaging in activities related to the safeguarding, maintenance, and effective transfer or commercialization of intellectual property linked to technologies originating from the institute. During the year 2021, ITMU achieved significant milestones, including licensing a total of four onion varieties to 91 seed companies at the institute level. This move fosters the dissemination and adoption of valuable agricultural innovations across various companies, contributing to the growth of the agricultural sector. Moreover, in an effort to promote collaboration and foster academic and student research, ITMU successfully established a partnership with Central Agriculture University (CAU) located in Imphal, Manipur. The following details provides a detailed overview of the notable achievements and activities undertaken by ITMU during 2021.

Technology licensing

Onion varieties

Variety	No of MoUs	Revenue (₹)
Bhima Shakti	41	41,00,000
Bhima Dark Red	23	23,00,000
Bhima Kiran	19	19,00,000
Bhima Super	8	8,00,000
Total	**91**	**91,00,000**

Collaboration with university for academic and student research

Name of university	Date of MoU	Purpose of collaboration
Central Agriculture University (CAU) Imphal, Manipur	1-12-2021	M Sc./Ph. D Students Training/Research

Licensing of onion varieties

Sr. No.	Company/ FPC/ Organisations	Revenue (₹)	Variety	Date of MoU
1.	Dinkar Seeds Pvt Ltd., Gujarat	100000	B. D. Red	08-06-2021
2.	M/s Shevgaon Taluka Farmers Producer Company Ltd., Shevgaon, Maharashtra	100000	B. Shakti	08-06-2021
3.	Kiyo Agri. Pvt. Ltd. MP	100000	B. Shakti	08-06-2021
4.	Kiyo Agri. Pvt. Ltd. MP	100000	B. D. Red	08-06-2021
5.	Patidar Traders, MP	100000	B. Shakti	08-06-2021
6.	Patidar Traders, MP	100000	B. D. Red	08-06-2021
7.	Shri Chavan Beej Bhandar, MH	100000	B. Shakti	08-06-2021

8.	Shri Chavan Beej Bhandar, MH	100000	B. D. Red	08-06-2021
9.	Sheetal Hybrid Seeds Private Limited., Jalna	100000	B. Super	08-06-2021
10.	Sheetal Hybrid Seeds Private Limited., Jalna	100000	B. Shakti	08-06-2021
11.	Prenic FPC Ltd. Nashik Maharashtra	100000	B. Shakti	10-06-2021
12.	Vishal Seeds Agro Industries Pvt. Ltd., Buldhana	100001	B. D. Red	24-06-2021
13.	Vishal Seeds Agro Industries Pvt. Ltd., Buldhana	100000	B. Kiran	24-06-2021
14.	Patil Biotech Pvt. Ltd., Jalgaon, Maharashtra	100000	B. Kiran	25-06-2021
15.	Patil Biotech Pvt. Ltd., Jalgaon, Maharashtra	100000	B. Shakti	25-06-2021
16.	Krija Hy-Gene Seeds Pvt. Ltd., Jalna, Maharashtra	100000	B. D. Red	30-06-2021
17.	Shri Samarth Seed Company, Jalna, Maharashtra	100000	B. Kiran	30-06-2021
18.	Growseeds Crop Science Pvt. Ltd., Jalna, Maharashtra	100000	B. D. Red	30-06-2021
19.	Keshavpushp Agro. Ind. Pvt. Ltd., Aurangabad, Maharashtra	100000	B. Kiran	30-06-2021
20.	Keshavpushp Agro. Ind. Pvt. Ltd., Aurangabad, Maharashtra	100000	B. Shakti	30-06-2021
21.	ODSF Agro Producer Company, Osmanabad, Maharashtra	100000	B. Super	30-06-2021
22.	RSR Seeds Corporation, Aurangabad, Maharashtra	100000	B. D. Red	30-06-2021
23.	Patil Crop Science Pvt. Ltd., Jalna, Maharashtra	100000	B. D. Red	30-06-2021
24.	Patil Crop Science Pvt. Ltd., Jalna, Maharashtra	100000	B. Kiran	30-06-2021
25.	VNR Seed Pvt.Ltd., Raipur, Chhattisgarh	100000	B. Shakti	01-07-2021
26.	VNR Seed Pvt.Ltd., Raipur, Chhattisgarh	100000	B. super	01-07-2021
27.	M/s Gajanan Traders, Nashik, Maharashtra	100000	B. Kiran	09-07-2021
28.	M/s Shri Datta Seeds Company, Nashik	100000	B. Kiran	13-07-2021
29.	M/s Divya Seeds Company, Jalna,	100000	B. D. Red	14-07-2021
30.	M/s Divya Seeds Company, Jalna,	100000	B. Shakti	14-07-2021
31.	Innvo Crop Science Pvt Ltd., Jalna	100000	B. D. Red	14-07-2021
32.	Jindal Crop Science Pvt Ltd., Jalna	100000	B. Shakti	14-07-2021
33.	Jindal Crop Science Pvt Ltd., Jalna	100000	B. D. Red	14-07-2021
34.	Surushe Seeds Maker, Buldhana	100000	B. Shakti	16-07-2021
35.	Apurva Seeds, Jalgaon	100000	B. D. Red	17-07-2021

36.	New Maharastra Traders, Jalgaon, Maharashtra	100000	B. Kiran	22-07-2021
37.	Eco Agri Seeds Pvt Ltd. Hyderabad	100000	B. D. Red	22-07-2021
38.	Eco Agri Seeds Pvt Ltd. Hyderabad	100000	B. Shakti	22-07-2021
39.	Kohinoor Seed Field India Pvt. Ltd., Delhi	100000	B. Super	23-07-2021
40.	Krushibindu Farmer Producer Company Limited	100000	B. Shakti	23-07-2021
41.	KASMADE SEEDS AND CHEMICAL PRIVATE LIMITED	100000	B. D. Red	30-07-2021
42.	Sahebrao Seeds India Pvt. Ltd.	100000	B. Shakti	04-08-2021
43.	ANKAI FARMERS PRODUCER COMPANY LIMITED	100000	B. Shakti	06-08-2021
44.	M/s Vanashri Seeds Nashik	100000	B. D. Red	06-08-2021
45.	M/s Vanashri Seeds Nashik	100000	B. Kiran	06-08-2021
46.	Godapravar FPC Limited, Ahmednagar	100000	B. Shakti	09-08-2021
47.	Jayghosh Agro Tech Pvt. Ltd., Nashik	100000	B. Shakti	11-08-2021
48.	Mandvi Valley Agro Pvt. Ltd	100000	B. Shakti	12-08-2021
49.	Bhumiputra Seeds, Buldana, Maharashtra	100000	B. D. Red	12-08-2021
50.	Bhumiputra Seeds, Buldana, Maharashtra	100000	B. Super	12-08-2021
51.	Prathmesh Seeds Nashik, Maharashtra	100000	B. Shakti	20-08-2021
52.	Prathmesh Seeds Nashik, Maharashtra	100000	B. D. Red	20-08-2021
53.	Krushi Kranti Hightech Agro Producer Company Limited	100000	B. Shakti	25-08-2021
54.	Mahalaxmi Hybrid Seeds India Pvt. Ltd.	100000	B. Shakti	30-08-2021
55.	New Bagwan Brothers	100000	B. Kiran	31-08-2021
56.	DCM Shriram Limited, New Delhi	100000	B. D. Red	31-08-2021
57.	Balaghat Agro Producer Company, Beed Maharashtra	100000	B. Shakti	22-09-2021
58.	Rahee Natural Seeds Pvt. Ltd.	100000	B. Shakti	22-09-2021
59.	Rahee Natural Seeds Pvt. Ltd.	100000	B. Super	22-09-2021
60.	Prathmesh Seeds Nashik, Maharashtra	100000	B. Kiran	22-09-2021
61.	Swara Samruddhi Seeds, Nashik	100000	B. Shakti	22-09-2021
62.	Sendriya Sheti Sonak Pimpalgaon Producer Company	100000	B. Kiran	23-09-2021
63.	Sampada Seeds Pvt Ltd., Jalna	100000	B. Shakti	23-09-2021
64.	Staralankar Farmer Producer Company	100000	B. Kiran	23-09-2021

65.	Daftari Seeds , Wardha, Maharashtra	100000	B. D. Red	28-09-2021
66.	Daftari Seeds , Wardha, Maharashtra	100000	B. Super	28-09-2021
67.	KASMADE SEEDS AND CHEMICAL PRIVATE LIMITED	100000	B. Kiran	28-09-2021
68.	Maharajya Group Farmers Producer Company Limited, Nashik	100000	B. Kiran	28-09-2021
69.	Maharajya Group Farmers Producer Company Limited, Nashik	100000	B. Shakti	28-09-2021
70.	Shri Kantabai Vitthal Agro Producer Company Limited	100000	B. Shakti	04-10-2021
71.	Gaurinand FPC Limited	100000	B. Shakti	04-10-2021
72.	Gargi Seeds Jalgaon	100000	B. Shakti	05-10-2021
73.	New Era Seeds Jalgaon	100000	B. Shakti	05-10-2021
74.	Pasaidan Farmer Producer Company Limited, Ahmednagar	100000	B. Shakti	22-10-2021
75.	Ulink Agritech Pvt. Ltd., Pune, Maharashtra	100000	B. D. Red	26-10-2021
76.	Ulink Agritech Pvt. Ltd., Pune, Maharashtra	100000	B. Shakti	26-10-2021
77.	Samruddhi Plant Sciences, Pune	100000	B. Shakti	28-10-2021
78.	Samruddhi Agri Tech Pvt. Ltd. Ahamdnagar	100000	B. Shakti	01-11-2021
79.	Promoderna Agritech LLP, Aurangabad Maharashtra	100000	B. Kiran	16-11-2021
80.	Siddhivinayak Seeds, Dewas, Madhya Pradesh	100000	B. D. Red	16-11-2021
81.	Siddhivinayak Seeds, Dewas, Madhya Pradesh	100000	B. Shakti	16-11-2021
82.	Vasna Shetkari PCL, Satara, Maharashtra	100000	B. Shakti	16-11-2021
83.	Rushikesh Seeds and Biotech, Budana, Maharashtra	100000	B. Kiran	17-11-2021
84.	Deola FPC Limited, Nashik Maharashtra	100000	B. Shakti	24-11-2021
85.	Pollen Bioseeds	100000	B. Kiran	24-11-2021
86.	Gopishwar Seeds Pvt. Ltd., Buldhana	100000	B. Shakti	29-11-2021
87.	Gopishwar Seeds Pvt. Ltd., Buldhana	100000	B. D. Red	29-11-2021
88.	Girnakhore FPCL, Deola, Nashik	100000	B. Kiran	30-11-2021
89.	Vishal Seeds Agro Industries Pvt. Ltd., Buldhana	100000	B. Super	02-12-2021
90.	Zenith Hybrid Seeds Private Limited, New Delhi	100000	B. Shakti	20-12-2021
91.	Gentex Agri Inputs Private Limited, Ahmedabad Gujarat	100000	B. Shakti	24-12-2021

I. Success Story

Performance of direct seeded *kharif* onion crop in eastern parts of Uttar Pradesh

Onion (*Allium* cepa L.) is mainly transplanted crop associated with high cost of labor requirement during transplanting. It can also be cultivated by direct seeding in the field. In the present study, direct seeded onion crop was sown on 25th Aug, 2021 and harvested on 26-30th Dec, 2021 when the transplanted crop failed due to erratic rainfall and water stagnation due to overflow of Ganga River near Gangetic region of Chunar Taluka in Mirzapur (UP) during 9-12th Aug, 2021. Whereas, in case of transplanted crop, seeds were sown on 15th Jun, 2021 to raise seedlings which were transplanted on 6-8th Aug, 2021 and harvesting was done on 18-22th Nov, 2021. The onion variety 'Bhima Super' was chosen for both the methods of onion planting and recommended package of practices were followed to raise the healthy crop. Direct seeded crop takes one month less time in comparison with transplanted crop because direct seeded crop harvested in 125 days after sowing whereas, transplanted crop harvested in 158 days (53 days in nursery and 125 days in main field). Direct seeded crop yielded 70.4 q/acre whereas, transplanted crop yielded slightly more i.e., 74.3 q/acre. About Rs. 1.0 lakh per acre net profit was noted in both the methods and bulbs were sold @ 1800/- per q after harvesting. Comparatively less input cost i.e., Rs. 5420/- per acre was noted in case of direct seeded crop in comparison to transplanted crop.

Table 1. Performance of onion production through seedling transplantation in *kharif* 2021

Farmer's Name	Production (q/ acre)	Output amount (Rs)	Input Cost (Rs)	Net Profit (Rs/ acre)
Mr. Nagesh Kumar	80.60	145080	32300	112780
Mr. Kapil Kumar	75.80	136440	30400	106040
Mr. Jayshankar	67.40	121320	28700	92620
Mr. Ramashankar	74.45	134010	31200	102810
Mr. Shambhu Sahani	73.30	131940	32000	99940
Mean	**74.31**	**133758**	**30920**	**102838**

Table 2. Performance of onion production through direct seeded crop in *kharif* 2021

Farmer's Name	Production (q/ acre)	Output amount (Rs)	Input Cost (Rs)	Net Profit (Rs/ acre)
Mr. Virendra K. Patel	79.20	142560	26300	116260
Mr. Manoj Kumar Singh	68.23	122814	24700	98114
Mr. Dhiraj Kumar Singh	65.80	118440	23200	95240
Mr. Saga Veer Singh	68.20	122760	27500	95260
Mr. Surendra Singh	70.40	126720	25800	100920
Mean	**70.37**	**126658.8**	**25500**	**101159**

The net profit was at par in both the methods of onion production but direct seeded crop is more economical because it of early maturing than transplanted crop, if both the crops were sown at the same time. Comparatively more double bulbs and bolters as well as weed problem were observed in direct seeded crop whereas, nursery management was not required in the direct seeded crop. Hence, direct seeded *kharif* onion crop can be promoted in eastern parts of Uttar Pradesh especially, in Mirzapur near Gangetic region to fulfill the domestic requirements and to fetch more income.

