भाकृ अनुप
ICAR

वार्षिक रिपोर्ट
Annual Report
2015-16

(ISO - 9001:2008 Certified Institute)

भा.कृ.अनु.प.– राष्ट्रीय अनार अनुसंधान केन्द्र
ICAR-National Research Centre on Pomegranate
(भारतीय कृषि अनुसंधान परिषद)
(Indian Council of Agricultural Research)
सोलापुर – 413 255
Solapur - 413 255

Printed: June 2016

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Scientist (Agrl. Structures & Process Engineering)

D.T. Meshram
Senior Scientist (Land and Water Management Engineering)

Summary in Hindi
N.V. Singh
Scientist (Hort.- Fruit Science)

Correct citation**:** ICAR- NRCP Annual Report 2015-16, ICAR- National Research Centre on Pomegranate, Solapur- 413 255, Maharashtra

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Published by the Director, ICAR-NRC on Pomegranate, Solapur- 413 255 and
Printed at Omkar Graphics, Parbhani Ph.02452-229977, E-mail: omkarpbn@gmail.com

वार्षिक प्रतिवेदन

Annual Report

2015-16

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PREFACE

ICAR-National Research Centre on Pomegranate (ICAR-NRCP) was established at Solapur, Maharashtra in 2005 by the Indian Council of Agricultural Research (ICAR), New Delhi to augment the production, productivity and utilization of pomegranate through basic, strategic and applied research. In the recent past, India witnessed a quantum jump in production and export and became the world leader in area and production of pomegranate. Due to its highest return on investment, pomegranate has become the means of livelihood security to many farmers dwelling in dryland regions of India in general and Maharashtra, Karnataka, Gujarat and Telangana states in particular.

In 2014-15, the area under pomegranate has increased sizably from 1.31 lakh ha to 1.81 lakh ha whereas the production from 13.45 lakh tonnes to 17.89 lakh tonnes. The area under pomegranate in Maharashtra state alone has increased from 90,000 ha to 1,28,650 ha due to awareness on various horticultural technologies supported by organized marketing.

ICAR-NRCP has standardized a protocol for extraction of virgin seed oil from pomegranate and a patent has been filed. Protocol was also standardized for minimal processing of pomegranate arils. Some of the new initiatives taken up are: Mera Gaon Mera Gaurav; m-Kisan; interactive touch screen kiosk in Marathi, Hindi and English language; new experiment on organic cultivation of pomegranate; Pilot plant for processing and total utilization; Layout of 9.9 km long lift irrigation system; Construction of 43 bed trainees hostel; Preparation of triggers for crop insurance of pomegranate, production of video film on ICAR-NRCP profile; analysis of soils for development of soil health cards. Besides in-house research projects, the ICAR-NRCP attracted extramural funding of ICAR for three additional research projects. Similarly ICAR-NRCP was also successful in obtaining research fund from NHB.

The scientists were deputed for training in various research institutes to strengthen the HRD activities and capacity building. During this year, ICAR-NRCP organized an one day national workshop on "Fruit cracking and soil health management" on 03.10.2015 under the chairmanship of Dr. N.K. Krishna Kumar, DDG (HS). A review meeting on the progress made under Flagship project in various coordinating centres was organized.

During the period under report, technologies viz. "Biohardening of *in-vitro* raised pomegranate plants" (M/s. HU Gugale Agrobiotech Company, Jamkhed, Ahmednagar) and "Processing of pomegranate juice and ready to serve beverage" (M/s. Bhauraya Distributors, Madha colony, Jule Solapur) were commercialized. Besides, MoU was signed with M/s. Bhauraya Distributors, Madha colony, Jule Solapur, Solapur for usage of ICAR-NRCP pilot plant as technology incubatee as a part of EDP and skill development programme of the centre.

I wish to place on record my sincere gratitude to Dr. T. Mohapatra, Secretary, DARE and Director General, ICAR for providing the opportunity to render my best service. I express my heartfelt thanks to Dr. N.K. Krishna Kumar, DDG (HS) and Dr. T. Janakiram, ADG (HS) for their unwavering support and constant guidance. My sincere gratitude to all the staff members of SMD (HS) for their kind cooperation and support rendered to this centre. Thanks are also due to Dr. C.D. Mayee, former Chairman, ASRB and Chairman, RAC for taking keen interest in the overall development of the institute. Last but not least, I'm thankful to all the scientific, technical, administrative and supporting staff of the institute for their whole-hearted support and cooperation.

June 30, 2016
Solapur

(R.K. Pal)
Director

ICAR - NRCP : AN INTRODUCTION

Pomegranate (*Punica granatum* L.) is an important fruit crop of arid and semiarid regions of the world. India is one of the leading producers of pomegranate in the world. In 2014-15, the annual increment in area under cultivation of pomegranate has strikingly gone up by 38.16 per cent compared to 2013-14. In India, it is cultivated over 1.81 lakh ha with an annual production of 17.89 lakh tonnes and average productivity of 9.88 tonnes/ha.

Maharashtra state experienced a very rapid growth in pomegranate area during the last 2 decades from 4,600 ha to 1,28,650 ha and accounts for 71.21 per cent of the total cultivated area under pomegranate in the country. Maharashtra is the leading producer of pomegranate in India followed by Karnataka, Gujarat and Andhra Pradesh. In recent past, pomegranate cultivation has been gaining momentum in Rajasthan, Orissa, Chhattisgarh, Uttarakhand, Madhya Pradesh, Himachal Pradesh and Tamil Nadu.

ICAR-National Research Centre on Pomegranate was established at Solapur, Maharashtra during the year 2005 by the Indian Council of Agricultural Research (ICAR), New Delhi with the focus of augmenting the production, productivity and utilization of pomegranate through basic, strategic and applied research. The centre has been functioning at Kegaon, Solapur in its newly built office- cum-laboratory building since 7th July 2013.

The experimental farms sprawl over 46.26 ha area at Kegaon and Hiraj villages with a pomegranate plantation area of 13 ha. Hi-tech polyhouses erected in the farm facilitate the R&D work on mass multiplication of elite, disease free planting material produced through tissue culture and screening of germplasm for bacterial blight tolerance. Protected cultivation of pomegranate was started inside the insect proof shade net houses. The experimental farms were equipped with the state-of-the-art automatic fertigation facilities and water harvesting structures. The national repository of pomegranate at ICAR-NRCP has 304 germplasm in the Field Gene Banks (FGBs). This includes 210 Indigenous Collections covering indignous wild collections from North Eastern states and western Himalayas, cultivated and local types besides 94 exotic collections from California, Afghanistan and Iran.

The major thrust areas of pomegranate research at ICAR-NRCP, Solapur covers crop improvement, crop production, crop protection and post harvest technology. The mandates of the centre are as follows.

- Basic, strategic and applied research on genetic resource management, crop improvement, production and protection technology for enhanced and sustained productivity of pomegranate.
- Transfer of technology and capacity building of stakeholders for enhancing and sustaining productivity of pomegranate.

ICAR-NRC on Pomegranate has made outstanding achievements in identification of causal organism for bacterial blight and developed an Integrated Disease and Insect Pest Management (IDIPM) schedule for management of insect pests and diseases affecting pomegranate. Bacterial blight in pomegranate has been the major impediment in the cultivatoion of pomegranate in India. In view of non availability of resistant sources for this dreaded disease, scientific sound management system and community approach are the important steps for mitigation of this challenge.

In this context, a video film was developed by ICAR-NRCP in three languages (English, Hindi, Marathi) for creating awareness on management of bacterial blight. An Android based mobile application, developed by ICAR-NRCP contains the basic information on pomegranate in three languages i.e. Hindi, Marathi and English for the benefit of pomegranate growers. In 2013, ICAR-NRCP Solapur was granted ISO 9001-2008 Certification. Interactive

touch screen kiosk in Marathi, Hindi and English language was installed in ICAR-NRCP during this year.

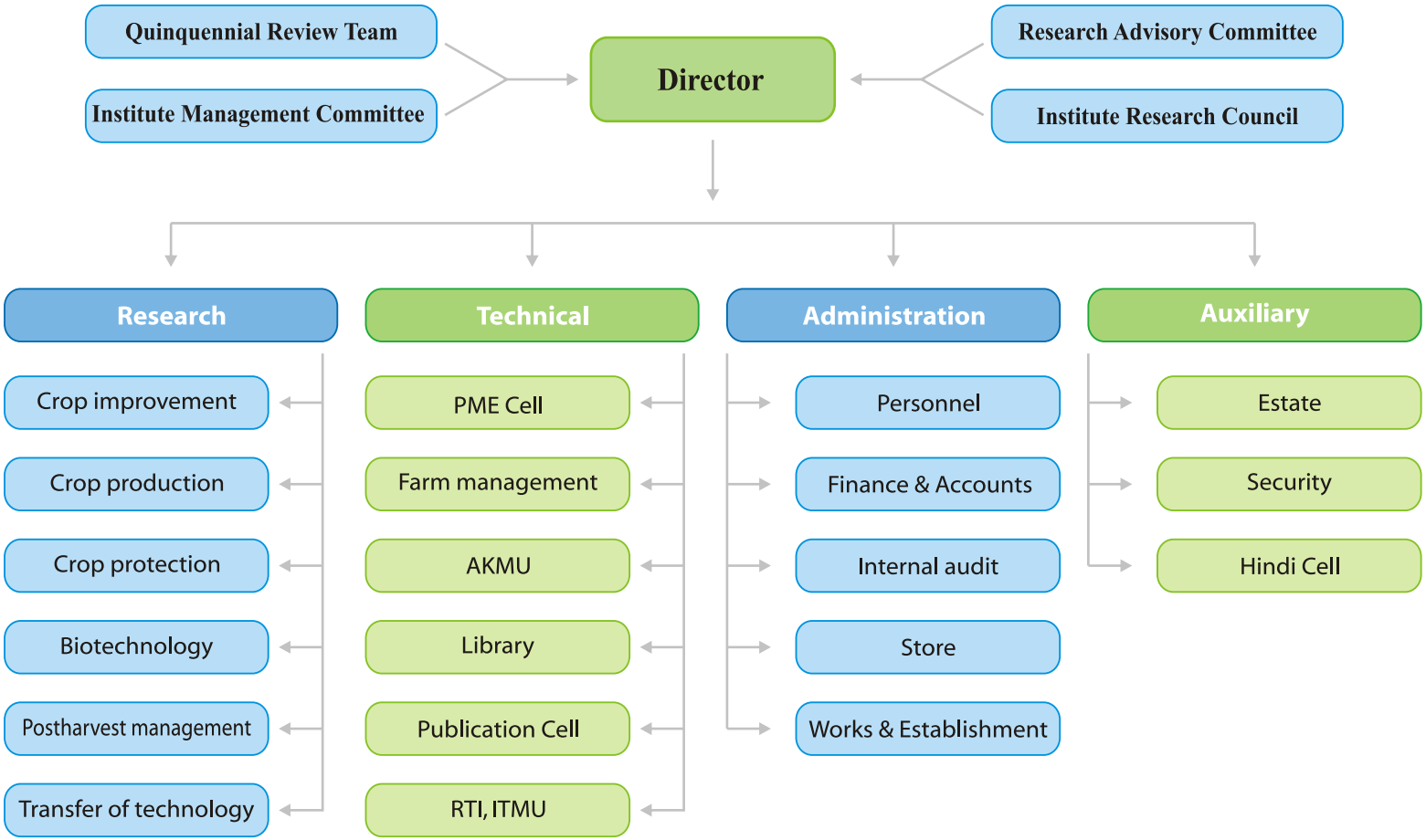
The low cost technology for production of disease free planting material through hardwood cuttings with 85% success has been standardized and commercialized. Protocol has been standardized for *in-vitro* propagation of pomegranate cv. Bhagwa along with bio-hardening and commercialized. Besides, the technology for preparation of RTS beverage from pomegranate juice has been commercialized. The protocol for extraction of virgin seed oil from pomegranate seeds has been standardized and a patent has been filed. The research team has identified potential endophytes and SSR markers linked with tolerance to bacterial blight. Crop insurance triggers of pomegranate have been prepared. A Hindi bulletin on 'Anar: Utpadan, Vipnanavem Upyogita' was published by ICAR-NRCP during this year for the benefit of pomegranate growers. Some of the new initiatives include: Mera Gaon Mera Gaurav, m-Kisan; Pilot plant for processing and total utilization, layout of 11km long lift irrigation system; Construction of 43 bed trainees hostel; analysis of soils for development of soil health cards.

ICAR-NRC on Pomegranate has been equipped with the state of the art facilities, laboratories and farms to carry out research on production, plant protection, crop improvement, and post harvest technologies of pomegranate. Many sophisticated equipments viz. PCR, Dry ashing system, MAP system, walk-in cold rooms, cabinet driers, grinding mill, color difference meter, cold press for seed oil extraction, food texture analyzer, high resolution microscopes, AAS, Photosynthetic apparatus etc. have been procured for various research activities. The ICAR-NRCP is regularly imparting both onsite and off-site trainings on various aspects of pomegranate cultivation. Apart from in-house research activities, the ICAR-NRCP also has various outreach programmes. ICAR-NRCP has attracted extramural funding of ICAR for three additional research projects. Similarly, ICAR-NRCP was also successful in obtaining research fund from NHB.

The institute is closely associated with All India Pomegranate Growers' and Research Association besides Maharashtra Pomegranate Growers' and Research Association, State Department of Horticulture, State Agricultural Universities, KVKs and other stakeholders associated with pomegranate cultivation. To cater the needs of a large number of farmers visiting the centre, a touch screen kiosk has been procured for demonstration of scientific management practices. The website of ICAR-NRCP designed as per the uniformity guidelines of ICAR offers the regular and timely update of weather, farmers' alert and important events etc besides freely downloadable publications for farmers and researchers.

A Society for Advancement of Research on Pomegranate (SARP) was registered by Director, ICAR-NRCP as its founder President with its HQ at ICAR-NRCP, Solapur. In 2015, ICAR-NRCP, Solapur has renewed ISO 9001-2008 Certification license granted for its high standard research and management activities. During this year, the Society (SARP) along with ICAR-NRCP has jointly organized a National Workshop on Fruit cracking and soil health management in pomegranate at ICAR-NRCP, Solapur.

Oraganizational Setup of ICAR-NRC on Pomegranate



कार्यकारी सारांश

भा.कृ.अनु.प.- राष्ट्रीय अनार अनुसंधान केन्द्र, सोलापुर में दस वैज्ञानिक, छह तकनिकी, पाँच प्रशासनिक एवं दो सहायक कर्मचारी हैं, यहाँ पर आठ प्रयोगशालाऐ और शोध प्रक्षेत्र भी हैं जो केगाँव एवं हिरज में स्थित है। वर्ष 2015-16 के दौरान विभिन्न शोध, प्रसार तथा अन्य गतिविधियों का विवरण निम्नलिखित है।

भा.कृ.अनु.प. - रा.अ.अनु.कें. के प्रक्षेत्र जीन कोष में कुल तीन सौ चार जनन द्रव्य (210 देशी जंगली / खेतीयोग्य / लोकल टाइप्स एवं 94 विदेशी जनन द्रव्य) हैं। इनके अलावा संयुक्त राज्य अमरीका, कृषी विभाग के 71 कठोर काष्ठ कर्तनों को भा.कृ.अन.प. - भा.बा.अनु.सं. के सौजन्य से इस वर्ष संग्रहीत किया गया है। छब्बीस जननद्रव्यों का 22 मात्रात्मक लक्षणों के लिए मृग बहार में चरित्र चित्रण भी किया गया है।

जंगली जननद्रव्यों में विचरण गुणांक (प्रतिशत) 18 बहुजीनिक लक्षणों के लिए प्रेक्षित किया गया। फल वजन (ग्रा.), फल व्यास (मि.मी.), फल लंबाई (से.मी.), क्राऊन लंबाई (मि.मी.) सौ दानों का वजन (ग्रा.) दाना लंबाई (मि.मी.), दाना चौड़ाई (मि.मी.) दाना प्रतिशत (%), छिलका प्रतिशत (%) एवं छिलका मोटाई जैसे मापदण्डो की उन्नति हेतु जंगली प्रकार जैसे आई सी - 318753, आई सी - 318720, आई सी - 318705, आई सी - 318779 एवं आई सी - 318740 के औसत मूल्य सबसे अधिक पाये गए तथा ये सभी भविष्य में इस्तेमाल में लाए जा सकता हैं। सातवें वर्ष में सात व्यवसायिक किस्मों के मूल्यांकन में सबसे अधिक उपज जी-137 (29.64 कि.ग्रा./पौधा) तथा उसके बाद गणेश (27.82 कि.ग्रा./ पौधा) में पाया गया हैं।

रा.अ.अनु.कें. संकरों नामत: एन आर सी पी - एच-6 एवं एन आर सी पी - एच-14 ताजा खाने के लिए तथा एन आर सी पी एच-4 एवं एन आर सी पी एच-12 की प्रसंस्करण हेतु पहचान की गई है।

सत्रह एसएसआर चिन्हकों के इस्तेमाल से 20 जननद्रव्यों के आनुवांशिक भिन्नता विश्लेषण में प्रेक्षित विषमयुक्त 0.12 - 0.50 के बीच पायी गई। डार्विन (DARWIN) साफ्टवेयर की मदद से स्कोरड डेटा के आधार पर इन जननद्रव्यों के प्रतिवृत्तविज्ञान संबंधन में सबसे अधिक अनुवांशिक असमानता (0.44) आई सी - 318733, ज्योति एवं जोधपुर संग्रहों के बीच पायी गई है।

कुल प्ररोहीवर्धमान तापमान दिवस (ग्रोईंग डिग्री डेज़) दस जननद्रव्यों (4 किस्म तथा 6 स्थानीय संग्रहीत जननद्रव्य) का 2390.30 से 3575.10^0 दि., पतझड़ से तुड़ाई के बीच पाया गया । जीडीडी पुष्पन के दौरान 932.80 - 1753.20^0 दि. तथा फलन के दौरान 284.90 - 903.50^{0}दि. के बीच पाया गया। फोटो थर्मल सूचकांक एवं ऊष्मा उपयोग दक्षता क्रमश: 18.20 - 19.90^{0}दि. एवं 0.70 - 8.9 ट/हे./डिग्री पायी गई।

सौ जननद्रव्यों के जाँच के दौरान 8 ब्लाईट विमुक्त, 46 कलेटोट्रायकम फल सड़न विमुक्त, 25 कलेटोट्रायकम एन्थ्रैक्नोज विमुक्त, 24 स्पेसीलोमा विमुक्त एवं कोई भी थ्रिप्स विमुक्त नहीं पाया गया था।

विभिन्न तरीकों से प्रवर्धित पौधों पर उपजे फलों के मात्रात्मक एवं गुणात्मक लक्षणों के मूल्यांकन से यह निष्कर्ष निकला की इन फलों में छिलका मोटाई, दाने से छिलके का अनुपात एवं कर्यिकी वजन हानी में कोई भी सार्थक अंतर नहीं था। इन सीटू दृढ़ काष्ठ कर्तन के द्वारा पौधों को उगाने की विधि का मनकीकरण किया गया है। मूलवृन्त आईसी - 318707 में अधिक लवणता स्थिती में सिर्फ 1.57% जैव भार की हानी हुई जबकी भगवा मे यह हानी 24.1% थी, अत: आईसी - 318707 प्राथमिक परिक्षण में लवण सहिष्णु पाया गया है।

बावन जननद्रव्यों के बीजू पौधों की दो महीनों की जांच में आईसी - 318712 एवं आईसी - 318735 के एक-एक पौधे ब्लाईट विमुक्त पाये गए जब की क्रमश : 9 एवं 16 पौधे इन जननद्रव्यों के प्रतिरोधक / सहिष्णु (10% के कम) पाये गए। अत: इन पौधों की पुन: जाँच के बाद इन्हे प्रजनन कार्यक्रम के अंतर्गत लाया जा सकता है।

आई सी - 318712 एवं 318735 के बीजू पौधों की जाँच से ब्लाईट विमुक्त पौधों की पहचान हुई। छ: गमा विकर्णीत पौधे, 42 जननद्रव्य, दो दारू के एक्सेसन्स एवं दारू-17 का पौधा ब्लाईट प्रतिरोधि/सहिष्णु पाया गया जिसमें क्रमश: 5 एवं 7% ब्लाईट आपतन चैलेंज इनाकुलेशन के उपरान्त पाया गया था।

जींक सल्फेट 0.3% के चार छिड़काव, दो छिड़काव पुष्पन के पहले और दो छिड़काव पुष्पन के बाद 30 दिनों के अंतराल पर अनार मे जींक परिपूर्णता पूर्ण करने में सबसे प्रभावशाली एवं सस्ते पाये गए। इसके फलस्वरूप

उपज, गुण (कुल घुलनशील ठोस, रस प्रतिशत, फ़िनाल, एस्कार्बिक असिड, एंथोसायनिन, इत्यादि) और जींक की मात्र फल में बढ़ी हुई पायी गई।

परिणाम यह दर्शाते हैं की अनार में अधिक अम्लता वाली मृदा पर ज्यादा बैक्टेरियल ब्लाईट आने का कारण पत्तीयों में मैग्नेसियम, कैल्सियम, मैंग्नीज और कॉपर की कमी तथा नत्रजन की अधिकता है। पौधों में ब्लाईट के प्रति मध्यम प्रतिरोध के लिए पोषक तत्वों की परिपूर्णता की सीमा 1.56 - 2.05%, 0.11 - 0.28%, 0.83- 1.20%, 1.6 - 2.16 %, 0.38 - 0.82%, 0.09 - 0.16% क्रमश: नत्रजन, फास्फेट, पोटैश, कैल्सियम, मैग्नेसियम एवं गंधक के लिए तथा 132.50 - 187.00, 31.60 - 58.40, 13.20 - 27.40 तथा 26.00 - 47.30 मि.ग्रा. / कि.ग्रा. क्रमश: लौह, मैंग्नीज, जींक तथा कॉपर के लिए होनी चाहिए।

नत्रजन तथा सेलिसायलीक एसिड का उचित मात्रा में उपयोग अनार में प्रतिरक्षा प्रणाली को बढ़ाकर ब्लाईट संक्रामण को घटाता है, इनकी सहक्रियाशीलता से नाइट्रेट रिडक्टेज एवं अन्य ओक्सीकरणरोधी तथा पौधों में खनिज पोषक तत्वों की मात्रा में बढ़ोत्तरी पायी गई। क्योंकि पत्ती में नत्रजन की मात्रा का घनिष्ठ संबंध पोर्टेबल क्लोरोफिल मीटर की रीडिंग से हैं, अत: इसके इस्तेमाल से हम पौधे में नत्रजन की मात्रा की निगरानी तथा ब्लाईट प्रबंधन कर सकते हैं, जिससे पर्यावरण के अनुकूल तरीके से ब्लाईट प्रबंधन किया जा सकता है।

विभिन्न सूक्ष्म सिंचाई प्रणाली की प्रभावकारिता की तुलना एवं मूल्यांकन उपसतहीय बूँद सिंचन से किया गया। विभिन्न सूक्ष्म सिंचन प्रणालियों में से दो लैटरल इन लाइन ठिबकों वाले उपसतहीय बूंद सिंचन को जल उपयोग दक्षता में सबसे बेहतर पाया गया। जैविक पलवार (गेहूँ, सूरजमुखी, गन्ने का बगास) तथा अजैविक पलवार (काला, चाँदनी एवं काला तथा हवादार पलवार) की प्रभावकारिता का मूल्यांकन सिंचाई जरूरत के लिए किया गया। गन्ने का बगास वाला पलवार सबसे बेहतर पाया गया। बाकि पलवारों की तुलना में जैविक पलवार वाले पौधों पर अधिक पुष्पन एवं फल प्राप्त हुए।

हस्त बहार में ईथरल 250 पीपीएम के छिड़काव से उभयलिंगी पुष्प (168.66 पुष्प / पौधा) बिना छिड़काव वाले पौधों (122.33 पुष्प / पौधा) से अधिक पाया गया।

अनार में प्रारंभिक मूल्यांकन में विभिन्न कटाई पद्धति के अंतर्गत फलस्थापन में कोई भी सार्थक अंतर एक, दो तथा तीन तना कटाई पद्धति में नहीं पाया गया। सर्वाधिक कक्षीय पुष्पन (70.40%) चार तना कटाई में पाया गया। जबकि अन्य कटाई पद्धतियों में अंतस्थकली पुष्पन (30.90 - 40.54%) ज्यादा पाया गया।

अर्धकत्रिम आहार पर फल भेदक के डिंभकों के सेवन के उपरांत तितलियों के सेमियोकेमिकल अध्ययन से मिथाइल ईस्टर आधारित फिरोमोन की पहचान हुई। फल चूषी शलभ के डिंभको को चार महीनों तक प्रयोगशाला परिस्थितियों में गुड़बेल पर रखा गया, इसका जीवनचक्र औसतन 30-33 दिनों के बीच पाया गया।

सबसे कम ब्लाईट आपतन तथा सबसे प्रभावशाली स्यूडोमोनास प्युटिडा (यूएचएसपीएस 16 और यूएचएसपीएस 11) तथा बैसिलस सबटिलिस पाए गए।

विभिन्न जैव संसाधनों में से गोमूत्र (5%) प्रक्षेत्र में बैक्टीरियल रोकने मे सबसे प्रभावशाली पाया गया।

महाराष्ट्र मे 3-7 दिनों में बैक्टीरियल ब्लाईट के अत्यधिक संक्रमण के मुख्य कारक तापमान सीमा 25-35^{0}से. के साथ 50% से अधिक सापेक्षिक आर्द्रता 10-16 घंटो के लिए पाए गए। अत: इन करकों की पहचान अनार में बैक्टीरियल ब्लाईट के पूर्वानुमान निदर्श के विकास के घटकों के रूप मे किया गया है।

बारह फफुदनाशी तथा 1 व्यावसायिक रसायनो में से प्रक्षेत्र परीक्षण मे एजोक्सिट्रोबिन 1 मि ली / ली की दर से फंफूद संक्रमण वाले फल सड़न को पूरी तरह से रोकने मे प्रभावी पाया गया।

अनार के बीज से अक्षत तेल निकालने की विधि का मानकीकरण किया गया तथा भा.कृ.अनु.प. - रा.अ. अनु.कें., सोलापुर ने इसके लिए पेटेंट भी दाखिल किया है। अनार के दानों के न्यूनतम प्रसंस्करण की विधि का भी मानकीकरण किया गया है।

इस केंद्र के वैज्ञानिक विभिन्न अनुसंधान संस्थानों में प्रशिक्षण हेतु गये ताकि मानव संसाधन विकास तथा क्षमता निर्माण को मज़बूती मिले। 2015-16 में भा.कृ.अनु.प. - रा.अ. अनु.कें. एवं सार्प, सोलापुर ने साझा तौर पर फलफटाव तथा मृदा स्वास्थ्य प्रबंधन पर एक दिवसीय राष्ट्रीय कार्यशाला का आयोजन दिनांक 3/10/2015 को उपमहानिदेशक (बा.वि.), डॉ. एन.के. कृष्णकुमार कि अध्यक्षता में किया था। विभिन्न

संस्थानो के आमंत्रित वक्ताओं ने फल फटाव एवं मृदा स्वास्थ्य प्रबंधन पर वाचन किया। फ्लैगशिप परियोजना के प्रगती की समीक्षा हेतु भा.कृ.अनु.प. - रा.अ.अनु.कें., सोलापुर ने सभी सहयोगी केन्द्रों की एक बैठक बुलाई थी।

वित्तीय वर्ष के दौरान सूक्ष्म प्रवर्धित पौधों के जैवकठोरीकरण की तकनीक को एम/एस एचयू गुगले एग्रोबायोटिक कंपनी, जामखेड़, अहमदनगर तथा अनार के रस का प्रसंस्करण तथा पीने के लिए तैयार पेय पदार्थ की तकनीक को एम/एस बहुराया डिस्ट्रीब्यूटर्स, जुले सोलापुर को हस्तांतरित किया गया तथा इनका व्यवसायिकरण हुआ। इसके अलावा एम/एस बहुराया डिस्ट्रीब्यूटर्स, माढ़ा कालोनी, जुले सोलापुर के साथ भा.कृ.अनु.प. - रा.अ. अनु.कें., सोलापुर के पायलट प्लांट को इंक्यूबेटी प्रशिक्षु के तौर पर उद्यमिता एवं कौशल विकास के अंतर्गत इस्तेमाल करने हेतु समझौता ज्ञापन पर हस्ताक्षर भी हुआ है।

मेरा गाँव मेरा गौरव, मोबाइल किसान, स्वच्छ भारत अभियान एवं इंटरेक्टिव टच स्क्रीन कियोस्क (मराठी, हिन्दी एवं अँग्रेजी), जैविक खेती पर अनार में प्रयोग, अनार में प्रसंस्करण एवं कुल उपयोग के लिए प्रायोगिक संयंत्र (पायलट प्लांट), 9.9 कि.मी. लम्बी उद्वहन सिंचन पद्धति बिछाना, तिरालिस पलंग वाले प्रशिक्षणार्थी छात्रावास का निर्माण, अनार में फसल बीमा के लिए प्रारंभिक मसौदा तैयार करना, भा.कृ.अनु.प. - रा.अ.अनु.कें., सोलापुर के प्रोफाइल पर चलचित्र का निर्माण, मृदा स्वास्थ्य कार्ड के लिए मृदा का विश्लेषण, विगत वित्तीय वर्ष के कुद्द नए पहल हैं। संस्थागत परियोजनाओं के अलावा, भा.कृ.अनु.प. - रा.अ.अनु. कें., सोलापूर ने भा.कृ.अनु.प. द्वारा वित्त पोषित बाह्य परियोजनाओं को आकर्षित किया तथा राष्ट्रीय बागवानी बोर्ड से भी एक परियोजना प्राप्त की है।

EXECUTIVE SUMMARY

ICAR-National Research Centre on Pomegranate (ICAR-NRCP), Solapur is having 10 scientific, six technical and five administrative and two supporting staff besides eight research laboratories and research farms located at Kegaon and Hiraj villages. The various research, extension and other activities undertaken during the year 2015-16 are summarized below.

In total, three hundred and four germplasm (210 - indigenous wild/cultivated/local types and 94 were exotic collections) have been maintained in the Field Gene Banks (FGB) of ICAR-NRCP. Besides, cuttings of 71 accessions of United States Department of Agriculture (USDA), USA have been collected from IIHR, Bengaluru this year and maintained. Twenty six pomegranate accessions were characterized for 22 quantitative traits in *Mrig* bahar.

In wild accessions, a higher CV (%) value was observed for 18 polygenic characters, while for seven traits in cultivated types. For improving fruit weight (g), fruit diameter, fruit length (cm), crown length (mm), 100 arils weight (g), aril length (mm), aril width (mm), aril recovery %, and rind thickness (mm), the wild types like IC-318753, IC-318720, IC-318705 IC-318779, IC-318740 were found to be promising ones. Evaluation of seven commercial cultivars during seventh year revealed that fruit yield was highest in G-137 (29.64kg/plant) followed by Ganesh (27.82kg/plant).

NRCP hybrids viz., NRCP H-6 and NRCP H-14 were identified for table purpose and NRCP H-4 and NRCP H-12 were identified for processing purpose.

The genetic diversity analysis among 20 genotypes using 17 SSR markers recorded an observed heterozygosity value between 0.12 to 0.50. The phylogenetic relationship among the selected germplasm from the scored data through DARWIN software recorded maximum genetic dissimilarity (0.44) between 'IC-318733' and 'Jyoti', 'IC- 318733' and 'Jodhpur collection.

Total growing degree days (GDD) accumulations of 10 genotypes (4 varieties and 6 indigenous collection) ranged from 2390.30 to 3575.10 ^{0}D from defoliation to harvesting period. The GDD ranged from 932.80 to 1753.20 ^{0}D at flowering stage and 284.90 to 903.50 ^{0}D at reproductive stage. The GDD was highest (3575.10 ^{0}D) in Bhagwa whereas it was lowest in IC-318707 (2390.20^{0}D). Photo-thermal index (PTI) and heat use efficiency (HUE) ranged from 18.20 to 19.9 ^{0}D/day and 0.70 to 73.60 tonnes ha^{-1}degree^{-1}, respectively.

Eight out of 100 germplasm were found free from bacterial blight besides 46 from *Colletotrichum* fruit rot, 25 from *Colletotrichum* anthracnose, 24 from *Sphaceloma* scab in FGB during *Mrig* bahar. However, none of the germplasm was found free from infestation by thrips.

The qualitative and quantitative evaluation of fruits harvested from plants raised through tissue culture, air layering and hard wood cuttings did not show any significant variation in rind thickness, aril to rind ratio and physiological loss in weight. The method of raising pomegranate plants through *in situ* hard wood cutting has been standardized. Rootstock IC- 318707 was found to be tolerant to salinity compared to Bhagwa.

Screening of seedling population of 52 germplasm for two months showed that one seedling each of IC-318712 and IC-318735 was free from BB whereas 9 and 16 seedlings of these accessions recorded resistant/ tolerant reaction (less than 10 %) to BB. Two seedlings were found free from bacterial blight disease.

Screening of seedling population of IC-318712 and IC-318735 led to the identification of progeny free from bacterial blight disease. Among 6 accessions of gamma irradiated population, 42 germplasm accessions and 2 accessions of Daru, Daru-1 (5%) and Daru-17 (7%) had low incidence of BB under challenge inoculation.

Foliar application of $ZnSO_4.7H_2O$ @ 0.3% four times viz. two sprays before flower bud initiation and rest two after fruit set at 30 days interval was found to be most effective and economical for supplementing Zn to the pomegranate plant. This resulted in significant increase in fruit yield, improvement in quality (TSS, Juice per cent, phenol, ascorbic acid, anthocyanin etc.) and enhancement in Zn content in the arils.

The results demonstrated that higher bacterial blight disease severity in pomegranate plant grown on soil having high pH was mainly due to low concentration of Mg, Ca, Mn and Cu and higher concentration of N in leaves. The sufficiency ranges of foliar nutrient concentration for imparting moderate resistance in plant against bacterial blight disease are 1.56-2.05%, 0.11-0.28%, 0.83-1.20%, 1.60-2.16%, 0.38-0.82%, 0.09-0.16% for N, P, K, Ca, Mg and S and are 132.50-187.00, 31.60-58.40, 13.20-27.40 and 26.00-47.80 mg kg^{-1} for Fe, Mn, Zn and Cu respectively.

Synergistic use of nitrogen and salicylic acid could remarkably reduce bacterial blight disease infection through enhancing defense mechanism of plants as indicated by enhancement in the activities of nitrate reductase, other antioxidant enzymes and elevated mineral nutrient content. As there exists a close relationship between leaf N concentration and portable chlorophyll meter reading, it could be very useful in monitoring plant N status and adoption of management practices accordingly for managing bacterial blight disease in pomegranate in environment friendly manner.

The efficacy of various micro irrigation methods using SDI system and its lateral geometry was evaluated. Among the various micro-irrigations methods, SDI with double inline lateral at 30 cm * 30 cm with four drippers was found best with respect to water use efficiency. Similarly, the efficacy of sugarcane baghas as bio-mulching was found superior to other mulching treatments. The biomulching induced higher flowering and number of fruits as compared to other mulches.

Spray of ethrel@250ppm at 3 weeks after defoliation resulted in production of highest number of bisexual flowers (168.66 nos./plant) compared to untreated (122.33 nos./plant) in hasth bahar.

Preliminary evaluation of pomegranate under different training system revealed that there was no significant difference in fruitset during third year among single, double and triple stem training system. Maximum no. of axillary flowering was observed (70.40%) in four stem training system. However, in other training systems, more no. of terminal flowering (31.90 - 40.56 %) was observed.

Rearing the larva on fruit borer on semi-synthetic diet followed by subjecting the adult butterflies for semiochemical research led to the identification of a methyl ester based pheromone compound. The larvae of fruit sucking moths were reared on *Tinospora cardifoilia* under the laboratory conditions consecutively for four months and the life cycle was completed on an average of 30-33 days.

Pseudomonas putida (UHSPS16 and UHSPS11) and *Bacillus subtilis* (UHSBS27 and UHSBS34) were most effective bioagents recording the least disease incidences. Preventive applications were superior to curative applications for effective blight management.

Among different bioresources, cow-urine (5%) effectively checked bacterial blight in field.

Temperature range between 25-35°C coupled with RH≥ 50% for 10-16 hours and intermittent rain were identified as major factors for severe outbreak of bacterial blight within 3-7 days in Maharashtra. Hence these factors have been identified for developing BB forecasting model for pomegranate.

In a field trial with 12 fungicides and 9 commercial formulations Azoxystrobin@1ml/l recorded no fruit rot due to rot causing fungus.

The process has been standardized for extraction of virgin seed oil from pomegranate and patent was filed by ICAR-NRCP. Protocol was also standardized for minimal processing of pomegranate arils.

The scientists have also undergone training in various research institutes to strengthen the HRD activities and capacity building. During this year, ICAR-NRCP organized an 'One day National Workshop on Fruit cracking and soil health management' on 03.10.2015 under the chairmanship of Dr. N.K. Krishnakumar, DDG (HS). Invited speakers from different institutes delivered lecture covered under Fruit cracking and Soil health management. A meeting was organized by ICAR-NRCP to review the progress made under Flagship project by various cooperating centres.

During the period under report, technologies viz. 'Biohardening of *in-vitro* raised pomegranate plants' (M/s. HU Gugale Agrobiotech Company, Jamkhed, Ahmednagar) and Processing of pomegranate juice and ready to serve beverage' (M/s. Bhauraya Distributors, Madha colony, Jule Solapur) were commercialized. Besidies, MoU was signed with M/s. Bhauraya Distributors, Madha colony, Jule Solapur, Solapur for usage of ICAR-NRCP pilot plant as technology incubate as part of the activity for EDP and skill development.

Some of the new initiatives taken up are: Mera Gaon Mera Gaurav; m-Kisan; Swachh Bharat Abhiyan; Interactive touch screen kiosk in Marathi, Hindi and English language; new experiment on organic cultivation of pomegranate; Pilot plant for processing and total utilization; Layout of 11km long lift irrigation system; Construction of 43 bed trainees hostel; Preparation of triggers for crop insurance of pomegranate, production of video film on NRCP profile; analysis of soils for development of soil health cards. Besides, in-house research projects, the ICAR-NRCP attracted extramural funding of ICAR for three additional research projects. Similarly ICAR-NRCP was also successful in obtaining one research grant from National Horticulture Board.

RESEARCH ACHIEVEMENTS

1. GENETIC RESOURCES

1.1. Germplasm collection

At ICAR-NRC on Pomegranate, Solapur, three hundred and four germplasm collection of pomegranate have been maintained in the Kegaon and Hiraj farms. Out of these 210 were indigenous wild/cultivated/local types and 94 were exotic collections. Recently, cuttings of 71 USDA accessions have been collected from ICAR-IIHR, Bengaluru and were plantedin polyethylene bags for proper root and shoot establishment under nursery condition. Besides, some important breeding materials consisting of selected advanced lines, new hybrids with desirable characteristics have been maintained at the research farms.

Pomegranate germplasm maintained at field gene bank of Kegaon research farm, ICAR-NRCP, Solapur

Pomegranate accessions of USDA maintained at ICAR-NRCP, Solapur

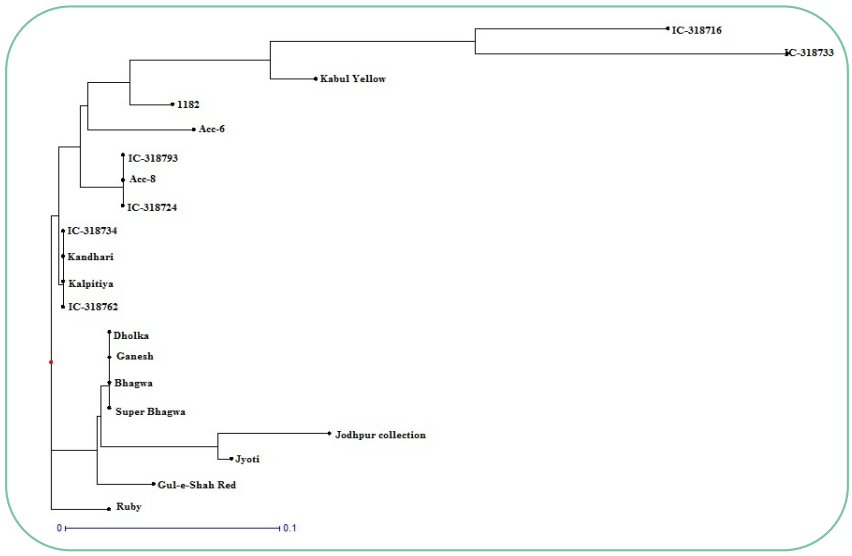
1.2. Germplasm evaluation

1.2.1.Molecular diversity analysis in pomegranate

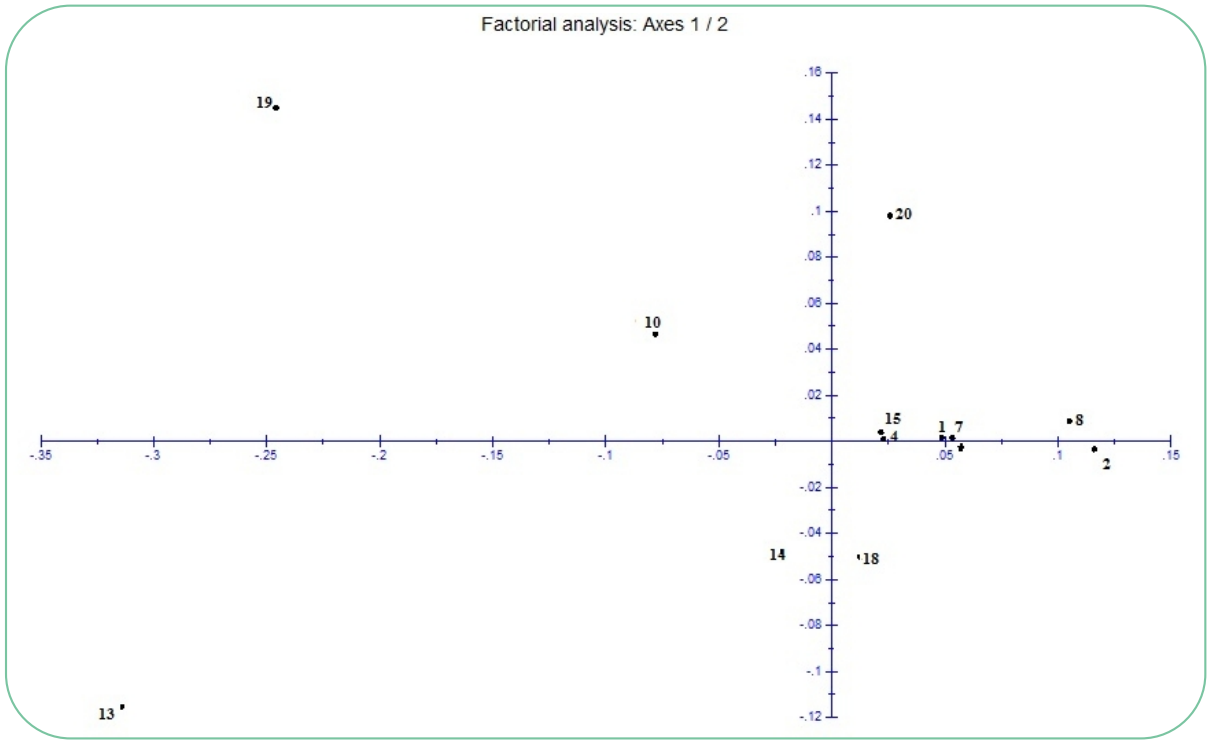
The genetic diversity among twenty pomegranate genotypes including cultivated varieties and wild germplasm was carried out by using simple sequence repeats (SSR) markers. Total seventeen SSR markers reported from the previous studies were screened across the twenty selected pomegranate germplasm to understand their diversity pattern at molecular level, out of these twelve were found to be polymorphic and five were monomorphic. These polymorphic primers have generated 29 SSR marker alleles, with average number of 1.71 alleles per locus. The maximum number of alleles was observed for twelve markers with two alleles each. Polymorphic information content (PIC) values ranged from 0.12 to 0.38 with an average of 0.29 per marker. The observed heterozygosity value ranged from 0.12to 0.50, with the mean value of 0.36.

DARWIN software was used to study the phylogenetic relationship among the selected germplasm from the scored data. Maximum genetic dissimilarity (0.44) was observed between 'IC-318733' and 'Jyoti', 'IC- 318733' and 'Jodhpur collection.Neighbor Joining cluster analysis gives the three separate clusters. Three clusters (cluster I-Wild types, cluster II-Cultivated, cluster III-Solitary cluster with single genotype) were derived from Unweighted Neighbor Joining (NJ) which uses a criterion of unweighted average on dissimilarity. Cluster I consisted of 12 genotypes, cluster II with 7 genotypes and cluster III was the solitary cluster with only one cultivated genotype (Ruby). Kabul Yellow, Kandhari and Kalpitiya are known to be cultivated types even then they were grouped with wild types because of their genetic similarity with wild accessions for fruit colour, seed hardness, total soluble solids (TSS) and acidity content.Bhagwa is the clonal selections from the segregating populations of the cross Ganesh X Guleshah Red, similarly Super Bhagwa is the selection from Bhagwa, hence they have showed the greater genetic similarity with the cv. Ganesh and Guleshah Red. As Ruby variety is known to be developed from a complex hybridization programme, molecularly it has been categorized in a separate cluster due to complexity in the genomic content.

The clustering analysis was well supported by principle component analysis (PCA). The first two axes of PCA with positive Eigen values accounted for 75.85 per cent per cent of the total variations, respectively. The first axis has accounted 59.71percent , whereas second axis covered 16.14 percent variance.



Dendrogram showing phylogenetic relationship among twenty pomegranate genotypes



Principal Co-ordinates Analysis (PCoA) co-ordinates explaining the total genetic variance of selected pomegranate germplasm

1.2.2. Genetic variation in germplasm for plant, leaf, floral and fruit characters

Twenty six pomegranate accessions were characterized for 22 quantitative traits in *Mrig* bahar of 2015-16. Out of Twenty five accessions, 17 were wild accessions collected from NBPGR regional station, Shimla and nine were cultivated types of pomegranate. The measured data has showed the presence of a significant diversity in the plant, leaf, flower and fruit quantitative traits. The mean, range, standard deviation and coefficient of the variation (CV) values for each characteristic among all the accessions were detailed. In wild accessions, among all quantitative characteristics tree spread (cm), leaf blade length (mm), leaf blade width (mm), petiole length (mm), calyx length (mm), calyx width(mm), petal length(mm), petal width(mm), fruit weight (g), fruit length (cm), fruit diameter (cm), crown length (mm), aril (%), 100 arils weight (g), aril length (mm), aril width (mm), rind (%) and rind thickness (mm) showed higher CV(%) values. Among wild accessions, IC-318705 (23.71mm, 19.94mm, 11.44mm and 8.27mm) was found to have maximum mean value for petal length(mm), crown length (mm), aril length (mm) and aril width (mm). Similarly, IC-318762(62.06 mm) and IC-318740 (2.90g), accession also recorded maximum leaf blade length (mm) and 100 seed weight (g).

In cultivated types, higher CV(%) values was observed for tree height (m), calyx width (mm), petal length (mm), petal width (mm), 100 seed weight (g), seed length (mm) and seed width (mm) traits. Maximum mean values for leaf blade width (mm), petiole length (mm), calyx length (mm), calyx width(mm), petal width (mm), fruit weight (g), fruit length (cm), fruit diameter (cm), aril (%), 100 arils weight (g), rind (%), seed length (mm) and seed width (mm) was recorded in P-13, P-23, P-26, P-16,

Jalore Seedless, Co-White and Gulesha Red germplasm when compared to cv. Bhagwa. Lower mean value of 1.67m for plant height (m) and 178.75 cm for tree spread was recorded in Gulesha Red and Jalore Seedless.

The present study witnessed that in cultivated types of pomegranate the genetic improvements have been made in quantitative traits as mentioned above through systematic breeding efforts made during the course of domestication period.

Genetic variation in plant, leaf, flower and fruit quantitative traits among pomegranate wild accessions collected from NBPGR, Shimla

Sl. No.	Characters	Mean	Range	SD	CV(%)
1	Tree height (m)	2.87	2.30-3.18	0.23	8.06
2	Tree spread N-S (cm)	291.76	230-373.33	44.33	15.20
	Tree spread E -W (cm)	290.92	213.33-380	45.96	15.80
3	Leaf blade length (mm)	44.80	34.35-62.06	7.23	16.13
4	Leaf blade width (mm)	15.03	11.30-17.55	1.74	11.59
5	Petiole length (mm)	4.28	2.83-5.07	0.64	14.87
6	Calyx length (mm)	32.52	27.03-37.77	3.51	10.80
7	Calyx width (mm)	10.57	7.69-13.10	1.31	12.40
8	Petal length (mm)	19.40	16.40-23.71	2.08	10.74
9	Petal width (mm)	12.70	10.89-16.24	1.40	11.06
10	Fruit weight (g)	133.85	60.01-202.77	47.67	35.62
11	Fruit length (cm)	5.78	4.44-6.78	0.72	12.54
12	Fruit diameter (cm)	5.90	4.75-6.77	0.68	11.45
13	Crown length (mm)	14.91	11.46-19.94	2.26	15.19
14	Aril (%)	54.39	30.13-69.49	14.35	26.38
15	100 arils weight (g)	28.01	16.85-35.50	6.71	23.97
16	Aril length (mm)	8.32	6.55-11.44	1.21	14.49
17	Aril width (mm)	5.39	3.44-8.27	1.54	28.48
18	Rind (%)	45.58	30.50-69.86	14.35	31.50
19	Rind thickness (mm)	2.65	1.00-6.56	1.57	59.21
20	100 seed weight (g)	2.37	1.78-2.90	0.31	13.03
21	Seed length (mm)	5.64	5.13-6.03	0.25	4.38
22	Seed width (mm)	2.41	2.04-2.64	0.13	5.51

Genetic variation in plant, leaf, flower and fruit quantitative traits among cultivated types in pomegranate

Sl. No.	Characters	Mean	Range	SD	CV(%)
1	Tree height (m)	2.19	1.67-2.65	0.28	12.98
2	Tree spread N-S (cm)	202.78	172.50-252.50	22.92	11.30
	Tree spread E-W (cm)	198.52	175.00-226.67	16.66	8.39
3	Leaf blade length (mm)	52.25	42.93-58.26	4.25	8.13
4	Leaf blade width (mm)	16.87	15.71-17.89	0.76	4.49
5	Petiole length (mm)	4.68	4.15-5.41	0.42	9.04
6	Calyx length (mm)	35.01	31.63-40.11	2.53	7.22
7	Calyx width (mm)	13.12	10.25-17.54	2.09	15.91
8	Petal length (mm)	19.86	15.70-22.74	2.33	11.75
9	Petal width (mm)	14.19	10.00-16.53	2.05	14.46
10	Fruit weight (g)	248.78	173-334.36	50.39	20.26
11	Fruit length (cm)	7.47	6.31-8.49	0.66	8.84
12	Fruit diameter (cm)	7.42	6.58-8.35	0.58	7.85
13	Crown length (mm)	15.72	13.75-18.00	1.44	9.18
14	Aril (%)	27.28	52.42-74.06	6.48	10.46
15	100 arils weight (g)	29.58	25.17-36.52	3.22	10.89
16	Aril length (mm)	10.49	9.20-11.28	0.62	5.91
17	Aril width (mm)	7.06	6.39-8.13	0.48	6.84
18	Rind (%)	27.36	25.91-47.54	6.52	17.19
19	Rind thickness (mm)	2.96	2.49-3.58	0.33	11.11
20	100 seed weight (g)	1.60	1.28-2.3	0.35	21.91
21	Seed length (mm)	6.19	5.74-6.94	0.33	5.32
22	Seed width (mm)	2.30	1.92-2.69	0.22	9.71

1.2.3. Determination of heat unit requirement of germplasm

The total GDD, photo-thermal index and heat use efficiency were estimated for IC-318712, IC-318740, IC318702, IC-318707, Acc.-01, Bhagwa, Patna-5, P-13, P-16, 1201, IC-318753 and 318779 during 2015-2016 in *Mrig* bahar. Total GDD accumulations of all the varieties ranged from 2390.30 to 3575.10 ^{0}D from defoliation to harvesting period. The growing degree days ranged from 932.80 to 1753.20 ^{0}D at flowering stage and 284.90 to 903.50 ^{0}D at reproductive stage. The lowest and highest GDD from defoliation to harvesting period buildup of 2390.20 ^{0}D for IC-318707 and 3575.10 ^{0}D for Bhagwa cv.Photo-thermal index (PTI) and heat use efficiency (HUE) of ten varieties ranged from 18.20 to 19.9 ^{0}D/day and 0.70 to 8.9 tones ha^{-1}degree^{-1} at flowering and reproductive stages.

Days to attain total growing degree, fruit set physiological maturity, Photo-thermal index and Heat Use Efficiency in twelve pomegranate varieties

Varieties	TD	Y (t/ha)	TGDD (^{0}D)	NLI (^{0}D)	FS (^{0}D)	M (^{0}D)	H (^{0}D)	PTI (^{0}D)	HUE (^{0}D)
Bhagwa	170-175	4.0	3575	319.4	1753	284.9	153.8	19.9	1.2
IC-318712	150-165	3.0	3012	319.4	1345.9	903.5	763.0	18.3	0.9
IC-318740	140-155	4.0	2840	319.4	1026	725.0	770.30	18.3	1.3
IC-318702	150-170	8.0	3093	319.4	1119.9	716.9	936.80	18.2	2.7
IC-318707	120-130	20.0	2390	319.4	1119.9	548.6	402.30	18.4	8.4
ACC-01	140-150	2.0	2755	319.4	1119.9	548.6	766.10	18.4	0.7
Patna-5	140-150	NF	--	--	--	--	--	--	--
P-13	140-145	11.0	2663	319.4	1101.2	548.6	525.50	18.4	4.3
P-16	141-147	13.0	2700	319.4	1364.8	716.7	487.90	18.4	4.6
1201	NF	NF	--	--	--	--	--	--	--
IC-318753	130-145	20.0	2662.8	319.4	1120.6	716.9	506.60	18.4	7.4
IC-318779	150-165	20.0	3012.7	319.4	932.80	903.3	856.50	18.3	8.9

(TD-Total days; ^{0}D-Degree days; NF- No Fruit; Y-Yield; TGDD-Total growing degree days; NLI-New Leaf Initiation; FS-Fruit setting; M-Maturity; H-Harvesting; PTI-Photo-thermal Index and HUE-Heat Use Efficiency)

1.2.4. Studies on Biochemical properties of selected germplasm

During 2015-16 the important biochemical properties of selected pomegranate germplasm were evaluated. The total soluble solids (^{0}Brix), acidity (%), antioxidant (mg/100ml of Ascorbic acid), total phenol (mg/L gallic acid), anthocyanin (mg/100ml) and ascorbic acid (mg/100ml), aril colour value (a*), Seed texture (seed rupturing point-N), oil recovery (v/w), juice percentage (%) were estimated in the selected nineteen germplasm. Among these ten were cultivated types (Co-white, Bhagwa, Jyoti, Ganesh, Arakta, Mridula, Kandhari, Kabul yellow, Ruby, KRS) and nine were wild types (IC-318754, IC-318790, IC-318753, IC-318779, IC-318705, IC-318762, IC-318707, IC-318793, IC-318712). Among wild germplasm, TSS (^{0}Brix), acidity (%), antioxidant (mg/100ml AA), total phenol (mg/l GAE), anthocyanin (mg/100ml) and ascorbic acid content (mg/100ml), aril colour a*, seed texture (N), oil recovery (v/w), juice recovery (%) ranged between 15.32-17.39^{0}Brix; 1.85-2.86%; 23.26-33.28 (mg/100mlAAE); 1262.44-2913.80 (mg/l GAE); 0.30-2.33(mg/100ml),10.42-15.00 (mg/100ml),2.64-18.35 (a* value i.e. redness), 60.28-78.91 (N), 7.10-16.0(ml/g), 27.56-48.00(%). While in cultivated types the TSS (^{0}Brix), acidity (%), total phenol (mg/l GAE), and Seed texture (N), were found in lower quantity when compared to wild types *viz*. 14.40-16.48^{0}Brix, 0.20-0.63(%), 873.40-1667.00 (mg/l GAE), and 27.46-40.48 (N) except high textural for Co-white and Kabul yellow. Higher concentration of antioxidant capacity (mg/100ml AAE), anthocyanin (mg/100ml), Ascorbic acid (mg/100ml), aril colour value (a*) and oil recovery (%) were found in cultivated types *viz*. 25.8-34.58 (mg/100mlAAE), 0.19-23.80 (mg/100ml), 11.81-15.75 (mg/100ml), 12.81-34.27 (a* i.e. redness) and14.0-29.0 (v/w). The

juice recovery (%) range for wild varieties was larger 27.56-48.00 % while that for commercial type was from 36.74-44.38(%). The study was found to be highly informative; these estimates can be correlated with the fruit yield and its related traits to make direct and indirect selection of desirable genotypes in future pomegranate breeding programmes.

1.2.5. Evaluation of commercial varieties of pomegranate

Seven commercial cultivars of pomegranate planted at a spacing of 4.5x3.0m were evaluated for their performance during the seventh year of planting in *Mrig* bahar. The cultivars differed significantly for yield and quality traits. The number of fruits/plant was highest in G-137 (95.6/plant) followed by Ganesh (91.2 / plant). Fruit weight was highest in G-137 (310.2g) followed by Jalore Seedless (305.0g). Fruit yield was highest in G-137 (29.64kg/plant) followed by Ganesh (27.82kg/plant). Bhagwa recorded the highest aril weight (35.2g/100 arils) followed by Ruby (32.1g/100arils) whereas it was least in Ganesh (26.4g/100 arils). The number of arils/fruit) was highest in Ganesh (696.00).Total soluble solids content was highest in Jalore Seedless (16.25°B) closely followed by G-137 (16.2°B). Ascorbic acid content was found to be 20.0 mg/100g in Ganesh followed by Arakta (19.2mg/100g). Total sugars content was highest in G-137 (13.70%) followed by Jalore Seedless (13.27%) and Ganesh (13.25%). Anthocyanin content was found to be on par in Mridula (369.99 mg.100g) and Arakta (381.87 mg/100g).

Evaluation of commercial cultivars of pomegranate for qualitative and qualitative traits

Particulars	Bhagwa	Ganesh	G-137
No. of fruits/plant	84.50	91.20	95.60
Fruit weight (g)	292.10	305.00	310.20
Fruit yield (kg/ha)	24.68	27.82	29.64
100 aril weight (g)	35.20	26.40	27.30
No. of arils/ fruit	480.33	696.00	688.00
TSS (°B)	15.90	16.10	16.20
Acidity (%)	0.49	0.45	0.45
Vit-C (mg/100g)	14.40	20.00	12.80
Reducing sugar (%)	11.11	11.76	12.12
Total sugar (%)	12.44	13.25	13.70
Anthocyanin (mg/100g)	360.00	104.38	21.13

Ganesh

Bhagwa

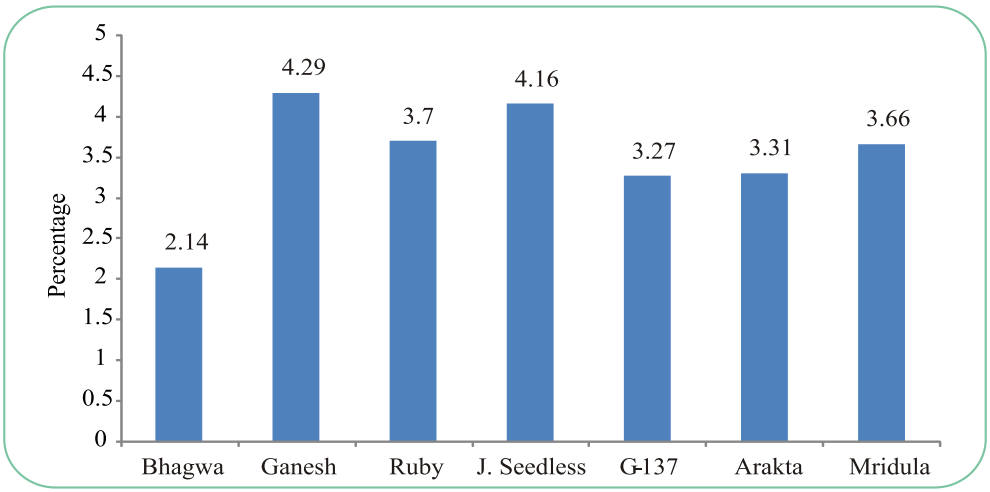
Arakta

G-137

Commercial varieties of pomegranate

1.2.6. Determination of fruit cracking in commercial varieties of pomegranate

The extent of fruit cracking in commercial cultivars of pomegranate was assessed during the *mrig* bahar of seven year old orchard. Fruit cracking ranged from 2.14 to 4.29%. The extent of fruit cracking was maximum in Ganesh (4.29%) followed by Jalore Seedless (4.16%). Fruit cracking was minimum in Bhagwa (2.14%).



Variability in the incidence of fruit cracking of pomegranate

1.2.7. Reaction of field germplasm to different diseases and insect pests

Screening of 100 germplasm in field gene banks revealed that eight were free from bacterial blight disease.

Screening of 100 germplasm in field gene banks revealed that 26 were free from anthracnose.

Germplasm reaction to Bacterial blight

Group	Blight Severity (%)	Germplasm	
		Number	Name
Disease Free/ tolerant	0.0	8	Nana, Yellow Nana, Kalpitiya x Rub, Nayana x Ruby, Ganesh x Nana, Acc.-51, Acc.- 15, H-24
Slightly susceptible	>0-10	25	Daru, B x[(Gxn)xD]- R1, Kalpitya x Ruby, H6, H21,H22, H25, H1, BX3/5 [(Gxn)xD] , 1194, Kabul Yellow, Ruby, Acc.- 50, [(GxD)xG]xR, Ruby, H11,Kerala Local, 1199, Nayana, 1205, 1204, Hybrid B, H2, H19, Hybrid A

(G- Ganesh, n-Nana, D-Daru, K-Kalpitiya, R- Ruby)

Germplasm reaction to Anthracnose (*Colletotrichum sp.)*

Group	Blight Severity (%)	Germplasm	
		Number	Name
Disease Free/ tolerant	0.0	26	Amlidana, Hybrid 6/4, Nayana x Ruby*, Ganesh x Nana*, Acc.- 51*, Acc.- 50, H1, H2, H3, H4, H5, H6, H8, H9, H10, H13, H14, H15,H16, H17, H18, H21, H22, H24, Dorsata, Alha
Slightly susceptible	>0-10	53	Hybrid A, Hybrid B, Hybrid 6/5,Kerala Local, Daru,[(GxD)XG]xR, [(Gxn)x(GxD)]xR, Hybrid 6/7, Nayana, Bx3/5 [(Gxn)xD], Yellow Nana , Hybrid 7/10, Kalpitya x Ruby, Kalpitiya x Ruby*, [(Gxn)x(GxD)]xR, H7, H23,Nana, Ruby, Kandhari, Yercaud HRS, Kabul Yellow, 1/2Gx9/2G, H25, 1199, B x[(Gxn)xD]- R1, Jodhpur Red, P-26,Tabesta, Jodhpur Collection, Bhagwa, Acc.- 15*, H11, H19, Dholka, Yercaud, Guleshah Red, Bassein Seedless, G-137, P-13,Muscut,Co-White, Bedanasri, Bedana Thinskin, Kalpitiya,1194,Mridula,Patna-5, H12, H20, Nimali

(G- Ganesh, n-Nana, D-Daru, K-Kalpitiya, R- Ruby)

Screening of 100 germplasm in field gene banks revealed that 28 were free from scab disease. Screening of 100 germplasm in field gene banksrevealed that 48 were free from *Colletotrichum* fruit rot.

Screening of 100 germplasm in field gene banks revealed that none were free from the incidence of thrips.

Germplasm reaction to Scab

Group	Blight Severity (%)	Germplasm	
		Number	Name
Disease Free/ tolerant	0.0	28	1204, 1199, Kalpitiya, Jodhpur Collection, Patna-5, Nana, Yellow Nana ,Amlidana, Hybrid 6/4, Guleshah Red, Kalpitiya x Ruby, Nayana x Ruby , Acc.- 51, Acc.- 50, H21,H24,Tabesta,17/2, Kabul Yellow, Kandhari, Yercaud HRS, Spin Sakaharin, Bedanasri, Dorsata, P-23, Maha, Alha, Jodhpur Red
Slightly susceptible	>0-10	41	Daru, Hybrid 6/5, Arakta, Nayana, Co-White, P-13, Kerala Local, Jyoti, Kalpitya x Ruby, [(Gxn)x(GxD)]xR, Hybrid 7/10, P-26, 1/2Gx9/2G, Ruby, Ganesh, Bassein Seedless, Surat Anar, Bedana Thinskin, A.K Anar, Dholka, Kasuri, [(GxD)XG]xR, Muscut, Bx [(Gxn)xD-R1, Nimali, Bosckalinsi, Mridula, G-137, [(GxD)XG]xR, Bhagwa, Hybrid 6/7, Ganesh x Nana, Bx3/5 [(Gxn)]xD, H22,H25,Yercaud, Jalore Seedless, KRS, Kabul Yellow, Bedana Sedana,H 23

(G- Ganesh, n-Nana, D-Daru, K-Kalpitiya, R- Ruby)

Germplasm reaction to fruit rot (*Colletotrichum sp.)*

Group	Blight Severity (%)	Germplasm	
		Number	Name
Disease Free/ tolerant	0.0	48	1204, 1194, 1199, Damini,Bedana Sedana, Patna-5, Yellow Nana*, Amlidana, Rosette, 6/4,7/10, Nayana x Ruby*,Ganesh X Nana*, [(GxD)XG]xR, [(Gxn)x(GxD)]xR Acc.- 51*, Acc.- 15*, Daru, H1, H2, H3, H4, H5, H6,H7,H8,H9,H10,H12,H13,H14, H15, H16, H17, H19, H20, H21, H22, H24*, 17/2, Surat Anar, Spin Sakaharin, Dorsata, P-23, Maha, Bedana Thinskin, Alha, Jodhpur Red
Slightly susceptible	>0-10	48	Hybrid A, Ganesh,IC-318720,[(GxD)XG]xR, Acc.- 50,Hybrid-6/5, Kerala Local, P-26, KRS, Jyoti, Nayana , Ruby, Hybrid B, 1/2Gx 9/2G, Jodhpur Collection, G-137, Kalpitiya x Ruby*, H23, Kalpitya x Ruby, BX3/5 [(Gxn)xD], Kandhari, Bassein Seedless, Bedanasri, Bosckalinsi, Kalpitiya, B x[(Gxn)xD]- R1,Tabesta, Dholka, Bhagwa, Kasuri, Kabul Yellow, P-13, Arakta, Mridula, Yercaud, Kabul Yellow,H11, Nimali, Guleshah Red, Yercaud HRS, Jallore Seedless, Muscut, Hybrid 6/7, Nana*, 1198, Co-White, 1205, H25

(G- Ganesh, n-Nana, D-Daru, K-Kalpitiya, R- Ruby)

2. CROP IMPROVEMENT

2.1 Hybridization

2.1.1. Hybridization for bacterial blight tolerance

Out of four crosses undertaken for development of bacterial blight tolerant hybrids, fruitset was found to be successful in all the four crosses. The fruitset ranged from 20.0 to 40.0 percent and was highest in 'Bhagwa x Acc-13' (40.0%).

Hybridization between commercial cultivar and bacterial blight resistant /tolerant lines

Cross	No. of flowers crossed	No. of fruits obtained	Fruitset (%)
Bhagwa x Hybrid -A	10	02	20.0
Bhagwa x { B x[(Gxn)x D]}*	15	05	33.3
Bhagwa x Acc. -13	10	04	40.0
Bhagwa x Kalpitiya	10	02	20.0

(*-B-Bhagwa, G-Ganesh, n-Nana, D- Daru)

Bhagwa x Hybrid-A

Bhagwa x {B x [(Gxn)x D]}

Bhagwa x Acc.-13

Bhagwa x Kalpitiya

Hybridization for bacterial blight tolerance

2.1.2. Hybridization for fruit cracking tolerance

Out of two crosses undertaken for development of fruit cracking tolerant hybrids, fruitset was found to be successful in both the crosses. The fruitset ranged from 33.3 to 40.0 percent and was higher in 'Bhagwa x IC-318712' (40.0%).