Fig. 1 Onion crop through Direct seeded during *kharif* 2021-22

J. Transfer of Technology

Training programs organized

Topic of Training	Sponsoring Agency	Date and Venue	No. of Participants
Late-*kharif* Onion Harvesting and Post-Harvest Management	MGMG, ICAR-DOGR, Pune	23rd Jan, 2021 Pondewadi, District Pune	22 Farmers
Late-*kharif* Onion Management	MGMG, ICAR-DOGR, Pune	1st Feb, 2021 Varude, District Pune	20 Farmers
Late-*kharif* Onion Harvesting and Post-Harvest Management	MGMG, ICAR-DOGR, Pune	5th Feb, 2021 Loni, District Pune	23 Farmers
Late-*kharif* Onion Harvesting and Post-Harvest Management	MGMG, ICAR-DOGR, Pune	2nd Mar, 2021 Varude, District Pune	26 Farmers
Late-*kharif* Onion Harvesting and Post-Harvest Management	MGMG, ICAR-DOGR, Pune	12th Mar, 2021 Gulani, District Pune	22 Farmers
Extending commercial cultivation of onion in eastern parts of Uttar Pradesh	ICAR-DOGR, Agrimitra FPO and GKRDF, Varanasi	12th March, 2021 Purushottampur, Narayanpur, Mirzapur (UP)	355 Farmers
Quality Seed Production of Onion and Garlic	TSP, ICAR-DOGR, Pune	23-24th Mar, 2021 Shravani and Palipada, District Nandurbar	40 Farmers
Onion Harvesting and Post-Harvest Management	MGMG, ICAR-DOGR, Pune	24th Mar, 2021 Loni, District Pune	22 Farmers
Onion Harvesting and Post-Harvest Management	MGMG, ICAR-DOGR, Pune	26th Mar, 2021 Wadgaon Pir, District Pune	23 Farmers
Rabi onion harvesting and post-harvest management	MGMG, ICAR-DOGR, Pune	9th Apr, 2021 Gadakhwadi, District Pune	25 Farmers
Strengthening farmer participatory value chain management in onion and garlic	MANAGE, Hyderabad	3-7th May 2021 at ICAR-DOGR, Pune	65 Participants
Training cum Awareness programme on "*Kharif* Onion Production in Uttar Pradesh" through virtual	ICAR-DOGR, Pune	25th May, 2021 at ICAR-DOGR, Pune	100 Horticultural officers and farmers from Uttar Pradesh

mode in collaboration with Department of Horticulture and Food Processing, Lukhnow (UP)			
Kharif onion nursery management	MGMG, ICAR-DOGR, Pune	11 Jun,2021 Gulani, District Pune	26 Farmers
Kharif Onion Production Technology	SCSP, ICAR-DOGR, Pune	14 Jun, 2021 KVK, Narayangaon, District Pune	25 Farmers
Nursery preparation for *kharif* onion crop	MGMG, ICAR-DOGR, Pune	17 Jun,2021 Pondewadi, District Pune	27 Farmers
Farmers Awareness cum Training programme on “Balanced Use of Fertilizer in Onion and Garlic” through virtual mode	ICAR-DOGR, Pune	18 Jun,2021 ICAR-DOGR, Pune	100 Farmers
Kharif Onion Production Technology	SCSP, ICAR-DOGR, Pune	19 Jun,2021 Taleghar, District Pune	19 Farmers
Kharif Onion Production Technology	SCSP, ICAR-DOGR, Pune	21 Jun,2021 ICAR-DOGR, Pune	28 Farmers
Kharif onion production technology	MGMG, ICAR-DOGR, Pune	23 Jun,2021 Wafgaon, District Pune	23 Farmers
Nursery management of *kharif* onion crop	MGMG, ICAR-DOGR, Pune	26 Jun,2021 Wadgaon Pir, District Pune	20 Farmers
Kharif onion nursery management	MGMG, ICAR-DOGR, Pune	28 Jun,2021 Khadakwadi, District Pune	24 Farmers
Kharif onion nursery management	MGMG, ICAR-DOGR, Pune	30 Jun,2021 Gulani, District Pune	20 Farmers
Late-*kharif* onion nursery management	MGMG, ICAR-DOGR, Pune	6 Jul,2021 Gosasi, District Pune	23 Farmers
Late-*kharif* onion nursery management	MGMG, ICAR-DOGR, Pune	9 Jul,2021 Warude, District Pune	25 Farmers
Online Sensitization Training Programme on “Onion Seed Production Technology”	ABI and ITMU, ICAR-DOGR, Pune	26 Jul,2021 ICAR-DOGR, Pune	50 Farmers

Onion Production Technology	TSP and SCSP, ICAR-DOGR, Pune	3 Aug, 2021 Terungan, Tal. Ambegaon, District Pune	75 Farmers
Azadi ka Amrut Mahotsav: Scientific Cultivation of Onion and Garlic	Project Director, ATMA, Dist. Dhule	23-25 Aug, 2021 ICAR-DOGR, Pune	42 Farmers from Tal. Sakri, District Dhule
Azadi ka Amrut Mahotsav: Commercialization of onion and garlic technology	TSP, ICAR-DOGR, Pune	18 Sep, 2021 ICAR-DOGR, Pune	25 Farmers from Tal. Chunar, District Mirzapur
Azadi ka Amrut Mahotsav: Late *Kharif* Onion Production Technology	SCSP, ICAR-DOGR, Pune	22 Sep, 2021 ICAR-DOGR, Pune	25 Farmers
Farmers-Scientists Interaction cum Training programme on "Azadi ka Amrut Mahotsav: Climate Resilient Technologies and Practices"	SCSP, ICAR-DOGR, Pune	28 Sep, 2021 ICAR-DOGR, Pune	43 Farmers from Tal. Karjat, District Ahmednagar
Commercial cultivation of onion and garlic	ICAR-DOGR, Pune under TSP	28-30 Oct, 2021 Nimboni, Raigan and Palipada in Navapur, Nandurbar	150 farmers
Azadi ka Amrut Mahotsav: Late *kharif* onion nursery management	MGMG, ICAR-DOGR, Pune	5 Oct, 2021 Ranmala, District Pune	23 Farmers
Azadi ka Amrut Mahotsav: *Kharif* onion harvesting and post-harvest management	MGMG, ICAR-DOGR, Pune	7 Oct, 2021 Warude, District Pune	29 Farmers
Azadi ka Amrut Mahotsav: *Rabi* onion production technology	MGMG, ICAR-DOGR, Pune	11 Oct, 2021 Khadakwadi, District Pune	26 Farmers
Azadi ka Amrut Mahotsav: *Rabi* Onion Production Technology	SCSP, ICAR-DOGR, Pune	14 Oct, 2021 KVK, Baramati	50 Farmers
Azadi ka Amrut Mahotsav: *Rabi* onion nursery management	MGMG, ICAR-DOGR, Pune	18 Oct, 2021 Loni, District Pune	28 Farmers
Azadi ka Amrut Mahotsav: *Rabi* Onion Production Technology	SCSP, ICAR-DOGR, Pune	27-29 Oct, 2021 ICAR-DOGR, Pune	33 Farmers
Azadi ka Amrut Mahotsav: *Rabi* onion and garlic technology	TSP, ICAR-DOGR, Pune	28-30 Oct, 2021 Nimbhoni, Raingan and Palipada, District Nandurbar	135 Farmers

Azadi ka Amrut Mahotsav: *Rabi* Onion Cultivation technology	TSP, ICAR-DOGR, Pune	1-3 Nov, 2021 ICAR-DOGR, Pune	39 Farmers from Bhimashankar and Bursewadi, District Pune
Azadi ka Amrut Mahotsav: *Rabi* onion cultivation practices	MGMG, ICAR-DOGR, Pune	6 Nov, 2021 Loni, District Pune	28 Farmers
Azadi ka Amrut Mahotsav: Commercialization of Onion Production Technology	SCSP, ICAR-DOGR, Pune	16 Dec, 2021 Mirzapur (UP)	108 Farmers

Participation in Exhibition

Exhibition	**Organizer**	**Date**	**Venue**
National Horticulture Fair (Online participation) Experts from ICAR-DOGR participated online and delivered lectures and answered queries	ICAR-IIHR, Bengaluru	8-12th February, 2021	ICAR-IIHR, Bengaluru
Participated in exhibition during National Conference on Plant Physiology	ICAR-NIASM and Indian Society for Plant Physiology	09-11th December 2021	ICAR-NIASM, Baramati

Lectures delivered

Topic	**Event and Organizer**	**Date and Venue**
Dr. Vijay Mahajan		
Quality onion production technology	Online organized by Agril. Deputy. Director, Agril Dept., Maharashtra	20.1.2021
Scientific cultivation of onion	Oganized bySAGE University, Indore, MP	21.1.2021
Onion varieties & seed production of onion	Online organized ICAR-IIHR, Bangalore.	9.02.2021
Scientific cultivation of onion& seed production	Irganized by Zoori Agro Chemicals Ltd. Goa, at ICAR-DOGR Kalus Farm	11.2.2021
Scientific cultivation of onion	Organized by Zoori Agro Chemicals Ltd. Goa, at Badi raja Agro Services, Savargaon, Junnar.	18.02.2021
Scientific cultivation of onion	Organized by Agril. Deptt., MS, at village Kusgav, Maval.	2.3.2021
Efficient use of water in onion & garlic	Online meeting to the farmers on kisan platform organised by ICAR-DOGR.	22.3.2021
Enhancing farmers income through high yielding varieties	Online collaborative training programme by ICAR-DOGR with MANAGE, Hyderabad from 3-7 May, 2021	4.5.2021

Kharif pyaz me poudhshala prabhandan	National workshop, Organized by KVK, Sardar Krishinagar, Dantiwada Aril. Univ, Sabarkantha, Gujrat	20.5.2021
Production technologies and processing of onion	Webinar on organized by KVK, Baramati	25.5.2021
Improved varieties of onion and garlic	Virtual mode for farmers awareness programme on "Balance use of fertilizer in onion and garlic organized by ICAR-DOGR.	18 June, 2021
Onion production technology	E-Kisan Gosthi, Kharif kanda Vyavasthapan organized by KVK, Pal, Jalgaon-1.	16.7.2021
Onion seed production, lagwad aani kandhyache keed va rog niyantran, kandhyachi sathavanook, ATMA Ahmadnagar and ICAR-DOGR.	Kopardi, Tal. Karjat organized by Agri. Dev. Trust, Baramati, Jamkhed Integrated Dev. Institute Mah. Agril. Dept, ATMA Ahmadnagar and ICAR-DOGR	23.8.2021
Onion bulb production to the farmers from Sakri, Dhule, Maharashtra	Organized by ICAR-DOGR under SCSP Programme	25 Aug., 2021
Scientific cultivation of onion"	On line zoom conferencing on organized by Balram Sandesh Platform, Ujjain, MP.	25.8.2021
Onion bulb production	Organized by ICAR-DOGR.	27 Oct., 2021
Importance of cleanliness in onion cultivation practices and daily life	Organized by ICAR-DOGR under SCSP	28 Oct., 2021
Promotion of onion & garlic cultivation"	SASRD, Nagaland University	6. Dec., 2021
Dr. A.J Gupta		
TSP activities and improved varieties of onion and garlic	Training programme on Onion Production Technology in Ambegaon near Bhima Sankar on 3 Aug, 2021	3 Aug, 2021 Ambegaon, Pune
Raising of early *kharif* onion through sets technology	Training-cum-awareness programme on raising of early *kharif* onion through sets technology on 18 Sept, 2021	18 Sept, 2021 Narayanpur, Mirzapur
Improved varieties of onion	Three days training programme on *Rabi* onion production technology on 27-29 Oct, 2021 under SCSP	27 Oct, 2021 ICAR-DOGR, Pune
TSP activities and improved varieties of onion and garlic	Three days training programme on cultivation of onion and garlic in tribal belts of Nandurbar on 28-30 Oct, 2021 under TSP	28-30 Oct, 2021 Navapur, Nandurbar
Importance and scope of TSP on onion and garlic	Three days training-cum-awareness programme on commercial cultivation of onion and garlic on 1-3 Nov, 2021 under TSP	1 Nov, 2021 ICAR-DOGR, Pune

Improved varieties of onion and garlic	Three days training-cum-awareness programme on commercial cultivation of onion and garlic on 1-3 Nov, 2021 under TSP	2 Nov, 2021 ICAR-DOGR, Pune
Scientific cultivation of onion	Kisan Sangosthi on scientific cultivation of onion on 16 Dec, 2021 by ICAR-DOGR and Agrimitra FPO, Varanasi	16 Dec, 2021 Mirzapur (UP)
Dr. S.S Gadge		
Harvesting and post-harvest management of late *kharif* onion	Training on Late *kharif* onion harvesting and post-harvest management organized under MGMG by ICAR-DOGR, Rajgurunagar, Pune	23 Jan, 2021 Pondewadi, District Pune
Harvesting, curing and grading of late *kharif* onion bulbs	Training on Late *kharif* onion management organized under MGMG by ICAR-DOGR, Pune	1 Feb, 2021 Varude, District Pune
Harvesting, curing and grading of late *kharif* onion bulbs	Training on Late *kharif* onion harvesting and post-harvest management organized under MGMG by ICAR-DOGR, Pune	5 Feb, 2021 Loni, District Pune
Late *kharif* onion harvesting and post-harvest management	Training on Late *kharif* onion harvesting and post-harvest management organized under MGMG by ICAR-DOGR, Pune	2 Mar, 2021 Varude, District Pune
Harvesting, curing and grading of late *kharif* onion bulbs	Training on Late *kharif* onion harvesting and post-harvest management organized under MGMG by ICAR-DOGR, Pune	12 Mar, 2021 Gulani, District Pune
Harvesting, curing and grading of onion bulbs	Training on Onion harvesting and post-harvest management organized under MGMG by ICAR-DOGR, Pune	24 Mar, 2021 Loni, District Pune
Late *kharif* onion harvesting and post-harvest management	Training on Onion harvesting and post-harvest management organized under MGMG by ICAR-DOGR, Pune	26 Mar, 2021 Wadgaon Pir, District Pune
Rabi onion harvesting and post-harvest management	Training on *Rabi* onion harvesting and post-harvest management organized under MGMG by ICAR-DOGR, Pune	9 Apr, 2021 Gadakhwadi, District Pune
Introduction of *Kharif* Onion Production in Uttar Pradesh	Training cum Awareness programme on "*Kharif* Onion Production in Uttar Pradesh" through virtual mode in collaboration with Department of Horticulture and Food Processing, Lukhnow (UP) organized by ICAR-DOGR, Pune	25 May, 2021 ICAR-DOGR, Pune
Kharif onion nursery management	Training on *Kharif* onion nursery management under MGMG organized by ICAR-DOGR, Pune	11 Jun,2021 Gulani, District Pune

Onion Production Technology in *Kharif* season	Training on *Kharif* Onion Production Technology under SCSP organized by ICAR-DOGR, Pune	14 Jun, 2021 KVK, Narayangaon, District Pune
Nursery preparation for *kharif* onion crop	Training on Nursery preparation for *kharif* onion crop under MGMG organized by ICAR-DOGR, Pune	17 Jun,2021 Pondewadi, District Pune
Kharif Onion Production Technology	Training on *Kharif* Onion Production Technology under SCSP organized by ICAR-DOGR, Pune	19 Jun,2021 Taleghar, District Pune
Kharif Onion Production Technology	Training on *Kharif* Onion Production Technology under SCSP organized by ICAR-DOGR, Rajgurunagar, Pune for the farmers of District Solapur	21 Jun,2021 ICAR-DOGR, Pune
Kharif onion production technology	Training on *Kharif* onion production technology under MGMG organized by ICAR-DOGR, Pune	23 Jun,2021 Wafgaon, District Pune
Nursery management of *kharif* onion crop	Training on Nursery management of *kharif* onion crop under MGMG organized by ICAR-DOGR, Pune	26 Jun,2021 Wadgaon Pir, District Pune
Onion nursery management in *kharif* season	Training on *Kharif* onion nursery management under MGMG organized by ICAR-DOGR, Pune	28 Jun,2021 Khadakwadi, District Pune
Kharif onion nursery management	Training on *Kharif* onion nursery management under MGMG organized by ICAR-DOGR, Pune	30 Jun,2021 Gulani, District Pune
Late *kharif* onion nursery management	Training on Late *kharif* onion nursery management under MGMG organized by ICAR-DOGR, Pune	6 Jul,2021 Gosasi, District Pune
Late *kharif* onion nursery management	Training on Late *kharif* onion nursery management under MGMG organized by ICAR-DOGR, Pune	9 Jul,2021 Warude, District Pune
Onion Production Technology	Training on Onion Production Technology under TSP and SCSP organized by ICAR-DOGR, Pune	3 Aug, 2021 Terungan, Tal. Ambegaon, District Pune
Role of Self-Help Groups in increasing socio-economic status of onion and garlic farmers	Training on Azadi ka Amrut Mahotsav: Scientific Cultivation of Onion and Garlic organized by ICAR-DOGR in collaboration with Project Director, ATMA, Dist. Dhule	23-25 Aug,2021 ICAR-DOGR, Rajgurunagar, Pune
Role of Self Help Groups in increasing socio-economic status of onion and garlic farmers	Training on Azadi ka Amrut Mahotsav: Commercialization of onion and garlic technology under TSP organized by ICAR-DOGR, Pune	18 Sep,2021 ICAR-DOGR, Pune