Hybridization between commercial cultivar and fruit cracking tolerant lines

Cross	No. of flowers crossed	No. of fruits obtained	Fruitset (%)
Bhagwa x IC -318712	20	08	40.0
Bhagwa x Patna -5	15	05	33.3

Bhagwa x IC-318712

Bhagwa x Patna-5

Hybridization for tolerance to fruit cracking

2.1.3. Hybridization for fruit quality improvement

Out of four crosses undertaken for development of hybrids with desirable fruit quality, fruitset was found to be successful in all the four crosses. The fruitset ranged from 20.0 to 33.3 percent and was highest in 'Bhagwa x Hybrid-7/10 (33.3%).

Hybridization between commercial cultivar and fruit cracking tolerant lines

Cross	No. of flowers crossed	No. of fruits obtained	Fruitset (%)	Desirable trait
Bhagwa x Hybrid 6/7	12	03	25.0	Titrable acidity
Bhagwa x Hybrid 7/10	12	04	33.3	Total soluble solids
Bhagwa x KRS	10	03	30.0	Rind thickness
Ruby x KRS	10	02	20.0	Rind thickness

Bhagwa x Hybrid 6/7

Bhagwa x Hybrid 7/10

Bhagwa x KRS

Ruby x KRS

Hybridization for fruit quality

2.1.4. Development of new genetic variants through hybridization

New pomegranate hybrids were developed through bi-parental hybridization programme to induce genetic variability for qualitative and quantitative traits including biotic and abiotic stresses. Bhagwa was used as female parent to make crosses with seven wild accessions viz., IC-318743, IC-318705, IC-318749, IC-318712, IC-318733, IC-318740 and IC-318702.

2.1.5. Generation advancement in pomegranate

To advance the F1 hybrid population of NRCP hybrids to F2 generation, F1 population of 20 NRCP hybrids were selfed and the successful fruitset was observed in all the hybrids. The germination percentage ranged from 16.0 to 51.0%. The germination was highest in NRCP H-17 (51.0%) followed by NRCP H-2 (48.0%) whereas it was least in NRCP H-20 (16.0%).

2.1.6. Evaluation of NRCP hybrids for table purpose

Seven hybrids (NRCP H-2, 5, 6, 8, 10, 14, 19) were evaluated during seventh year of planting in mrig bahar in comparison with Bhagwa. The number of fruits was highest in NRCP H-6 (125.0 /plant). Fruit yield per plant was highest in NRCP H-6 (35.64 kg/plant) followed by NRCP H-14 (33.14 kg/plant). Total soluble solids content was highest in NRCP H-14 (17.8°) closely followed by NRCP H-6 (17.6°B). Vitamin-C content was highest in NRCP H-6 (19.6mg/100g) followed by NRCP H-14 (19.2mg/100g). Total sugar content was highest in NRCP H-14 (15.94%). Anthocyanin content was highest in NRCP H-2 (467.15mg/100g) followed by NRCP H-6 (390.78mg/100g).

Evaluation of table purpose hybrids for yield and quality traits

Particulars	Bhagwa	NRCP H-6	NRCPH-14
Maturity (days)	180	165	165
No. of fruits/plant	84.50	125.00	115.00
Fruit weight (g)	292.10	285.12	288.20
Fruit yield (kg/plant)	24.68	35.64	33.14
100 aril weight (g)	35.20	40.50	32.50
Total soluble solids (°B)	15.90	17.60	17.80
Acidity (%)	0.49	0.44	0.51
Vitamin-C (mg/100g)	14.40	19.60	19.20
Reducing sugar (%)	11.11	14.28	14.81
Total sugar (%)	12.44	15.91	15.94
Anthocyanin (mg/100g)	360.00	390.78	121.43

NRCP H-6

NRCP H-14

NRCP hybrids for table purpose

2.1.7. Evaluation of NRCP hybrids for processing purpose

Thirteen hybrids (NRCP H-1, 3, 4, 7, 9, 11, 12, 13, 15, 16, 17, 18, 20) were evaluated during seventh year of planting in mrig bahar in comparison with Amlidana. The no. of fruits was highest in NRCP H-9 (120.0 /plant). Fruit yield per plant was highest in NRCP H-12 (30.90 kg/plant) followed by NRCP H-4 (28.84 kg/plant). NRCP H-18 recorded the highest aril weight (38.5 g/100 arils) followed by NRCP H-13 (38.0g/ 100arils). Total soluble solids content was highest in NRCP H-13 (17.6°B) closely followed by NRCP H-18 (17.5°B). Titrable acidity content was highest in NRCP H-4 (5.76%) followed by NRCP H-12 (4.80%). Vitamin-C content was highest in NRCP H-4 (18.8 mg/100g) followed by NRCP H-12 (18.4mg/100g). Total sugar content was highest in NRCP H-1 (13.82%) followed by NRCP H-18 (13.74%). Anthocyanin content was highest in NRCP H-16 (490.07mg/100g) followed by NRCP H-11 (487.78mg/100g) and NRCP H-12 (462.55mg/100g).

Evaluation of table purpose hybrids for yield and quality traits

Particulars	Amlidana	NRCP H-4	NRCPH-12
Maturity (days)	145	140	140
No. of fruits/plant	60.30	110.0	105.0
Fruit weight (g)	228.10	262.20	294.25
Fruit yield (kg/plant)	13.68	28.84	30.90
100 aril weight (g)	36.0	30.0	33.0
Total soluble solids (°B)	16.6	15.9	16.7
Acidity (%)	4.30	5.76	4.80
Vitamin-C (mg/100g)	14.4	18.8	18.4
Reducing sugar (%)	11.11	11.42	12.53
Total sugar (%)	12.50	12.53	12.93
Anthocyanin (mg/100g)	50.20	59.83	462.55

NRCP H-4

NRCP H-12

NRCP hybrids for processing purpose

2.2. Induced mutation

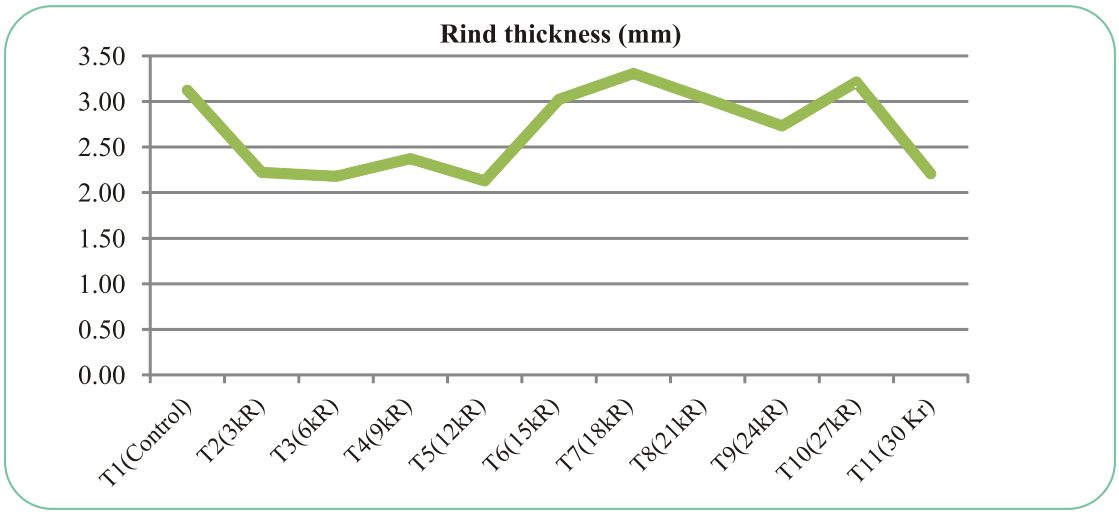
2.2.1. Evaluation of gamma irradiated populations of pomegranate cv. Ganesh

In order to create variability, the seeds of cv. Ganesh was exposed with 3-30kR gamma irradiation during 2007 and subsequently planted in the field during 2010. The fruits of Ganesh mutants were harvested from seven years old trees and evaluated for their physico-chemical traits. Mean fruit weight (278.73g) was maximum with on-par fruit length (95.42mm) and diameter (78.92mm) in 3kR treatment when compared to control (275.60g, 96.77mm and 78.35mm). At 18kR treatment, the rind thickness (mm) and T.S.S (°Brix) mean value (3.31mm, 16.40°Brix) was slightly higher than the control mean value (3.13mm, 15.50° Brix) with the same mean acidity % value (0.32%). All the treatments have showed non-significant effect in improving aril % and aril size mean value of the evaluated population. However, significant effect on rind% means was observed at 30kR (50.90%) when compared to control (36.56%).

Maximum variation in the population was observed for fruit weight (42.38%), Rind thickness (35.20%), and Rind (23.26%) in 24kR treatment and Acidity (31.91%) in 15kR treatment when compared to control (19.50%, 11.84%, 7.71% and 20.94%). Significant diversity was also observed for fruit qualitative traits like fruit colour (Yellow, pink, red, dark red and their combinations) and aril colour (Light yellow, light pink, pink, red, deep red andtheir combinations). Some of the promising genotypes which were on-par and/or above control mean value have been identified through inducing genetic mutation in cv. Ganesh.

List of promising genotypes identified in the gamma irradiated population of cv. Ganesh

Sl. No.	Trait name	No. of promising mutants	Range
1	Fruit weight (g)	28	339.72 - 452.40
2	Fruit length (mm)	5	108.70 - 109.74
3	Fruit diameter (mm)	51	83.98 - 93.74
4	Aril recovery (%)	19	68.07 - 75.63
5	Total soluble solids (°B)	149	16.29 - 18.71
6	Acidity (%)	40	0.40 - 0.56
7	Aril length (mm)	30	11.43 - 14.49
8	Aril width (mm)	30	7.30 - 9.33
9	Rind thickness (mm)	32	3.62 - 5.63



Effect of gamma irradiation treatments on rind thickness of cv. Ganesh

2.3. Screening of germplasm for bacterial blight resistance

Screening for bacterial blight resistance was done in several batches depending on seeds and hardwood cuttings of different germplasm and hybrids made available throughout the year.

2.3.1. Screening of Seedling population

Set 1: Selected seedling population of 7 accessions and Bhagwa as standard susceptible variety were screened under standardized artificial inoculation technique with *X. axonopodis* pv. *punicae* isolate Xap 104 during June –August 2015. Out of 104 seedlings tested, 1 seedling of Acc. 9 and 2 seedlings of IC-318724 were tolerant showing only 8-10% BB. None was BB free.

Selected seedlings population of germplasm tested for bacterial blight resistance (Set 1)

Germplasm	Number tested	Max BBD range	Tolerant (No.) ≤ 10% BB
Acc-9	11	8.0-95	1
Acc-10	9	20-50	0
1258	2	48-50	0
1199	5	25-90	0
1205	17	15-90	0
IC-318706	28	15-90	0
IC-318724	29	10-75	2
Bhagwa	3	50-75	0
Total	104	8.0-90	3
Screening period: 01.6.15-05.8.15, *X. axonopodis* pv. *punicae* isolate used: Xap 101			

Set II: In another experiment large seedling population of 8 IC accessions was tested by challenge inoculation with *Xanthomonas axonopodis* pv. *punicae* isolate Xap 105 in nethouse for bacterial blight (BB) resistance on 80 day old seedlings from August to October 2015. All seedlings showing BB infestation were removed periodically at 15 days interval. Bacterial blight free seedlings in different IC collections, ranged from 3.29% in IC-318762 to 18.27% in IC-318705. The BB free seedlings were transplanted in polythene bags for second screening. All affected seedlings had BB incidence and severity above 10 percent.

Seedling population of varieties Ganesh and Bhagwa was screened in BB affected field at Kegaon in rainy season. All the seedling population of Bhagwa (255) and Ganesh (228) was severely affected with BB by October.

Seedling population of germplasm tested for bacterial blight resistance

Accession No.	Seedlings tested	Infected#	*BBD free in 2 months	
	Number	Number	Number	Percent
IC-318703	5677	4877	800	16.40
IC-318705	2836	2398	438	18.27
IC-318724	2122	2040	82	4.02
IC-318728	3385	3097	288	9.30
IC-318734	3209	2822	387	13.71
IC-318754	3152	2664	488	18.32
IC-318762	1224	1185	39	3.29
IC-318779	3583	3251	332	10.21
Ganesh**	228	162	0.00	0.00
Bhagwa**	225	200	0.00	0.00
TOTAL	25641	22334	2854	11.69

Date of planting June 1, 2015; Screening period: 08.8.15-10.10.15
X. axonopodis pv. *punicae* isolate used: Xap 105
* Seedlings transplanted in bags for second screening
\# BB incidence and severity on leaves above 10 percent
** Seedlings evaluated in BB affected field, rest in polyhouse

80 days old seedlings

Seedlings with initial BB symptoms

BB affected seedlings removed in packs of 100

Close up of BB symptoms on removed seedlings

Screening of seedling population by challenge inoculation

Set III : Seedling population of 52 germplasm collectio ns were screened for BB resistance over a period of two months from 21.1.16 -21.3.16. One seedling each of IC-318712 and IC-318735 were free from BB and respectively 9 and 16 seedlings of these accessions recorded resistant / tolerant reaction (less than 10 %) to BB (Table 3). All three seedlings of IC-318764 recorded resistant / tolerant (<10%) BB reaction. These BB free and tolerant seedlings may be used as promising genotypes for breeding programmes after rescreening.

Reaction of seedlings population of pomegranate germplasm to BB in challenge inoculation (Set III)

Code	Germplasm No.	Total No. of plants	Number of Seedlings in disease grade*				
			0	1	2	3	4
6	IC 318734	21	0	1	1	8	11
7	IC-318740	10	0	0	1	7	2
8	IC-318764	3	0	2	1	0	0
9	IC-318762	16	0	4	1	8	3
10	IC-318707	14	0	4	4	3	3
11	IC-318735	19	1	10	6	0	2
12	IC-318712	10	1	5	4	0	0
16	IC-318790	9	0	1	0	0	8
29	1258	7	0	1	1	2	3
30	Almoda	18	0	2	4	11	1
31	Yercaud Local	1	0	0	0	0	1
35	Acc.-5	7	0	1	4	0	2
36	P-26	24	0	0	2	2	20
37	Bhagwa	6	0	0	1	0	5
	Total	682	2	31	65	170	414

Period of Screening: Jan 21 to Mar 21, 2016
X. axonopodis pv. *punicae* isolate used: Xap111
*BB Grade 0=No disease, 1= 0-5% , 2= >5-10%, 3= >10-25%, 4= >25-100% BB incidence

2.3.2. Screening of plants raised from hard wood cuttings

Plants were raised by planting stem cuttings of individual varieties or accessions. Established plants were screened in polyhouse using standard challenge inoculation method. Plants were 3-6 months old in different screenings done in batches during the year.

Set I: Twenty five NRCP Hybrids (H1-H25) were screened for BB resistance through challenge inoculation along with standard variety Bhagwa. All were highly susceptible to BB incidence ranging from 50-88%. In a parallel screening 36 germplasm accessions were also screened. Only 3 accessions such as Daru-1, Daru-17 and Rosette were tolerant to BB with respectively 5-7% BB incidence under challenge inoculation.

Reaction of NRCP hybrids to bacterial blight in challenge inoculation (Set Ia)

Variety	Incidence %	Severity grade	Variety	Incidence %	Severity grade
NRCP H-1	87	4	NRCP H-13	70	2
NRCP H-2	50	3	NRCP H-14	80	4
NRCP H-3 (i)	78	4	NRCP H-15	72	3
NRCP H-3 (ii)	85	4	NRCP H-16	62	3
NRCP H-4	60	3	NRCP H-17	55	3
NRCP H-5	58	4	NRCP H-18	70	3
NRCP H-6	60	4	NRCP H-20	62	4
NRCP H-7	65	4	NRCP H-21	88	3
NRCP H-8	70	3	NRCP H-22	70	3
NRCP H-9	62	4	NRCP H-23	72	3
NRCP H-10	77	3	NRCP H-24	77	1
NRCP H-11	75	4	NRCP H-25	50	4
NRCP H-12	78	3	Bhagwa	72	4

Period of Screening: May 20 to July 24, 2015
No. of plants screened / variety : 5-7
Age of plants 3 months.
X. axonopodis pv. *punicae* isolate used: Xap 98
BB Severity Scale: 0=No disease, 1= >0-10% , 2= >10-25%, 3= >25-50%,
4= >50-75%, 5=>75-100% BB

Reaction of selected field germplasm to bacterial blight in challenge inoculation (Set Ib)

Variety	Incidence %	Severity grade	Variety	Incidence %	Severity grade
Kalpitiya-1	55	3	Daru-10	20	1
Kalpitiya-3	50	2	Daru-11	12	1
Kalpitiya-5	75	3	Daru-17	7	1
Kalpitiya-10	70	3	Daru-14	42	2
Nayana-9	57	2	Daru-1	5	1
Nayana-8	52	3	P-15	40	2
Nayana-6	80	4	Rosette	5	1
Nayana-7	60	3	Rosette	45	1
Nayana-5	50	3	DDG/R	72	3
Nayana-4	62	3	Kalpitiya xRuby	58	3
Nayana-2	70	3	DDG/R2	68	2
Nayana-3	42	2	Bedana Sedana	82	4
Nayana-11	65	4	DDG/R3	55	2
Nayana-12	60	3	Amlidana	58	2
Daru-2	30	2	Acc-15	62	3
Daru-5	22	2	Acc-50	75	3
Daru-9	40	2	Acc-51	60	2
Daru-7	30	1	Bhagwa	72	4

Period of Screening: May 20 to July 24, 2015
No. of plants screened per variety : 5-7
Age of plants 3 months.
X. axonopodis pv. *punicae* isolate used: Xap 98
BB Severity Scale: 0=No disease, 1= >0-10% , 2= >10-25%, 3= >25-50%, 4= >50-75%, 5=>75-100% BB

Set II: Plants raised from hard wood cuttings (6-7 plants of each) of selected 6 accessions of gamma irradiated population were screened using spray method of challenge inoculation with *X. axonopodis* pv. *punicae* isolate Xap 101. None was free from BB. Blight incidence ranged from 42-75%

Reaction of plants raised from hard wood cuttings of selected gamma irradiated seedling population to bacterial blight (Set II)

Variety	Max BB incidence	Tolerant/free (n o.)
320	42	0
348 A	55	0
375	70	0
388	58	0
391	75	0
528 A	60	0

Period of Screening: June 1– Aug. 5, 2015, *X. axonopodis* pv. *punicae* isolate used: Xap 101

Set III: In another experiment plants raised from hardwood cuttings of 24 germplasm collection were screened for BB resistance over a period of two months from January 21 –March 21, 2016 with spray inoculation. None were free from BB and 19 hard wood cuttings recorded less than 5% BB, however most of the population screened was moderately to highly susceptible.

Reaction of stem cutting population of pomegranate germplasm to BB in challenge inoculation (Set III)

Code number	Germplasm name	Total No. of plants	Number of Seedlings in each disease grade				
			0	1	2	3	4
53	Wild	18	0	0	3	13	2
54	IC-1253	19	0	0	3	9	7
55	IC-1256	14	0	0	0	7	7
56	IC-1272	20	0	0	2	12	6
57	IC-1259	23	0	0	1	3	19
58	IC-318793	9	0	3	2	2	2
59	IC-318716	16	0	8	6	2	0
60	1181	6	0	0	0	2	4
61	IC-318718	4	0	2	1	1	0
62	IC-318743	7	0	0	1	4	2
63	IC-318712	16	0	0	3	7	6
64	P-26	7	0	0	0	0	7
65	P-23	5	0	0	0	1	4
66	Bhagwa	5	0	0	0	0	5
67	1201	4	0	0	0	3	1
68	Acc-1	9	0	3	3	1	2
69	P-13	7	0	0	0	3	4
70	IC-318707	8	0	1	5	2	0
71	P-16	4	0	0	0	1	3
72	Patna-5	4	0	0	0	0	4
73	IC-318740	10	0	1	0	3	6
74	IC-318779	11	0	0	1	0	10
75	IC-318753	12	0	0	0	7	5
76	IC-318702	6	0	1	2	3	0
	Total	**244**	**0**	**19**	**33**	**86**	**106**

Period of Screening: Jan 21 to Mar 21, .2016

X. axonopodis pv. *punicae* isolate used: Xap111

BB incidence Scale: 0=No disease, 1= >0-5% , 2= >5-10%, 3= >10-25%, 4= >25-100% BB incidence

Seedling population of 8 IC accessions (tested by challenge inoculation) and 2 varieties Ganesh and Bhagwa (tested in field in BB affected plot) were screened for BB resistance. Bacterial blight free seedlings in different IC collections (total 25188 seedlings), ranged from 3.29-18.32%, whereas all the seedling population of Bhagwa (255) and Ganesh (228) were severely affected with BB in rainy season. The BB free seedlings have been transplanted in polythene bags for second screening.

In another experiment seedling population of 52 germplasm collections and plants raised from hardwood cuttings of 23 germplasm collection were screened for BB resistance over a period of two months. One seedling each of IC-318712 (total 10 seedlings) and IC-318735 (total 19 seedlings) was free from BB and respectively 9 and 16 seedlings of these accessions recorded tolerant reaction (less than 10 %) to BB and thus these seedlings may be used as promising genotypes for breeding programmes after rescreening.

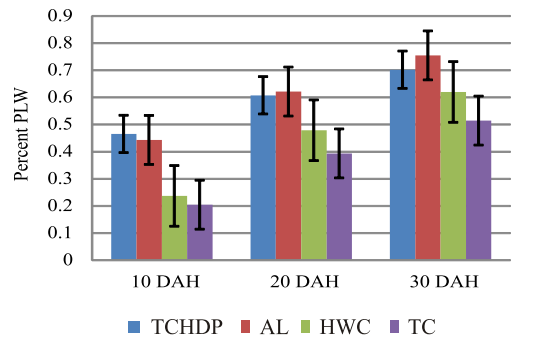
Among 6 accessions of gamma irradiated population, 42 germplasm accessions and varieties only 2 accessions of Daru and Daru 17 were resistant / tolerant to BB with respectively 5 and 7% BB incidence under challenge inoculation. Among 25 NRCP Hybrids (H1-H25) screened for BB resistance through challenge inoculation, all were found highly susceptible to bacterial blight disease. However, the incidence was lesser in some of the hybrids compared to Bhagwa.

3. CROP PRODUCTION

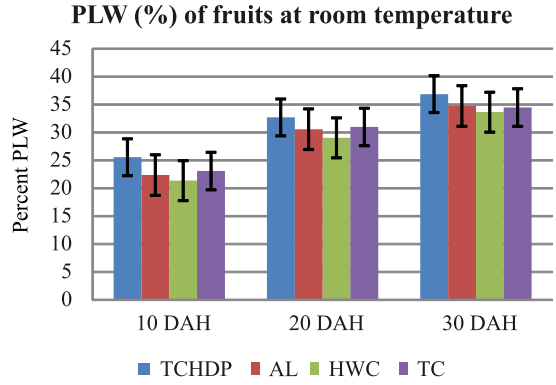
3.1 Plant Propagation

3.1 Evaluation of physiological loss in weight (PLW) of fruits harvested from different types of planting material

The study was undertaken in the year 2015-16 to evaluate the physiological weight loss (%) of fruits harvested from plants raised through different types of planting material. The experiment was set up simultaneously under cold storage conditions with 5°C and 80% relative humidity and at room temperature with 27°C temperature and 35 % relative humidity using same number of fruits harvested from plants raised through different planting material. Under cold store conditions at 10 DAH (days after harvest) the maximum and at par PLW was registered by fruits of tissue cultured plants planted under high density (0.466 %) and fruits of air layered plants (0.443%), However, among fruits of hard wood cutting raised and tissue culture raised plants under normal density, the PLW were at par. Similar pattern was observed with fruits kept at room temperature, where at 10 DAH the maximum PLW was registered by fruits of tissue cultured plants planted under high density (25.558%) which was followed significantly by fruits on plants raised through other methods including fruits of tissue cultured plants under normal density. However, at 20 and 30 DAH the PLW of fruits on plants raised thorough different methods were at par. The physiological loss in weight was much higher in case of fruits kept at room temperature as compared to fruits under cold store conditions.



(TCHDP- Tissue cultured plants under high density; AL- Air layered plants; HWC- Hard wood cutting raised plants; TC- Tissue cultured plants)



(TCHDP- Tissue cultured plants under high density; AL- Air layered plants; HWC- Hard wood cutting raised plants; TC- Tissue cultured plants)

PLW of fruits of pomegranate plants raised through tissue culture, air layering and hardwood cutting

Quality evaluation of fruits harvested from pomegranate plants raised through tissue culture, air layer and hardwood cutting as planting material

An experiment was initiated in the year 2014-15 and 2015-16 to evaluate the comparative performance of pomegranate cv. 'Bhagwa' plants raised through different methods of propagation namely, tissue culture, air layering and hardwood cutting. The experiment was designed according to RBD with 4 treatments and 4 replications. Average fruit yield per unit area (405 m^2) and 100 aril weight

were found to be significantly influenced by the type of planting material used. Fruit yield was significantly higher in tissue cultured plants under high density and hard wood cutting raised plants (167.808 and 141.655 kg, respectively) as compared to other treatments. Similarly, fruits on plants raised through tissue culture and hard wood cuttings had significantly bolder arils than fruits on air layered plants. All other quantitative and qualitative parameters were not affected significantly by the type of planting material. The experiment was initiated with the objective to find out any significant qualitative and quantitative fruit variations particularly rind thickness between fruits harvested from tissue culture raised plants and plants raised through other methods. The results supported the quality and quantity parity among fruits raised on plants propagated through different methods except for fruit yield and 100 aril weight.

Quantitative and qualitative evaluation of 'Bhagwa' harvest raised through different propagation methods

Type of Saplings	Avg . Fruit Yield/unit area (kg)	Avg. Fruit Wt. (g)	100 Aril Wt. (g)	Avg. Rind Wt. (g)	Avg. Rind Thickness (mm)	TSS (°Brix)	Acidity (%)	Aril/rind ratio	Aril Bioyield point	Seed rupturing point
TCHDP	167.80^{a}	258.66	34.37^{a}	101.91	2.57	15.60	0.44	1.29	7.99	34.80
AL	129.41^{b}	236.22	27.33^{b}	94.53	2.79	15.41	0.43	1.12	6.54	32.22
HWC	141.65^{a}	244.83	39.13^{a}	101.83	2.75	15.90	0.44	1.36	7.10	32.16
TC	105.65^{bc}	258.07	33.68^{a}	110.00	3.38	15.87	0.43	1.25	8.87	33.83

(TCHDP- Tissue cultured plants under high density; AL- Air layered plants; HWC- Hard wood cutting raised plants; TC- Tissue cultured plants)

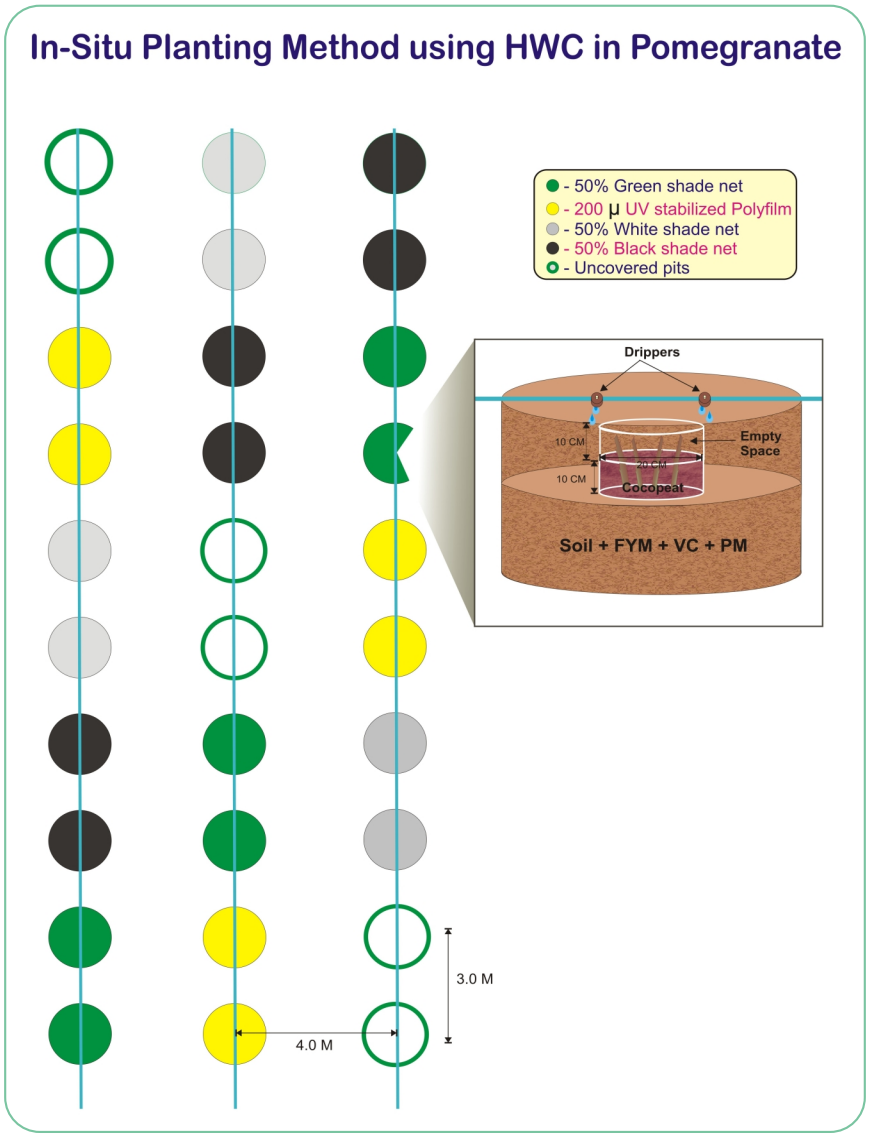
***In situ* hardwood cutting**

An experiment was initiated in the year 2015-16 to evaluate the influence of different shading options on success of *in situ* hard wood cutting. All the three shade nets were having 50 % shading effect and UV resistant, the polythene sheet was 200 micron thick UV stable and punctured with pin holes. Most of the observed parameters were found to be significantly influenced by pit covering material. *In situ* cutting success was at par in all the three types of shade nets but was significantly higher than the pits covered with polythene sheet and open pits. Similarly, sprout length was also significantly influenced by the covering material. The correlation study suggested that the difference between outside and inside temperature had significant impact on cutting success and sprout length. Open pits and polythene sheet covering were unable to lower down the temperature (scorching heat) inside the pits as done effectively by shade nets of different colours. The results might have been entirely opposite if the planting would have been done in winters. The root and shoot fresh weight were also significantly influenced by the optimum ambience created inside the pits by different shade nets with the highest values achieved with white shade net covering (2.56 and 11.86 g, respectively). The method of *in situ* hard wood cutting and a comparative cost economics of *in situ* hard wood cutting planting have been worked out.

Comparative evaluation of different pit covering materials on *in situ* hard wood cutting in cv. Bhagwa

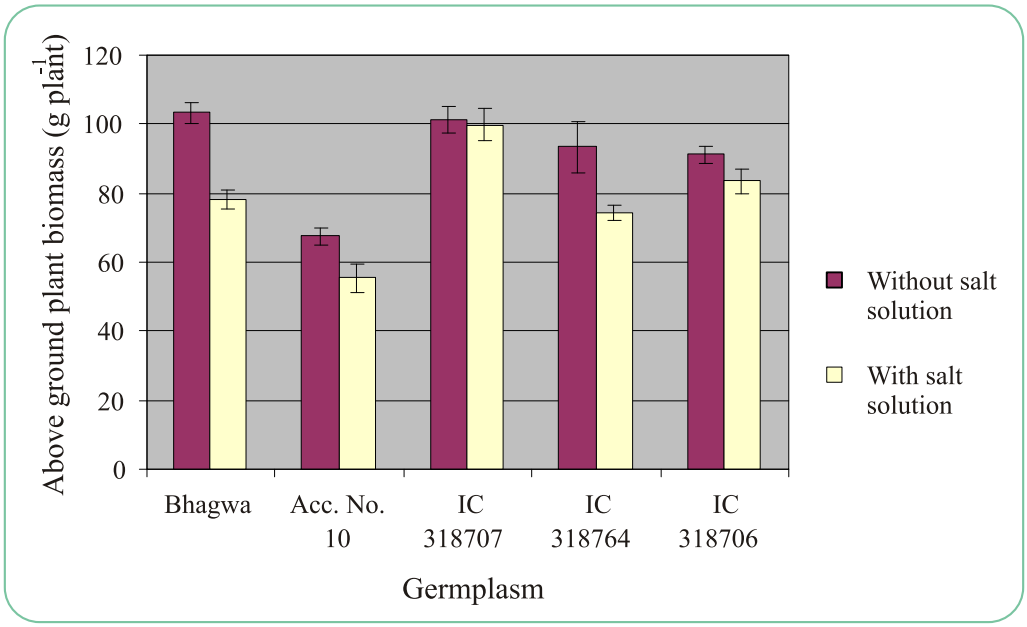
Type of Shade net	Cutting Success (%)	Avg. Sprout length (cm)	Temperatu re Difference (°C)	Relative Humidity Difference (%)	SPAD Value	Root Fresh wt. (g)	Shoot Fresh wt. (g)
Open	52.45^{b}	1.81^{b}	1.142^{b}	4.83^{c}	46.36	0.83^{d}	2.42^{e}
Black Shade Net	84.77^{a}	9.79^{a}	2.52^{ab}	11.50^{b}	43.54	1.86^{b}	9.34^{b}
White Shade Net	89.72^{a}	10.38^{a}	3.244^{a}	12.167	47.45	2.56^{a}	11.86^{a}
Green Shade Net	84.77^{a}	8.22^{a}	2.639^{ab}	12.66^{b}	45.03	1.48^{c}	7.45^{c}
Polythene Sheet	54.95^{b}	4.65^{b}	-1.282^{c}	21.33^{a}	46.41	1.05^{d}	5.912^{d}

The economics monetary benefit of *in situ* HWC planting with 75% cutting success was worked out as Rs. 28589/- per hectare as compared to conventional planting. This includes profit from sale of additional planting material produced.



Screening of germplasm against salinity

NaCl (160 mili moles) treatment resulted in reduction in growth of above ground biomass in all the five germplasm taken for evaluation. Lower the reduction in plant growth, higher the tolerance of germplasm to the soil salinity. The results of the experiment indicated the minimum growth reduction in IC 318707 (1.57%) followed by IC 318706 (8.50%) as compared to Bhagwa (24.00%). This is one of the criteria for screening the tolerance of germplasm against soil salinity.



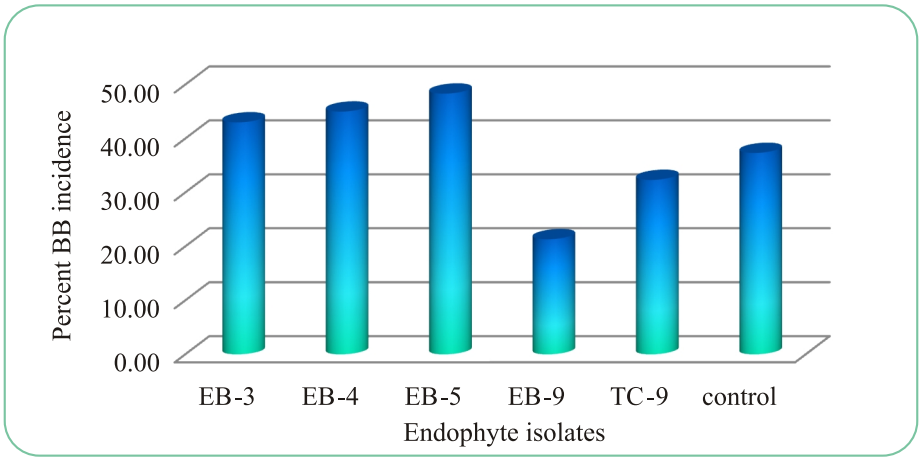
Effect of soil salinity on the above ground growth of pomegranate

***In vitro* propagation**

During the year 2015-16 fifteen new combinations of basal media and growth regulator combinations were tried for enhancing *in vitro* multiplication of micro shoots, among different combinations maximum number of side shoots were obtained with three combinations namely, modified MS medium supplemented with TDZ + NAA + Zeatin, BAP + NAA + Zeatin and BAP + Kinetin + NAA. Among rooting media, the maximum rooting success was obtained with modified MS medium (3/4 Macro salt concentration) + IBA (1 mg/l).

Endophytes for controlling bacterial blight

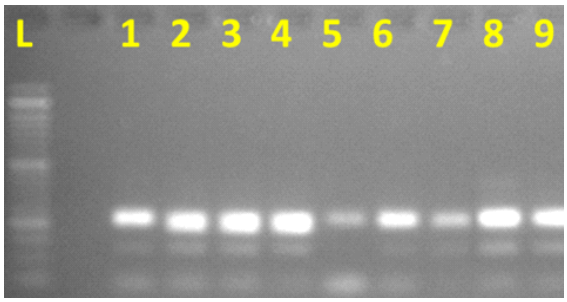
Promising endophytes from pomegranate were evaluated in pot culture trials for control of bacterial blight. Among 5 bacterial endophytes from pomegranate tested against Xap, *Bacillus subtilis* isolate EB-9 was most promising with 42.86% reduction in BB over control



Percent bacterial blight reduction with pomegranate endophytes in two months

Perspective utilization of SSR markers for testing of genetic fidelity in tissue cultured plantlets of cv. Bhagwa

The present study was conducted during 2015-16 to identify variety specific robust SSR markers for further utilization in clonal fidelity testing of tissue culture raised clones of pomegranate. Initially, Bhagwa plantlets collected from Indapur, Ankoli, ICAR-NRCP, Solapur (Hardwood cutting & Tissue culture, field) and its closely related varieties were tested to identify Bhagwa specific markets using 20 SSR markers. Out of 20 markers, five were found polymorphic between Ganesh and Guleshah Red. These five markers were selected for further testing. Among these five polymorphic markers, PgSSR-35, PgSSR-70 and PgSSR-87 markers could able to clearly distinguish "Bhagwa" from its closely related varieties (Arakta and Mridula). Further, these markers could be used in testing clonal fidelity in tissue cultured cv. Bhagwa plantlets.



PgSSR-70 marker [1-Bhagwa (Indapur); 2-Mridula; 3-Arakta; 4-Guleshah Red; 5-Ganesh; 6-Bhagwa (Field); 7-Bhagwa (Tissue culture); 8-Bhagwa (Hardwood cutting); 9-Bhagwa (Ankoli)]

3.2. Nutrient Management

Micronutrient management in pomegranate for enhancing yield and quality:

Effect of Zn application on pomegranate fruit yield, fruit attributes and quality

Application of Zn through different source and methods significantly increased pomegranate fruit yield except foliar application of EDTA chelated Zn. Foliar application of $ZnSO_4$ @ 0.3%, amino acid chelated Zn @ 2 ml litre^{-1} and fertigation of EDTA-Zn @ 12.5 g Zn plant^{-1} recorded maximum fruit yield and also highest number of fruits per plant. Significant improvement in total soluble solid (TSS) content was also noted in these three treatments. Maximum average fruit weight and highest tritratable acidity were recorded in foliar application of amino acid chelated Zn and fertigation of EDTA-Zn. It was also observed that Zn application significantly increased juice content of fruit, fruit length and diameter.

Foliar application of $ZnSO_4$ and fertigation of EDTA-Zn significantly increased anthocyanin content of arils. Significant improvement in ascorbic acid content of juice was also noticed with foliar application of $ZnSO_4$ and amino acid chelated Zn and fertigation of EDTA-Zn.

a) Control

b) Foliar application of $ZnSO_4$

Effect of foliar application of $ZnSO_4$ on fruit yield and its attributes

Effect of different methods of Zn application on micronutrient content in fruit

Foliar application of $ZnSO_4$ and fertigation of EDTA-Zn significantly increased fruit Fe content and the former practice significantly increased Fe content in edible part of the fruits i.e. arils also. There was no reduction in Mn content in edible arils owing to application of Zn.

Although, only foliar application of $ZnSO_4$ could able to increase Zn content of whole fruit, however, this method and other two methods of supplementing Zn viz, foliar application of amino acid chelated Zn and fertigation of EDTA-Zn effectively increased Zn content of arils, the most edible part. It was also noted that foliar application of $ZnSO_4$ does not lead to declination of Cu content in edible arils.

Effect of different methods of Zn application on bacterial blight disease infestation in pomegranate

Bacterial blight disease caused by *Xanthomonas axonopodis* pv. *punicae* is a serious threat to pomegranate industry. Bacterial blight disease incidence and severity were assessed on leaves as well as fruits over the fruiting period. Although, there was not much reduction in incidence of bacterial blight disease in leaves, foliar application of $ZnSO_4$ could able to reduce the severity of disease in leaves, while other methods of Zn application did not. But foliar application of $ZnSO_4$ and fertigation of EDTA-Zn significantly reduced disease incidence and severity on the fruits.

Deficiency symptoms of micronutrients

Iron:

- Iron deficiency chlorosis symptoms appear on rapidly growing shoots.
- Inter-veinal area of leaves truns into yellow colour but vein remains green.
- At sever deficiency chlorotic spot become necrotic.

chelated Zn @ 2 ml $litre^{-1}$ and fertigation of EDTA-Zn @ 12.5 g Zn $plant^{-1}$ recorded maximum fruit yield and also highest number of fruits per plant. Significant improvement in total soluble solid (TSS) content was also noted in these three treatments. Maximum average fruit weight and highest tritratable acidity were recorded in foliar application of amino acid chelated Zn and fertigation of EDTA-Zn. It was also observed that Zn application significantly increased juice content of fruit, fruit length and diameter.

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Iron deficiency

Iron deficiency

Zinc

- Leaf lamina become narrow and leaf margin gets chlorotic which later on turns to yellow.
- At severe deficiency, chlorotic spot turns necrotic
- Internode get shorter and leaf arise from node form a cluster resembling broom
- Fruit size get reduced

Zinc deficiency symptoms

Zinc deficiency symptoms

Manganese

- Appearance of light green mottle between the main veins
- A band of darker green left bordering the main veins while the inter-venal chlorotic areas become pale green or dull yellowish in colour.
- At severe deficiency, pink pigmentation appears in inter-venal area.

Manganese deficiency symptoms

Manganese deficiency symptoms

Foliar application of $ZnSO_4.7H_2O$ @ 0.3% four times viz. two sprays before flower bud initiation and rest two after fruitset at 30 days interval was found to be most effective and economical for supplementing Zn to the pomegranate plant. This resulted significant increase in fruit yield, improvement in quality (TSS, Juice per cent, phenol, ascorbic acid, anthocyanin etc.) and enhancement in Zn content not only in fruit but also in edible part i.e. arils.

3.3. Water management

3.3.1. Comparison of various irrigation methods with sub-surface drip irrigation system for pomegranate production

The experiment was conducted on comparative performance evaluation of micro-irrigation methods to find out the effect of growth

performance of 3rd year pomegranate orchard. Six treatments were replicated four times in RBD during 2015-16. Various micro-irrigation treatments encouraged plant growth, reduced moisture evaporation and also regulated soil temperature. Maximum plant height, flowers, branches and stem diameter was recorded in SDI with double laterals (30*30 cm) followed SDI with double laterals (30*40 cm), SDI with double laterals (30*50 cm), DI with double laterals (4D), SDI with single laterals (30 cm) and DI with single lateral (2D) Soil moisture withholding was also higher in the SDI with double laterals (30*30 cm). The highest number of flowers, fruit and Soil temperature is in SDI with double lateral at 30*30 cm. The seasonal values of water requirement to be applied to pomegranate tree ranged from 760 to 1710 liters/year/tree for 3rd year pomegranate plant.

In lateral geometry experiment, 3 main treatments and 6 sub-treatments in split-plot design were conducted to find out the effect of 3rd year old age pomegranate orchard during 2015-16. The seasonal values of water requirement to be applied to pomegranate tree were 3640 liters/year/plant. The 0.40*ETr is the best treatment having double laterals with 4 drippers followed by ring type and single lateral (2D) and maximum plant height, branches, stem diameter, flowers, fruits and soil temperature was recorded in 0.40*ETr with double lateral. Average of three monthly shaded area (m^2), wetted area (%), total area of leaves (m^2) and leaf area index at solar noon hours is mentioned.

SDI at 30 cm spacing & bearing

Ring type DI with six drippers &bearing

Cumulative growth performance and water use in various micro-irrigation methods during April, 2015 to March, 2016

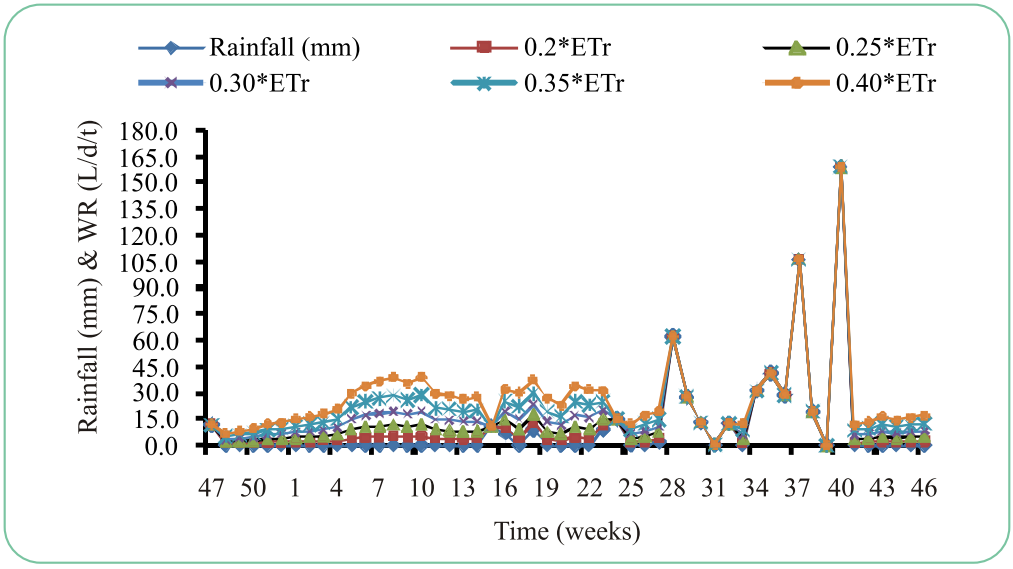
Treatments	Water use (Liters.)	Plant height (cm)	Plant spread (cm)		Stem diameter (cm)	Flowers (Nos.)	Fruits (Nos.)	Soil Temp (^{0}C)
			EW	NS				
T_1	760	123	107	104	73	48	36	25.70
T_2	950	129	119	122	95	52	48	25.50
T_3	1140	130	131	127	75	51	42	25.70
T_4	1330	124	117	116	81	49	42	25.60
T_5	1520	120	106	105	95	65	32	24.84
T_6	1710	128	122	118	103	38	41	24.80

(T_1-SDI with single lateral (30 cm), T_2 - SDI with double laterals (30*30 cm), T_3-SDI with double laterals (30*40 cm), T_4- SDI with double laterals (30*50 cm), T_5-DI with single lateral (2D) and T_6-DI with double laterals (4D)) (Spacing-4.5 x 2 m)

Cumulative growth performance in lateral geometry experiment (April, 2015 to March, 2016)

Treatments (0.15 to 0.40*ETr)	Plant height (cm)	Plant spread (cm)		Stem diameter (cm)	Flowers (Nos.)	Fruits (Nos.)	Soil Temp (^{0}C)
		EW	NS				
T_1	125	120	110	2.5	48	33	20.30
T_2	130	132	130	3.5	68	45	19.89
T_3	129	133	110	2.6	53	37	19.44

(T_1- Single lateral (2D), T_2 - Double laterals (4D), T_3-Ring type (6Di)), (Spacing-4.5 x 2 m)



Pomegranate evapotranspiration, ETp (liters/day/plant)

Monthly shaded area, wetted area and leaf area index

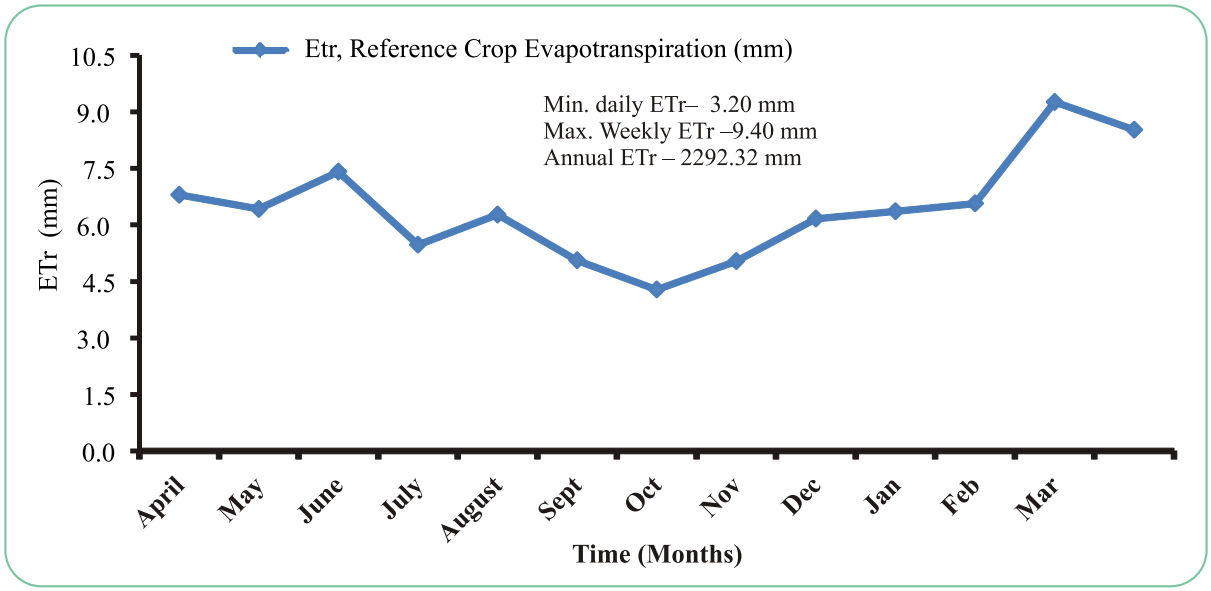
Months	APP (m2)	SA (m2)	WA (%)	TA (m2)	LAI_{SN}
April-July (2015)	9	1.32	20.25	4.69	3.59
Aug.-Nov (2015)	9	1.99	25.23	6.98	3.52
Dec-Mar.(2016)	9	2.11	30.24	7.02	3.32

(APP-Area per plant (m^2), SA – Shaded area (m^2), WA-Wetted area(%), TA-Total area of leaves (m^2) and LAI_{SA}- Leaf area index at Solar noon hour (m^2/m^2), (Spacing-4.5 x 2 m)

3.3.3. Effect of mulches and irrigation level on yield, quality and WUE of pomegranate

Estimation of Reference Crop Evapotranspiration (ET_r, mm)

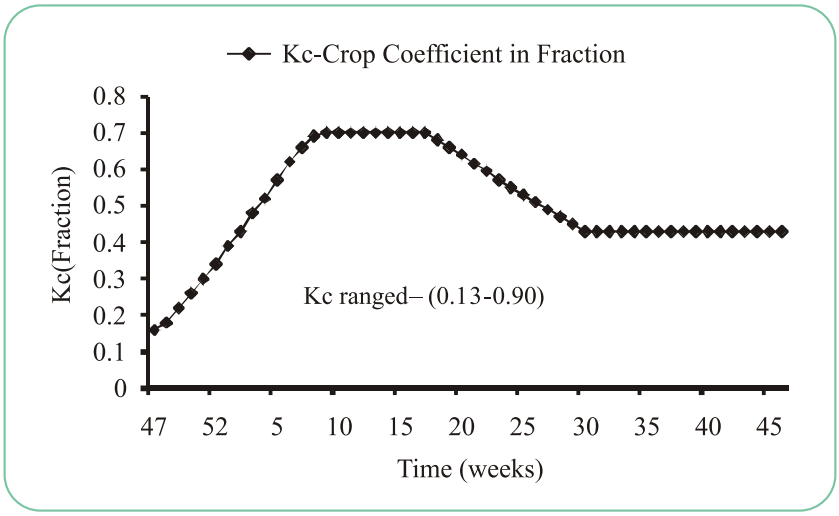
Reference crop evapotranspiration (ET_r, mm) is the major component of pomegranate water requirement. It is the quantity of water transpired by plants during their growth or retained in the plant tissue and the moisture evaporated from the surface of soil and vegetation. It is used to describe the atmospheric "demand" for water. The major factors affecting reference crop evapotranspiration are climatic parameters. Consequently, reference crop evapotranspiration is a climatic parameter and can be computed from weather data. Reference crop evapotranspiration expresses the evaporative power of the atmosphere at a specific location and time of the year and does not consider the crop characteristics and soil factors. Hence, the daily climatic data for the period of April, 2015 to March, 2016 were used to determine daily, weekly and monthly reference crop evapotranspiration (ET_r) by using Penman-Monteith Method. The monthly ET_r values were worked out. The yearly reference crop evapotranspiration (ET_r) obtained are 2292.32 mm. The ET_r was maximum in May (19-21 SMW) and minimum in September (35-39 SMW). The daily minimum and maximum ET_rranged from 3.20 to 9.40 mm.



Monthly ETr (mm) values from April, 2015 to March, 2016 at experimental site

Development of crop coefficient (K_c) values

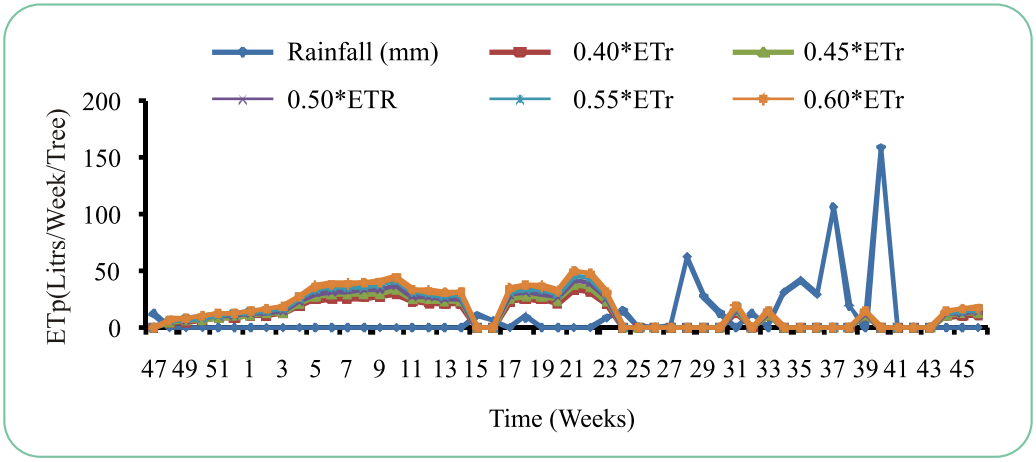
Crop coefficients are needed to estimate pomegranate evapotranspiration (ET_p) with reference crop evapotranspiration (ET_r). These coefficients are dimensionless numbers that are multiplied by the ET_r values to know pomegranate evapotranspiration in mm. It varies with crops, age, phenological stages, location, by time of the years and specific cultural or management practices. Therefore, the weekly crop coefficient values were computed by using equation (Kc = 0.014x+0.08) and converted in monthly basis. The monthly crop coefficient curve for pomegranate tree in 4th year is presented in Fig. Figure indicates that the values of crop coefficient increases from 0.16 to 1.10 due to the development, maturation of the leaf surface, increased number of leaves, foliage, water sprout, flowers and fruits of the tree during 4th year. The K_c values increases linearly from March to May months due to increases in number of leaves, water sprout, luxors, flowers, fruits and shaded area as observed from the representative trees and decreases from June to July months due to removing of water sprout, leaf drop and harvesting of fruits. The crop coefficient (0.70-0.90) increases in the month of January to March due to increases excess water sprout, foliage and management practices.



Crop coefficient curve for 4th year pomegranate plants

Estimation of Pomegranate Evapotranspiration (ETp, liters/day/tree)

The daily water to be applied through drip irrigation system at 90 % efficiency from April, 2015 to March, 2016 ranged from 6–40 liters/day/tree for 4th old age of pomegranate tree at 0.50*ETr is the best. It gradually increases or decreases during different development stages of pomegranate tree due to the variation of reference crop evapotranspiration, pan coefficient, wetted area and crop coefficient values. Lower Kcvalues represent slower plant growth and lower plant canopy cover, indicating lower ETp. The annual pomegranate evapotranspiration is 10073 liters / year / tree and water to be applied to pomegranate tree ranged from 4009 to 6009 liters/year/tree based on different irrigation levels 0.40 to 0.60.. The critical stages wise water requirement in L $stage^{-1}t^{-1}$ including number of days for pomegranate Bhagwa cv. (*i.e.* new leaf initiation, crop development, maturity and harvesting) were identified .



Daily pomegranate evapotranspiration (liters/day/plant) of 4th year plants

Critical pomegranate plant stages for irrigation in *Hasta* Bahar for 4th year plants

Critical stages for Irrigation	Nos. of days	WR for SDI in ($L\ S^{-1}t^{-1}$) for 3rd	WR for LG in ($L\ S^{-1}t^{-1}$) for 3rd	WR for IOM in ($L\ S^{-1}t^{-1}$) for 4th	WR for OM in ($L\ S^{-1}t^{-1}$) for 4th
New leaf initiation	22-25	30-40	40-60	115-150	150-180
Crop development (Flowering to fruit Setting)	70-80	275-300	385-400	1190-1350	1485-1560
Mid (Fruit development)	60-70	283-350	395-450	1422-1550	1777-2000
Harvesting(Fruit removal)	45-60	207-240	290-350	1237-1360	1600-1800

(WR-Water Requirement; $L\ S^{-1}t^{-1}$-Litres per stage per tree; SDI-Subsurface drip irrigation system; LG-Lateral geometry; OM-Organic mulch and IOM-Inorganic mulch)

Pomegranate Evapotranspiration for Inorganic and Organic Mulches (ETp, litres/day/plant)

An experiment on different organic (i.e. Wheat, Safflower and Sugarcane baggas) and inorganic mulches (i.e. Black and White, Black and Pervious) was conducted to find out the effect of mulches on soil properties and growth of pomegranate. Eight treatments including control were replicated four times in split plot design. Various-mulching treatments encouraged plant growth, reduced moisture evaporation and also regulated soil temperature. Depletion of soil moisture was very high in untreated plants. Maximum number of fruits was recorded in sugarcane baggas and pervious mulches with 0.50*ETr, followed by wheat, safflower and black and white and black. Soil moisture retention was also higher in the black mulch treated plants.

Growth parameters

Bhagwa cv. of pomegranate was evaluated for their growth parameters in organic and inorganic. Plant height, plant spread (EW & SE), stem diameter, stem girth, thorn length, flowers and number of fruits ranged from 115 to 175 cm, 125 to 174 cm, 120 to 145 cm, 3.5 to 4.9 cm, 2.9 to 3.2 cm , 2.8 to 4.2 cm, 70 to 107 flowers and 40 to 76 fruits.


Organic mulch with bearing


Inorganic mulch with bearing

Growth performance under organic and inorganic mulching

4th Year Days	Plant height (cm)	Plant spread (cm)		Stem diameter (cm)	Stem girth (cm)	Thorn length (cm)	No. of Flowers	No. of Fruits
		EW	SE					
Organic mulch (0.35 to 0.75*ETr)								
T1	115	125	120	3.3	2.6	2.7	240	48
T2	142	130	140	3.8	2.9	3.4	270	56
T3	165	146	135	4.7	2.8	3.6	308	76
T4	140	130	130	4.2	2.7	3.9	90	43
Inorganic mulch (0.35 to 0.75*ETr)								
T1	126	152	130	3.5	2.8	2.8	258	40
T2	148	160	139	3.6	3.0	2.9	250	55
T3	166	170	138	4.5	2.8	3.8	340	85
T4	139	145	132	4.1	2.9	3.9	160	50

(Organic mulch - T_1- Wheat, T_2-Safflower, T_3-Sugarcane baggas, T_4-Control and Inorganic mulch-T_1-Black and White, T_2-Black, T_3-Pervious,T_4-Control)

Economics of Mulching

Economics of pomegranate under different organic mulches (pooled)

Treatments	Cost of cultivation (Rs./ha)	Gross income (Rs./ha)	Net income (Rs./ha)	B:C Ratio
T1-Sugarcane baggas	439420	1020000	580580	2.32
T2-Wheat straw	425720	910000	484280	2.13
T3-Pady straw	429720	840000	410280	1.95
T4- Control	539630	750000	210370	1.38

The economic analysis of different mulch materials revealed that, amongst the locally available mulch materials, all proved better than control treatment. Out of three organic mulches, sugarcane baggase were found most profitable with respect to net returns and benefit: cost ratio followed by wheat straw and paddy straw.

Economics of pomegranate under different inorganic mulches (pooled)

Treatments	Cost of cultivation (Rs./ha)	Gross income (Rs./ha)	Net income (Rs./ha)	B:C Ratio
T1-Black	854553	1080000	225447	1.26
T2-Black & White	854553	1170000	315447	1.37
T3-Pervious	861401	1380000	518599	1.60
T4- control	932230	720000	212230	0.77

The economic analysis of different mulch materials revealed that mulching with pervious material in pomegranate is most profitable which has the highest gross return, net income and B: C ratio. Inorganic mulches and improve the CO_2 availability in the plant which ultimately led to the higher photosynthesis. Black plastic mulch has an additional advantage that the absence of light within it did not allow photosynthesis under the film and weed growth decreased. On the contrary with transparent films, the presence of light with the improved condition of growth (heat, moisture, good soil structure) encouraged weed growth.

3.4. Fertigation

Effect of fertigation of N-P_2O_5-K_2O on flowering behaviour and soil fertility status of pomegranate

Application of water-soluble N-P-K fertilizer through irrigation water significantly increased percent hermaphrodite flowers by 7.74% and percent fruitset by 46.31% in comparison with application of N-P-K fertilizers in solid forms. The maximum increase in percent hermaphrodite flowers (10%) and per cent fruit set (52.09%) were recorded when 75% of recommended dose (RD) of N-P-K fertilizers were applied through irrigation water at 7 days interval according to the crop need. Water soluble fertilizers applied through irrigation water at 7 days interval resulted higher percent hermaphrodite flower production (62.36%) and per cent fruitset (47.53%) compared to application of the same at 15 days interval.

Study of soil fertility status at flowering stage indicated that application of water soluble N-P-K fertilizers with irrigation water at 75% of RD at 7 days interval recorded highest amount of available N and K content of soil, while, the application of same at 50% of RD at 15 days interval noted highest available soil P content. Further, application of 75% of RD of N-

P-K through fertigation at both 7 and 15 days interval recorded significantly higher DTPA extractable Mn content of soil while, 50% of RD of N-P-K applied through fertigation at 15 days interval noted higher DTPA extractable Fe and Zn content of soil. Fertigation of 75% of RD of N-P-K at 15 days interval resulted significantly higher DTPA extractable Cu content of soil.

3.5. Crop management

3.5.1. Effect of growth regulators on production of hermaphrodite flowers of pomegranate

Different growth regulators (NAA@ 50,100,150ppm; GA@10,20,30ppm & Ethrel @250,500,750ppm) were foliar sprayed to pomegranate cv. Bhagwa at 3 weeks after defoliation during the hasth bahar to study their efficacy in producing more number of hermaphrodite flowers. The number of hermaphrodite flowers was maximum in Ethrel@500ppm (170.0 flowers /plant) which was on par with Ethrel @250ppm (168.66 flowers / plant). Control registered the minimum no. of bisexual flowers (122.33 flowers/plant).

3.5.2. Evaluation of pomegranate under different training systems

Preliminary evaluation of pomegranate under different training system revealed that there was no significant difference in fruitset during third year among single, double and triple stem training system. The fruitset ranged from 44.44 to 56.44% with highest fruitset in single stem (56.44%). Maximum no. of axillary flowering was observed (70.40%) in four stem training system. However, in other training systems, more no. of terminal flowering (31.90 - 40.56 %) was observed.

Evaluation of pomegranate under different training systems

Training system	Total bisexual Flowers (no./plant)	Total fruits (no./plant)	Fruit set (%)	Axillary flowers (no./plant)	Axillary flowering (%)	Fruit yield (kg/plant)
5 Stem	104.3	50.1	48.05	71.00	68.10	12.36
4 Stem	98.0	48.9	49.89	69.00	70.40	12.13
1 Stem	45.0	25.4	56.44	26.75	59.44	6.35
2 Stem	51.0	27.8	54.50	30.60	60.00	7.10
3 Stem	78.3	40.85	52.20	49.75	63.57	10.25
Control (>5stem)	108.0	48.0	44.44	72.00	66.66	12.69

Single stem

Double stem

Triple stem

Four stem

Five stem

Control (>5 stem)

Evaluation of pomegranate under different training systems for flowering

Single stem

Double stem

Three stem

Four stem

Five stem

Control (>5 stem)

Evaluation of pomegranate under different training systems for yield

4. CROP PROTECTION

4.1 Borer pests

4.1.1 Standardization of rearing protocol for pomegranate fruit borer under laboratory conditions

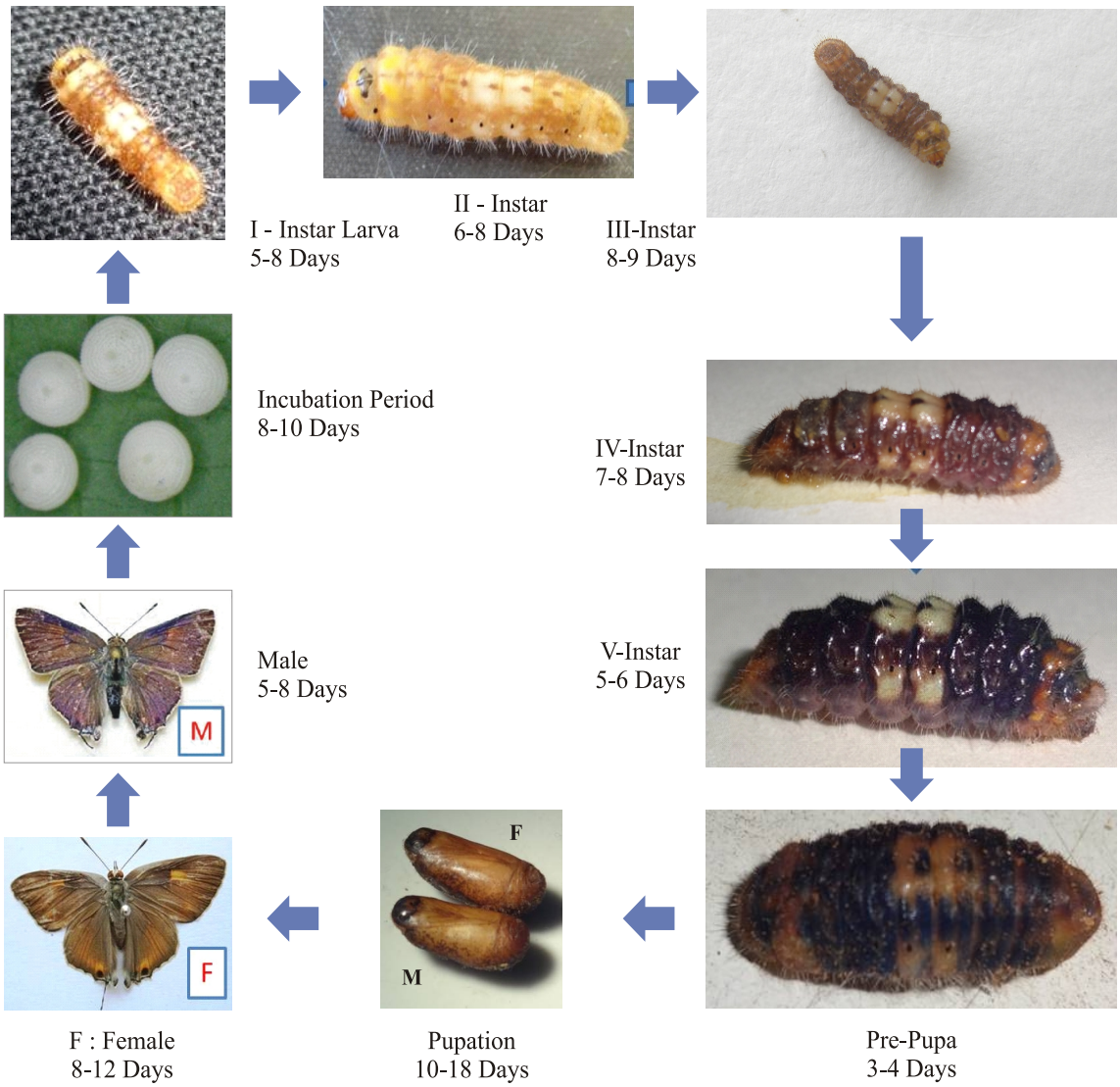
Laboratory rearing of the pomegranate fruit butterfly (*Deudorix isocrates*) was carried out on pomegranate fruits and on semisynthetic diet under ambient room conditions (T = 27 ± 1°C; RH = 70 ± 10%; 12L: 12D). This work aims in assessing the biological parameters of this insect species on these two substrates. The female laid round creamy white eggs singly but also in pair either on the fruits or on the side cloth walls of rearing cases and sometimes on the upper or lower surface of the cage. Hatching of eggs was not observed from the insects which were reared on both the substrates. The first instar larvae emerged from field collected eggs and they accomplished their total imago development in 45.3 ± 1.82 days on pomegranate and in 35.3 ± 1.88 days on artificial diet. On semisynthetic diet and pomegranate fruits, the pre-oviposition periods were 1.2 ±0.42 and 1.8 ±0.31 days respectively whereas ovipositional periods were 3.6±1.07 and 5.8±1.52 days respectively. The fecundity on pomegranate was 27.4 ± 3.30 as compared 28.5 ± 4.20 from artificial diet reared females.