Late *Kharif* Onion Production Technology	Training on Azadi ka Amrut Mahotsav: Late *Kharif* Onion Production Technology under SCSP organized by ICAR-DOGR, Pune	22 Sep,2021 ICAR-DOGR, Pune
ICAR-DOGR technologies of onion and garlic	Farmers-Scientists Interaction cum Training on "Azadi ka Amrut Mahotsav: Climate Resilient Technologies and Practices" under SCSP organized by ICAR-DOGR, Pune	28 Sep,2021 ICAR-DOGR, Pune
Late *kharif* onion nursery management	Training on Azadi ka Amrut Mahotsav: Late *kharif* onion nursery management under MGMG organized by ICAR-DOGR, Pune	5 Oct,2021 Ranmala, District Pune
Kharif onion harvesting and post-harvest management	Training on Azadi ka Amrut mahotsav: *Kharif* onion harvesting and post-harvest management under MGMG organized by ICAR-DOGR, Pune	7 Oct,2021 Warude, District Pune
Rabi onion production technology	Training on Azadi ka Amrut Mahotsav: *Rabi* onion production technology under MGMG organized by ICAR-DOGR, Pune	11 Oct, 2021 Khadakwadi, District Pune
Rabi Onion Production Technology	Training on Azadi ka Amrut Mahotsav: *Rabi* Onion Production Technology under SCSP organized by ICAR-DOGR, Pune	14 Oct,2021 KVK, Baramati
Onion nursery management in *rabi* season	Training on Azadi ka Amrut Mahotsav: *Rabi* onion nursery management under MGMG organized by ICAR-DOGR, Pune	18 Oct,2021 Loni, District Pune
Rabi Onion Production Technology	Training on Azadi ka Amrut Mahotsav: *Rabi* Onion Production Technology under SCSP organized by ICAR-DOGR,, Pune	27-29 Oct,2021 ICAR-DOGR, Pune
Rabi Onion Cultivation technology	Training on Azadi ka Amrut Mahotsav: *Rabi* Onion Cultivation technology under TSP organized by ICAR-DOGR, Pune	1-3 Nov,2021 ICAR-DOGR, Pune
Rabi onion cultivation practices	Training on Azadi ka Amrut Mahotsav: *Rabi* onion cultivation practices under MGMG organized by ICAR-DOGR, Pune	6 Nov,2021 Loni, District Pune
Thangasamy, A.		
Good Agricultural Practices of onion value chain	Online training program on "Strengthening Farmer Participatory Value Chain Management in Onion and Garlic" organized by ICAR-DOGR, Pune and Manage, Hyderabad at ICAR-DOGR, Pune	May 3-7, 2021 ICAR-DOGR, Pune

Integrated nutrient and water management	Three day training programme on Scientific Onion Cultivation of Onion and Garlic organized by ICAR-DOGR, Pune	August 23-25, 2021 ICAR-DOGR, Pune
Dr. Rajiv B Kale		
Improved onion production technology	Delivered Lecture in training to Farmers of shirur tahsil Pune under the ATMA	15 Sept, 2021 Shirur, District Pune
Improved onion production technology	Delivered Lecture in training to Farmers of Kendur village shirur tahsil Pune organised by KVK Narayangaon, ATMA and Kendriymata FPO	15 Sept 2021 Kendur, District Pune
Improved onion production technology	Delivered Lecture in training programme to Farmers of Khandala Tahsil, Satara organised by ATMA	25 Oct, 2021 Khandala, District Satara
Seed production, onion cultivation pest and disease management and new schemes	Delivered lecture on during training programme for Agriculture department officials of Karjat jamkhed tahsils of Ahmednagar district, Maharashtra organized at KVK Baramati, Pune	25-26 Sept, 2021 Baramati, District Pune
Dr. Soumia PS		
Safe use of pesticides in onionand garlic	Three days training programme on ‘Scientific Cultivation of Onion and Garlic’ under ATMA Scheme	25th August 2021 ICAR-DOGR,
Safe use of pesticides in onionand garlic	Three days training programme on ‘Scientific Cultivation of Onion and Garlic’ underSCSP Scheme	28th September 2021 ICAR-DOGR,
Insecticide safety management	Three days training programme on ‘Scientific Cultivation of Onion and Garlic’ underTSP Scheme	28th October 2021 ICAR-DOGR
Insecticide safety management	Three days training programme on ‘Scientific Cultivation of Onion and Garlic’ under SCSP Scheme	3rd November 2021 ICAR-DOGR
Dr. Bhushan R. Bibwe		
Post-Harvest Management of Soyabean, Ground nut, Onion and Gram	DBT BioTech Kisan Hub, Agricultural development trust, Baramati	13th Nov, 2021 Online mode
Entrepreneurship in Onion and Garlic Processing	IDP sponsored training on Agricultural food processing, packaging and Marketing Dept of Agril Process and Food Engg, OUAT. Bhubaneshwar	20th Dec 2021 Online mode
Processing and value addition of onion & garlic	Three days training program on ‘Scientific cultivation of onion and garlic’	24th Aug 2021 ICAR-DOGR
Post Harvest Management’	Three days training program on ‘*Rabi* onion production technology’	28th Oct 2021 ICAR-DOGR

Post Harvest Management'	Three days training program on 'Commercial cultivation of onion and garlic'	02th Nov 2021 ICAR-DOGR
Dr. Yogesh Khade		
Exploring the underutilized wild *Allium*s for farmers	Training programme on 'Strengthening farmer participatory value chain management in onion and garlic' organized by ICAR-DOGR and MANAGE, Hyderabad	3-7 May, 2021 at ICAR-DOGR
Integrated Disease Management in onion	Training programme on Advances in onion cultivation under arid hot conditions organized by ICAR-CIAH, Bikaner	12th July, 2021 at ICAR-CIAH, Bikaner
Onion harvesting, curing, storage and post-harvest management	Training programme on 'Scientific cultivation of onion and garlic' by ICAR-DOGR	23-25 August, 2021 at ICAR-DOGR
Integrated nutrient and weed management	Training programme on '*rabi* onion production technology' by ICAR-DOGR	27-29 October, 2021 at ICAR-DOGR
Integrated nutrient and weed management	Training cum awareness programme on 'Commercial cultivation of onion and garlic' by ICAR-DOGR	1-3 November, 2021 at ICAR-DOGR
Dr Jayalakshmi		
IPM in sustainable onion and garlic production	Training programme on "Strengthening farmer participatory value chain management in onion and garlic	3-7 May, 2021 (Online) by ICAR-DOGR and Manage, Hyderabad.
Insect Pest Management in Onion	Virtual training on "Improved Onion Cultivation Technologies"	12-13 November, 2021 for the field staffs of Bayer India Limited.
Insect pests' management on onion and garlic	National Horticulture Fair NHF, 2021(virtual)	8 -13 Feb, 2021, ICAR-IIHR, Bengaluru.
Sourav Ghosh		
Nursery management and Micro-irrigation in Onion and Garlic	Nursery management and Micro-irrigation in Onion and Garlic	23-25th August, 2021 ICAR-DOGR, Pune

Mera Gaon Mera Gourav

ICAR-DOGR conducted various training programmes in 15 villages viz., Gadakwadi, Varude, Gulani, Wafgaon, Jawulke, Khadakwadi, Loni, Pondewadi, Dhamni, Ranmala,Gosasi, Mitgudwadi, Kanhur Mesai, Khairewadi and Khairenagar. We have created awareness about cleanliness among the people of these villages and conducted cleanliness activities by involving the villagers under Swachh Bharat Abhiyan (16-31 December 2021). In total, 22 training programmes were conducted in fifteen villages adopted under MGMG scheme attended by 550 farmers of District Pune.

K. Research Projects

Institutional Projects

1. **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, Dr. Vishwanath Y., Mrs. Ashwini P. Benke, Dr Pranjali A. Gedam, Dr. Manjunath Gowda D C., Dr. Soumia P.S., Dr. Y. P. Khade, Mr. Ashok Kumar, Dr. Shabeer Ahmed (NRCG, Pune) and Dr. Geetika Malik (ICAR-CITH, Srinagar)
2. **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. Ashok Kumar and Dr. Kiran Bhagat (DFR, Pune)
3. **Genetic improvement of red onion**
   PI: Dr. Amar Jeet Gupta and **Co-PIs:** Dr. V. Mahajan, Mrs. Ashwini P. Benke, Dr. S. Anandhan, Dr. Manjunatha Gowda, Dr. Yogesh P. Khade, Dr. S.J. Gawande, Dr. V. Karuppaiah, Dr. Kalyani Gorrepati and Dr. Pranjali A. Gedam
4. **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
5. **Biotechnological approaches for improvement of onion**
   PI: Dr. Anandhan S. and **Co-PIs**: Dr.Soumia P.S and Dr. Y.P. Khade
6. **Transfer of improved onion and garlic technologies and impact assessment**
   PI: Dr. S.S. Gadge and Co-PIs: Dr. R.B. Kale
7. **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. Bhushan Bibwe, Dr. Sourav Ghosh and Dr. Shabeer Ahmed (NRCG, Pune)
8. **Abiotic stress management in onion and garlic**
   PI: Dr. Pranjali Gedam and **Co-PIs:** Dr. V. Mahajan, Dr. A. J. Gupta, Dr. S.J. Gawande, Dr. A. Thangasamy, Dr. Y.P. Khade, Dr. Kiran Bhagat, Dr. Shabeer Ahmed (NRCG, Pune)
9. **Bio-intensive IPM strategies for insect pests of onion and garlic**
   PI: Dr. V. Karuppaiah and **Co-PIs:** Dr. Ram Dutta, Dr. A. Thangasamy, Dr. Vishwanath Y., Dr. Soumia P.S. and Dr. Sourav Ghosh
10. **Enhancement of seed quality and productivity in onion**
    PI: Dr. Vishwanath Y. and **Co-PIs:** Dr. Kalyani Gorrepati
11. **Extraction and encapsulation of bioactive compounds from *Allium* species**
    PI: Dr. Kalyani Gorrepatti and **Co-PIs**: Dr. S.S. Gadge, Dr. R.B. Kale, Dr. Bhushan Bibwe and Dr. Ashok Kumar
12. **Refinement of storage technologies in onion and garlic**
    PI: Dr. Kalyani Gorrepatti and **Co-PIs**: Dr. S.S. Gadge, Dr. R.B. Kale, Dr. Bhushan Bibwe and Dr. Ashok Kumar

13. **Novel approaches for transfer of onion and garlic technologies**
    PI: Dr. R.B. Kale and **Co-PIs**: Dr. S.S. Gadge and Dr. Sourav Ghosh
14. **Genetic improvement of garlic through conventional and biotechnological approaches**
    PI: Mrs. Ashwini P. Benke and Co-PIs: Dr. V. Mahajan, Dr. A. J. Gupta, Dr. S.J. Gawande, Dr. Vishwanath Y., Dr. Manjunath Gowda D C. and Dr. Geetika Malik (ICAR-CITH, Srinagar).
15. **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 Mrs. Ashwini P. Benke
16. **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, Dr. Kalyani Gorrepati and Dr. Sourav Ghosh
17. **Processing and value addition in onion and garlic**
    PI: Dr. Bhushan Bibwe and **Co-PIs:** Dr. Kalyani Gorrepatti
18. **Mechanization in onion and garlic**
    PI: Dr. Bhushan Bibwe and **Co-PIs**: Dr. S.S. Gadge, Dr. Kalyani Gorrepatti and Dr. R.B. Kale
19. **Breeding for abiotic stress tolerance in *Allium* species**
    PI: Dr. Y.P. Khade and **Co-PIs:** Dr. V. Mahajan, Dr. A. J. Gupta and Dr. Pranjali A. Gedam
20. **Management of sprouting in onion and garlic**
    PI: Dr. Ashok Kumar and **Co-PIs:** Dr. Kalyani Gorrepatti, Dr. Bhushan Bibwe and Dr. Sourav Ghosh
21. **Development of improved agronomic practices in onion and garlic**
    PI: Dr. Sourav Ghosh and **Co-PIs:** Dr. A. Thangasamy, Dr. Ashwini P. Benke, Dr. Bhushan Bibwe and Dr. Shabeer Ahmed (NRCG, Pune)
22. **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

Externally Funded/Other Projects

1. **Project 1: All India Network Research Project on Onion and Garlic (AINRPOG)**
   Nodal Officer, Dr. V. Mahajan, Funding: ICAR
2. **Project 2: DUS testing of Onion and Garlic**
   Nodal Officer, Dr. A.J. Gupta, Funding: PPV&FRA
3. **Project 3: Intellectual Property Management and Transfer- Commercialization of Agricultural Technology Scheme (IPMTCATS)**
   PI: Dr. Rajiv B Kale, Member Secretary, Funding: ICAR
4. **Project 4: Agri Business Incubation Project**
   PI: Dr. Rajiv B Kale, **Co-PI:** Dr. Kalyani Gorrepati, Funding: ICAR

5. **Project 5: Tribal Sub-Plan (TSP) for onion and garlic**
   Nodal Officer: Dr. A.J. Gupta, Co-Nodal Officers: Dr. S. S. Gadge, Dr. R. B. Kale, Mrs. Ashwini P. Benke, Mr. A. R. Wakhare, Mr. H. S. Gawali
6. **Project 6: North East Hill Plan**
   Nodal Officer: Dr. V. Mahajan, Co-Nodal Officer: Dr. S.S. Gadge, Funding: ICAR
7. **Project 7: Scheduled Caste Sub-Plan (SCSP) for onion and garlic**
   Nodal Officer: Dr. S. S. Gadge, Co-Nodal Officers: Dr. R.B. Kale and Dr. A. Thangasamy, Funding: ICAR
8. **Project 8: Haploid induction in onion (*Allium cepa* L.) through genome elimination**
   PI: Dr. S Anandhan, Funding: ICAR-National Fellow
9. **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
10. **Project 10: Tapping the potential of stingless bee *Tetragonula iridipennis* Smith for pollination enhancement and profitable onion seed production**
    PI: Karuppaiah V, Funding: SERB-Department of Science and Technology, New Delhi
11. **Project 11: 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
12. **Project 12: 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
13. **Project 14: POLY4 Rate Response Trial on Onion and Garlic**
    PI: Dr. A. Thangasamy, Funding: AngloAmerican, New Delhi
14. **Project 15: Evaluation of bio-efficacy of GPH 1821 for controlling weeds in onion**
    PI: Dr. A. Thangasamy, Funding: UPL India Ltd. Mumbai
15. **Project 16: Bio-efficacy Evaluation of Bensulf SUPERFAST on Onion**
    PI: Dr. A. Thangasamy, Funding: Smartchem Technologies Limited, Pune

L. Awards, Honors, Recognition

1. Dr. Vijay Mahajan, Principal Scientist (Horticulture) received Fellow of CHAI Award-2021 for outstanding contribution and commitment to the furtherance of Horticulture from CHAI, New Delhi on 16.9.2021 at PJTSAU, Rajendranagar, Hyderabad.
2. Dr. Vijay Mahajan, Principal Scientist (Horticulture) awarded with Fellow of Indian Society of Vegetable Science- 2018 on 24.1.2021.
3. Dr. Vijay Mahajan, Principal Scientist (Horticulture) awarded with "Life Time Achievement Award – 2021" of International Scientist Award of Engineering, Science and Medicine on 6-7 March, 2021 at Goa, organized by VDGOOD Technology.
4. Dr. Amar Jeet Gupta was conferred with ISVS Fellow of Indian Society of Vegetable Science
5. Dr. Amar Jeet Gupta, Principal Scientist (Horticulture) was honored with the 'Outstanding Scientist Award-2021' by Gautam Kalloo Research and Development Foundation, Varanasi for his outstanding contribution in the promotion of improved varieties and production technologies of onion.