Duration of different life stages of *Deudorix isocrates* on pomegranate fruit and semisynthetic diet under laboratory condition

Sl. No	Particulars	Duration (days) of life stage on			
		Semisynthetic diet		Pomegranate fruit	
		Range	Average	Range	Average
1	Pre-oviposition (days)	1-2	1.2±0.42	1-3	1.8±.31
2	Oviposition (days)	2-5	3.6±1.07	2-6	5.8±.52
3	Post-oviposition (days)	4-7	5.22±1.22	5-8	7.2±1.61
4	Fecundity (no.)	21-30	27.4±3.30	25-32	28.2±4.72
6	Larval period (days)	33-38	35.3±1.88	43-48	45.3±1.82
7	Viability of pupae (%)	-	81.6±2.6	-	83.1±3.1

Diet ingredients for rearing of pomegranate fruit borer

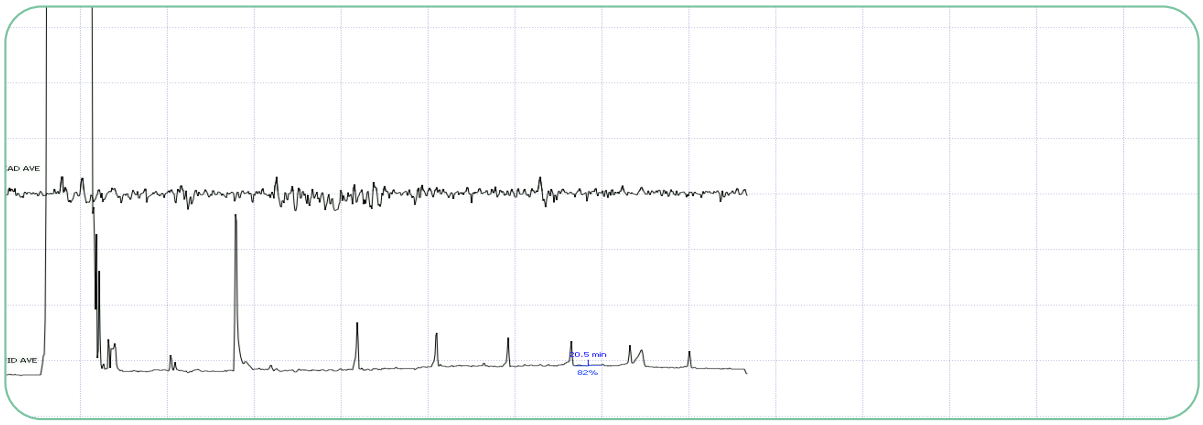
Ingredients	Quantity	Ingredient	Quantity
Gram flour	105g	Methyl para-hydroxy-benzoate	2g
Yeast tablets	25 tablets	Sorbic acid	1g
Water	400 ml	Streptomycin sulphate	0.25
Agar agar	12.75 g	Multivetaplex capsules	2 no.
Water	400 ml	Formaldehyde-10% solution	2 ml
Ascorbic acid	3.25g	Pomegranate rind powder	5g



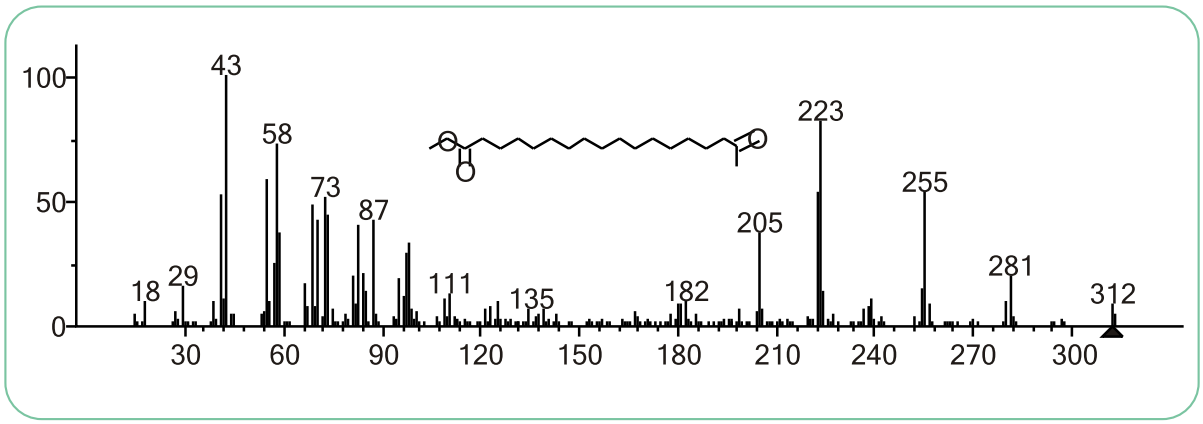
4.1.1 Behavioural and attraction studies of pomegranate fruit borer to plant volatile and female abdominal glandular extraction

The laboratory reared freshly emerged virgin adult male and females were kept in separate cages. The calling behaviour of the butterfly was observed i.e. the rigorous shaking of wings and raising of the abdominal tip of the body. The abdominal tip of both male and female was cut with the micro-scissors and taken into the glass vials with Dichloromethane (HPLC grade), vortexed and subjected to centrifuging at10000 rpm. Solution was filtered through the membrane filter and the pure dirt free liquid was collected in small glass vials. The antenna of the freshly emerged adult male and female were cut and subjected to the response of antenna to the injected liquid to GC-EAD (Gas chromatography and electro-anttenogram detector). Based on the response of the antennae to the injected liquid at specific retention time the compound was detected. The detected compound was identified with the help

of the GC-MS (Gas chromatography and mass spectrometry). The compound was identified as a methyl ester based pheromone compound for the pomegranate fruit borer.



Detection of the compound with help of GC-EAD



Identification of the pheromone compound with help of GC-MS

4.1.3. Studies on the biological control of pomegranate fruit borer

Experiment was conducted to know the effectiveness of the *Telinomus sps.* parasitoid under laboratory conditions. The field parasitized eggs of *Deudorix isocrates* was collected from the field and kept for hatching. The adult parasitoids emerged from the eggs were identified as *Telinomus sp.* with the help of experts and females were separated from males. The females were used for the further parasitization. Out of 10 eggs collected from field, five were parasitized (50% parasitization). Four out of five emerged were females (80% emergence).

The adult female parasitoids emerged from the field parasitized eggs were further used for evaluating the parasitizing efficiency on *Deudorix isocrates* eggs. In total, thirteen eggs of *Deudorix isocrates* were exposed to four adult parasitoids which led to parasitisation of nine eggs out of emergence of 10 adult, results in 69.23% parasitisation and 60% of female emergence. This result indicates that the *Telinomus sp.* may serve as good parasitoid under field conditions for the management of pomegranate fruit borer.

Percent parasitism of *Deudorix isocrates* eggs by *Telinomus sp.* under laboratory conditions

No. of eggs collected from the field	No. of eggs parasitized	No. of adults emerged	% parasitism	% Female emergence
10	**5**	**5**	**50**	**80**
No. of *Deudorix isocates* eggs exposed for *Telinomus sp*	No. of eggs parasitized	No. of adults emerged	% Parasitism	% Female emergence
13	**9**	**10**	**69.23**	**60**

4.1.4. Collection, identification and laboratory rearing of fruit sucking moth

Three different species of fruit sucking moths were collected from the experimental plot, H-6 of NRCP and from Pakri village, Solapur, from first week of August to third week of October. The collected adults were brought to laboratory, kept in rearing cages and identified as male and female with the sex ratio of 1:2. The fruit sucking moth larvae emerged from the laboratory laid eggs of moths were reared on *Tinospora cardifoilia* under the laboratory conditions consecutively for four months and the life cycle was completed on an average of 30-33 days. The adult moth was large, robust with large eyes. Single adult moth lived up to 8-10 days and lay about 200-350 eggs. Spherical eggs were laid singly on *Tinospora cardifolia* and walls of rearing cages, muslin cloth and mosquito net which were provided as substrate for egg laying. Incubation period for egg was 4-5 days. The larval stage passed through five instars and took 4-5 days, 2-2.5 days, 2.5- 3 days, 2.5-3 days, and 3.5-4 days, respectively. Full grown caterpillars were 50-60 mm long and were bright coloured with orange, yellow and blue spots on speckled body and were semiloopers. Pupation took place in a transparent pale whitish silken cover, which lasted for 13-14.5 days. The duration of egg to egg-laying adult female was about 32 to 37 days. Moths of genus *Eudocima* had a highly specialized proboscis with hardspines capable of piercing hard and tender pomegranates. Adult males and female moth penetrates the fruits at night and damaged fruits became soft owing to secondary infections from different fungi and bacteria. Punctured holes on fruits with oozing fruit juice were noticed.

Biology of *Eudocima materna* (L.) on *Tinospora cardifolia*

Stage	Duration (days) at 27±1°C
Egg	4-5
Larva I	4-5
II	2-2.5
III	2.5-3
IV	2.5-3
V	3.5-4
Total larval duration	14.5 – 17.5
Pupa	13-14.5
Total developmental period	32-37

Egg

First instar larva

Second instar

Third instar

Fourth instar

Fifth instar

Male & female pupa

Life stages of *Eudocima materna*

Eudocima materna

Eudocima fullonia

Eudocima homaena

Different species of fruit sucking moth

- In the multiple choice feeding preference tests the pomegranate fruit and juice were preferred over the diluted honey solution and jaggery fermented with bread yeast.
- The experiment on choice and non-choice test was conducted under the laboratory conditions for the feeding preference of fruit sucking moth on banana, guava, pomegranate and tomato. Among these the guava and banana were preferred over the others.
- The trap was being evaluated for fruit sucking moth with selected food lures (punctured pomegranate, pomegranate juice, diluted honey and fermented jaggery). No catches of fruit sucking moth was found.

4.2. Sucking pests

4.2.1. Laboratory evaluation of feeding potential of *Scirtothrips dorsalis*

Thrips (*Scirtothrips dorsalis*) were maintained in laboratory to study the feeding potential and fecundity of different predatory anthocorid bugs on the target host. Thrips were collected from the pomegranate plants and reared on fresh red rose in the lab condition. The rose flower stalks were wrapped with the cotton and inserted into a glass vial filled with water, in such way that the rose flower stalk should touch the water level. This setup was placed on an inverted petri plate and covered with glass chimney. The rim of the chimney at the base was sealed using parafilm to avoid escape of thrips from the top of the chimney. Field collected thrips were released on the flower and the open end of the chimney was covered using black muslin cloth, fastened with rubber band, two sets as described above were kept at a time. Fresh flowers were inserted into the chimney after 2-3 days so that the thrips from the old dry flower can move to the fresh flowers. Predators *Blaptostethus pallescens* were reared on thrips and it completed its life cycle (Average 52 days) by feeding on an average of 350-400 thrips under the laboratory conditions.

Efficacy of different treatments on pomegranate thrips and fruit borer on Bhagwa and Ganesh variety

Treatment	Particulars	Reduction (%) of pest population in			
		Bhagwa		Ganesh	
		Thrips	Fruit borer	Thrips	Fruit borer
T1	Cyantroniliprole	78.13	98.40	63.95	97.19
T2	Thiamethoxam 25 WG	75.75	98.26	59.92	95.15
T3	Thiacloprid 21.7 SC	87.74	98.09	68.05	97.10
T4	Dimethoate 30 EC	67.59	98.37	47.61	95.87
T5	*Verticillium leccani*	54.12	98.42	49.61	95.59
T6	Dimethoate 30 EC + FORS	50.25	96.78	39.28	96.47
T7	Control (Water + Sticker)	20.04	89.06	19.62	87.38

4.2.2.Evaluation of different insecticides and bio-pesticides for the management of pomegranate pests.

Among the seven treatments imposed for the management of thrips, Thiacloprid provided better reduction of thrips in Bhagwa (87.74%) and Ganesh (68.05%). This was followed by Cyantroniliprole for reduction of thrips in Bhagwa (78.13%) and Ganesh (63.95%). All the treatments imposed kept fruit borer infestation below 5% as compared to the control (11-13%) and there was no significant difference among the treatments in reducing the fruit borer infestation in both the varieties.

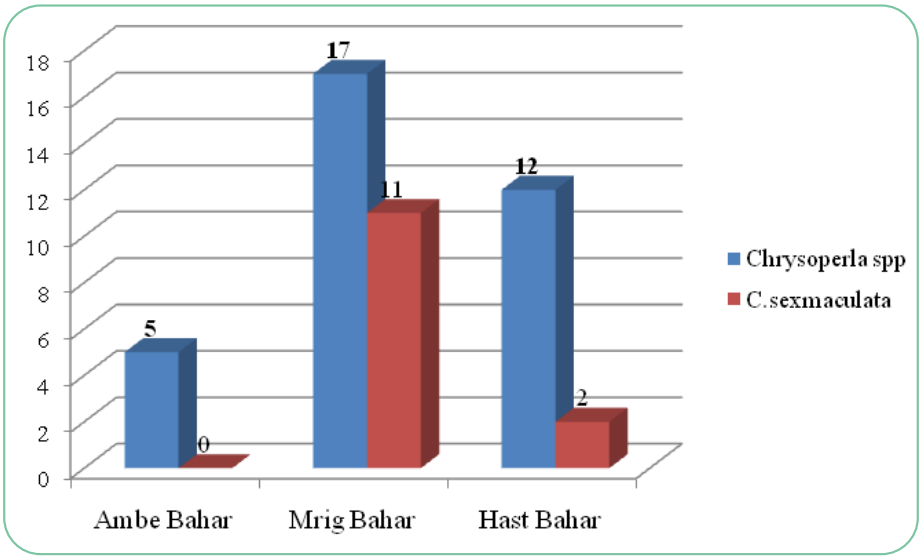
4.2.3. Studies on seasonal incidence of insect pests and their natural enemies

The electronic solar light trap was being evaluated for the borer pest of pomegranate and on an average two adult beetles of shot hole borer trapped per day in solar electronic trap and no stem borer and fruit borer catch was recorded.

Months	Damage percent	
	Thrips	Fruit borer
August	45.60	0.62
September	53.81	101
October	61.25	1.93
November	74.00	2.46
December	79.12	2.22
January	47.76	1.09

Seasonal incidence of pomegranate fruit borer and thrips

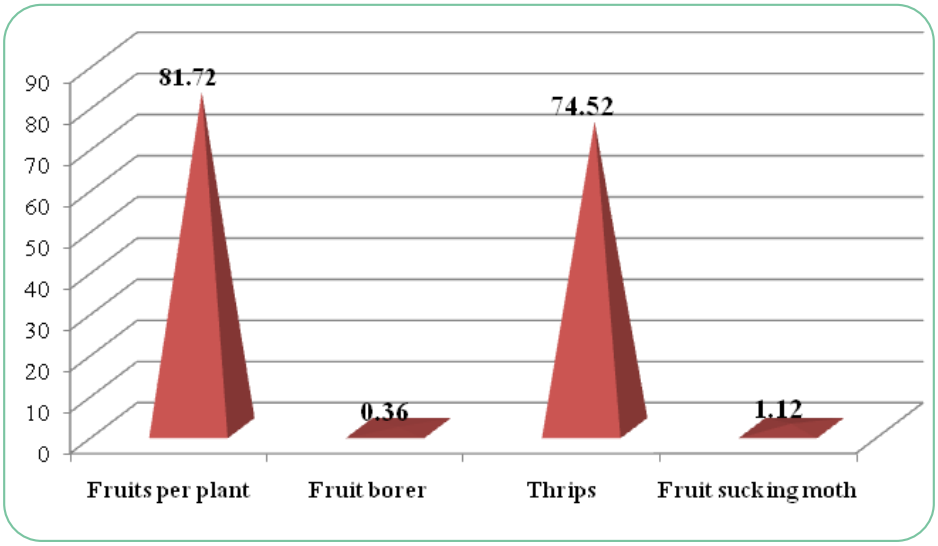
- Data was recorded on the seasonal incidence of pomegranate pests in Kegaon and Hiraj farms of NRCP from August 2015 to January 2016. On an average thrips (*Scirtothrips dorsalis* Hood) incidence was highest in month of Dec (79.12%), the incidence of fruit borer is almost same in both months in Nov and Dec (2.46 % and 2.22%), respectively.
- Among natural enemies, Coccinellid beetle (*Coccinella sexmaculata*) and Green lace wing (*Chrysopela sp*) were having the highest activity. The highest number of *Chrysoperla sp* was found in mrig bahar (17 no.) and least number was found in ambe bahar (5 no.), and highest number of *C. sexmaculata* was found in mrig bahar (11 no.)



Seasonal incidence of natural enemies of pomegranate pests

4.2.4.Survey of important insect pests of pomegranate

- Survey was conducted in Akluj, Girjani, Izori, Paniv, Bagechiwadi, Khandali, and Pilivemalsira taluk the severe incidence of shot hole borer was found in one field (20% plants infested) and fruit borer incidence was 25- 30% in all the field and very severe incidence of fruit sucking moth (50-60%) and thrips damage (60-70%) in all the fields.
- Survey was conducted at Wadegaon and Sangewadi, of Solapur district and the data was recorded on the incidence of the fruit borer (0.36%) and thrips (74.52 %) and fruit sucking moth (1.12%).



Incidence of fruit borer, thrips and fruit sucking moth during the survey

- The survey was conducted on the incidence of different insect pests of pomegranate in Ambalaga, babalad, Jambaga B of Gulbarga district. The lower incidence of pomegranate fruit borer 1-2% Vand the thrips incidence was 5-10% in Babalad and two plants with the stem borer damage were noticed in Jambaga B. No pest incidence was reported in Ambalaga.

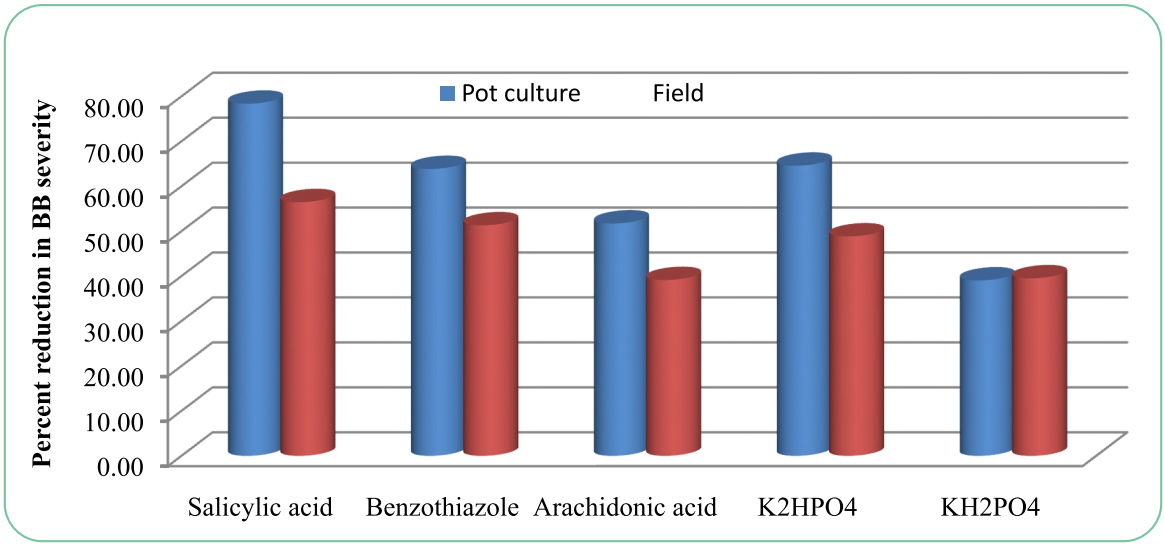
4.3. Bacterial blight

The highlights of work done during 2015-16 under the "Flagship Project on Integrated Approach to Eradicate Pomegranate Bacterial Blight" by nodal agency ICAR-NRCP, Solapur and coordinating Centres –ICAR-IIHR Bengaluru, ICAR-IARI New Delhi, UHS Bagalkot and YSPUHF Nauni, Solan is summarized here.

4.3.1. Promising novel agents for bacterial blight management

4.3.1.1.Chemical agents and Nutrients

SAR Activators : Eight compounds capable of activating systemic acquired resistance (SAR) were evaluated at 50 and 100 ppm against bacterial blight (BB) of pomegranate caused by *Xanthomonas axonopodis* pv. *punicae* (Xap) in pot culture studies at YSPUHF, Nauni, Solan, Himachal Pradesh. Chemicals were sprayed after 72 hours of Xap inoculation. All chemicals significantly reduced BB severity over control which recorded 59.09% BB severity. Salicylic acid recorded highest BB reduction of 78.37% at 100 ppm followed by K_2HPO_4 and benzthiazole with 64.58 and 63.84% reduction respectively. The effective chemicals were further evaluated at 100 ppm for field efficacy. Maximum BB reduction was in salicylic acid (56.46%) followed by Benzthiazole (51.30%) and K_2HPO_4 over control with 87.4% BB severity.



Reduction in bacterial blight with SAR chemicals in pot culture and field

4.3.1.2. Establishment of nutrient sufficiency range for imparting disease resistance in plants against bacterial blight

Nutritional survey revealed that concentration of Ca, Mg, Mn and Cu in leaves were significantly high in moderately resistant germplasms, while N, K and S concentration were observed to be high in susceptible ones. Bacterial blight disease severity on foliage and leaf nutrient concentration built a databank, which was divided to moderately resistant (disease severity $\leq$ 20%) and susceptible (disease severity >20%) sub-populations based on their impact on yield loss. Mean, standard deviation and variance were calculated for each subpopulation. The mean values (in moderately resistant subpopulation) of 10 nutrients expression were selected as the diagnostic norms for imparting moderate resistance to the pomegranate plant. As per DRIS analysis, leaf nutrient status of N 1.56-2.05%, P 0.11-0.28%, K 0.83-1.20%, Ca 1.60-2.16%, Mg 0.38-0.82%, S 0.09-0.16% and micronutrients viz. Fe 132.50-187.00 mg kg^{-1}, Mn 31.60-58.40 mg kg^{-1}, Zn 13.20-27.40 mg kg^{-1} and Cu 26.00-47.80 mg kg^{-1} could result in imparting moderate resistance to bacterial blight disease. Nutrient imbalance indices of susceptible germplasm diagnosed through DRIS and CND had linear relationship ($R^2 = 0.93$ and $R^2 = 0.82$) with bacterial blight disease severity and are suitable for diagnosis of nutrient imbalances. Deficiency of Ca was observed as the cause of disease in 80% of the susceptible germplasm studied. The next important nutrient deficiencies in the susceptible germplasm were Cu (77.14%), Fe (77.14%), Mn (68.57%) and Mg (65.71%).

Validation of DRIS norms : DRIS approach was used to evaluate the nutritional status of twenty-one pomegranate cv. Bhagwa orchards from Mohol, Sangola and Pandharpur talukas of Solapur district, Maharashtra, India with prevalence of bacterial blight disease severity 34.62-92.20%, 49.70 – 86.45% and 26.92 – 35.75% respectively. DRIS nutrient imbalance indices were higher in Sangola and Mohol taluks compared to Pandharpur. Accordingly, bacterial blight disease severity was significantly higher in Sangola and Mohol talukas as compared to Pandharpur. In all the orchards Mg, Ca and Mn were most limiting nutrient and Cu was found limiting in 52.38% orchards which made plant susceptible to bacterial blight disease. Leaf N and K concentrations was higher in pomegranate orchards of Sangola and

Mohol while Mg, Ca and Mn concentrations was higher in pomegranate orchards of Pandharpur talukas registering lower bacterial blight disease severity compared to Sangola and Mohol talukas.

The results demonstrated that higher bacterial blight disease severity in pomegranate plant grown on high pH soil was mainly due to lower concentration of Mg, Ca, Mn and Cu and higher concentration of N in leaves.The sufficiency ranges of foliar nutrient concentration for imparting moderate resistance in plant against bacterial blight disease are 1.56-2.05%, 0.11-0.28%, 0.83-1.20%, 1.60-2.16%, 0.38-0.82%, 0.09-0.16% for N, P, K, Ca, Mg and S and are 132.50-187.00, 31.60-58.40, 13.20-27.40 and 26.00-47.80 mg kg^{-1} for Fe, Mn, Zn and Cu respectively.

4.3.1.3. Effect of Nitrogen and salicylic acid on plant response to bacterial blight infection : Foliar application of SA at the rate of 300 ppm generated an increase of above-ground dry mass per plant by 64.97%, improved chlorophyll content of leaves and enhanced concentration of macro-elements and micro-elements particularly Mn and Zn in leaves irrespective of different N application rates. It also increased apparent N recovery by the plant and the recovery was more with N supply at 50% of the recommended dose. The activities of nitrate reductase (NR), superoxide dismutase (SOD), catalase and peroxidase enzymes increased significantly in response to the application of SA. However, maximum response of SA was recorded when it was sprayed after soil application of N at 100% of recommended dose. As a consequence, this combination recorded least bacterial blight infection with average severity of 11.58% followed by no N supplied plant under challenged inoculation of pathogen. However, no N application for sustainable production is a not a feasible option. A very close relation between leaf N concentration and chlorophyll meter readings was established (R^2 = 0.89) which could be useful for monitoring leaf nitrogen concentration with a portable chlorophyll meter.

Synergistic use of nitrogen and salicylic acid could remarkably reduce bacterial blight disease infection through enhancing plant's own defense mechanism as indicated by enhancement in the activities of nitrate reductase, other antioxidant enzymes and elevated mineral nutrient content. As there exist a close relationship between leaf N concentration and portable chlorophyll meter reading, it could be very useful in monitoring plant N status and adoption of management practices accordingly for managing bacterial blight disease in pomegranate in environment friendly manner.

4.3.1.4.Plant oils

Neem oil, pongamia oil, clove bud oil, clove oil were evaluated at UHS Bagalkot for inhibition of Xap. Clove oils were shown to be effective under *in vitro* conditions. Clove oil and clove bud oil were highly effective recording inhibition of 27.3 and 24.0 mm respectively.

Inhibition of Xap with plant oils at different concentrations *in vitro*

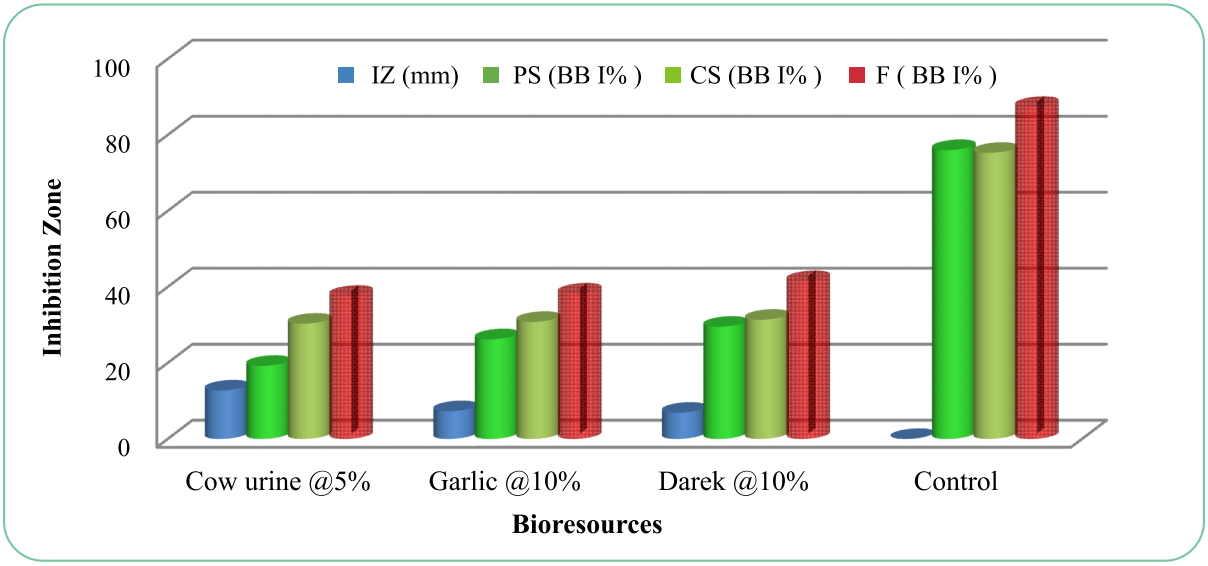
Plant oils	Inhibition zone (mm) at different oil concentrations			
	200 ppm	400 ppm	600 ppm	800 ppm
Neem oil	0.00	2.30	3.00	3.00
Pongamia oil	2.00	4.00	4.00	4.00
Clove bud oil	4.60	5.00	24.60	27.30
Clove oil	3.00	6.00	21.00	24.00
Control	0.00	0.00	0.00	0.00

Effect of different concentrations of clove oil against bacterial blight under greenhouse conditions

Clove oil (%)	BB incidence (%) on 20 days after inoculation	
	Curative	Preventive
0.10%	0.83	1.10
0.25%	1.00	1.07
0.50%	0.75	1.00
0.75%	1.00	1.50
1.00 %	1.17	1.60
Control	31.83	36.05

4.3.1.5. Bioresources

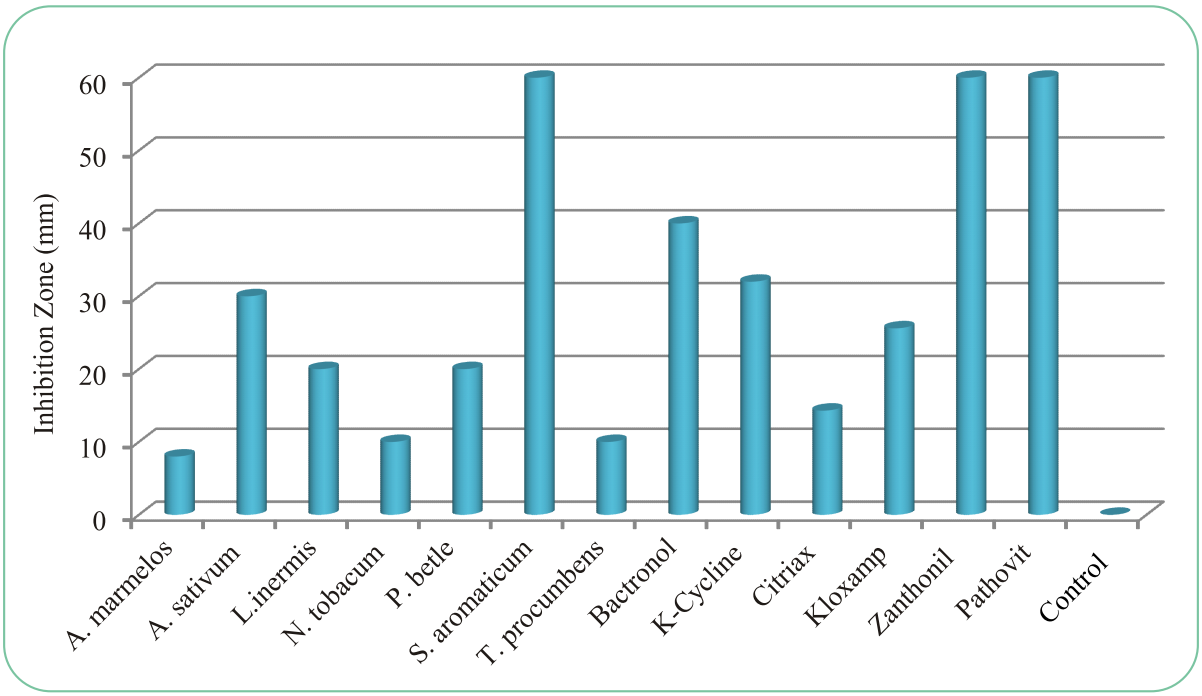
Eleven bioresources including cow urine and ten plant leaf extracts were evaluated at 4 concentrations against *X. axonopodis* pv. *punicae* under *in vitro* conditions at YSPUHF, Solan. Cow urine at 5 percent concentration exhibited maximum inhibition the growth of Xap with an inhibition zone of 12.75 mm. None of the plant extracts recorded inhibition of Xap at 5% concentration, However, inhibition zone of 10.59 mm was observed in garlic (*Allium sativum*) at 25% concentration and 6.90 mm in darek (*Melia azedarach*). Sprays of cow urine in greenhouse and field were also found most effective in reducing BB incidence followed by garlic and darek. Other botanicals exhibited lower efficacy and that to at high concentration of 10% and above in field trials.