Dr. Amar Jeet Gupta, Pr. Scientist "Outstanding Scientist Award-2021"

6. Dr. R. B. Kale, S.S. Gadge and Dr. Major Singh received 'Best Case Study Award 2021'in Case Documentation Drive conducted by VAMNICOM Pune to Strengthening Farmer Participatory Agricultural Supply Chain: A Case Study of Maharashtra State-Level Farmer Producers Company (MAHA-FPC) presented by R. B. Kale, S. S. Gadge and Major Singh.

7. Dr Bhushan Bibwe awarded with prestigious Institutions of Engineers (IEI) 'Young Engineer Award' on the occasion of 36th Indian Engineering Congress (26-28th Dec, 2021) at New Delhi.

Dr. Bhushan Bibwe, Scientist (ICAR-DOGR) "Young Engineer Award' 2021"

M. Publications

Papers in Refereed Journals

1. Benke AP, R Krishna, V Mahajan, WA Ansari, AJ Gupta, A Khar, P Shelke, A Thangasamy, TPA Shabeer, M Singh, KP Bhagat, DC Manjunatha Gowda. 2021. Genetic diversity of Indian garlic core germplasm using agro-biochemical traits and SRAP markers. Saudi Journal of Biological Sciences, 28, 4833–4844.
2. Benke AP, V Mahajan, DC Manjunatha Gowda, DN Mokat. 2021. Interspecific hybridization in *Allium* crops: status and prospects. Genet Resource Crop Evolution, https://doi.org/10.1007/s10722-021-01283-5.
3. Das TK, Ghosh S, Das A, Sen S, Datta D, Ghosh S, Raj R, Behera B, Roy A, Vyas AK and Rana DS, 2021. Conservation agriculture impacts on productivity, resource-use efficiency and environmental sustainability: A holistic review. Indian Journal of Agronomy, 66: S111-S127.
4. Gedam PA, Thangasamy A, Shirsat DV, Ghosh S, Bhagat KP, Sogam OA, Gupta AJ, Mahajan V, Soumia PS, Salunkhe VN, Khade YP, Gawande SJ, Hanjagi PS, Ramakrishnan RS and Singh M. 2021. Screening of onion (*Allium* cepa L.) genotypes for drought tolerance using physiological and yield based indices through multivariate analysis. Frontiers in Plant Science. 12:01-16.
5. Gupta AJ, Benke AP, Mahajan V and Singh M 2021. Evaluation of genetic diversity and development of core collection of onion. Indian Journal of Horticulture 78 (1):25-34.
6. Gupta AJ, Mahajan V, Singh SR, Sheemar G and Singh M. 2021. Response to selection through introgression breeding in onion (*Allium cepa* L.). Vegetable Science. 48 (1): 49-55.
7. Gupta AJ, Jayaswall K, Khar A, Mahajan M, Kad SK, Singh M. 2021. Analysis of genetic diversity among Indian garlic (*Allium sativum* L.) genotypes using SSR markers and morphological traits. Vegetable Science 48 (2):219-227.
8. Jayaswall K, Sharma H, Bhandawat A, Sagar R, Jayaswal D, Kumar A, Chaturvedi P, Mahajan V, Kumar S and Singh M. 2021. Chloroplast derived SSRs reveals genetic relationships in domesticated *Allium*s and wild relatives. Genetic Resources and Crop Evolution, https://doi.org/10.1007/s10722-021-01235-zpp.1-10.
9. Kale RB, Gadge SS, Jayaswall K, Patole A, Mahajan V. and Singh M. 2021. Ethno-veterinary medicinal uses of garlic (*Allium* sativum) by livestock rearers. Indian Journal of Traditional Knowledge 20(2) 426-435.
10. Kale RB, Gadge SS, Jayaswall K, Patole A, Mahajan V. and Singh M. 2021. Validation of ethnoveterinary medicinal practices of onion (*Allium cepa*). Indian Journal of Traditional Knowledge, 20(3) 775-783.
11. Kale RB, Gadge SS, Jayaswall K, Patole A, Mahajan V. and Singh M. 2021. Ethano-veterinary medicinal uses of garlic (*Allium* sativum) by livestock rearers. Indian J. of Traditional Knowledge, 20(1).
12. Karuppaiah V, PS Soumia, PS Shinde, A Benke, V Mahajan and M Singh. 2021. Evaluation of garlic genotypes for resistance to *Thrips tabaci* Lindeman. Indian

Journal of Entomology 83. Online published Ref. No. e20284 DoI No.: 10.5958/0974-8172.2021.00128.0.

13. Mahajan V, Major Singh, K Bhagat, Kuldeep J, P Ghodke, AJ Gupta, D Shirsat, K Gorrepati, O Sogham and R Bhat. 2019. Medicinal Importance of Underutilized *Allium*s. International J. of Noni Research. 14 (1&2), 37-44.
14. Mahajan V, Manjunatha Gowda DC, Gupta AJ, Benke A and Singh M. 2021. Onion (*Allium cepa* L.) Breeding for quality traits and export. Vegetable Science. 48 (2): 123-135.
15. Singh M, Gedam P. and Vijay Mahajan. 2021. Approaches for Enhancing Water Productivity in Onion and Garlic. Shodh Chintan Vol. 12 & 13, 226-231.
16. Manjunatha Gowda DC, Benke AP, Bhagat KP, Mahajan V, Jayaswall K. and Singh M. 2021. Characterization and relative mineral quantification of male gametophytes of garlic chives (*Allium tuberosum* Rottler ex Sprengel). Genetic Resource & Crop Evolution, http://doi.org/10.1007/s10722-021-01-01300-7.
17. Meena VS, Bibwe B, Bhushan B, Jalgaonkar K, Mahawar MK (2021). Physicochemical Characterization of Selected Pomegranate (*Punica granatum* L.) Cultivars. Turkish Journal of Agricultural Engineering Research (TURKAGER), 2(2): 425-433, https://doi.org/10.46592/turkager.2021.v02i02.015.
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19. Roylawar P, Khandagale K, Randive P, Shinde B, Murumkar C, Ade A, Singh M, Gawande S. and Morelli M. 2021. *Piriformospora indica* Primes Onion Response against Stemphylium Leaf Blight Disease. *Pathogens*, 10(9), https://doi.org/10.3390/pathogens10091085
20. Singh M, V Mahajan, K Bhagat, J Kuldeep, P Ghodke, D Shirsat, K Gorrepati and R Bhat. 2019. Nutra-Pharmaceutical Values of Onion and Garlic. International J. of Noni Research. 14 (1&2), 45-51.
21. Singh S, Anandhan S, Singh RK. 2021. Interaction between *Arbuscular Mycorrhiza* and Rhizobacteria with legumes: A promising strategy to fight with abiotic stress. World J Agri & Soil Sci. 7(3): WJASS.MS.ID.000662.
22. Somasundaram S, Satheesh V, Singh V, Anandhan S. 2021.A simple flow cytometry-based assay to study global methylation levels in onion, a non-model species. Physiology and Molecular Biology of Plants. 27 (8):1859-1865.
23. Soumia PS, Srivastava C, Guru Prasanna Pandi G. and Subramanian S. (2021). DNA fingerprinting of bruchid resistant mung bean genotypes using SSR markers. Indian Journal of Entomology, 83: doi: 10.5958/0974-8172.2021.00039.0.
24. Surve AP, Chandavshive AV, Bhalekar MN, Joshi VR, Khade YP and Kumar B. Effect of Phule micronutrient mixture grade I application on growth and yield of *kharif* onion (*Allium cepa*). 2021. Indian Journal of Agronomy 66(4): 512-514.
25. Thangasamy A, Kalyani Gorrepati, Pranjali H Ghodke, Ahammed Shabeer TP, Manjusha Jadhav, Kaushik Banerjee and Major Singh (2021). Effects of sulfur fertilization on yield, biochemical quality, and thiosulfinate content of garlic. Scientia Horticulturae. 289. https://doi.org/10.1016/j.scienta.2021.110442.

26. Tripathi PC, HM Jadhav, AA Qureshi, V Sankar, V Mahajan and KE Lawande. 2021. Morphological and biochemical properties of garlic (*Allium sativum* L.) collections. Journal of Spices and Aromatic Crops, Vol. 30 (1): 81-89.

Lead Papers

1. Singh M, P Gedam and V Mahajan. 2021. Approaches for Enhancing Water Productivity in Onion and Garlic. Presented as key note paper in “Global Conference on Innovative Approaches for Enhancing Water Productivity in Agriculture including Horticulture” on 17.9.2021 at PJTSAU, Rajendra Nagar, Hyderabad in 16-19 Sept., 2021 organized by CHAI, New Delhi.
2. Mahajan V, DC Manjunatha Gowda, AJ Gupta, A Benke and M Singh. 2021. Onion (*Allium cepa* L.) breeding for quality traits and export. International Conference on vegetable research and innovations for nutrition, entrepreneurship and environment, 14-16 Dec., 2021 at IIVR, Varanasi, organized by Indian Society of Vegetable Science.

Papers and Abstracts in Conference/Seminar/Symposia

1. Bhagat KP, Gupta AJ, Jawalekar KV, Upadhyay AK, Mahajan V and Singh M. 2021. Study of photosensitivity and photosynthetic efficiency in onion varieties for cultivating round the year under climate change scenario. Souvenir In: Indian Horticulture Congress-2021 on Horticulture for Health, Livelihoods and Economy, Nov 18-21, 2021 organized by IAHS at CSAUAT, Kanpur. p 132.
2. Gupta AJ, Kumar A, Gorrepati K, Chauhan H, Mahajan V, Benke AP, Satpute P and Singh M. 2021. Characterization and evaluation of widely cultivated garlic (*Allium sativum* L) cultivars of Indian origin. In: International Conference on Vegetable Research and Innovations for Nutrition, Entrepreneurship and Environment (ICVEG-21), Dec 14-16, 2021 organized by ISVS, Varanasi. p 30.
3. Gupta AJ, Gadge SS, Kale R and Singh M 2021. Enhancing livelihood security of tribal farmers through technological interventions in onion and garlic. In: International Conference on Vegetable Research and Innovations for Nutrition, Entrepreneurship and Environment (ICVEG-21), Dec 14-16, 2021 organized by ISVS, Varanasi. p 466.
4. Gupta AJ, Mahajan V and Singh M. 2021. Genetic diversity and improvement in onion for wide adaptability. Souvenir In: Indian Horticulture Congress-2021 on Horticulture for Health, Livelihoods and Economy, Nov 18-21, 2021 organized by IAHS at CSAUAT, Kanpur. p 131.
5. Jayalakshmi K, Alok K Srivastava, Nazia Manzar, Abhijeet S Kashyap, Alok K Singh, Pramod Kumar Sahu, Anil K Sexena, Raju J and Ram Dutta. Isolation, characterization and bio-management of *Villosiclava virens*, a unique flower-infecting fungus causing rice false smut disease in India. Virtual National Symposium on Sustainable Plant Health Management Amidst Covid Pandemic: Challenges and Strategies”01-03 December 2021, 49p.
6. Karuppaiah V, Soumia PS and Major Singh. 2021. Arthropod pollinators of onion and their forage trend, role in seed production. In proceedings of 2nd International Web-Conference on Food Security Through Sustainable Agriculture (FSSA) during 20-21 September, 2021 at Indore, MP, India. p. 57.

7. Karuppaiah V, Soumia PS and Major Singh. 2021. Bio-efficacy, phytotoxicity and safety to natural enemies of co-formulated granular insecticide on onion under open field condition. In: Vegetable Research and Innovations for Nutrition, Entrepreneurship and Environment. International Conference at ICAR-Indian Institute of Vegetable Research, Varanasi, India from December 14 to 16, 2021, p. 294-295.
8. Mahajan V, Manjunatha Gowda DC, Gupta AJ, Benke AP and Singh M. 2021. Onion (*Allium cepa* L.) breeding for quality traits and export. Souvenir In: International Conference on Vegetable Research and Innovations for Nutrition, Entrepreneurship and Environment (ICVEG-21), Dec 14-16, 2021 organized by ISVS, Varanasi. pp 147-149.
9. Manjunatha Gowda DC, Benke AP, Gupta AJ, Mahajan V and Singh M. 2021. Manifestation of heterosis in onion: A way forward for development of F_1 hybrids. In: International Conference on Vegetable Research and Innovations for Nutrition, Entrepreneurship and Environment (ICVEG-21), Dec 14-16, 2021 organized by ISVS, Varanasi. p 22.
10. Ram Dutta, Jayalakshmi K, Suresh J Gawande, Sharath MN, Vishal S Gurav and Major Singh. 2021. Biocontrol potential of native *Trichoderma* spp. against anthracnose/twister disease of onion Virtual National Symposium on Sustainable Plant Health Management Amidst Covid Pandemic: Challenges and Strategies. 01-03 December 2021, 93p.
11. Ram Dutta, Suresh J Gawande, Jayalakshmi K, Sharath MN, Vishal S Gurav, Ram Bomble and Major Singh. Efficacy of Amritpani based organic formulations for crop health and management of major fungal diseases of onion. International Conference on Vegetable Research and Innovations for Nutrition, Entrepreneurship and Environment (ICVEG-21) 14-16th December 2021 303p.
12. Singh M, Gupta AJ, Gadge SS, Kale R, Rai N and Singh GN. 2021. Extending commercial cultivation of onion in eastern parts of Uttar Pradesh: A success story. In: International Conference on Vegetable Research and Innovations for Nutrition, Entrepreneurship and Environment (ICVEG-21), Dec 14-16, 2021 organized by ISVS, Varanasi. p 459.
13. Singh M, Mahajan V and Gupta AJ. 2021. Strategical development and scope of export of onion and garlic from India. Souvenir In: International Conference on Vegetable Research and Innovations for Nutrition, Entrepreneurship and Environment (ICVEG-21), Dec 14-16, 2021 organized by ISVS, Varanasi. pp 77-88.
14. Thangasamy A, Pranjali A Gedam, Soumia PS, Sourav Ghosh, Karuppaiah V, Vijay Mahajan and Major Singh. 2021. Inter-annual variability in monsoon rainfall and its distribution on plant growth and yield of *kharif* onion in tropical region of India. In: Behera TK et al., Abstract Book, Vegetable Research and Innovations for Nutrition, Entrepreneurship and Environment. International Conference at ICAR-Indian Institute of Vegetable Research, Varanasi from December 14 to 16, 2021, p.224.

Report

1. Gadge SS, Mahajan V, Benke A, Dutta R, Gupta AJ, Karuppaiah V and Gedam P. 2021. ICAR-DOGR Annual Report 2020. ICAR-DOGR, Pune. 269 p.