Effect of selected bioresources on inhibition zone (IZ) of Xap *in vitro*

(IZ – Inhibition zone; PS (BBI%) – Bacterial blight incidence on leaves due to preventive spray;
CS (BBI%) – Bacterial blight incidence on leaves due to curative spray;
F (BBI%) – Bacterial blight incidence on fruits due to preventive spray)

In a separate experiment at IIHR Bengaluru, the antibacterial activity of 28 botanicals and 8 chemicals and botanical commercial formulations were investigated against the bacterial blight pathogen, *X. axonopodis* pv. *punicae in vitro*. Of the 28 botanicals tested, only seven, viz., *Aegle marmelos* (Bael), *Allium sativum* (Garlic), *Lawsonia inermis* (Henna), *Nicotiana tabacum* (Tobacco), *Piper betle* (Betel), *Syzygium aromaticum*(Clove) and *Tridox procumbens* (Coat buttons) exhibited antibacterial activity against *X. axonopodis* pv. *punicae*. *S. aromaticum* showed maximum inhibition zone of 60.0 mm diameter followed by *A. sativum* (30.0 mm), *L. inermis* (20.0 mm) and *P. betle* (20.0 mm). The antibacterial activity of clove was significantly high as compared to the commercial bactericide, K-Cyline and Bronopol @ 500ppm. Results also showed that, the botanical pesticides -zanthonil and pathovit @ 0.2%, exhibited maximum inhibition zone of 60 mm and hence may be explored for the management of bacterial blight of pomegranate in field conditions.



In vitro* screening of botanicals and commercial formulations against *X. axonopodis* pv. *punicae

4.3.1.6. Effect of plant hormones and signal molecules

The growth hormones and growth regulators are generally used in pomegranate production. The experiment was designed at UHS Bagalkot to understand their role and influence on bacterial blight disease severity. Before using them under the field condition, their effect was checked under greenhouse condition. The NAA and GA treatment were found to improve the plant resistance as it recorded the least leaf blight incidence. Whereas, nitric oxide treatments were less effective or not effective in different methods.

Effect of plant hormones and signal molecules on bacterial blight under greenhouse conditions

Treatment	Per cent disease reduction over control in spray*		
	Pre-inoculation	Post -inoculation	Co-treatments
	a	b	c
NAA at 40 ppm	81.236	78.784	57.375
GA_3 at 50 ppm	81.090	75.937	37.333
2,4-D at 30 ppm	47.695	35.351	31.228
Paclobutrozol at 200 ppm	47.246	24.024	41.422
Ethrel at 200 ppm	44.634	30.079	64.243
Salicylic acid at 1 mM	51.572	60.047	15.598
Chitosan at 75 ppm	42.045	55.133	43.666
Nitric oxide at 0.1 mM	45.746	7.936	-3.022
Bronopol at 500 ppm	50.490	64.943	57.152
* Percent incidence in control (a) 35.135 (b) 31.165 and (c) 21.535			

In field conditions, all tested hormones/growth regulators contributed in blight reduction and improved yields in comparison to control. Ethylene treatment at low concentration recorded no fruit blight with improved fruit yield colour and size, which needs to be further validated.

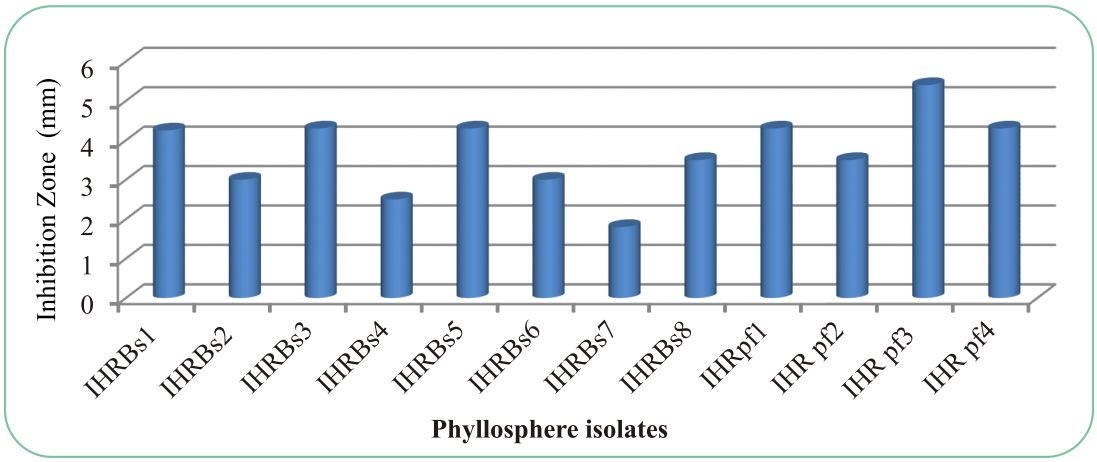
Effect of plant hormones and signal molecules on bacterial blight and fruit yield under field conditions

Treatment	Per cent disease reduction over control*			Percent yield increase over control
	Fruits	Leaves	Stems	
	a	b	c	d
NAA at 40 ppm	41.28	81.97	74.48	52.31
GA_3 at 50 ppm	70.11	95.58	74.75	70.31
2,4-D at 30 ppm	83.91	94.99	60.68	60.31
Paclobutrozol at 200ppm	83.41	87.81	57.37	88.92
Ethrel at 200 ppm	100	100	100	90.77
Salicylic acid at 1 mM	52.80	69.03	40.82	16.15
Chitosan at 75 ppm	64.76	19.28	30.68	32.77
Nitric oxide at 0.1 mM	63.31	84.26	61.37	32.00
Bronopol at 500 ppm	77.50	98.89	82.75	41.85
* Percent incidence in control (a) 27.61 (b) 25.35 (c) 14.50 and yield in control (d) 6.5kg/plant				

4.3.1.7. Biological agents

4.3.1.7.1. Bio-agents screening at ICAR- IIHR, Bengaluru

Twelve bacterial isolates were isolated from the phylloplane of pomegranate at ICAR-IIHR. Among them, eight have been identified as *Bacillus subtilis* and four have been identified as *Pseudomonas fluorescens*. Antagonistic reaction against *Xap* for all the 12 bacterial isolates was tested under *in vitro*. The inhibition zone of *Bs* isolates against *Xap* ranged from 1.80 to 4.30 mm and that of *Pf*, it ranged from 3.50 to 5.40 mm.



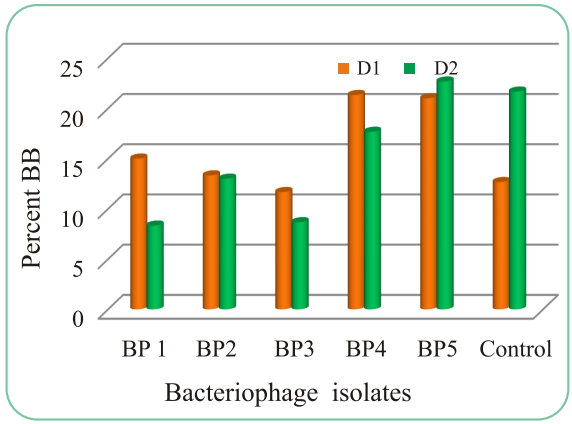
Inhibition of *X. axonopodis* pv. *punicae* in dual culture with *Pseudomonas fluorescens (Pf)* and *Bacillus subtilis* (Bs) isolates

In search for eco-friendly and effective management strategies, various bio-agents including bacteriophages, endophytes and other rhizosphere and phyllosphere bio-agents were evaluated in pot culture and field trials at different coordinating centers. The results are summarized below.

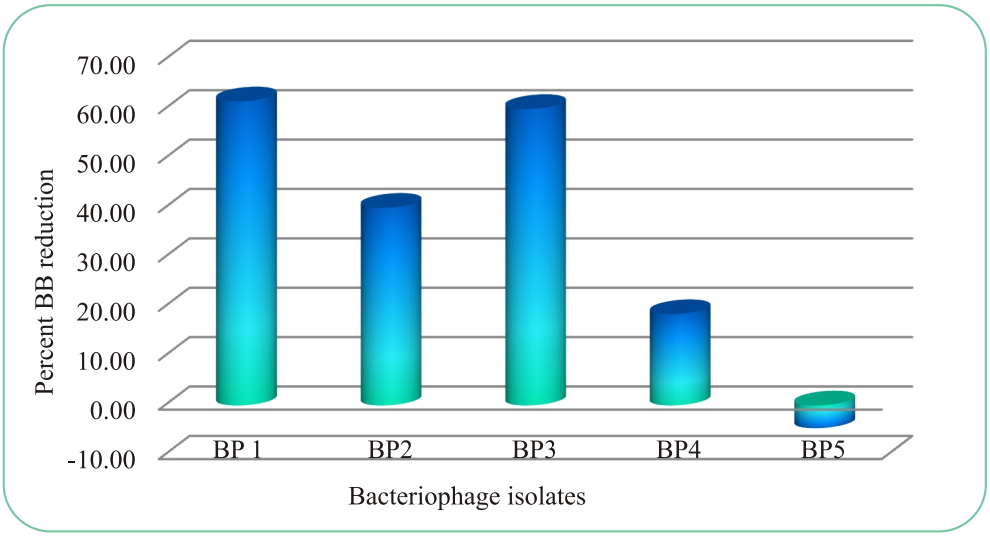
4.3.1.7.2. Bio-agents screening at ICAR- NRCP Solapur

4.3.1.7.2.1. Bacteriophage for controlling bacterial blight

Bacteriophages were isolated from different soil samples. Pure cultures were sprayed on infected pot culture plants showing BB symptoms. One out of four bacteriophage isolates (Sample 1) against *Xap* collected from soil below BB infected plant showed promise with 44.5% reduction in BB over a period of one month, whereas control plant recorded 71.1% increase in BB in the same period. All treatments when compared on a single date after one month, Isolate 1 recorded 61.55% less BB than control.



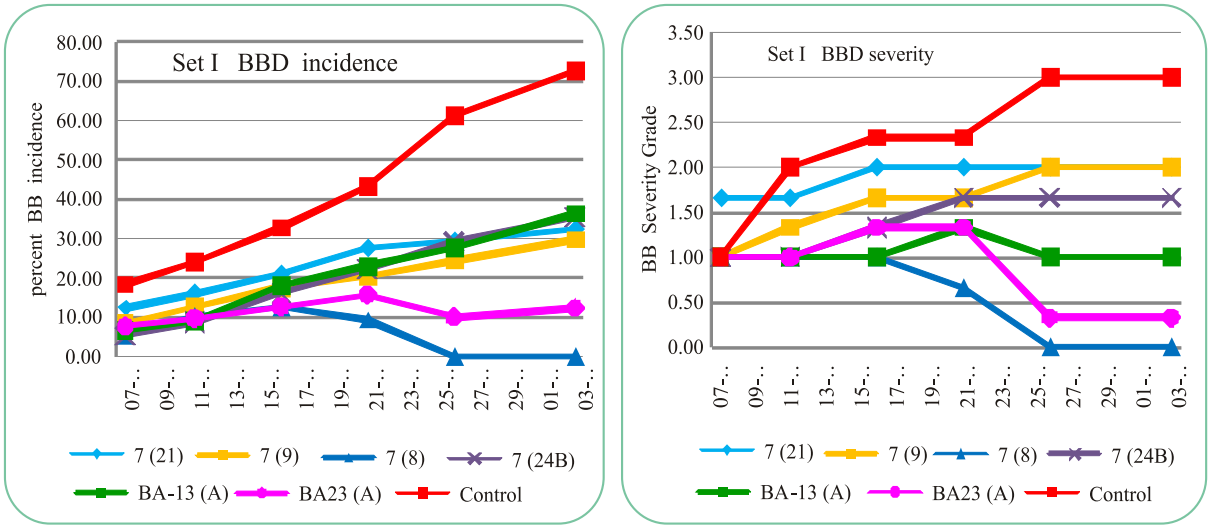
Percent bacterial blight at zero date (D1) and 1 month after bacteriophage sprays (D2)



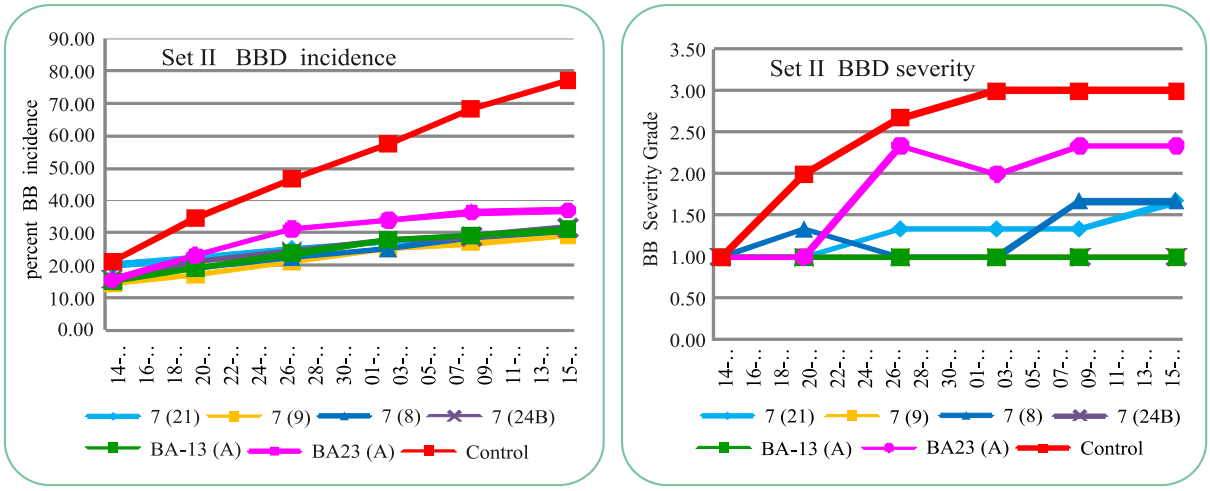
Percent bacterial blight reduction over control, 1 month after bacteriophage sprays

4.3.1.7.2.2. Fungal and bacterial bioagents

All four fungal and two bacterial bio-agent isolates tested against BB in pot culture trials, effectively reduced BB incidence. The reduction ranged from 50-100% when bio-agent sprays were initiated as prophylactic sprays and 51-62% when sprayed after appearance of BB symptoms. Fungal isolate 7(8) and bacterial isolate BA23(A) were most promising in reducing BB severity (100 and 83% reduction respectively) when used as prophylactic sprays.



Reduction in bacterial blight (BB) incidence and severity with promising bioagents. Set I: Prophylactic sprays

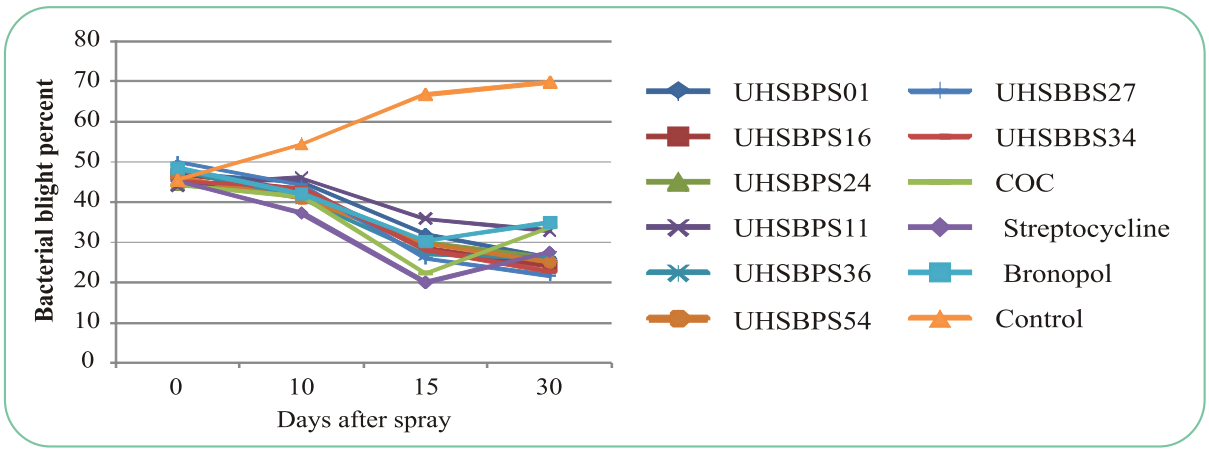


Reduction in bacterial blight (BB) incidence and severity with promising bioagents. Set II: Post disease appearance sprays

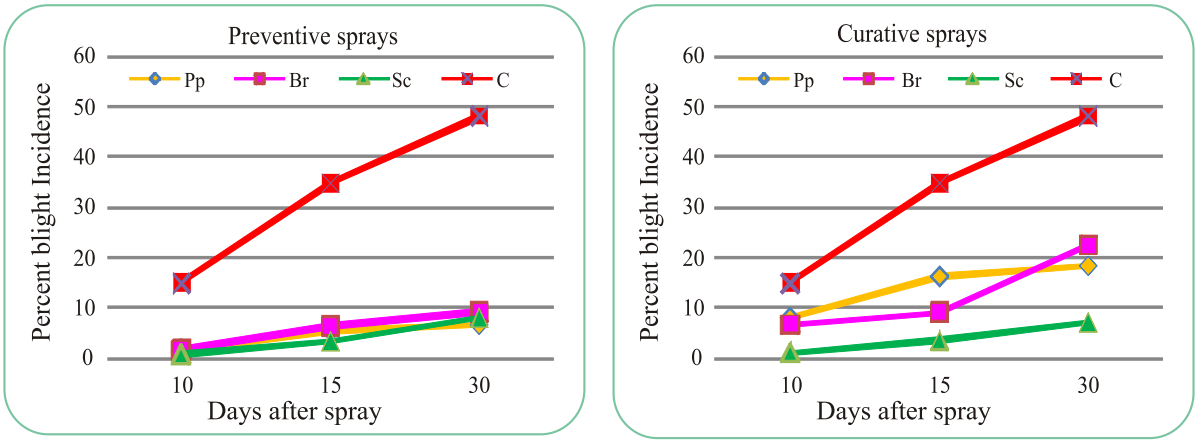
4.3.1.7.2.3. Field evaluation of bioagents: A replicated field trial with 3 UHS Bagalkot bioformulations, 6 NRCP bioagents including endophytes and one IIHR bioformulation was conducted at NRCP; 1 NRCP bioagent, 2 UHS Bagalkot formulations and 1 IIHR commercial formulation and IDIPM schedule recorded no BB as there was low BB disease incidence(Max. 1.75% in control).

4.3.1.7.3. Bioagents screening at UHS Bagalkot

***Pseudomonas* isolates :** A large number of *Pseudomonas* isolates were screened for bioefficacy against Xap *in vitro,* polyhouse and field at UHS Bagalkot. The effective isolates which recorded more than 50% inhibitions were identified using 16S and rRNA sequence procedure and submitted to gene bank and obtained the accession numbers. In all 13 *Pseudomonas putida* and one each of *Pseudomonas monteili, Pseudomonas plecoglossicida, Pseudomonas geniculate* have been submitted. Some *Bacillus subtilis* isolates have also been collected and identified. All bioagents resulted in reduction of BB at 30th day and was at par or better than chemicals in vogue under greenhouse conditions. *P. putida* isolate UHSBPS16 and *B.subtilis* isolate UHSBBS27 were most effective. In a separate experiment it was found that preventive sprays were more effective than curative sprays.

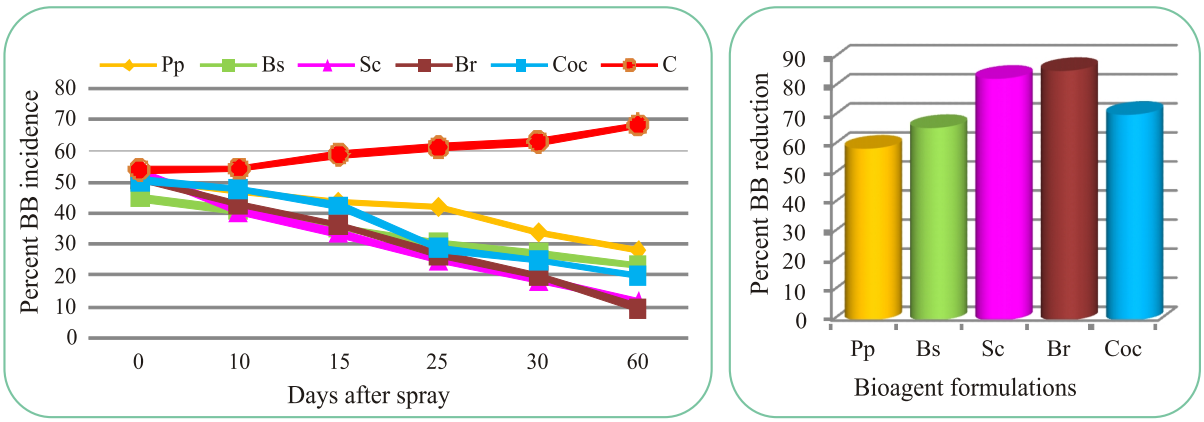


Efficacy of bioagents against bacterial blight disease under greenhouse conditions



Efficacy of *Pseudomonas putida* isolate UHSPp-16 for blight management in pot culture
(Percent blight incidence in preventive and curative sprays with Pp (*Pseudomonas putida)*; Br (2-bromo-2-nitropropane-1, 3-diol); Sc (streptocycline) and check (c)

In the successive use of bio-agents, the reduction of disease was reported both in the treatment of *Pseudomonas* and *Bacillus* as well. *Bacillus* treatment recorded 66.24% reduction and *Pseudomonas* treatment recorded 59.12% over control with 68.48% BB incidence. BB reduction was above 80% in streptocycline and bronopol and 70% in copper oxychloride. Apart from the disease suppression ability, the total biomass increase was high in the bio-agents formulation treatments whereas in the synthetics, no such beneficial effects were recorded.



Efficacy of liquid formulations of bioagents against bacterial blight under field condition:
Four (4) sprays at 10 days interval of Pp (*P. putida@ 5ml/l)*, Bs (*B. subtilis*@5ml/l), Sc (streptocycline @0.5g/l), Br (2-bromo-2-nitropropane-1, 3-diol @0.5g/l), Coc (Copper oxychloride @ 0.25g/l)

4.3.1.7.4. Isolation, characterization and evaluation of leaf associated epiphytic bacteria

Screening of bioagents at IARI, New Delhi

A total of 30 phyllospheric epiphytic bacteria isolated from leaf samples collected from Solapur were subjected to confrontation assay with *X. axonopodis* pv. *punicae.* Additionally 10 bacterial endophytes isolated by NRCP- Solapur were also included in the assay. Eight of the phyllospheric epiphytic bacteria and 3 endophytes from NRCP were found to suppress the bacterial pathogen *in vitro*. Interestingly these antagonistic bacteria were found to

antagonize fungal pathogens like *Ceratocystis fimbriata* and *Colletotrichum gloeosporioides* causing wilt and anthracnose in pomegranate. Highly antagonistic bacterial isolates were subjected to species identification using *16S rDNA sequencing*. Among the collections, *Bacillus* species dominated.

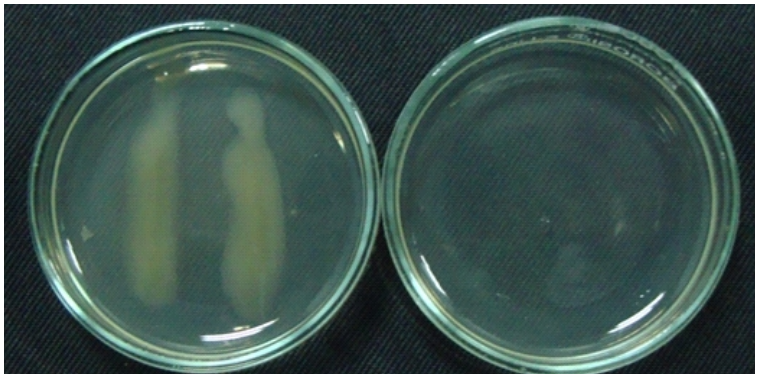
Identification of leaf associated bacteria from pomegranate

Isolate	16S rDNA (bp)	Species identity
P1	1125	*Pseudomonas stutzeri*
P2-1	1429	*Bacillus amyloliquefaciens*
P4	1407	*Rhizobium pusense*
P7-2	1104	*Agrobacterium fabrum*
P11	1071	*Acinetobacter schindleri*
P16	1062	*Brevundimonas terrae*
P19	1392	*Microbacterium esteraromaticum*
P25	1423	*Bacillus safensis*
TC-6	1426	*Bacillus subtilis*
TC-130	1414	*Bacillus licheniformis*
TC-310	1424	*Bacillus tequilensis*

Antagonistic effect of leaf associated bacteria on *Xanthomonas axonopodis* pv. *punicae*

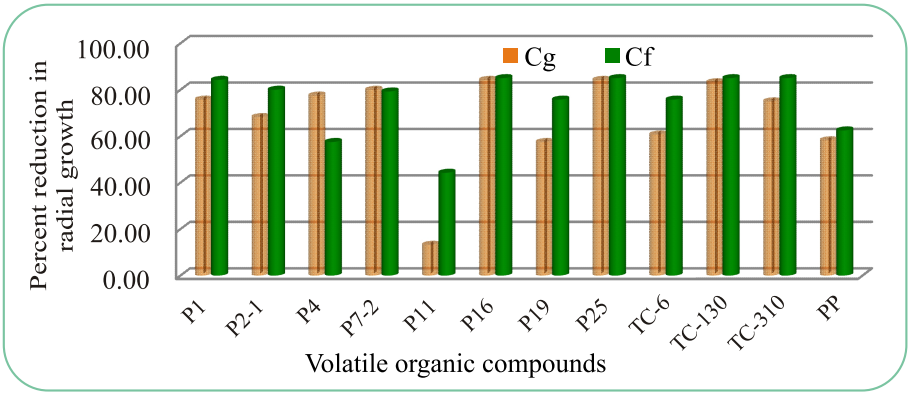
Organism		Antagonistic activity against *Xanthomonas axonopodis* pv. *punicae*	
		*Bacteriostatic	*Bactericidal
P1	*Pseudomonas stutzeri*	1	2
P2-1	*Bacillus amyloliquefaciens*	2	2
P4	*Rhizobium pus ense*	1	1
P7-2	*Agrobacterium fabrum*	1	1
P11	*Acinetobacter schindleri*	3	4
P16	*Brevundimonas terrae*	1	1
P19	*Microbacterium esteraromaticum*	3	4
P25	*Bacillus safensis*	1	1
TC-6	*Bacillus subtilis*	1	1
TC-130	*Bacillus licheniformis*	1	1
TC-310	*Bacillus tequilensis*	1	1
PP	*Pseudomonas putida*	1	1
	Mock	4	4

* 1. Highest 2. Moderately high 3. Moderate 4. No effect

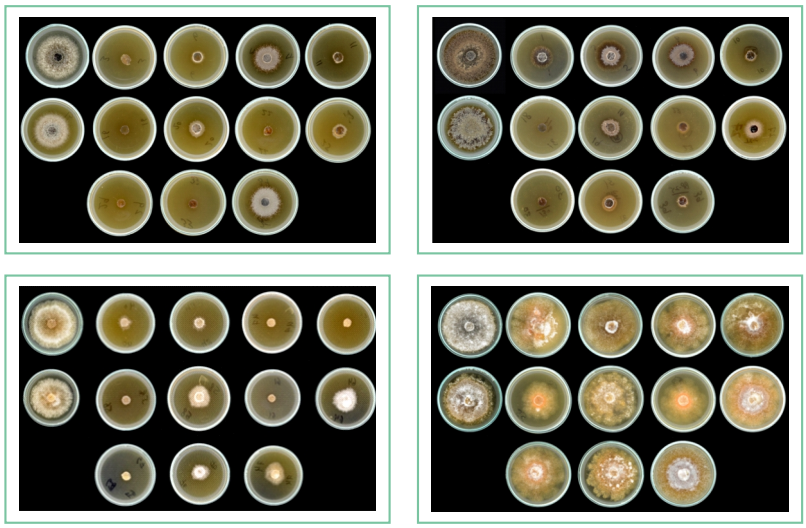


Check plate of Xap Exposed plate of Xap

Inhibitory effect of leaf associated bacterial volatile organic compounds on *Xanthomonas axonopodis* pv. *punicae*



Percent reduction in radial growth of *Colletotrichum gloeosporioides* (Cg) and *Ceratocystis fimbriata* (Cf) with leaf associated bacterial volatile organic compounds



Antagonistic effect of leaf associated bacterial volatile organic compounds on two fungal pathogens, *Ceratocystis fimbriata* (a-b) and *Colletotrichum gloeosporioides* (c-d)

In the successive use of bio-agents, the reduction of disease was reported both in the treatment of *Pseudomonas* and *Bacillus* as well. *Bacillus* treatment recorded 66.24% reduction and *Pseudomonas* treatment recorded 59.12% over control with 68.48% BB incidence. BB reduction was

4.3.2. Studies on host pathogen interaction

Basic understanding of plant bacterial interaction is essential to devise long term strategies for mitigating bacterial blight of pomegranate. In this direction programme on deciphering the phenotypic interaction of bacterial virulence factor, XopN effector on different germplasm was carried out at IARI, New Delhi.

4.3.2.1. Role of *Xanthomonas* Outer Protein (XopN) effector as a pathogenicity factor : Role of *Xanthomonas* Outer Protein (XopN) effector as a pathogenicity factor for *Xanthomonas axonopodis* pv. *punicae* was established with the help of cell death assay conducted using mutants defective for XopN expression. For this, XopN-deletion mutant of *X. axonopodis* pv. *punicae* (ΔXopN) was developed. The deletion mutant, ΔXopN, could not suppress the hypersensitive reaction (HR) induced by PAMP Triggered Immunity (PTI)-inducer strain that revealed the role of XopN in pathogenesis. The mutant showed significantly higher accumulation of defense associated H_2O_2 compared to the wild type upon *in planta* inoculation which suggests a possible role of XopN effector in suppressing oxidative burst.

4.3.2.2. Role of XopN in the regulation of H_2O_2 production on pomegranate leaves : The role of XopN, one of the crucial effectors of *X. axonopodis* pv. *punicae*, in the regulation of ROS, more accurately the H_2O_2 production was investigated on pomegranate leaves. Earlier we qualitatively estimated the H_2O_2 production on pomegranate leaves. The quantitative analysis also revealed that XapΔxopN produced significantly higher H_2O_2 compared to the wild counterpart. This, clearly suggested that XopN contributed to the regulation oxidative burst and subsequent ROS-mediated defense response. Though the level of H_2O_2 production varied across the germplasm, however in all cases the mutant induced higher H_2O_2 production

4.3.2.3. Study on structural and biochemical changes during host pathogen interactions : Structural and biochemical changes in pomegranate plant particularly in the infection foci of leaves in response to pathogen infection were studied at UHS Bagalkot. The following gene expression was recorded in response to challenge inoculation, and same were being cloned and submitted for the gene bank and accession numbers were obtained.

Genes cloned in response to Xap	Accession number
Pathogenesis related protein (PR-1)	*–KU977458*
Pathogenesis related protein (PR_2) b_1_3glucanse	*_KU977460*
Pathogenesis related protein (PR-4) -Chitinase	*-KU977459*
Pathogenesis related protein (PR-5)	*yet to be assigned*
Phenylalanine ammonia lyase (PAL)	*yet to be assigned*
Catalase (CAT)	*yet to be assigned*
Transcription factor -1	*KU977461*

4.3.3. Phenotyping and Genome wide analysis of Xap strains

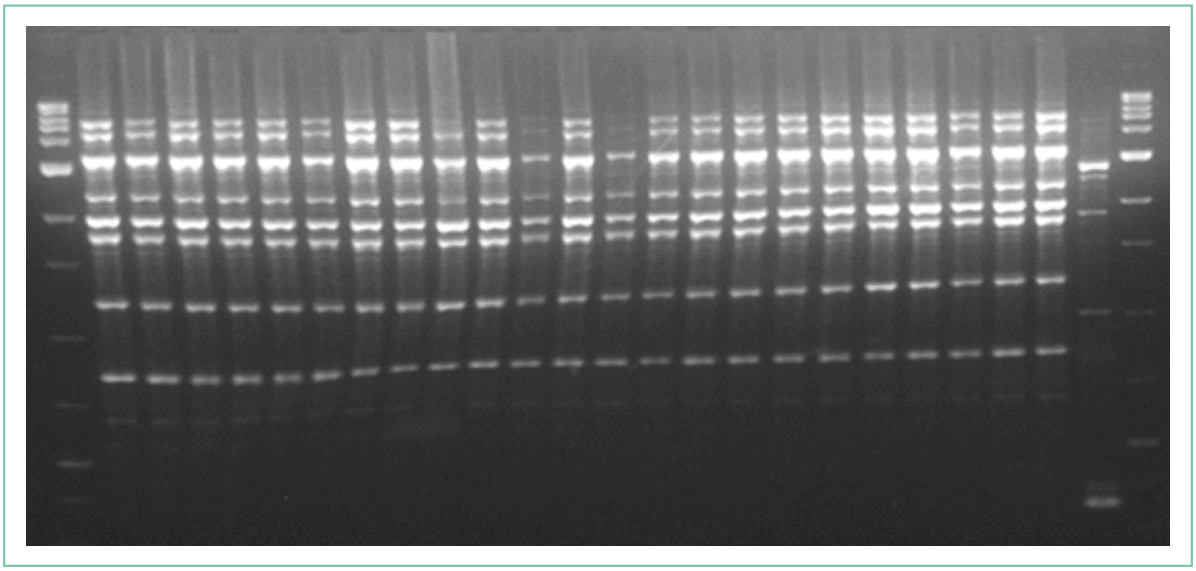
Surveys were conducted in eight districts *viz*. Hamirpur, Kangra, Bilaspur, Mandi, Solan, Shimla, Kinnaur and Sirmaur of Himachal Pradesh for recording status of bacterial blight and collecting *X. axonopodis* pv. *punicae* isolates. The varieties grown in these areas included Kandhari Kabuli, Kandhari Hansi, Ganesh, Mridula and Bhagwa. None of the pomegranate areas or varieties in the state was free from the disease. Maximum disease incidence (68.30%) was recorded in Dhanda area of Shimla district followed by Mahota area in Mandi district in wild pomegranate (64.86%). All Xap isolates collected were sent to IARI. Other collaborating centers also sent Xap isolates collected to IARI.

4.3.3.1.Genotyping of *X. axonopodis* pv. *punicae*

Several bacterial isolates from pomegranate bacterial blight were sent by collaborating centers during the year to IARI, New Delhi for genotyping. Out of these, twenty isolates were identified as *X. axonopodis* pv. *punicae* .

The identification was based on key phenotypic features of *X. axonopodis* pv. *punicae viz.* inherent slow growth rate, fuscan pigment production in media, temperature, pH and salt sensitivity. These isolates were further identified through box PCR and multilocus sequencing typing. A total of 8 genes having 9 loci along with 16S RNA gene were amplified, sequenced and analyzed. These genes are dnaK, fusA, fyuA, gapA, gltA, gyrB (locus 1, locus 2), lepA, and rpoD. Along with these highly conserved housekeeping genes, less conserved Internal Transcribed Spacer (ITS) i.e. a region between 16SrRNA and 23SrRNA region was also subjected for PCR amplification and sequencing of 21 isolates of *X. axonopodis* pv. *punicae* conducted.

Box-PCR : No variation was observed in amplification profiles generated from genomic DNA of 21 *X. axonopodis* pv. *punicae* isolates collected from different pomegranate growing areas of India. This clearly indicated that there is no variation among the isolates collected from different parts of the country

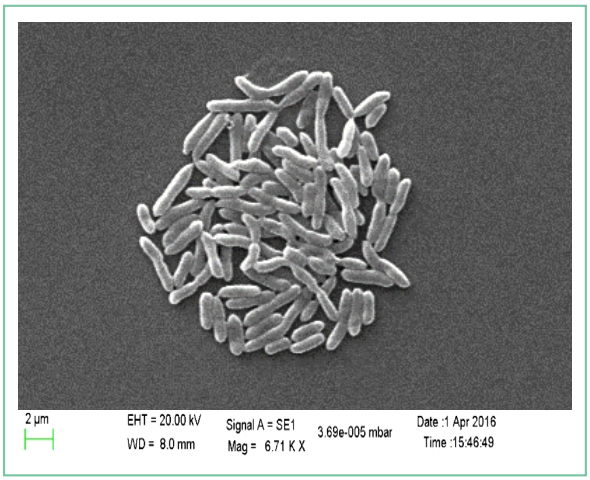


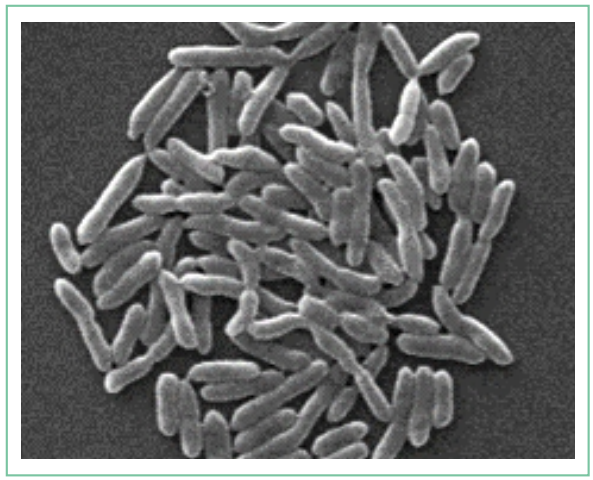
Box-PCR profile of *Xanthomonas axonopodis pv. punicae isolates (Xap)* collected from different pomegranate growing areas of India. (Lane 1 and 26: DNA size marker ladder; Lanes 2-7: *Xap* from Himachal Pradesh; Lanes 8-10: *Xap* from Delhi; Lanes: 11-21: *Xap* from Maharashtra; Lanes: 22-23: *Xap* from Karnataka; Lanes: 24: *Xap* from Andhra Pradesh; Lane 25: *X. oryzae* pv. *oryzae* as out group)

Multi Locus Sequencing Typing : A total of 23 isolates of *X. axonopodis* pv. *punicae* was subjected to MLST along with sequencing of 16S rRNA gene and intergenic region between 16S rRNA and 23S rRNA. No sequence variation was observed in any of the loci analysed indicating no variation within the pathovar of *X. axonopodis* pv. *punicae* and hence, are clonal population. The observation was further confirmed in comparative analysis of ITS sequences. All 21 *X. axonopodis* pv. *punicae* isolates were found to have similar ITS sequence.

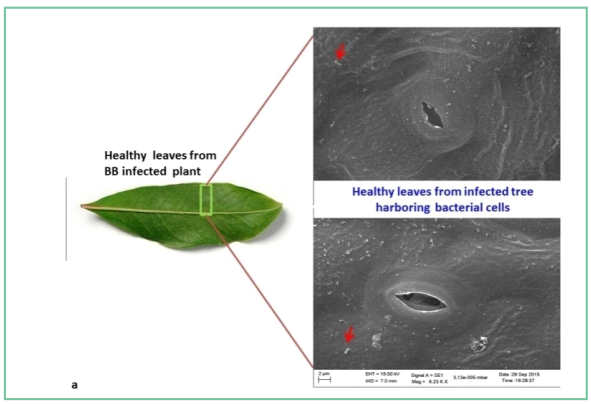
4.3.4. Analysis of phyllosphere microbiome of pomegranate in relation to bacterial blight

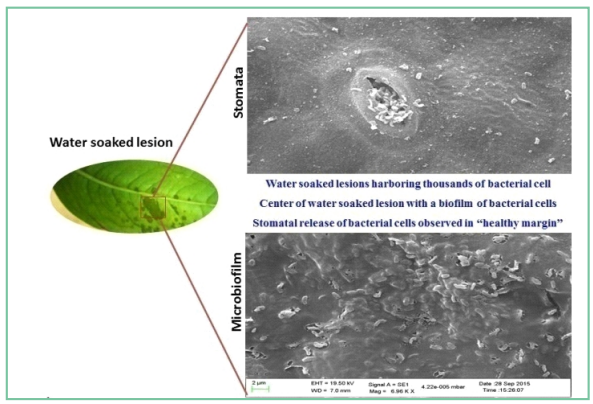
Phyllosphere of pomegranate harbours different microbes and is a niche for bacterial blight pathogen, *X.axonopodis* pv. *punicae*. Insight into bacterial blight progression in relation to phyllosphere microbes can provide valuable information about the disease outbreak, epidemiology and mutualistic as well as antagonistic microbial interactions among the microbial cells including *X. axonopodis* pv. *punicae* on leaf surface. Leaf samples collected from bacterial blight affected pomegranate orchards in Solapur region were imaged and analysed in Scanning Electron Microscope at IARI, New Delhi. Electron microscopic images clearly revealed stomatal release of *X. axonopodis* pv. *punicae* on pomegranate leaf.

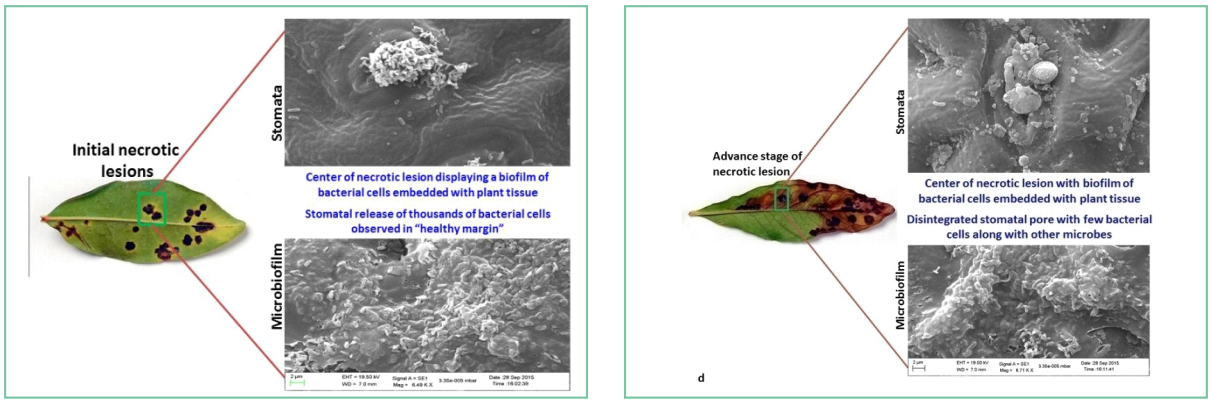




SEM image of pure culture of *X. axonopodis* pv *punicae* (Courtesy IARI, New Delhi)







SEM images of bacterial blight affected pomegranate leaves: (a) Healthy leaf from bacterial blight affected pomegranate plant; (b) Early water soaked lesion; (c) Initial necrotic blight lesion (d) Advanced necrotic lesion with microbial succession (Courtesy IARI, New Delhi)

4.3.5.Developing cultivar(s) resistant to pomegranate bacterial blight

4.3.5.1. Germplasm Introduction : During the reporting period 57 accessions were introduced from USDA at IIHR, Bengaluru. This is in addition to 132 accessions of previous year. A new block of germplasm comprising of over 400 plants was established for evaluation and breeding program.

Pomegranate accessions introduced from USDA at ICAR-IIHR, Bengaluru

4.3.5.2. Hybridization: Twenty eight pomegranate lines which were identified for their superiority for various character (large, attractive fruits with bold arils and high TSS) from the population exposed to mutagenic treatments and progenies derived from Bhagwa X Daru were multiplied and planted in the replicated trial plot for further evaluation along with check varieties at IIHR, Bengaluru.

Hybridization between Cv. Bhagwa as female parent and bacterial blight tolerant lines (Nana, Daru, IIHR-30 and Nayana) as male parent was taken up. A total of 110 flowers were control pollinated and 47 hybridized fruits were harvested for raising seedling progeny.

Fruits harvested from hybridization between cv. Bhagwa and bacterial blight tolerant lines

S. No	Cross	No of flowers crossed	No. of crossed fruits harvested	Fruitset (%)
1	Bhagwa x IIHR-30	40	16	40
2	Bhagwa x Nana	25	9	36
3	Bhagwa x Nayana	20	10	50
4	Bhagwa x Daru	25	12	48

At ICAR-NRCP, Solapur, progenies were raised in nursery for five newly developed hybrids of pomegranate obtained through hybridization. The five hybrids include, Bhagwa x Nana, Bhagwa x Daru, Bhagwa x P-5, Bhagwa x 1199 and Bhagwa x Acc.-5. The germination percentage ranged from 12.0 to 59.0 %. The germination was highest in Bhagwa x Nana (59.0%) followed by Bhagwa x P-5 (47.0%). Germination was minimum in Bhagwa x Acc.5 (12.0%).

4.3.5.3. Screening of germplasm : Twenty three genotypes/cultivars were screened for disease resistance and susceptibility against bacterial blight at YSPUHF, Solan. Eight genotypes were susceptible, 3 were moderately susceptible and 12 were highly susceptible to the disease. None of the genotypes/cultivars were resistant or moderately resistant to bacterial blight of pomegranate. Out of these, Spin Shakari, Anar Alok and Guleshah were moderately susceptible.

Further, ten hybrids (Crosses) of pomegranate were evaluated for BB resistance / tolerance. All were moderately to highly susceptible to BB. The highest disease severity was recorded in China Seedling × Khandhari Hansi Seedling (56.78 per cent) while the least disease severity was recorded in Belgium Seedling×G137 hybrids (25.19 %).

Reaction of pomegranate germplasm at YSPUHF, Solan to bacterial blight

Cultivar/Germplasm	Disease severity (%)	Cultivar/Germplasm	Disease severity (%)
Anar Alok	28.42	Ganesh	45.76
Anar Shirin	39.87	Guleshah	20.34
Anar Shirin Mohammad Ali	31.89	Ichkdana	61.51
Anar-Post-E-Safed-Shirin	55.13	Jodhpur Red	65.33
Bedana Sadana	61.62	Kandhari Hansi	35.20
Bhagwa	51.05	Mridula	32.91
Bush Dwarf	46.28	Musket White	62.65
Chawla	50.55	Nabha	67.51
China Seedling	36.32	P-75-K-5	53.76
Dalim	62.54	Spin Shakari	16.89
Dholka	53.65	Uthukalla Hakubotan	35.67
G-137	58.43		

At ICAR-NRCP, Solapur, progenies were raised in nursery for five newly developed hybrids of pomegranate obtained through hybridization. The five hybrids include, Bhagwa x Nana, Bhagwa x Daru, Bhagwa x P-5, Bhagwa x 1199 and Bhagwa x Acc.-5. The germination percentage ranged from 12.0 to 59.0 %. The germination was highest in Bhagwa x Nana (59.0%) followed by Bhagwa x P-5 (47.0%). Germination was minimum in Bhagwa x Acc.5 (12.0%).

4.3.6. Integrated disease management of bacterial blight

4.3.6.1. IDM Schedule at UHS Bagalkot : Development of IDM module for the management of bacterial blight of pomegranate: In an attempt to develop IDM, 7 different treatments comprising antibiotics, bactericides and bioagents alone or in combination were tested in a replicated field trial at UHS Bagalkot. Bioagents were sprayed after giving a temporal gap of 8-10 days after synthetic spray.

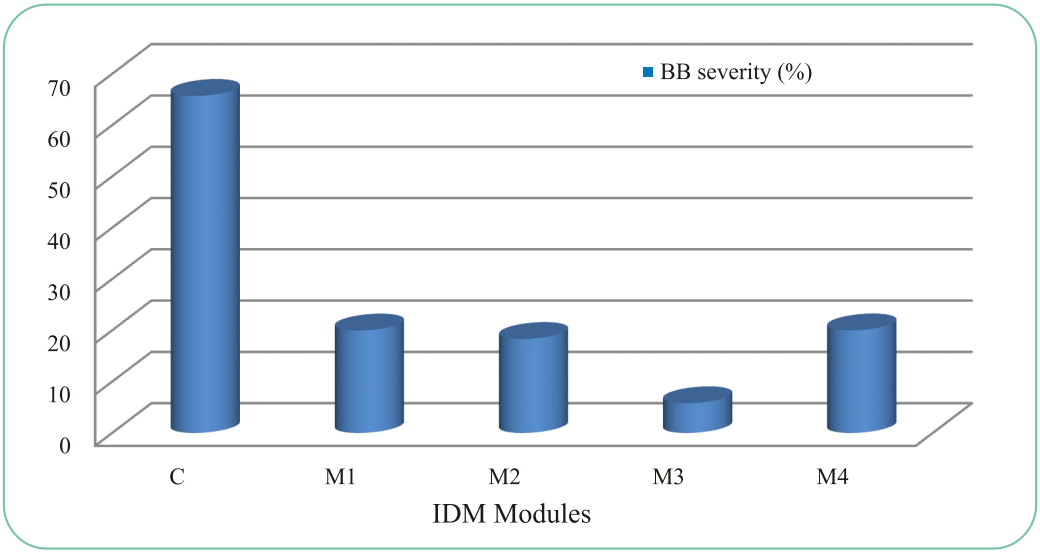
Treatment details for IDM schedule	
T1	1 Spray of Copper oxy chloride (3g/l) + Streptocycline (0.5g/l) + Bronopol (0.5g/l)
T2	1 spray of *P. putida* 8 day after Copper oxy chloride (3g/l) + Antibiotic (0.5g/lt) + Bronopol (0.5g/l)
T3	2 spray of *P. putida*-8 days interval after Copper oxy chloride (3g/l) + Streptocycline (0.5g/l) + Bronopol (0.5g/l)
T4	Soil amendment with consortia of *P. putida* and T. *harzianum-100gm* /Plant+ with 2 sprays of DR in 8 days interval after Copper oxy chloride (3g/l) + Streptocycline (0.5g/l) + Bronopol (0.5g/l) along with micronutrient sprays (Ca, B, Mg, Zn)
T5	*P. putida* , 3-Sprays 10 days interval
T6	2 sprays of Copper oxy chloride (3g/l) + Spteptocyline(0.5g/l) + Bronopol (0.5g/l)
T7	COC 2g + Streptocycline 0.5g as Standard check from University

All the combinations were found effective for suppression of the disease. However, T4 with 2-sprays of bioagents along with soil application of consortia was found effective which replaces the 1-spray of antibiotic and other bactericides in a month. A total of 5 sprays of antibiotics were successfully omitted in one fruiting seasons which accounts for an approximate Rs. 25000.00 /ha. The soil application of consortia of bioagents and foliar application of *P. putida* together with foliar application of micronutrients has additional benefit for improving the resistance. Analysis of data showed that treatment T4 gave lowest BB incidence (9.67%), maximum fruit yield (27.8Kg/plant) and cost : benefit ratio (10.14), hence, can be validated for confirmation in second year.

Performance of different IDM module for management of bacterial blight

Treatments	Disease Incidence (%)	Disease severity (%)	No. of fruits/plant	Fruit weight (gm)	Fruit yield per plant (kg)	B:C ratio
T1	25.82	3.88	80	283.2	20.5	6.34
T2	23.12	6.62	90	237.5	21.2	7.48
T3	11.53	4.75	86	263.2	24.9	9.05
T4	9.67	2.37	99	291.2	27.8	10.14
T5	27.94	12.56	82	192.5	14.8	5.13
T6	20.01	8.61	77	222.5	17.2	7.20
T7	29.45	4.88	76	249.1	15.7	5.90

4.3.6.1. IDM Schedule at Dr Y S Parmar UHF, Nauni, Solan : In all 18 IDM modules were evaluated in a field trial. Each treatment was applied at 15 days interval. Amongst eighteen treatment combinations none of the treatments provided complete control of the disease, though treatment (M 3) consisting of combination of Copper oxychloride + Streptocycline + Cow urine + Garlic + Salicylic acid recorded minimum disease severity (5.79 %). The maximum yield of healthy fruits per tree (18.10 Kg/tree) was also recorded in this treatment. The next best module for BB control was (M2) with COC + Streptocycline + Salicylic acid (18.32%) followed closely by (M1) having COC + Streptocycline + Garlic (19.97 %) and (M4) with COC + Streptocycline + Cow urine + Garlic + Arachidonic acid (19.99%). The control (C) recorded 68.70% severity of blight.



Percent BB severity in selected IDM modules tested at YSPUHF, Solan

4.3.6.3. IDM Schedule at NRCP

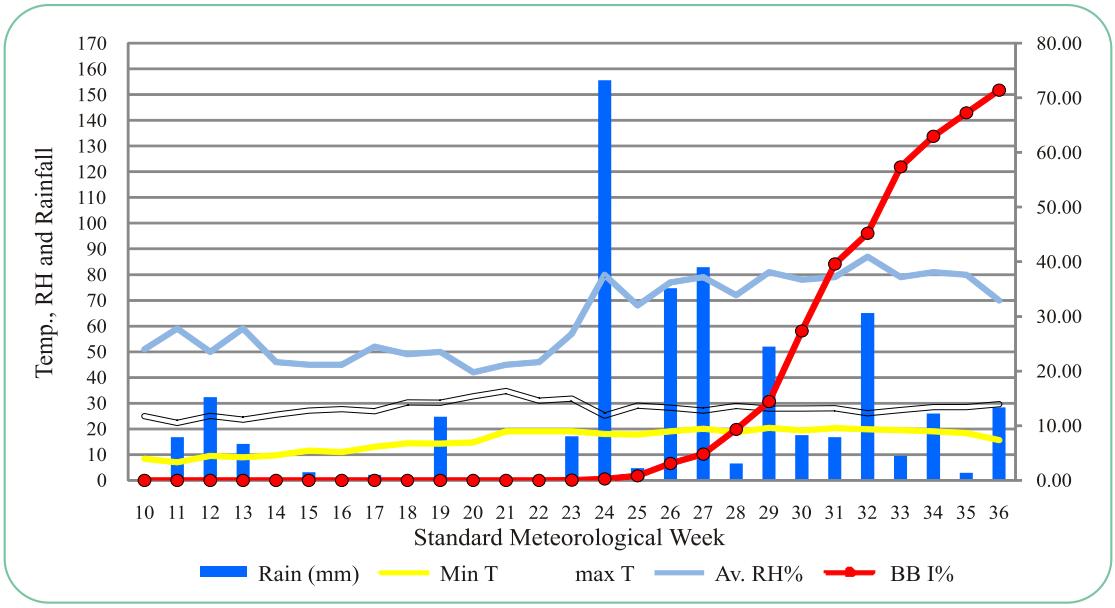
IDIPM schedule with minor modifications was evaluated in H-25 plot at Hiraj in late *mrig bahar* crop. Two bio-formulations were added at 6 month interval and nitrogen dose was reduced and applied as 4 split doses after fruit set. Produce of 2.99t from 554 plants (5.39 kg/plant) with bacterial blight incidence below 5% and good fruit colour and shine was achieved.

Produce from a modified IDIPM plot H-25 at Hiraj research farm of NRCP

4.3.6. Development of blight prediction model

In major pomegranate growing areas of Mahrashtra, Karnataka, Telangana and Andhra Pradesh, bacterial blight of pomegranate is observed throughout the year in affected orchards in mild to severe form. Hence, the forecasting model for losses due to blight will depend on weather conditions that aggravate blight severity rather than blight appearance. Based on last 6 years data at NRCP, Solapur weather parameters were identified for severe blight development. Temperature range between 25-35°C coupled with RH≥ 50% for 10-16 hours and intermittent rain were identified as major factors for severe outbreak of bacterial blight within 3-7 days. Hence these factors have been identified for developing and validating BB forecasting model for pomegranate in 2016-17.

At Himachal Pradesh where this disease is affecting all pomegranate areas weather parameters and BB incidence were recorded during the crop season, from March 1st week (10th SMW) to September 1st week (36th SMW). The data was recorded on eight different cultivars of pomegranate grown in the region. The blight started increasing after 24thSMW (June 2nd week) when there was a heavy rain and max temperature reached 25°C + RH 80% . There after blight incidence constantly increased due to regular rains every week, RH between 70-88% coupled with max. temperature between 25-30°C and minimum mostly around 20°C.



Blight progress in relation to weather parameters during 2015-16 at pomegranate orchard at YSPUHF, Nauni, Solan (HP)

4.4. Fungal diseases

4.4.1. Evaluation of formulation for fungal problem and physiological disorders

In a field trial commercial formulations and pomegranate seed oil were evaluated for fungal problems and disorders in pomegranate. Azoxystrobin @1ml/l recorded no fruit rot due to rot causing fungus and 82.14% reduction in abiotic fruit cracking over control with 3.64% fruit cracking incidence. However, due to unfavorable weather conditions for disease development, the fungal disease pressure was too low for any conclusive inference.

Effect of different formulations on fungal fruit spots, rots and disorders in pomegranate

Treatment	Fruit Spot I (%)	Fruit Spot Severity Grade	Fruit Rot (%)	Sun Scald (%)	Abiotic Cracking (%)	Rejected Fruits (%)	Fruit (No/ plant)	Fruit yield/plant (kg)	Av. Fruit Wt. (g)
FS1	2.89	1.00	0.72	5.75	5.19	6.65	29.77	4.70	157.9
FS2	3.25	1.33	1.30	4.36	2.91	4.21	29.16	5.20	178.5
FS3	4.16	1.00	1.34	10.33	4.60	6.77	27.24	4.01	147.1
FS4	2.87	1.00	1.00	11.35	4.08	5.92	26.97	5.20	192.9
FS5	3.82	1.00	0.66	8.28	2.71	4.69	34.63	5.92	170.8
FS6	2.90	1.00	0.00	9.61	0.65	1.26	33.46	5.64	168.7
FS7	2.24	1.00	0.88	9.90	3.14	4.74	27.20	5.06	186.2
FS8	2.88	1.00	1.00	7.81	11.25	13.90	31.00	4.55	146.8
FS9	2.11	1.00	0.99	11.34	5.60	7.12	34.57	5.48	158.6
FS10	4.08	1.00	1.00	7.16	3.53	4.53	36.28	6.00	165.4
FS11	3.19	1.00	1.50	10.03	4.05	7.14	36.32	5.30	145.8
FS12	3.80	1.00	1.00	6.13	3.64	4.64	30.73	5.09	165.6

FS1- Chlorothalonil @ 2g/l; **FS2 -** Chlorothalonil @ 2g/l + Thiophenate Methyl @ 1g/l; **FS3 -** Chlorothalonil @ 2g/l + Pr opiconazole @ 1ml/l; **FS4-Validamycin 3% (a) Spray:** 2.5ml/l **(b) Soil Drenching @** 5.0ml/l (30 days interval only 2 drenching); **FS 5**- Pulsor @ 0.2ml/l ; **FS6-** Azoxystrobin @1ml/l ; **FS7-** Cabrio-Top @1ml/l; **FS8-** Kuber @1gm/l; **FS9-** Carbendazim @1g/l, Merger @ 3gm/l, Thiophenate Methyl @1g/l, Cabrio-Top @ 1ml/l, Propiconazole @ 1ml/l Hexaconazole @ 1ml/l, Chlorothalonil @ 2g/l, Azoxystrobin @1ml/l Chlorothalonil @ 2g/l (sprayed alternatively); **FS10- 1**st**Lemmox** @ 1.5ml+ citric acid 1g/ l; **FS11-** Pomegranate Seed Oil @ 2ml/l; **FS12-** Control (Water Spray)

4.4.3. Isolation of organisms associated with various diseases

4.4.3.1. Damping off of seedlings

The damping off of pomegranate seedlings was observed as patches of toppled pomegranate seedlings in the bed almost within 20-25 days of sowing and 1 week of emergence. The affected seedlings were removed and washed. Typical girdling of roots with browning of the root till tip giving wire stem look to the seedling was observed. Isolations resulted in fungus *Rhizoctonia solani.*

Damping off of pomegranate seedlings due to *Rhizoctonia solani* (a) Toppled seedlings in the bed (b) wire stem symptom in affected roots (c) healthy roots

4.4.3.2. New symptoms of scab

In the germplasm block some pomegranate accessions were observed to have knob like protuberances below the point of rusetting on skin and the fruits were distorted to varying extent. Microscopic examination and repeated isolations on media plates resulted in *Sphaceloma sp*. which cause scab of pomegranate. This type of scab symptom was observed for the first time on fruits.

Pomegranate scab (a) New symptom with protuberance (b) commonly observed scab

4.4.4. New fungal isolates

Isolation of associated pathogens from diseased samples collected and received from pomegranate orchards were done and pure culture maintained in refrigerated storage. In all 11 Isolates of *C. fimbriata* (CF22 – CF32) causing wilt, 11 of *Sphaceloma sp*. (SB16- SB26) causing scab, 4 of *Cercospora* sp. (CR16-CR19) causing black fruit spot and 10 isolates of *Colletotrichum gleosporioides* causing fruit rot were collected from Maharashtra, Gujarat, Tamil Nadu and Karnataka.

5. POST HARVEST TECHNOLOGY

5.1 A process for extraction of virgin pomegranate seed oil

A process of extraction of virgin pomegranate seeds oil from marc was invented. The process includes standardization of extraction process right from cleaning of marc (ie. remaining portion of fruit after juice extraction) for getting clean seeds, moisture reduction, size reduction, and standardization of oil extraction temperature with objective of higher recovery of oil while retaining important fatty acid profile components such as linolenic acid methyl ester, linolic acid methyl ester and eicosanoic acid methyl ester and antioxidant activity.

5.1.1. Effect of moisture content of seeds on virgin oil recovery

The seed oil recovery is studied for different moisture content in cold press for *Bhagwa* and *Ganesh* cultivars. The desired moisture content of ground seeds (4, 6 and 8 % db) was maintained by either adding moisture or drying at 40˚C.The extraction process is carried at 60˚C for this experiment. The other operational parameters maintained in extraction process included duration of pressing/extraction was 3 hours and pressure of extraction was kept 550 kgf/cm^2. It was revealed from the results that the oil recovery decrease with increase in moisture content for both the cultivars. The pomegranate seed oil recovery of 19.05 % and 19.50 % can be achieved for Bhagwa and Ganesh cultivars, respectively, with seed moisture content of approximately 6 % on dry basis. However, further reduction in moisture content does not significantly increase the recovery of pomegranate seed oil for both the cultivars.

5.1.2. Temperature of extraction and its effect on the recovery of virgin oil

The temperature of extraction has significant effect on recovery of seed oil. However the advantage of seed oil recovery is significant only up to 60°C and recovery increases very insignificantly above 60 °C. The fatty acid composition for different extraction temperature was determined and depicted respectively for Bhagwa and Ganesh. The reduction in antioxidant activity is also visible with increase in temperature of extraction. The selected important quality parameter such as antioxidant activity and important constituents such as linolenic acid methyl ester, linolic acid methyl ester and eicosanoic acid methyl ester were determined. It is very clear from results that there is decrease in linolenic acid, linolic acid, eicosanoic acid and antioxidant activity with increase in temperature of seed oil extraction.

The percentage retention of important fatty acid component linolenic acid methyl ester for cultivar *Bhagwa* is 64.34 % and 96.31 % at 60°C when compared with that of at 40 °C which goes on decreasing up to 28.92 % and 84.32 % at 100 °C. Similar is the case with other components and antioxidant activity. Looking in to increase in recovery with increase in temperature and corresponding decrease in important fatty acid component and antioxidant activity the temperature of 60 °C is found to be optimum temperature for extraction of virgin pomegranate seed oil without losing on recovery of oil.

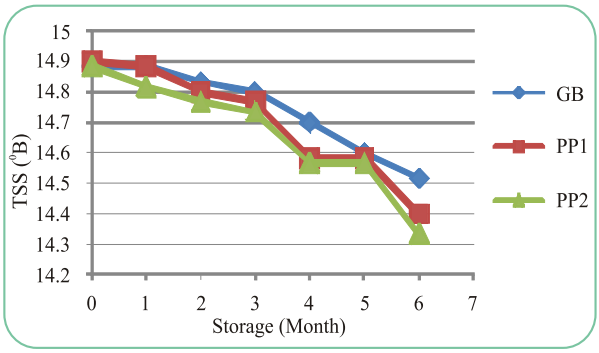
5.2 Effect of packaging material on quality of pomegranate juice in storage

The pomegranate juice is susceptible to degradation in terms of colour, nutritional quality, microbial quality and sensory acceptability during storage. The studies were conducted to determine the effect of storage temperature and packaging material on quality of pomegranate juice during storage. The freshly extracted pomegranate juice was pasteurized at 80˚C for 5 minutes. The juice samples were packaged in glass bottle, PP1 (0.40 mm), and PP2 (0.35 mm) bottles while still hot. The juice bottles

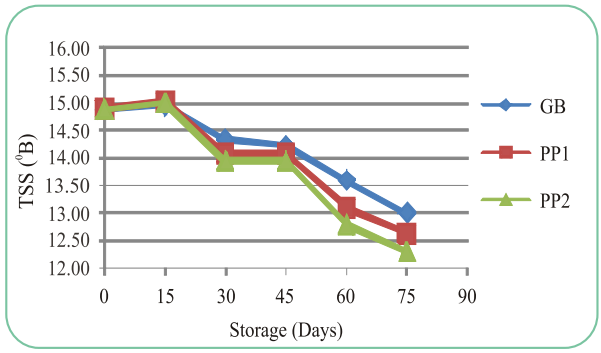
were stored at room temperature and low temperature (5 ˚C). The changes in TSS, pH, total sugars, reducing sugars, non-reducing sugars, ascorbic acid, anthocyanin, antioxidant activity, total phenol content, color values with hunter colorimeter, total plate count and sensory evaluation were done during storage at 15 days interval for room temperature stored samples while for low temperature stored samples at 30 days interval.

Pomegranate juice packaged in glass, PP1 and PP2 bottles for storage studies

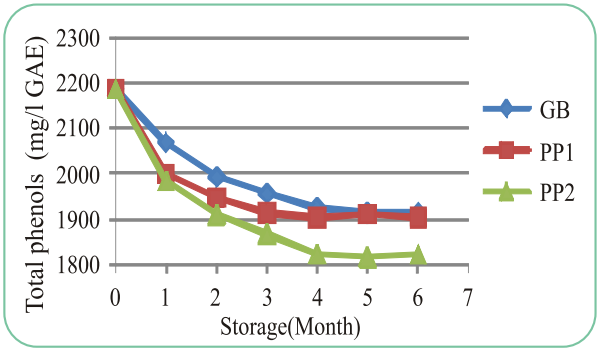
The results revealed that all the samples stored at room temperature were within safe microbial plate count of 2 log cfu/ml up to 60 days of storage. Whereas the juice samples in all packaging material stored at low temperature were within safe limits of total microbial plate count up to 6 months and experiment on storage at low temperature is still continued. The results for changes in TSS, total phenol content, antioxidant capacity, and color value a* were depicted in graphical form. The TSS decreased during storage TSS retention was highest 13 °Brix in glass bottles after 6 months storage at low temperature. The lowest retention of TSS was found in PP2 bottle stored at room temperature. Pomegranate juice exhibits good antioxidant capacity primarily due to its high level of phenolic acids, flavonoids and other polyphenolic compounds. The results suggested correlation between changes in phenols and antioxidant activity at both storage conditions. The total phenol content and antioxidant activity reduces with storage duration. The juice stored at room temperature shows very little reduction in antioxidant capacity up to 30 days and latter it reduces at higher rate. In storage at low temperature the total phenols and antioxidant capacity reduces rapidly up to 1 month and 2 months respectively but even after six months of storage high levels of total phenols 1913, 1903 and 1823 mg/L GAE in glass, PP1and PP2 respectively and antioxidant capacity of 18.60, 18.48 and 18.25 mg/100ml of AAE in glass, PP1and PP2 respectively. The colour values a* were measured and found to be acceptable at room temperature storage only up to 2 months which were reduced up to 31.41, 29.41 and 26.50 from initial value of 44.17 in glass, PP1and PP2 respectively. However in low temperature storage colour value a* was maintained up to 43.05, 41.82 and 41.90in glass, PP1and PP2 respectively from initial a* value of 45.42. The sensory score suggest low temperature stored juice in all packaging is acceptable up to 6 months and room temperature stored juice had acceptability only up two months.