Book Chapters

1. Bibwe B, Mahawar MK, Kalnar Y, Kannujia PK, Jalgaonkar K 2021. Low-cost storage structures in Book- Postharvest Management of Horticultural Crop by Surajit Mitra. Jaya publishing house, Delhi, Chapter- 13: 206-224
2. Das TK, Sen S, Ghosh S, Paramanik B, Datta D and Roy A. 2021. Integrated Weed Management in Crops and Cropping Systems: Concept, Needs and Challenges. In: Integrated Pest Management Strategies for Sustainable Agriculture (*Eds.*) N. Nair and A. Guha. New Delhi Publishers, New Delhi, Kolkata, pp. 286.
3. Datta D, Ghosh S and Singh SV. 2021. Biofortification strategies for achieving food and nutritional security. In: Pharmacognosy & Nutrition Vol. 2 Ed. N. K. Maurya. Virgin Sahityapeeth Publisher, pp. 65-89.
4. Datta D, Ghosh S, Saha R and Nath CP. 2021. Cover Crops: Potential and Prospects in Conservation Agriculture. In: Conservation Agriculture and Climate Change: Impact and Adaptation (*Eds*.) R Saha, D Barman, MS Behera and G Kar. New India Publishing Agency, New Delhi. pp. 496.
5. Jaiswal S, Kumar A, Priya J, Anandhan S, Singh S, Singh RK. Genome Editing for Metabolic Engineering in Plants. In: Genome Editing in Plants, 155-170p (2021)
6. Kale RB, Gadge SS and Singh M. 2021. Strengthening Farmer Participatory Agricultural Supply Chain: A Case Study of Maharashtra State-Level Farmer Producers Company (MAHA-FPC) in 'Catalyzing Sustainable Development through Producers Collectives: Case Studies from India's Hinterland' Published by VAMNICOM, Pune.
7. Sutar A, Kale RB, Singh Sharadveer. 2021. Disturbed Vegetables Supply Chain during COVID-19 and the Emerging Role of Farmer Producer Organizations. Book of Proceedings of National Conference on Corporate Governance and Sustainable Competitiveness in Agriculture Collectives (Co-operatives & Farmer Producers' Organization) 15-17th December 2021 (Virtual mode) published by VAMNICOM, Pune, PP-40-47.
8. Mahawar MK, Jalgaonkar K, Kannaujia PK, Chander Bhan and Bibwe B. 2021. Harvesting and Postharvest Handling of Fruits in book- Postharvest management of horticultural Crop by Surajit Mitra. Jaya publishing house, Delhi, Chapter- 19: 359-376.
9. Meena RP, Ghosh S, Jatav SS, Chitara MK, Jinger D, Gautam K, Ram H, Jatav HS, Rana K, Pradhan S and Parihar M, 2021. Microbial Mediated Biodegradation of Plastic Waste: An Overview. Bioremediation Science from Theory to Practice, pp.154-169.
10. Nebapure S, Soumia PS, Yele Y, Guru Pirasanna Pandi G., and Prasannakumar, NR. 2021. Semiochemicals. In: Reproductive Strategies in Insects, CRC Press Publisher, 243-257.
11. Singh S, Singh RK, Anandhan S, Priya J, Jaiswal S, Kumar A. Advances in Genome Editing. In: Genome Editing in Plants. 227-240p. (2021).
12. Soumia PS, Guru Pirasanna Pandi, G, Krishna R, Waquar Akhter Ansari, Jaiswal DK, Verma JP and Major Singh. 2021. Whitefly-Transmitted Plant Viruses and Their Management. In: Singh KP, Jahagirdar S, Sarma BK. (*Eds*). Emerging Trends in Plant Pathology. Springer, Singapore. https://doi.org/10.1007/978-981-15-6275-4_8

13. Soumia PS, Krishna R, Jaiswal DK, Verma JP, Yadav J, Singh M. 2021. Entomopathogenic Microbes for Sustainable Crop Protection: Future Perspectives. In: Yadav A.N., Singh J., Singh C., Yadav N. (Eds). Current Trends in Microbial Biotechnology for Sustainable Agriculture. Environmental and Microbial Biotechnology. Springer, Singapore. https://doi.org/10.1007/978-981-15-6949-4-19

Technical/ Extension Bulletins

1. Singh M, Gupta AJ, Gadge SS, Kale RB, Rai N and Singh GK 2021. *Uttar Pradesh Ke Poorvi Bhagon Me Pyaj Ki Vyavsaik Kheti Ka Vistar: Ek Safalta Ki Kahani.* Technical Bulletin No.36. ICAR-DOGR, Pune. 12 p.
2. Singh M, Gupta AJ, Gadge SS, Kale RB, Rai N and Singh GN 2021. Extending commercial cultivation of onion in eastern parts of Uttar Pradesh: A success story. Technical Folder No. 35. ICAR-DOGR, Pune pp.10.
3. Singh M, Gupta AJ, Gadge SS, Kale RB, Rai N and Singh GN. 2021. Extending commercial cultivation of onion in eastern parts of Uttar Pradesh: A success story (Hindi). Technical Folder No. 36. ICAR-DOGR, Pune pp.12.

Technical/ Popular Articles

1. Chaware GG, Shirsat D and Karuppaiah V. 2021. *Krushi Utpadakta Vadhisathi Madhmashi Mahatvach*i, Agrowon, May, 2021
2. Chawar, GG, Shirsat D and Karuppaiah V. 2021. *Kahani Jiwandayini Madhmashichi*, Krushakonnati, May, 2021.
3. Chaware G.G and Karuppaiah V. 2021. *Kitaknashake Fawartana Ghawyachi Kalji*, Krushakonnati, June, 2021.
4. Chaware GG, Karuppaiah V. 2021. "*Kanda Pikavaril Ekatmik Keed Vyavastapan*". Krushakonnati, February, 2021.
5. Gadge SS and Kale R B. 2021. *Kanda Pikache Mar, Karpa Rogan Sah Ful Kidyan Pasun Sanrakshan* (Onion plant protection from Anthracnose, Purple blotch and Thrips) Agrowon. 30th July 2021. Sakal Media Group, Pune. pp. 11-14.
6. Gadge SS and Kale RB. 2021. *Adhunik Bahumajli Kanda Sathvan Tantradnyan* (Advanced Multistorey Storage Structure for Onion) March 2022. Agrowon Calendar 2022. Published on 25th December 2021. Sakal Media Group, Pune. p.3.
7. Gadge SS. and Kale RB. 2021. *Kanda Lagwadichi Sutre* (Onion Cultivation Technology) Agrowon. 28th May 2021. Sakal Media Group, Pune. p. 9.
8. Karuppaiah V, Chaware GG and Soumia PS. 2021. Thrips IPM in onion. Agriculture and Environment E-Newsletter, 2(12): 14-16. Article ID: AEN-2021-02-12-004
9. Karuppaiah V and Soumia PS. 2021. Garlic Vectors and Their Management. RashtryaKrishi, 15(1): 73-75.
10. Karuppaiah V and Soumia PS. 2021. Integrated Pests and Pollinators Management (IPPM) Strategies for Onion Seed Production. RashtryaKrishi, 15(1): 87-89.
11. Vijay Mahajan, A Benke and RB Kale. 2021."*Kanda Beejo Utapadan*". Shetakari (November), 33-34.
12. Vijay Mahajan, AP Benke, A Thangasamy and S.S. Gadge. 2021. "*Lasoon Lagwad Vyavasthapan*". Shetakari (September), 25-26.

13. Vijay Mahajan, Pranjali Gedam, Rajiv Kale and Ashwini Benke. 2021. "*Kanda Va Lasoon Sanshodhan Sanchalanalaya*: *Ek Parichay*". Shetakati (July), 46-47.
14. Vijay Mahajan, RB Kale and PA Gedam 2021. *Rabi Kanda Lagwadva Peek Niyojan*". Shetakari (September), 22-24.

Ready Reckoners

1. Karuppaiah V and Soumia PS. 2021. 'Pest Calendar' for Onion and Garlic. Hosted in ICAR-DOGR website for knowledge dissemination.

E-Publications

1. Ghosh S, Kale R, Soumia PS, Kumar A, Gadge SS, Dutta R, Gawande SJ, Thangasamy A and Major Singh (2021). Nursery management in onion part I - Seed treatment and sowing-Video clip. Prepared and published by ICAR-Directorate of Onion and Garlic Research, Pune.
2. Ghosh S, Kale R, Soumia PS, Thangasamy A, Gadge SS, Kumar A and Major Singh (2021). Nursery management in onion part II - Land preparation and crop husbandry-Video clip. Prepared and published by ICAR-Directorate of Onion and Garlic Research, Pune.

Videos

1. Nursery Management-I: Seed Treatment and Sowing https://www.youtube.com/watch?v=K5Ox6Kg43A8
2. Nursery Management-II: Land Preparation and Crop Husbandry https://www.youtube.com/watch?v=e1IFHVSpvp4

TV Shows/ Radio Talks

1. Dr Vijay Mahajan delivered radio talk on "*Kharif Kanda Ropvatika Vyavasthapan*" broadcasted on 30.4.2021, All India Radio, Pune.
2. Dr Vijay Mahajan delivered TV talk "*Kharif Hangamatil Kanda Pikatil Keed Va Rog Vyavasthapan*, recorded on 7.7.2021, DD Shayadri, Mumbai Doordarshan broadcasted on 27.7.2021.
3. Dr Vijay Mahajan delivered radio talk "*Rabi Kandyace Sudharit Vaan Va Rop Vatika Vyavasthapan*" broadcasted on 5.10.2021, All India Radio, Pune
4. Dr Vijay Mahajan delivered TV talk on "Use of foliage of wild *Alliums*" direct telecast on 28.1.2021 by DD Sahydari, Mumbai.
5. Gadge S.S. 2021. *Rangda Kanda Vyavsthapan* (Management of late-*kharif* onion). TV show. Interview telecasted on 5th November 2021. Krishi Darshan, Doordarshan Sahyadri.
6. Khade Y. Delivered Krishidarshan -Phone-in-Live Programme on topic "*Kanda Pikatil Khat va Pani Vyavasthapan*" on 15th July, 2021 on DD Sahyadri at Warli, Mumbai
7. Gadge SS. 2021. *Kanda Sathvnukiche Adhunik Tantradnyan* (Advanced technology of onion storage). Radio talk broadcasted on 2nd April 2021. All India Radio, Pune.

8. Gadge SS. 2021.*Kanda Pikamadhye Santulit Khatache Mahattva* (Importance of balanced fertilizer in onion crop). Radio talk broadcasted on 12 October 2021. All India Radio, Pune.
9. Khade Y. Radio talk on "*Kanda Beej Kadhani Ani Prakriya*" at All India Radio, Pune on 12th April, 2021
10. Kale RB. Radio talk on Onion Seed Production (*Kanda Bijotpadan*) at All India Radio on 21st Oct 2021
11. Kale RB. TV Talk on 'Modern technology of onion storage' telecasted on 04.05.2021 by DD Sahyadri channel.
12. Kale R. B. delivered TV Talk on 'Entrepreneurial opportunities in Onion and Garlic crop' telecasted on 03.09.2021 by DD Sahyadri channel.
13. Kale RB. TV Talk on '*Vyavsayik Kanda Bijotpadan- Sandhi Aani Aavhane'* (Commercial Onion Seed production: Opportunities and Challenges) telecasted on 18th Nov 2021 Krushi darshan programme by DD Sahyadri channel.

Documentary

ICAR-DOGR produced a documentary film of five minutes on Success story of TSP on "Commercial cultivation of onion and garlic" in Tribal belts of Nandurbar (Maharashtra) in March 2021 (English, Hindi and Marathi).

N. Institutional Activities

National Science Day Celebration

ICAR-DOGR celebrated National Science Day (NSD) on 1st March 2021. The programme was celebrated to commemorate the discovery of "Raman Effect" by great physicist and Nobel Prize winner Sir C. V. Raman. The aim of celebration was to encourage and create awareness towards importance of science in daily life. The theme for National Science Day 2021 was 'Future of STI: Impact on Education Skills and Work'. Mrs. Ashwini Benke, scientist and coordinator of programme welcomed all the participants and briefed about program. Mr. Ashok Kumar initiated various activities under the programme and briefed biography of Sir C.V. Raman. Dr. Saurav Ghosh, scientist (Agronomy) conducted the virtual competitions for the staff and their children namely drawing on "Use of science in daily life" for the students below 10 years, theme of speech was "Online mode of teaching can replace traditional classes in future" organized for class VI to X and e posters were presented on "Green technology in agriculture". Later, prizes were distributed to winners of each competition. Dr. V. Mahajan spoke on use of science and its history in human life and related mythological stories. Director Dr. Major Singh added his remarks on importance on National Science Day and recalled the contribution by Nobel laureate, physicist Sir C.V. Raman on this day in 1928. He emphasized on role of innovative ideas in routine life. The total 40 participants comprising Scientist, Technical, Administrative staff and RA/YP's attended program.

National Science Day 2021 at ICAR-DOGR

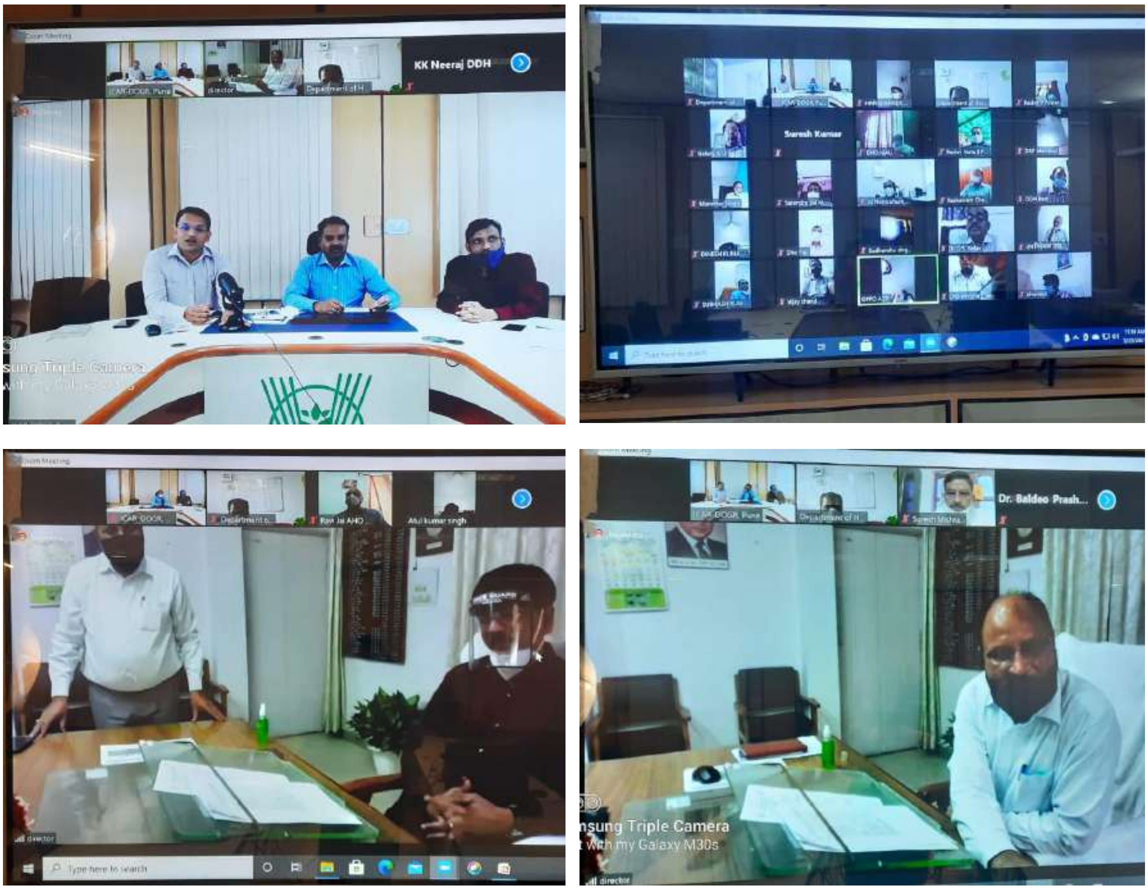
International Women's Day Celebration

The Women Cell of ICAR-DOGR organized International Women's Day 2021 with the ICAR theme "Women leadership in Agriculture: Entrepreneurship, Equity, and Empowerment" in the conference hall, ICAR-DOGR, Rajgurunagar on Monday, March 8, 2021. During the first part of the program, all ICAR-DOGR staff along with students and YP/SRF and RA attended the virtual program arranged by ICAR Headquarters. In the second session of the program Mrs. Ashwini Benke, chairman of women cell, ICAR-DOGR welcomed all the participants and briefed them about the history of the international women's day celebration. Later on, Dr. Major Singh, Dr. Amar Jeet Gupta, Dr. Chaudhari, and Mrs. Ashwini Benke felicitated five women farmers identified under Tribal Sub Plan (TSP), Bhima Shankar, Tal Ambegaon, and Dist. Pune for their distinct work in farming and improving the social status of their own family. The farmer lady Mrs. Bhimabai Lohkare expressed her thought on adopting the techniques of poultry farming and initiates small-scale business for a group of ladies. This program was chaired by Dr. Major Singh, Director who spoke on the History of Women's days and the need for gender equality, empowerment of women. Dr. V. Mahajan, Principal Scientist (Hort.) spoke on the need for freedom for women at the workplace. Dr. Amar Jeet Gupta, Prin. Scientist (Hort.) described success stories on "Women in agriculture: role in the improvement of livelihood of the family". Overall, 80 participants attended the program. The arrangement of the program was made in such a way that gathering can awaken and sensitize Women's Equality and uniqueness rather than gender biases.

Progressive women farmers being felicitated on International Women's Day

Training for Promotion of *Kharif O*nion Production in Uttar Pradesh

A training-cum-awareness programme was organized by ICAR-Directorate of Onion and Garlic Research, Pune in collaboration with Department of Horticulture and Food Processing, Lucknow (UP) on 25th May, 2021 through virtual mode. A total of 100 participants including Deputy Director Horticulture, District Horticulture Officers and Farm Managers of Horticulture Department of Uttar Pradesh and progressive farmers of AGRIMITRA Farmers Producer Company, Mirzapur attended the programme. Dr. Major Singh, Director, ICAR-DOGR, Rajgurunagar, Pune; Shri Manoj Singh, Additional Chief Secretary Horticulture, Govt. of UP; Dr. R. K. Tomar, Director, Department of Horticulture and Food Processing, Lucknow (UP); and Dr. D. P. Yadav, Deputy Director Horticulture, Lucknow graced the occasion. Dr. S. S. Gadge, Senior Scientist (Agril. Extension), ICAR-DOGR welcome the participants and briefed about training programme to the participants. Dr. D. P. Yadav, Deputy Director Horticulture, Lucknow introduced about participants from Department of Horticulture and Food Processing, Lucknow (UP). Dr. R. K. Tomar, Director, Department of Horticulture and Food Processing, Lucknow (UP) appreciated the efforts of ICAR-DOGR taken in technology development on onion and garlic and transfer in the country including Mirzapur (UP). Dr. Tomar described his departmental action plan regarding promotion of *kharif* onion cultivation in Uttar Pradesh. He requested to ICAR-DOGR regarding technical support and guidance to extend onion production in 5000 ha areas in UP including 2000 ha in *kharif* season during 2021-22. Dr. Major Singh, Director, ICAR-DOGR, Rajgurunagar, Pune aware about importance of onion cultivation and said that the eastern parts of Uttar Pradesh have immense potential for *kharif* onion cultivation. Dr. Singh assured farmers that the Directorate will continue to support onion cultivation in Uttar Pradesh and other suitable areas. Dr. Amar Jeet Gupta, Principal Scientist, ICAR-DOGR & Coordinator of the Training, gave PPT presentation on "*Kharif* Onion Production in Uttar Pradesh". Dr. Gupta emphasized on the current situation of onion cultivation as well as livelihood security of farmers through commercial cultivation of *kharif* onion. Dr. Gupta also appreciated the farmers for adoption and their active involvement in cultivation of *kharif* onion in Chunar Tahsil of Mirzapur. The production and productivity of onion in Mirzapur have been remarkably increased by 93% and 32%, respectively after intervention of ICAR-DOGR technologies in collaboration with AGRIMITRA and GKRDF. Shri Manoj Singh, Additional Chief Secretary Horticulture, Lucknow, Govt. of UP, said that India has achieved remarkable growth in onion production and scientists have good contribution in onion and garlic research and development in the country. There is need of more attention towards policy framework to mitigate price crises in onion. He appreciated the efforts by ICAR-DOGR in promotion of *kharif* onion in India especially in eastern parts of UP and suggested to his District Horticulture Officers to adapt improved onion varieties and technologies to extend *kharif* onion production in Uttar Pradesh. The programme was ended by vote of thanks expressed by Dr. Rajiv Kale, Scientist (Agril. Extension), ICAR-DOGR, Pune.



Training on *Kharif* Onion Production in UP

Independence Day Celebration

ICAR-DOGR celebrated 75th Independence Day on 15th August 2021, All the staff including scientist, technical, administrative, SRF, JRF, YP and contractual were present for the event. On this occasion Dr. Major Singh, Director, ICAR-DOGR hoisted the national flag and addressed to the staff of ICAR-DOGR.

Dr. Major Singh addressing the DOGR Staff on Independence Day-2021

16th *Parthenium* Awareness Week

The *Parthenium hysterophorus,* locally called carrot weed, Gajar-ghas or Congress grass has been considered one of the most problematic alien invasive weeds. It spread in cropped, non-cropped and forest areas, and invaded about 35 million hectares of land throughout the country including Andaman & Nicobar and Lakshadweep. Earlier, it was not considered a serious weed in hilly areas and north-eastern region. But now, it has invaded larger part of hilly areas in Himachal Pradesh, Uttarakhand, Jammu & Kashmir and north-eastern states. Looking at the seriousness and magnitude of the threat posed by this weed, Indian Council of Agriculture Research directed ICAR institutes to organize 16th Parthenium Awareness Week from 16 to 22nd August, 2021. As per the directives of ICAR, New Delhi, ICAR-Directorate of Onion and Garlic Research (ICAR-DOGR), Pune organized "16th Parthenium Awareness Week" from 16-22nd August, 2021 under the guidance of the Director, ICAR-DOGR. During this week, various activities have been carried out to create awareness about Parthenium weed among the common people and farmers. Parthenium Awareness Week was observed by following the COVID guidelines issued of Govt. of India.

हिन्दी पखवाड़ा

हर वर्ष की भांति इस वर्ष भी हिंदी पखवाड़े का आयोजन संस्थान में 14-28 सितंबर 2021 किया गया | हिंदी पखवाड़ेका उद्घाटन 14 सितंबर (मंगलवार) 2021 को हुआ जिसमें संस्थान के सभी वर्गके कर्मचारी एवं अधिकारी ने हिस्सा लिया | निदेशक महोदय, सभी को राजभाषा केउच्चतर इस्तेमाल, प्रचार एवं प्रसार के लिए हिंदी प्रतिज्ञा दिलाई | राजभाषा कार्यान्वयन समिति के सदस्य सचिव, अशोक कुमार ने संस्थान में हिंदीपखवाड़े के अंतर्गत आयोजित होने वाले कार्यक्रम का विवरण प्रस्तुत किया | हिंदी पखवाड़े चार प्रतियोगिताएं, हिंदी टिप्पण एवं प्रारूप लेखनप्रतियोगिता, हिंदी निबंध लेखन प्रतियोगिता, हिंदी वाद-विवाद प्रतियोगिता, हिंदी प्रश्न-मंच प्रतियोगिता का आयोजन किया गया | हिंदी प्रतियोगिताओं केगुणवत्तापूर्ण एवं निष्पक्ष मूल्यांकन के लिए एक निर्णायक मंडल का गठन कियागया जिसमें संस्थान के डॉ विजय महाजन (प्रधान वैज्ञानिक), डॉ राम दत्ता (प्रधान वैज्ञानिक), डॉ अमरजीत गुप्ता (प्रधान वैज्ञानिक), श्री अमरेंद्रकिशोर (प्रशासनिक अधिकारी) एवं श्री राजेंद्र प्रसाद वर्मा (सहायकनिदेशक, राजभाषा विभाग, गृह मंत्रालय) को सदस्य मनोनीत किया गया |

हिंदी टिप्पण एवं प्रारूप लेखनप्रतियोगिता में डॉ राजीव बलिराम काले, वैज्ञानिक को प्रथम, श्री राम यशवंतबोंबले, सहायक तकनीशियन को द्वितीय, श्रीमती नेहा राजेश गायकवाड, सहायक कोतृतीय एवं चार अन्य को सांत्वना पुरस्कार से सम्मानित किया गया | हिंदीनिबंध लेखन प्रतियोगिता में जसवंत कुमार पटेल, हेलो को प्रथम रामकृष्ण कोद्वितीय, धनंजय विठ्ठल सिरसात को तृतीय एवं चार अन्य प्रतियोगियों कोसांत्वना पुरस्कार दिया गया | हिंदी भाषा तथा इससे जुड़े रोचक तथ्यों परआधारित एक प्रश्न मंच प्रतियोगिता का भी आयोजन किया गया जिसमं संस्थान केसभी वर्गों से प्रतियोगी शामिल हुए| इस प्रतियोगिता में भी समूह 'सी' कोप्रथम, समूह 'ई' को द्वितीय, समूह 'एफ' को तृतीय एवं चार अन्य प्रतियोगी कोसांत्वना पुरस्कार दिए गए | शिक्षा में बढ़ती निजी भागीदारी के विषय पर एकवाद-विवाद प्रतियोगिता का भी आयोजन किया गया जिसमें बिबवे भूषण रत्नाकर, वैज्ञानिक को प्रथम, राजीव बलिराम काले वैज्ञानिक को द्वितीय, रोहिणी भट्टको तृतीय एवं चार अन्य को सांत्वना पुरस्कार से सम्मानित किया गया | डिजिटलमाध्यमों के बढ़ते उपयोग को ध्यान में रखते हुए "हिंदी अनुवाद एवं टाइपिंगटूल्स" पर श्री राजेंद्र प्रसाद वर्मा, सहायक निदेशक (हिंदी), राजभाषाविभाग, गृह मंत्रालय नें कर्मचारियों को हिंदी में टाइपिंग एवं विभिन्नभाषाओं में अनुवाद के

कई उपयोगी टूल्स के बारे में बताया, जिससे हिन्दीभाषा में कार्य करने की ईक्षा सहजता एवं कुशलता का विकाश हो पाएगा | हिन्दी पखवाड़े का समापन समारोह 28 सितम्बर (मंगलवार) को किया गया जिसके मुख्यअतिथि भी श्री राजेंद्र प्रसाद वर्मा थे | निदेशक महोदय नें संस्थान में हिन्दी के उपयोग तथा इसकी आवश्यकता पर बल देते हुए सभी कर्मचारियों से हिंदी भाषा में कार्य करने की अपील की |

Poshan Vatika Maha Abhiyan and Tree Plantation

ICAR-Directorate of Onion and Garlic Research organized Poshan Vatika Maha Abhiyan and Tree Plantation on September 17, 2021 at ICAR-DOGR, Pune. Sixty-five farmers from Pune Districts attended the programme. During this programme, Dr. R. B. Kale, Scientist (Agricultural Extension) presented a lecture on Nutri-cereals and their role on human health. On this occasion, Dr. Ram Dutta, Principal Scientist, ICAR-DOGR addressed the farmers and distributed onion seeds to the famers. Further, 19 mango and 81 foxtail palm plants were planted within ICAR-DOGR campus during this occasion. Poshan Vatika Maha Abhiyan and Tree Plantation were observed by following the COVID guidelines issued of Govt. of India.

12th Annual Workshop of AINRPOG

ICAR-Directorate of Onion Garlic Research (DOGR), Pune organized the XII Annual Group meeting of All India Network Research Project on Onion and Garlic though virtual mode due to covid-19 at ICAR-DOGR on 12-13th October, 2021. The group meeting was attended by scientists and private firms from various parts of the country. The inaugural session was chaired by Dr. A.K. Singh, DDG (HS), ICAR, New Delhi. Dr. K.E. Lawande, former Vice Chancellor, Dr. BSKKV, Dapoli and Ex-Director, ICAR-DOGR, Pune a guest of honor gave and Dr. Vikramaditya Pandey, ADG Hort. ICAR, New Delhi were the guests of honor. Dr. Major Singh, Director, ICAR-DOGR welcomed all the guests for workshop. Dr. A.K. Singh, DDG (HS), ICAR, New Delhi in his inaugural address emphasized the importance of quality seed production for the farmers of the public sector developed varieties. Further he emphasized on mechanization in onion cultivation to reduce the cost of production. Besides, he highlighted the scope of expansion of onion cultivation to the non-traditional areas. Dr K.E. Lawande Dr. Major Singh, Director, ICAR-DOGR, presented the project report, wherein he elaborated about AINRPOG and its achievements. NHRDF award was announced by Dr P K Gupta, Director, NHRDF and conferred to Dr. A. S. Dhatt, Additional Director Research (Hort.), PAU, Ludhiana. Technical session I (General and Interactive session) was chaired by Dr. K. E. Lawande and Co-Chaired Dr Vikramaditya Pandey, ADG (Hort.) and Dr A.S. Dhatt, DRS (Hort.), PAU, Ludhiana. Dr. Vijay Mahajan, Nodal Officer presented action taken report. Chairman appreciated the efforts taken by the AINRPOG team for successfully implementing all the recommendations given in the previous meeting. PIs from different network centres and nodal center presented their progress report in this session. Technical Session II was chaired by Dr. R. P. Gupta, Ex-Director, NHRDF and Co-Chaired by Dr. B. K. Pandey, ADG (Hort.) and Dr. Manish Das, Pr. Scientist, ICAR, N. Delhi. In this session PIs from different network centres and nodal center presented their progress report related crop production and crop protection trials. Plenary session was chaired by Dr. A. K. Singh, DDG (Hort.), ICAR. N. Delhi, which was Co-Chaired by Dr. Major Singh, Director, ICAR-DOGR and Dr. P.K Gupta, Director, NHRDF. Recommendations were finalized in plenary session and the meeting was ended with the vote of thanks by Dr. Vijay Mahajan, Nodal Officer, AINRPOG.

Vigilance Awareness Week

ICAR- Directorate of Onion and Garlic Research, Pune has observed the Vigilance Awareness Week, 2021 from 26th October, 2021 to 01st November, 2021 with the theme "Independent India @ 75: Self Reliance with Integrity". The Observance Week was commenced with a pledge on 26th October, 2021 at 11:00 am by all the staff members of the Directorate to maintain public service, truthfulness, honesty and transparency without corruption in this Institution.

ICAR -DOGR staff taking Oath on Vigilance Awareness Week

During the Observance Week, various activities were organized such as pledge, display of banners and posters, lecture, various competitions such as debate, essay and quiz competition for staff of the directorate to create awareness among the employees against the corruption. On the last day, Dr. Major Singh, Director, ICAR-DOGR distributed prizes to the winners of various competitions organized during the Vigilance Awareness Week. In his concluding remark Director stressed upon the importance of transparency and integrity for the public servants. The Vigilance Awareness Week was concluded on 01nd November, 2021 with Vote of Thanks by Dr Suresh Gawande, Principal Scientist and Vigilance Officer of ICAR-DOGR.

World Soil Day and Farmers Scientist Interface meeting

ICAR-DOGR celebrated world soil day on December 5, 2021. The programme was celebrated to raise awareness of the importance of soil to the sustenance of the life on earth. The theme for world soil day 2021 is Halt Salinization, Boost Soil Productivity. Posters on World Soil Day were displayed inside and outside the campus to raise awareness among the people. Farmers-scientist interface meeting was organized on December 6, 2021 as a part of world soil day celebration. Dr. Rajiv Kale, Scientist welcomed all the participants and briefed about the programme. Dr. Thangasamy, A., Senior Scientist and Nodal Officer, Soil Health Card Scheme delivered lecture on Importance of soil testing and balanced Fertilization. Dr. A. J. Gupta, Principal Scientist briefed about varieties and technologies developed by ICAR-DOGR. Farmer-Scientist interaction was also organized during the meeting and all the scientists from ICAR-DOGR were participated in the event. Dr. Ram Dutta, Principal Scientist and I/C Director, ICAR-DOGR in his remarks stated about the importance of world soil day. Fifty-two farmers and twelve students from Pune district were participated in the event. During the meeting, farm inputs were distributed to the farmers. The meeting ended with vote of thanks. World soil day was celebrated by following the COVID guidelines issued of Govt. of India.

Kisan Sangosthi on commercial cultivation of onion in Mirzapur

ICAR-Directorate of Onion and Garlic Research in collaboration with Gautam Kalloo Research and Development Foundation and Agrimitra Farmer Producer Company organized a Kisan Sangosthi on commercial cultivation of onion on 16th Dec, 2021 at Dhanwantri Devi Inter College, Jalalpur Mafi, Narayanpur Block, Mirzapur. A total of 108 progressive farmers including 38 women from different parts of Mirzapur, Varanasi, Sonbhadra, Ballia and Vindhyachal participated in this program. The program was presided over by Mr. Mahendra Singh, Ex-Gram Pradhan, Jalalpur Mafi. The chief guest of the program was Dr. P.S. Naik, Ex-Director, ICAR-IIVR, Varanasi; Guest of Honor were Dr. Major Singh, Director, ICAR-DOGR, Pune; Dr. Vijay Mahajan, Principal Scientist (Horticulture), ICAR-DOGR, Pune and Mr. Pawan Kumar Prajapati, District Agriculture Officer, Mirzapur; Honorable Members, Dr. Nagendra Rai, Principal Scientist, ICAR-IIVR, Varanasi and Dr. Amar Jeet Gupta, Principal Scientist, ICAR-DOGR, Pune also graced the event by their presence. Dr. Amar Jeet Gupta coordinated the Kisan Sangosthi, in which Dr. Nagendra Rai and Dr. Govind Narayan Singh, Social Worker had an important contribution to the event. Dr. Gautam Kalloo, Ex-Deputy Director General (Horticulture), ICAR and ExVice-Chancellor, JNKVV, Jabalpur gave a message to the farmers to promote natural farming. Dr. P.S. Naik praised the farmers of Mirzapur for their pioneering role in adopting new agricultural technologies and keeping food security in mind. Dr. Naik appreciated the efforts of ICAR-DOGR in the development of onion and garlic technologies and their transfer to the farmer's field. Apart from this, he said that more attention and efforts are needed to increase the storage capacity of the crop. Stabilizing onion prices and doubling the income of farmers, commercial cultivation of *kharif* onion need to be promoted to meet the farmers' requirements. The special guest of the program Dr. Major Singh said that there is a huge potential for the production of *kharif* onion in Mirzapur, so the farmers of the region need to adopt advanced technologies developed by ICAR-DOGR, Pune, for which the institute will help to disseminate the applications of the technologies developed for the cultivation of onion in Mirzapur and other suitable areas. Dr. Singh also mentioned that Eastern Uttar Pradesh especially Mirzapur is proving to be a suitable area for *kharif* onion production, which can make it a hub for *kharif* onion production in the coming years, increasing the production of *kharif* onion as well as stabilizing the prices of onion in the country. Dr. Nagendra Rai emphasized and motivated the farmers to mobilize into Farmer Producer Companies to achieve a stable income for themselves. Dr. Vijay Mahajan appreciated the farmers and spotting the great potential of *kharif* onion production in Mirzapur and its role in filling the gap of onion supply, advised the farmers to adopt the improved technologies for onion cultivation to increase the onion productivity in the country and stabilize its market prices. Mr. Pawan Kumar

Prajapati briefed the farmers about natural farming and its role in combating and preventing global warming and other changes in the atmosphere. Dr. Amar Jeet Gupta presented the current status of onion cultivation and explained how farmers of Mirzapur can secure their livelihood through the commercial cultivation of *kharif* onion. Dr. Gupta appreciated the farmers for their active participation and cultivation of onion in Chunar Tehsil of Mirzapur. The production and productivity of onion in Mirzapur have increased significantly by 93% and 32%, respectively, by adopting the technologies developed by ICAR-DOGR along with the support from AGRIMITRA and GKRDF. Social worker Dr. Govind Narayan Singh was honored for his effective involvement in this program. On the occasion, Dr. Amar Jeet Gupta, Principal Scientist (Horticulture) was honored with the 'Outstanding Scientist Award-2021' by Gautam Kalloo Research and Development Foundation, Varanasi for his outstanding contribution in the promotion of improved varieties and production technologies of onion. Based on the performance of field demonstrations conducted by ICAR-DOGR in Mirzapur in the last four years, it has been found that the area of Mirzapur is highly suitable for *kharif* onion production. *Kharif* onion has also proved to be more beneficial for commercial cultivation as compared to *rabi* onion along with other traditional vegetables grown in Mirzapur areas.

Kisan Sangosthi on commercial cultivation of onion in Mirzapur

O. Human Resource Development

Dr. Amar Jeet Gupta

- External Examiner for evaluation of Ph.D. (Horticulture) Vegetable Science Thesis and conducted Viva-voice on 16.10.2021 in Virtual Mode of Mr. Ajay Kumar Pandav (Roll No.10633) in Horticulture (Vegetable Science) IARI, New Delhi vide No. PGS/Expert-1 ID-2503/PT-2753 dated 16.8.2021.
- External Examiner for evaluation of M.Sc. Horticulture in Vegetable Science Thesis of Ms. Masal Sonali Madhukar (Reg. No. K-19/314), Mahatma Phule Krishi Vidyapeeth (MPKV), Rahuri vide No. ACK/ACD/Thesis-Veg. Sci./SMM/3814/2021 dated 03 Sep 2021.
- Course Director for three days training-cum-awareness programme on "Commercial cultivation of onion and garlic" during 1-3rd Nov, 2021 organized at ICAR-DOGR for tribal farmers.

Dr. S. S. Gadge

- Participated in online sensitization training programme on "Onion seed production technology" organized under Agri Business Incubation (ABI) project and ITMU project at ICAR-DOGR on 26th July 2021.
- Participated in Training cum Awareness programme on "*Kharif* Onion Production in Uttar Pradesh" through virtual mode in collaboration with Department of Horticulture and Food Processing, Lukhnow (UP) on 25th May 2021.

Dr. S Anandhan

- Presented on "Exploring Epigenetic variability: New source for biotic stress tolerance: at Brain Storming on Prospects and challenges for identification of novel genes for biotic stress mitigation in Crops" held on 7th July 2021 through online by NIBSM, Raipur.
- Dr. S. Anandhan Organized IBSC meeting of ICAR-DOGR on 22nd Dec.2021.

Dr. V Karuppaiah

- Attended National Horticulture Fair NHF, 2021 (Virtual) from 8-13th Feb. 2021, IIHR, Bengaluru.
- Attended International Conference on Agriculture, Forestry, Horticulture, Aquaculture, Animal Sciences, Food Technology, Biodiversity, and Climate Change: Sustainable Approaches" (AFHAFBC-2021) on 8th August, 2021, Krishi Sanskriti, New Delhi.
- Attended 2nd International Web-Conference on Food Security Through Sustainable Agriculture (FSSA).1-22nd September, SVV Vishwavidyalaya, Indore.

Dr. Rajiv B. Kale

- Presented a paper on 'Disturbed Vegetables Supply Chain" during COVID-19 and the Emerging Role of Farmer Producer Organizations' authored by Sutar, RB Kale, Sharadveer Singh in National Conference on Corporate Governance and Sustainable Competitiveness in Agriculture Collectives (Cooperatives & Farmer Producers' Organization) 15-17th December 2021 (Virtual mode) Organized by Vaikunth Mehta National Institute of Cooperative Management Pune in collaboration with Ministry of Corporate Affairs, Government of India.

- Organized Kisan Diwas and Staywardship day for awareness on farm safety for farmers in collaboration with Coromandel International Ltd on 23rd Dec. 2021.
- Attended onion stakeholders meet on Agri export policy of Govt. of India on 8th June 2021 organized by APEDA, New Delhi.
- Attended meeting on production of breeder seeds by SAU and ICAR institutes on 21st Dec. 2021.
- Organized world soil day celebration on 05th Dec. 2021 and Farmer-Scientist interface meeting on 06th Dec. 2021.
- Attended ABI Advisory Committee meeting of ICAR-NRC-Grapes on 21.09.2021, 29.09.2021, 18.10.2021, 17.12.2021.
- Organized programme and delivered lecture on 'Food and Nutrition for farmers' under Azadi Ka Amrit Mahotsav on 26th August 2021 at ICAR-DOGR, Pune.
- Farmers-Scientists interface on "Climate resilient technologies and practices of onion and garlic" under SCSP on 28 Sept. 2021 for 50 farmers of Karjat Ahmednagar.
- Delivered presentation on 'Controlled onion storage structure' during the meeting on Harvest and Post-harvest management of onion under the chairmanship Joint secretory, (MIDH) DA and FW New Delhi on 17th Dec. 2021.
- Delivered presentation on "Improved Storage Technology" in the virtual meeting on post-harvest technologies in onion, organized by MOFPI and DAC New Delhi on 7th Dec. 2021.
- Delivered Lecture on 'Improved Onion cultivation Technology' in 66th Farmer Scientist forum programme organized virtually by Krishi Vigyan Kendra, Aurangabad on 01st September 2021.

Dr. Soumia P.S

- Attended International Conference on: "Vegetable Research and Innovations for Nutrition, Entrepreneurship and Environment" Organized at ICAR-Indian Institute of Vegetable Research, Varanasi, India from 14-16th Dec. 2021.
- Attended XIIth Annual Group Meeting of All India Network Research Project on Onion and Garlic organized by ICAR-DOGR, Pune during 12-13th October, 2021 at ICAR-DOGR Organized by ICAR-Directorate of Onion and Garlic Research, Pune.

Dr. Bhushan Bibwe

- Participated in one day Generic online training (29th April, 2021) in cyber security organized by Ministry of Electronics and Information Technology, GOI.
- Attended the International Webinar (29th May, 2021) on "Agricultural Entrepreneurships for Milenial Circles" organized by Kadiri University, Indonesia.
- Attended the Webinar (17th June 2021) on cold chain technologies, convergence and capacity building organized by ASSOCHAM, New Delhi, India.
- Participated and completed successfully AICTE Training and Learning (ATAL) Academy Online Elementary (29-06-2021 to 03-07-2021) FDP on "Non-Thermal

Processing of Food Products" organized by College of Food Processing Technology and BioEnergy. AAU, Anand, GJ.

Dr. Yogesh P. Khade

- Presented a Poster on "Molecular characterization of short-day onion genotypes by Intron Length Polymorphic (ILP) markers" authored by Salunkhe SR, Khade YP, Manjunatha Gowda DC, Shalaka RS, Mahajan V and Singh M. during International Conference on Vegetable Research Innovations for Nutrition, Entrepreneurship and Environment (ICVEG-21) on 14-16th December, 2021 at IIVR, Varanasi, Uttar Pradesh, India.
- Attended one day online webinar on 'Plant Tissue Culture techniques and Skill Development' organized by Dr. PDKV, Akola on 15.09.2021.
- Attended exhibition at ICAR-NIASM Baramati during "National Conference on Plant Physiology" organized by ICAR-NIASM and Indian Society for Plant Physiology during 9-11th Dec. 2021

P. Conferences/ Seminars/ Symposia and Workshops/ Group Meetings

Dr. Vijay Mahajan

- National level technical committee of term sheets, weather triggers and risk periods for crop notified under "RWBCIS" on 22.02.2021, organized by Ministry of Agril. & Farmers welfare, Dept. of Agrl. Coop. & Farmers Welfare, New Delhi.
- IMC meeting of NRCG, Pune online on 23.3.2021 being IMC member at NRCG, Pune vide email dated 13.3.2021 & F.No. NRCG/2(33)/IMC/2019- Estt. /3188 dt. 12.3.2021.
- IMC meeting ATARI, Pune on 4.03.2021 online being IMC member of ATARI, Pune vide F.No. Admin.2-12/ATARI-P/2017 dt. 22.02.2021.
- RAC member: 81th RAC meeting of NHRDF on 26.3.2021 at NHRDF, New Delhi
- Guest of Honour at KVK, Delhi on 26.3.2021 in training programme on use of energy efficiency in agriculture.
- 26th IRC meeting ICAR-DOGR on 12th July, 2021 and 17-18th Aug, 2021.
- 82nd Scientific Advisory Committee meeting of NHRDF held on 19.10.2021 at NHRDF, New Delhi.
- Launching new product meeting/programme on 22nd Nov. 2021 at Ritz-Calrton Hotel, Pune organized by Smartchem Tech. Ltd, Deepak Fertilizers and Petrochemicals Corporation Ltd., Pune
- National workshop Kharif Pyaz Ki Kheti Part-I, 20.5.2021, organized by KVK, Sardar Krishinagar, Dantiwada Aril. Univ, Sabarkantha, Gujrat.
- Election Officer, IJSC, ICAR-DOGR, held on 9.7.2021 vide F.No. 2-39/2015-16/I.J.S.C./DOGR/2021-22/396, dated 17.6.2021
- IMC meeting of ICAR-CPRI, Shimla as member on 17.8.2021 on virtual mode vide letter F.No. 07-18/2020/CAO (Vol. VI), dt. 9.7.2021.
- "Finalization of Breeder seed indent of Vegetable crops for *rabi* 2022-23" held online on 25.8.2021 organized by Asst. Seed. Commissioner (Seeds), DCA & FW, Min. of Agriculture and Farmers Welfare, New Delhi.
- Review meeting online to discuss VIP references, RTI, CP Gram portal, Swachhata, Azadi Ka Amirit Mahotsav" organized by DDH (Hort.), ICAR, New Delhi on 21 Oct., 2021.
- 9th Annual General Council meeting of CHAI held on 16.9.2021 at PJTSAU, Rajendranagar, Hyderabad, Telangana organized by CHAI, New Delhi.
- One day Brainstorming (Online) for researchers on "Onion & Garlic Improvement in Genomic Era" organized by ICAR-DOGR & ISA on 20.11.2021.
- MACP online meeting on 2.12.2021 of ICAR-DOGR Staff as Chairman, vide office order No. 2-56/2006/Estt./19/1774 dated 3.11.2021.
- Presented a poster in Virtual National Symposium on Sustainable Plant Health Management Amidst Covid Pandemic: Challenges and Strategies" organized by IPS (sz) and ICAR-CPCRI, Kasargod 01-03 Dec 2021.

Chairman/ Member in committees

- Chairman, DPC of Assistant-Assistant Administrative Officer, ICAR-DOGR on 28.5.2021 vide office order F.No. 2-59/2015-16/Estt/part-III/ 201 dated 25.5.2021.
- Expert member of selection board for promotion of Associate Professor and Assistant Professor at MPKV, Rahuri on 28th July, 2021 vide letter No. MPKV/Admn-A/128-3/2021, dated 12th July, 2021.
- Member "Celebrating@100 activities nominated by ICAR vide order F.No. 5-37/2021-Hort. Sci-I, dated 13.8.2021.
- Chairman "Celebrating@100 activities nominated by ICAR-DOGR vide order F.No. 2-98/ Circular (NF)/ Estt/ 20-21/ 976, dated 18.8.2021.
- Chairman, selection committee of YP-II under AINRPOG on 25, 26, 27 Aug., 2021 and 1, 2 and 3rd Sept., 2021 & 6-7 Sept., 2021 vide office order F.No. 2-62/AINRPOG/2020-21/Estt/YP(Recruitment)/ 992 dated 20.8.2021.
- Chairman, DPC for clearance of probation/ Confirmation of Admn. Staff, ICAR-DOGR 29.9.2021 vide letter No. 1-3/99/Estt-II/1357 dated 27.9.2021.
- Co-Chairman, Technical Session 2: Technological advancements in improving water productivity. On 17th Sept., 2021 at PJTSAU, Rajendra Nagar, Hyderabad in Global conference on "Innovative Approaches for enhancing water productivity in agriculture including Horticulture 16-19th Sept., 2021 organized by CHAI, New Delhi.
- Expert member, DPC for assessment of STA (T-4) & ST (T-2) for promotion on 27.9.2021 vide letter No. NIASM/2-59/2021/629, dated 21.9.2021.
- DDG Nominee for Assessment committee for career advancement of 11 ARS Scientist of NIASM, Baramati on 4.3.2022 vide ICAR letter F. No. NIASM/2-62/ 2021/1800 dated 17.2.2022 and F. No. NRM/ 22-4/ 2021-IA-II (Comp. No.158503) dated 5.10.2021.
- Member evaluation of Assessment of ICAR-DOGR, ARS Scientist under CAS of 11 scientist vide order F.No.2-37/2018/Estt/21/2212 dated 23.12.2021.
- Chairman, Financial upgradation of ICAR-DOGR staff under MACP vide office order No. 2-56/2006/Estt./19/1774 dated 3.11.2021.
- Nodal officer, Kisan Sarathi vide F.No. PME General/2020/2236 dt. 29.12.2021.

Dr. Amar Jeet Gupta

- Monitoring of intercropping experiment of onion variety 'Bhima Shakti' at ICAR-IISR, Lucknow from 5-6th Jan, 2021.
- Monitoring of DUS trials on onion and garlic at Division of Vegetable Science, ICAR-IARI, New Delhi
- Monitoring of onion breeder seed production four plots in Nandurbar, MH on 23rd March, 2021.
- Attended International Webinar on Exchange of PVP Post Control Measures organized by PPV&FRA, New Delhi on 8th April, 2021.
- Monitoring of *kharif* onion demonstrations conducted at selected tribal farmers under TSP at Ambegaon taluka near Bhima Shankar, on 3rd Aug, 2021.
- Monitoring of *kharif* onion demonstrations conducted at selected farmers' fields to promote onion production in unexploited areas of Mirzapur district of UP on 18th Sept, 2021.

- Participated in 12th Annual Group Meeting of AINRPOG held by ICAR-DOGR, Pune in virtual mode on 12-13th Oct, 2021.
- Monitoring of kharif onion demonstrations conducted at selected tribal farmers under TSP in Navapur taluka of Nandurbar on 28-30th Oct, 2021.
- Participation and presentation in Indian Horticulture Congress-2021 on Horticulture for Health, Livelihoods and Economy, Nov 18-21st 2021 organized by IAHS at CSAUAT, Kanpur on Nov 18-21st, 2021.
- Participation and presentation in International Conference on Vegetable Research and Innovations for Nutrition, Entrepreneurship and Environment (ICVEG-21) held on Dec 14-16th, 2021 at ICAR-IIVR, Varanasi.
- Monitoring of onion demonstrations conducted at selected farmers' fields of Mirzapur district of UP on 16th Dec, 2021.
- Expert for Kisan Sarathi Programme from ICAR-DOGR to provide domain specific advisories to KVK's/ Kisan Sarathi Programme w.e.f. 29.12.2021 on 29th Dec, 2021.
- Nominated as Member of Selection Committee for interview of the post of Senior Scientist and Head, Subject Matter Specialist-Agronomy, Programme Assistant (Computer) and Assistant in KVK, Pal (Jalgaon), 15-16th Jan, 2021.
- Nominated as Chairman of Monitoring Committee of onion breeder seed production plots at Peth, DOGR Kalus and Manjari Farms of DOGR varieties, 18th Feb, 2021.
- Monitoring of onion breeder seed production three plots at KVK, Jalna (MS) and visited BeejSheetal Seeds Pvt. Ltd., Jalna, 1st March, 2021.
- Monitoring of demonstrations on onion and garlic under TSP conducted at fields of tribal farmers in Nandurbar, 23-24th March, 2021.
- Act as Member of Expert Group for monitoring 'DUS Testing trials of garlic' at ICAR-DOGR, Pune constituted by PPV&FRA, New Delhi, 8th March, 2021.
- Act as Chairman of Selection/ Departmental Promotion Committee for selection of Asstt. Administrative Officer at ICAR-ATARI, Pune on 23rd Dec, 2021.

Dr. S.S. Gadge

- Attended DG, ICAR's meeting with scientists of ICAR institutes through virtual mode on 28th October 2021.

Dr. A Thangasamy

- Attended 12th Annual Workshop of AINRPOG Organized by ICAR-DOGR, Pune online during 12-13th October 2021.
- Attended International webinar on Soil Spectroscopy: An Emerging Technique for Rapid Soil Health Assessment organized by ICAR-Indian Institute of Soil Science, Bhopal & World Agroforestry (ICRAF), Nairobi on 01st October 2021.
- Attended International Webinar Conference (Virtual) on Alternate Cropping Systems for Climate Change and Resource Conservation ICAR-Indian Institute of Farming Systems Research, Modipuram, Meerut-250110 during 29th September to 1st October 2021
- Attended International conference on Vegetable Research and Innovations for Nutrition, Entrepreneurship and Environment (ICVEG-21) Indian Society of Vegetable Science, ICAR-IIVR, Varanasi during 14-16th December 2021.

Dr. V. Karuppaiah

- Poster presentation in Virtual National Symposium on Sustainable Plant Health Management Amidst Covid Pandemic: Challenges and Strategies" organized by IPS (sz) and ICAR-CPCRI, Kasargod 01-03rd Dec 2021.
- Attended Annual Workshop on Onion and Garlic (AINRPOG)- Online on 12-13th October, 2021, ICAR-Directorate oof Onion and Garlic Research, Pune, Maharashtra
- Attended International Conference on Vegetable Research and Innovations for Nutrition, Entrepreneurship and Environment (ICVEG-21) from 14-16th December, 2021, IIVR, Varanasi, Uttar Pradesh.

Dr. Rajiv B Kale

- Member of Inter-ministerial panel for Review of projects under operation green Scheme of Ministry of food processing and Industries, New Delhi.
- Expert member of the committee of consultative group meeting for registration of Geographical indication of Kanthaloor Vattavada Veluthulli / Garlic called by office of Geographical Indication registry Chennai at Kerala dated 17.12.2021
- Expert member of Bureau of Indian standards panel for developing Indian Standards for 'Supply Chain of Onions' during various meeting conducted in 2021
- Expert member of Bureau of Indian standards panel for developing Indian Standards for 'Warehouse management'
- External Expert Member in Advisory Committee of Agri-Business Incubation Centre of NRC-Grapes, Pune.
- Attended and delivered presentation on 'Controlled onion storage structure' during the meeting on Harvest and post-harvest management of onion under the chairmanship Joint secretory, (MIDH) DA and FW New Delhi on 17.12.2021
- Onion stakeholders meet on Agri export policy of Govt. of India on 8th June 2021 organized by APEDA, New Delhi
- Attended meeting on production of breeder seeds by SAU and ICAR institutes on 21.12.2021
- Attended Meeting on Onion and grapes cluster facilitation cell organized by MSAMB, Nashik office on 15.02.2021

Dr. Bhushan Bibwe

- Participated in meeting/ video conference (VC) for discussion on harvest and post-harvest management of onion on 07.12.2021 organized by Director (MIDH), Dept of Agri. & farmers Welfare, GOI.

Dr. Jayalakshmi K.

- Presented a poster in Virtual National Symposium on Sustainable Plant Health Management Amidst Covid Pandemic: Challenges and Strategies" organized by IPS (sz) and ICAR-CPCRI, Kasargod 01-03rd Dec 2021

Q. PERSONNEL

Retirement/ Superannuation, Promotion/ Assessment, New Joining

A. Retirement/ Superannuation

Sr. No.	Name	Designation	Date of Birth	Date of Superannuation
A	**Administrative Staff**			
1.	Shri. Prahalad Singh Tanwar	Asstt. Admin. Officer	10.05.1961	31/05/2021

B. Promotion /Assessment

Sr. No	Name and Designation	Pay Band and Grade Pay	Promoted post	Promoted Post -Pay Band and Grade Pay	Date of Promotion
A	**Administrative Staff**				
1.	Mrs. Mangala S. Salve, Assistant	PML-6	Assistant Admin. Officer	PML- 7	01.06.2021
B.	**Technical Staff**				
1.	Shri. Vishal Shivaji Gurav	PML-5	Sr. Technical Assistant	PML-6	16.01.2020

C. Transfer

Sr. No.	Name of Officer/ Official	Joining date at ICAR-DOGR, Pune	Transferred on	Transferred to
	A. Scientific			
1.	Dr. Kiran P. Bhagat, Scientist	26.05.2017	29.01.2021	ICAR-DFR, Pune
2.	Sri Kuldip, Scientist	10.04.2015	18.02.2021	ICAR-IISS, Mau
3.	Dr. Vishwanath R. Yalamalle, Scientist	23.04.2010	18.10.2021	ICAR-IARI, New Delhi
4.	Sri. Ashok Kumar, Scientist	08.10.2018	16.10.2021	ICAR-IARI, Jharkhand
5.	Dr. Sourav Ghosh, Scientist	15.04.2019	08.10.2021	ICAR-CRIJAF, Barrackpore
	B. Administrative			
1.	Mrs. Vijaya Amol Bhumkar	07.09.2009	09.11.2021	ICAR-DFR, Pune

C. Skilled Support Staff				
1.	Shri. Amol D. Fulsundar	13/12/2006	02.08.2021	ICAR-NRCG, Pune
2.	Shri Shivaji S. Gopale,	22.06.2007	02.08.2021	ICAR-NRCG, Pune

D. New Joining

Sr. No.	Name & Designation	PML & Basic	Date of appointment at ICAR-DOGR	Relived From
1.	Dr. Jayalakshmi K. (Plant Pathology)	PML-10, Basic Rs. 59,400/-	11.10.2021	ICAR-NBAIM, MAU

STAFF STRENGTH (As on 31.12.2021)

Category	Sanctioned Strength	In Position	Vacant
Scientific	22+1	17+1	05
Technical	10	10	00
Administration	15	06	09
Skilled Support Staff	11	08	03
Total:	**58+1**	**43+1**	**15**

Scientific Staff Strength (As on 31.12.2021)

Sr. No	Name of Discipline	Revised Cadre Strength							
		Scientist		Sr. Scientist		Pr. Scientist		Total	
		SS	IP	SS	IP	SS	IP	SS	IP
1.	Agricultural Biotechnology	1	0	1	1	0	0	2	1
2.	Agricultural Entomology	2	2	0	0	0	0	2	2
3.	Agricultural Extension	1	1	1	1	0	0	2	2
4.	Agricultural Structure and Process Engineering	2	2	0	0	0	0	2	2
5.	Agronomy	1	0	0	0	0	0	1	0
6.	Genetics and Plant Breeding	2	1	0	0	0	0	2	1
7.	Plant Biochemistry	1	0	0	0	0	0	1	0
8.	Plant Pathology	1	1	1	1	1	1	3	3
9.	Plant Physiology	1	1	0	0	0	0	1	1
10.	Seed Science and Technology	1	0	0	0	0	0	1	0
11.	Soil Science	1	1	0	0	0	0	1	1
12.	Vegetable Science	2	2	1	1	1	1	4	4
Total		**16**	**11**	**4**	**4**	**2**	**2**	**22**	**17**

Scientific Staff (As on 31.12.2021)

Sr. No.	Name	Designation
1.	Dr. Major Singh	Director
2.	Dr. V. Mahajan	Pr. Scientist
3.	Dr. Ram Dutta	Pr. Scientist
4.	Dr. A. J. Gupta	Pr. Scientist
5.	Dr. S. J. Gawande	Pr. Scientist
6.	Dr. S. Anandhan	Pr. Scientist
7.	Dr. S.S. Gadge	Sr. Scientist
8.	Dr. A. Thangasamy	Sr. Scientist
9.	Dr. V. Karuppaiah	Sr. Scientist
10.	Dr. Kalyani Gorrepati	Sr. Scientist
11.	Dr. R.B. Kale, Scientist	Sr. Scientist
12.	Mrs. Ashwini P. Benke	Scientist (SS)
13.	Dr. Pranjali A. Gedam	Scientist (SS)
14.	Dr. Manjunatha Gowda DC	Scientist (SS)
15.	Dr. Soumia P.S.	Scientist (SS)
16.	Dr. Bhushan Ratnakar Bibwe	Scientist (SS)
17.	Dr. Yogesh P. Khade	Scientist

Administrative Staff

Sr. No.	Name	Designation
1.	Sh. Amrendra Kishore	Administrative Officer
2.	Sh. Dilip B. Mundharikar	PS to Director
3.	Mrs. Mangala S. Salave	Assistant
4.	Mrs. Neha R. Gaikwad	Assistant
5.	Sh. Rajan K. Dedage	Upper Division Clerk
6.	Sh. Nilesh S. Warkar	Upper Division Clerk

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	Technical Officer
5.	Sh. D.M. Panchaal	Sr. Technical Assistant
6.	Sh. B. A. Dahale	Technical Assistant
7.	Sh. Vishal S. Gurav	Technical Assistant
8.	Sh. H.S. Gavali	Technical Assistant
9.	Sh. Ram Y. Bombale	Sr. Technician
10.	Mrs. Poonam V. Shelke	Sr. Technician

Skilled Supporting Staff

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

R. Financial Statement

FINANCIAL STATEMENT 2020-21		
ICAR-DOGR, PUNE (₹in Lakhs)		
BUDGET HEAD	**BUDGET 2020-21**	**EXPENDITURE 2020-21**
SALARY	650.38	631.84
PENSION	25.85	7.31
TOTAL (A)	**676.23**	**639.15**
CAPITAL	20.00	20.00
GENERAL	450.00	299.97
NETWORK PROJECT	-	150.03
NEH - CAPITAL	2.80	2.80
NEH - GENERAL	80.00	80.00
TSP - GENERAL	27.08	25.96
SCSP - CAPITAL	10.00	6.89
SCSP - GENERAL	51.54	44.82
TOTAL (B)	**641.42**	**630.47**
GRAND TOTAL (A+B)	**1317.65**	**1269.62**

FINANCIAL STATEMENT 2020-21	
REVENUE GENERATION	**AMOUNT (₹*in* Lakhs)**
SALE OF FARM PRODUCE	02.52
SALE OF PUBLICATION	00.06
LICENSING FEES	03.13
ANALYATICAL TESTING FEES	01.20
PROFIT FROM RFS	35.16
INTEREST FROM TDR	04.22
OTHER INCOME	04.25
TOTAL	**50.54**

S. Meteorological Data

Meteorological data for Jan -Dec 2021

Month	Maximum Temp (°C)	Maximum Temp (°C)	Relative humidity 8 am (%)	Relative humidity 2.30 pm (%)	Wind Velocity (mm)	Sunshine Hour (h)	Rainfall (mm)	Evaporation rate (mm)
January	28.7	13.0	80.6	56.7	2.95	7.01	0.0	3.91
February	31.4	12.6	75.6	54.6	2.61	8.34	0.0	3.85
March	35.5	15.2	65.0	49.5	2.87	8.01	0.0	4.97
April	37.5	17.8	68.1	48.5	4.26	8.34	0.0	5.16
May	34.9	19.9	79.0	56.9	6.99	7.18	67.6	4.70
June	28.6	19.3	86.6	74.0	6.88	5.12	207.2	3.13
July	28.8	20.5	86.6	79.1	8.21	3.40	120.8	2.63
August	28.5	21.3	87.5	77.7	6.77	4.26	6.0	1.76
September	28.6	23.6	87.8	75.7	5.53	2.69	132.2	1.17
October	31.6	21.0	81.7	67.0	3.11	6.52	95.0	2.14
November	30.2	14.8	75.5	60.8	3.62	6.35	11.0	3.23
December	27.9	10.5	83.0	63.0	2.13	6.26	67.0	2.52

हर कदम, हर डगर

किसानों का हमसफर

भारतीय कृषि अनुसंधान परिषद

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