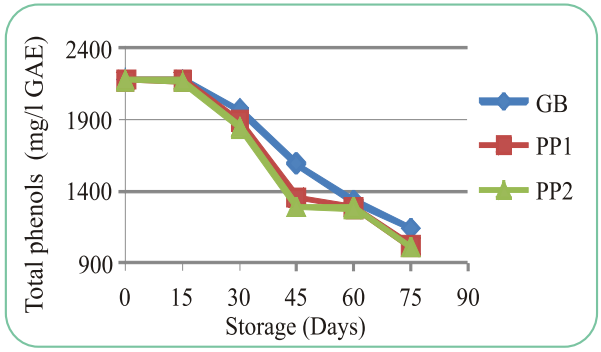
Changes in TSS in low temperature storage



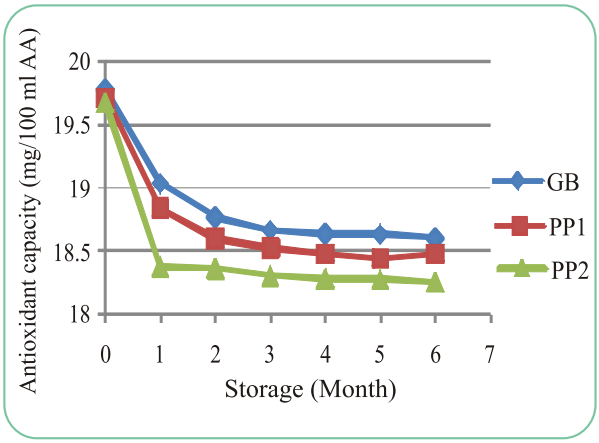
Changes in TSS in room temperature storage



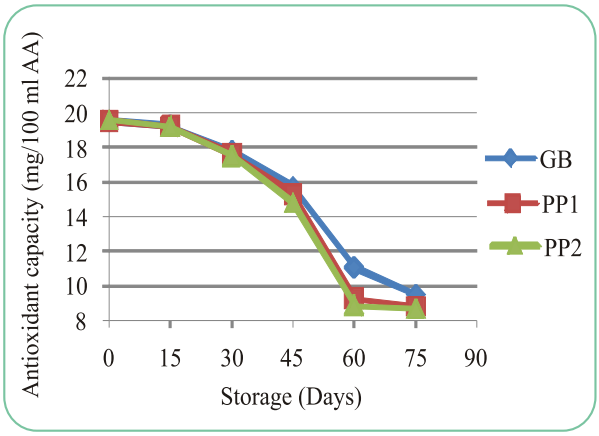
Changes in total phenols in room temperature storage



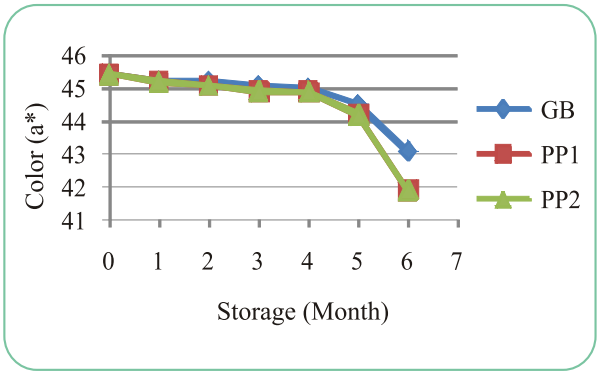
Changes in total phenols in room temperature storage



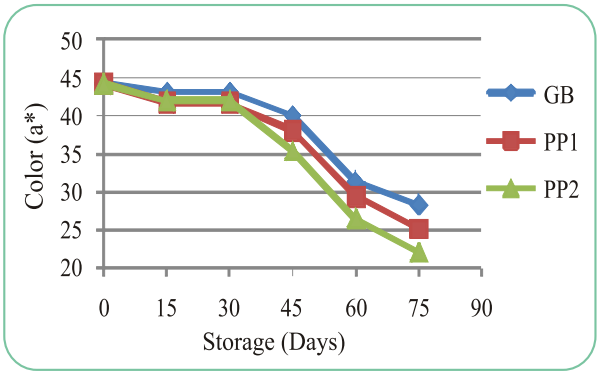
Changes in antioxidant capacityat low temperature storage



Changes in antioxidant capacityatroom temperature storage



Changes in color a*at low temperature storage



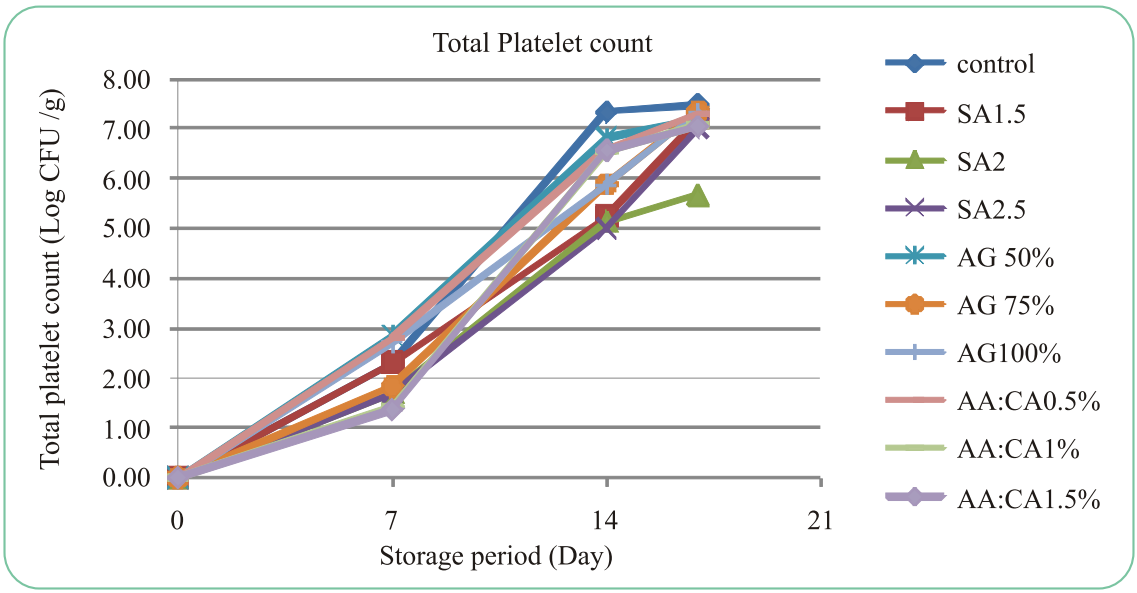
Changes in color a*at room temperature storage

5.3. Minimal Processing of pomegranate arils

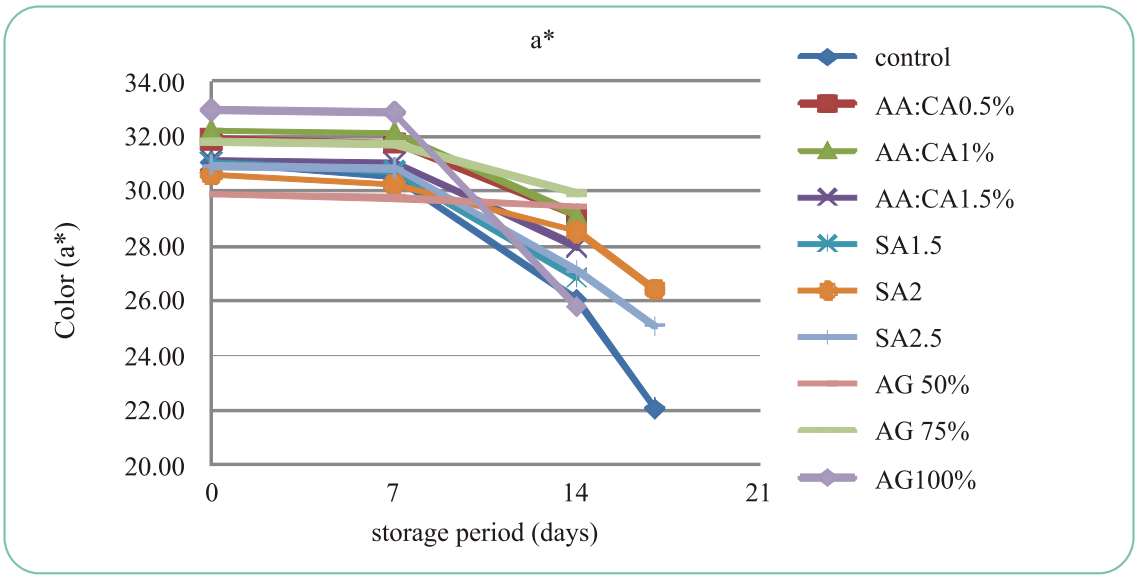
The effect of pretreatments on minimal processing of arils was studied with screened out pretreatments from results of studies conducted in 2014. The pretreatment of salicylic acidic 1.5, 2 and 2.5 mM, Aloe vera gel 50, 75 and 100%, AA:CA 0.5, 1 and 1.5 % were studied for effect on shelf life.

5.3.1 Effect of pretreatment on microbial quality, colour, and texture during storage

The pretreatment and storage duration had significant effect on microbial growth in minimally processed arils. The effect of pretreatments on total platelet count is depicted in Fig5.1.The total platelet count was increased with storage duration. The maximum total platelet count of 7 log CFU/g (Spanish legislation) was considered as shelf life indicator and experiments were stopped after reaching that platelet count. Thus SA 2 and SA 2.5 shown total microbial count less than 7 log CFU/g up to 17 days. However control samples were found safe only up to 7 days of storage. On 14th day of storage the pretreatment SA2.5, followed by SA2, AG 100, AG75 were found lowest total platelet count.



Effect of pretreatments on microbial count during storage of minimally processed pomegranate arils.



Effect of pretreatments on color (a*) during storage of minimally processed pomegranate arils

The effect of pretreatment on a* values were depicted. The a* values were reduced in general for all pretreatments showing decrease in redness of the arils during storage. The maximum decrease in redness was found in control and maximum retention of redness i.e. a* values on 14th day were found in AG 75% treated samples however on 17th day the maximum retention was found in SA2% followed by SA2.5%.

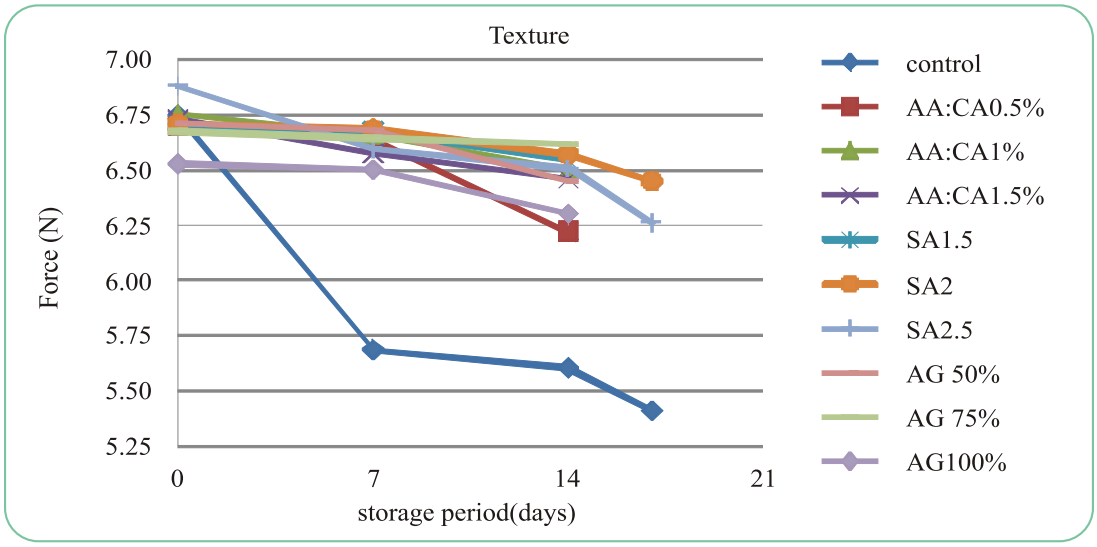
The texture of minimally processed arils was decreased during storage for all pretreatments. The texture of samples treated with SA 2% shown highest texture values on 17th day and on 14th day the highest texture values were found in samples treated with SA2 % followed by AG 75%. The texture values were reducing showing increase in softness of the aril tissues. The low values of texture as compared to untreated control samples show increase in firmness in treated samples.

5.3.2. Biochemical analysis

The changes in important biochemical parameters such as TSS, acidity, anthocyanin, phenolic content, antioxidant capacity, ascorbic acid, non-reducing, reducing and total sugars were also studied. The treated samples were found to retain more biochemical components as compared to control samples during storage.

5.3.3. Sensory quality

The effect of minimal process on the sensory quality of pomegranate arils during storage at 5^{0}C is depicted. On the basis of sensory score such as aril colors, texture, taste SA2mM treated samples were found to be acceptable on 17th day of storage. However on 14th day of storage the AG75% samples were adjudged as best followed by SA2.5mM pretreatment.



Effect of pretreatments on texture during storage for minimally processed pomegranate arils

Control on 7th Day

Salicylic Acid 2 mM on 17th day

Aloe Vera Gel 75 % on 14th day

5.4.Grading

Seven commercial cultivars were examined with respect to fruit grading. The fruits harvested from the trees were sorted into different grades and were counted. The percentage of different grades are as follows. King size fruits was highest in G-137 (3.12%) followed by J. Seedless (2.40%). Queen size fruits was highest in Ganesh (15.21%) followed by G-137 (13.54%). Prince sized fruits was highest in Ruby (39.02%) followed by Jalore Seedless (38.55%).

Table. Percentage of fruits of different grades from commercial varieties

Variety	>500g/fruit	400-500 g/fruit	300-400 g/fruit	200-300 g/fruit	<200 g/fruit
Bhagwa	1.19	11.90	35.71	28.57	22.61
Ganesh	2.17	15.21	33.69	27.17	21.73
Ruby	1.21	10.97	39.02	26.82	21.95
J. Seedless	2.40	10.84	38.55	26.50	22.89
G-137	3.12	13.54	33.33	27.08	22.91
Arakta	0.73	7.31	34.14	31.70	25.60
Mridula	0.78	7.89	34.21	31.57	25.00

5.5. Evaluation of commercial varieties of pomegranate for juice recovery

Nine commercial cultivars were evaluated for their juice recovery by two methods ie. Extraction from cut fruits (halved fruits) by using hand press and extraction of juice from separated arils. The juice recovery was found to be comparatively higher from arils compared to halved fruits. Arakta recorded the highest juice recovery (43.98% from halved fruits; 46.15% from arils).

Table. Juice recovery(%) of commercial varieties of pomegranate by different methods

Variety	Juice recovery (%)	
	Extraction from halved fruits	Extraction from arils
Bhagwa	35.06	39.67
Ganesh	34.14	42.49
Ruby	41.05	42.45
J. Seedless	38.61	44.82
G-137	39.12	42.28
Arakta	43.98	46.15
Mridula	43.35	45.90
Dholka	31.20	43.19
Jyoti	36.26	41.49
CD (5%)	3.57	1.97

6. EXTERNALLY FUNDED PROJECTS

6.1. Establishment of DUS centre at ICAR-NRCP, Solapur

Salient features of fifteen pomegranate germplasm collected from ICAR-NBPGR Regional Station, Shimla, were recorded for plant, leaf, flower and fruit morphological, physico-chemical properties as per the DUS guidelines. In total, 35 characters were recorded in each accession, during 2015-16. All the accessions have recorded higher plant height with spreading and dense foliage habit. Out of 15 accessions, three accessions viz., IC-318764, IC-318762 and IC-318734, were found to have longer-mediumsizedleaves when compared to others having medium sized leaves. These germplasm were having lanceolate and obtuse type leaves. IC-318702, IC-318712, IC-318793 and IC-318749 were found to have shorter petiole length, compared to others. The petiole colour was in lower level in all germplasm except IC-318705, IC-318712 and IC-318793 accessions. IC-318754, IC-318740, IC-318702, IC-318793, IC-318764, IC-318735 and IC-318749 recorded medium-narrow sized flowers. All the accessions had single type, orange coloured calyx and corolla with medium sized petals.

Out of 15 germplasm, seven were having smaller short-medium (IC-318740, IC-318712, IC-318764, IC-318762), short-small (IC-318702, IC-318793, IC-318735) sized fruits, while others had medium sized fruits. Fruits are medium maturing with oval to ovate shape with yellowish red to reddish yellow coloured rind. IC-318702, IC-318749, IC-318734, IC-318793, IC-318764 and IC-318735 were found have medium rind thickness. Aril size ranged from short-narrow, medium-broad, short-medium, short-broadsize with light yellow to light pink colour. Seeds of all the accessions were found to be hard with short-short, narrow-medium and medium-narrow size. IC-318735 and IC-318723 had medium TSS (^{0}B) and high acidity (%), while others had high TSS (^{0}B) and high acidity (%). Per cent fruit juiciness in all the germplasm was found to be low. The DUS characteristics recorded for these pomegranate germplasm would be very useful to make trait specific selection and further developing core collection for the desirable traits.

6.2. Consortium Research Platform on Agrobiodiversity

During 2015-16, 10 wild germplasm of pomegranate were characterized for 33 morphological, physico-chemical properties as per the minimal descriptors, ICAR-NBPGR, New Delhi. The plant height of these accessions ranged from 2.58-3.18m, with 2.28-3.45 m plant diameter. Leaf length and width varied from 36.52-53.22 mm and 11.37-18.00mm respectively. Accessions IC-318702, IC-318793, IC-318764, and IC-318740 were found to be highly thorny ones. The number of hermaphrodite flowers in accession IC-318790 was found maximum (221.67/plant). Number of fruits per cluster was maximum in IC-318705 (average 5 fruits/cluster). Fruits of all the accessions had rusted surface, without any ridges. Fruits are yellowish red to reddish yellow coloured rind. Fruit length and width was maximum in IC-318705 (8.50cm) and IC-318753 (6.77cm) respectively. Maximum fruit weight was observed in IC-318753 (202.77g) and minimum in IC-318793 (59.34g). Number of arils per fruit ranged from 124.90 (IC-318740) - 395.07 (IC-318790). Aril colour was observed to be light yellow to light pink in colour. Rind weight (g) was maximum in IC-318764 (71.06g) to IC-318793 (32.37g). TSS (^{0}Brix), acidity (%) and Juice content (ml/g) was in the range of 15.32-18.00^{0}Brix, 1.85-3.06% and 21.31-48.01 ml/g respectively. Seeds of all the accessions were found to be hard.

6.3. Evaluation of chitosan derivatives and chitosan based formulation XANSIL to control bacterial blight of pomegranate

(Funded by Swasti Agro &Bioproducts Pvt. Ltd., Pune)

In a polyhouse trial, challenge inoculation with *X. axonopodis* pv. *punicae*, preventive sprays of chitosan derivatives gave better control compared to

application after blight appearance. Preventive sprays resulted in maximum reduction of bacterial blight (BB)in Chitosan Derivative-1 followed by Derivative-2 and Derivative-3 with more than 40% BB reduction, Formulation Xansil, however, was not effective. Xansil recorded same incidence as control, when sprays were taken after BB symptom appearance whereas derivatives recorded higher reduction of BB than Xansil.

In a field trial with Xansil formulation, no differences were recorded with respect to bacterial blight or other diseases and insect pest damage as the disease pressure was too low for drawing any inference. Leaf and fruit samples have been sent for biochemical analysis.

6.4. Performance evaluation of Fosetyle –Al 80WP (Aliette) and other protection range chemicals of Bayer Crop Science Limited on pomegranate health and productivity (Funded by Bayer Crop Science Limited, Mumbai.)

A field trial was conducted at ICAR-NRCP in rainy season. Bacterial blight disease pressure was too low to evaluate different treatments. Abiotic cracking was lowest in IDIPM+Bayer protocol integrated treatment (1.59%) against 5.51% in untreated control. Percent rejected fruits due to cracking and fruit borer were lowest (2.34%) in integrated (IDIPM+Bayer protocol) treatment, whereas it was 7.0% in control.

Six farmers plots have been adopted jointly by BCSL and ICAR-NRCP for demonstrations, 2 each for *mrig bahar* (Wadegaon and Sangewadi in Sangola District Solapur), *hasta bahar* (Velapur and Khandali in Malshiras, Solapur) and *ambe bahar* (Tandulwadi and Malewadi in Malshiras, Solapur) season. Bayer protocol did not give additional benefits over farmer's protocol in disease management. Trials in other seasons are in progress.

6.5. Horticultural crop pest surveillance and advisory project for Mango, Pomegranate, Banana, Citrus and Sapota

(Funded by State Hort. Department, Commensurate of Agri., Pune)

Surveys were conducted in 33.5 ha pomegranate area covering 4 districts, 4 talukas and 15 villages. Blight was observed in severe form in only Patilwadi , Tk. Shahada Dist. Nandurbar. Thrips infestation was second major problem. Both wilt and blight were commonly recorded in moderate to severe form in TalukChikli, Dist. Buldhana. Nutrient deficiencies (Ca, Zn, Fe and Mn) were very severe in an organic plot at Jalana with 30% plants showing deficiency symptoms.

Status of Diseases and insect pests in Nandurbar and Buldana districts of Maharashtra

District	Taluk	No. of orchard	Incidence of diseases and insect pests (%) in pomegranate							
			Area (ha)	BB	Wilt	Fungal Fruit Spots	Fruit Rot	Thrips	Fruit Borer	Other Pests
Nandurbar	Nandurbar Shahada, Nibhar	13	11.13	6.59	0.73	3.39	0.03	15.04	1.26	5.14
Buldana	Chikli	5	15.5	25	11.31	-	-	-	-	-

Bacterial blight (left) and wilt (right) affected orchard at Patilwadi village, Nandurbar

6.6. Evaluating bioefficacy of formulations Avtar and Merger in the management of fungal leaf/fruit spots and rots of pomegranate (Funded byIndofil Chemicals Company, Mumbai.)

The project was concluded and final report submitted. Spray application of Merger and Avtar @ 2.5 and 3.0% at 14 day intervals significantly reduced different fungal leaf and fruit spot diseases caused by species of *Colletotrichum* (in traces), *Cercospora* and *Sphaceloma*, in comparison to control and were either significantly better or at par with standard check IDM. The treatments simultaneously gave significantly higher fruit yield of pomegranate. No Phytotoxic effect was observed with any of the phytotoxic doses tested, in our trials.

6.7. Evaluating performance of poly propylene non-woven bags with respect to diseases, insect pests, physiological disorders and quality of pomegranate fruits (Funded by Reliance Industries Pvt. Ltd.)

The project was concluded and final report was submitted. Polypropylene non-woven bags (PPNW) bags and butter paper bags were found equally effective in improving some parameters and may be used need based. Bagging improved fruit quality, colour and TSS. Bagging increased BB and fruit rots. Bagging was most effective for managing damage due to fruit sucking moth. Butter paper bags were superior to PPNWB in reducing sunscald and fruit cracking. Bagging material needs to be UV stabilized for improving durability of bags in harsh climate.

6.8. Micronutrient management in pomegranate for enhancing yield and quality (Network project)

Foliar application of $ZnSO_4.7H_2O$ @ 0.3% four times viz. two sprays before flower bud initiation and rest two after fruitset at 30 days interval was found to be most effective and economical for supplementing Zn to the pomegranate plant. This led tosignificant increase in fruit yield, improvement in quality (TSS, Juice per cent, phenol, ascorbic acid, anthocyanin etc.) and enhancement in Zn content not only in fruit but also in edible part i.e. arils.

7. RESEARCH PROGRAMMES AND PROJECTS

Institute Research Projects

S. No.	Project Title	Principal Investigator	Status
1.	Conservation, characterization and sustainable use of diversity in pomegranate	Dr. (Mrs.). Shilpa Parashuram	Ongoing
2.	Genetic improvement of pomegranate for yield, quality and resistance to biotic stresses through conventional breeding and biotechnological approaches	Dr. K. Dhinesh Babu	Ongoing
3.	Development and refinement of integrated production technologies for improved productivity	Dr. D.T.Meshram	Ongoing
4.	Propagation, bio-hardening and mass multiplication of elite planting material in pomegranate (*Punica granatum* L.)	Dr. N.V. Singh	Ongoing
5.	Development and refinement of integrated crop protection technologies for improved productivity of pomegranate	Mr. Mallikarjun	Ongoing
6.	Post harvest management value addition and improving knowledge of stakeholders for increasing production and marketing of pomegranate	Dr. Nilesh N. Gaikwad	Ongoing
7.	Flagship project on integrated approach to eradicate bacterial blight	Dr. (Mrs.). Jyotsana Sharma	Ongoing

Externally Funded Projects

S No.	Programme	Project Title	Principal Investigators	Status
1	Project under RKVY	Horticultural crop pest surveillance and advisory project for Mango, pomegranate & Banana	Director, ICAR-NRCP	Ongoing
2	Intellectual Property Right	Intellectual property management and transfer/commercialization of Agriculture Technology scheme	Director, ICAR-NRCP	Ongoing
3	Technology development and transfer scheme of NHB	Demonstration of model pomegranate production practices for effective management of bacterial blight disease	Director, ICAR-NRCP	Ongoing
4	DUS project	Establishment of DUS centre at NRC on Pomegranate	Director, ICAR-NRCP	Ongoing
5	Contract research Project	Evaluation of chitosan derivatives and chitosan based formulation XANSIL to control bacterial blight of pomegranate (Funded by Swasti Agro &Bioproducts Pvt. Ltd., Pune)	Dr. (Mrs.). Jyotsana Sharma	Ongoing

S No.	Programme	Project Title	Principal Investigators	Status
6	Contract research Project	Performance evaluation of Fosetyle –Al 80WP (Aliette) and other protection range chemicals of Bayer Crop Science Limited on pomegranate health and productivity (Funded by Bayer Crop Science Limited, Mumbai)	Dr. (Mrs.). Jyotsana Sharma	Ongoing
7.	Project under Extramural Fund of ICAR	SNP marker based mapping of bacterial blight genes in pomegranate (*Punica granatum* L.)	Dr. H.B. Shilpa	Ongoing
8	Project under Extramural Fund of ICAR	Development of fruit based carbonated drink from pomegranate and grapes	Dr. N. Gaikwad	Ongoing
9	Project under Extramural Fund of ICAR	Trait specific characterization of indigenous and exotic pomegranate accessions to arrive at core collection for genetic improvement programme	Dr. K. Dhinesh Babu	Ongoing
10	NHB project	Mechanization in pomegranate cultivation and its demonstration	Dr. N.V. Singh	Ongoing
11	Consultancy project	Implementation of total orchard management practices for pomegranate plantation	Dr. N.V. Singh	Ongoing
12	Contract research Project	Evaluating bioefficacy of formulations Avtar and Merger in the management of fungal leaf/fruit spot and rots of pomegranate (Funded by Indofil Chemicals Limited)	Dr. (Mrs.). Jyotsana Sharma	Completed
13	Contract research service (Paid up trial)	Evaluating performance of poly propylene non-woven bags with respect to diseases, insect pests, physiological disorders and quality of pomegranate fruits (Funded by Reliance Industries Pvt.Ltd.)	Dr.(Mrs.). Jyotsana Sharma	Completed

Tribal Sub-plan

S No.	Project Title	Principal Investigator	Status
1	Introduction of pomegranate cultivation (*Punica granatum* L.) to tribal farmers of Gadchiroli District	Director, ICAR-NRCP	Ongoing

Inter-institutional Collaborative Projects

Project Title	Collaborative Institutes	Principal Investigators	Status
Delineation of potential areas for pomegranate cultivation in India using remote sensing and GIS techniques	ICAR-NRCP, Solapur, NBSSLUP, Nagpur	Dr. D.T. Meshram ICAR-NRCP	Ongoing
Micronutrient management in pomegranate for enhancing yield and quality (Externally funded Network project)	ICAR-IIHR, Bangalore, ICAR-NRCP, Solapur,	Dr. Ashis Maity, ICAR - NRCP	Ongoing
Consortia research platform on borer pests (Externally funded)	ICAR-IIHR, Bangalore ICAR-NRCP, Solapur	Dr. Mallikarjun ICAR-NRCP	Ongoing
Outreach programme on management of sucking pests in horticultural crops (Externally funded)	ICAR-IIHR, Bangalore ICAR-NRCP, Solapur	Dr. Mallikarjun ICAR-NRCP	Ongoing
Response of pomegranate to deficit irrigation and partial root zone drying (Externally funded under CRP on water)	ICAR-IIWM, Bhubaneshwar ICAR-NRCP, Solapur	Dr. D.T. Meshram ICAR-NRCP	Ongoing
All India Coordinated Research Project on Arid Zone Fruits	ICAR-CIAH, Bikaner ICAR-NRCP, Solapur	Dr. K. Dhinesh Babu Dr. N.V. Singh ICAR-NRCP	Ongoing

Introduction of pomegranate cultivation (*Punica granatum* L.) to tribal farmers of Gadchiroli district

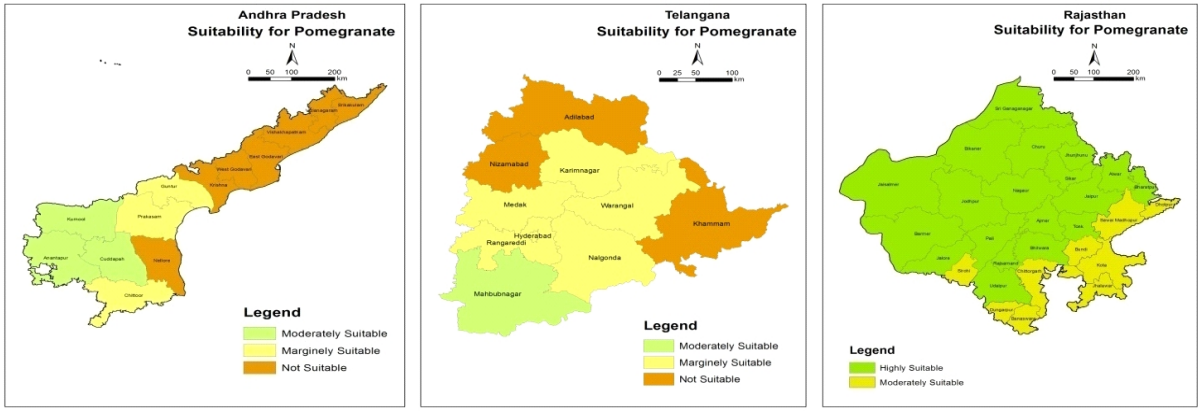
Ten tribal farmers were selected for demonstration of pomegranate cultivation in light texture soil at Sironcha taluka of Gadchiroli district of Maharashtra (i.e. Villages- Bamani, Ranggapalli, Mukalikonda, Pochanpalli and Venkatpura). Each of the ten farmers was given 325 plants of pomegranate variety 'Bhagwa' along with inputs. Technical knowhow was given on cultivation of pomegranate. The performance of pomegranate plantation in light soil was recorded. The activities are in progress.

Pomegranate planting material distributed to tribal farmers at Sironcha taluk of Gadchiroli district

Planting done by Mahila Sarpancha

Delineation of potential areas for pomegranate cultivation in India using Remote Sensing and GIS Techniques

Collaborative project with ICAR-NBSS & LUP, Nagpur and ICAR-NRCP, Solapur was approved. for pomegranate cultivation potential areas in respect of highly suitable, moderately suitable, marginally suitable and not suitable for Andra Pradesh, Telangana and Rajsthan States, India based on rainfall distribution pattern were prepared and documented.



Potential areas for pomegranate cultivation in Andhra Pradesh, Telangana and Rajasthan states, India

8. TRANSFER OF TECHNOLOGY

8.1. Organization of Training/Workshop and other Programmes by NRCP, Solapur

Sl.No.	Name of Training programme	Venue	Participants	Date
1.	Three days training programme on Skill Development in Pomegranate Production and Value addition	ICAR-NRCP, Solapur	19 persons of Yuva Mitra, NGO which is confederation of FPO, Sinner, Nashik District	19.01.16-21.01.16
2.	Three days awareness cum training on 'Protection of plant varieties, farmers rights and model pomegranate production'	ICAR-NRCP, Solapur	25 farmers from Karnataka	21.09.15-23.09.15
3.	Interface meeting with farmers on pomegranate cultivation under Mera Gaon Mera Gaurav (MGMG) scheme	Nandgaon	50 farmers	03.02.16
4	Interface meeting with farmers on pomegranate cultivation under MGMG	Wagdhari, Akkalkot	50 farmers	03.02.16
5	Training cum awareness programme on Pomegranate cultivation under Mera Gaon Mera Gaurav Scheme	Ambalga,	100 farmers and other villagers	04.02.16
6	Training cum awareness programme on Pomegranate cultivation under Mera Gaon Mera Gaurav Scheme	Jambaga B.	100 farmers and other villagers	04.02.16
7	Training programme on "Awareness cum Training Programme on PPV&FR Act, 2001 and Model Pomegranate Production"	ICAR-NRCP, Solapur	20 farmers of Odisha& Rajasthan	08.04.15-10.04.15
8	Propagation, model production practices and value addition in pomegranate	ICAR-NRCP, Solapur	20 employees of M/s. Shree Ram Nursery, Gandhidham, Gujarat and SMSs of KVK, Solapur and Mohol	27.10.15-29.10.15
9	Training program on "Propagation, model production practices and value addition in pomegranate"	ICAR-NRCP, Solapur	20 farmers and officers of Sabarkantha, Gujarat	08.12.15-10.12.15
10	Farmers' training programme at on pomegranate cultivation	KVK, Danta, Barmer	KVK, Danta, Barmer	05.08.15.
11	Training for tribal farmers on "Skill development on water management in pomegranate for tribal farmers of Sironcha taluk of Gadchiroli Dt.	ICAR-NRCP, Solapur	20 Tribal farmers of Sironcha taluk of Gadchiroli Dt.	22.02.16-25.02.16

Technology transfer agreement singed by ICAR - NRCP

MoU signed with M/s. Bhauraya Distributors for usage of pilot plant and one month skill development training in pomegranate juice and RTS development

MoU signed for technology licensing of pomegranate juice & RTS

HU Gugle Agrobiotech Company, Jamkhed, Ahmednagar

8.2. Organization of Workshop/meeting with farmers

Sl.No.	Name of Training programme	Venue	Participants	Date
1.	One day training programme on pomegranate production, processing and value addition	Chikhali, Buldhana	50 Farmers around Chikhali	15.01.16.
2.	Outreach programme for pomegranate export along with APEDA, MSAMB and Yuva Mitra	Sinnar, Nashik	50 Farmers and members of FPO & exporters	29.09.15
3.	Quality production of Pomegranate & Export	Sakal International learning center, Pune	65 trainees	27.6.15; 28.8.15; 02.11.15
4.	One day workshop on Pomegranate production and value addition organized by state Agricultural department in collaboration with ICAR-NRCP	Kahanapur, Mandal Balanagar, Telangana	300 farmers	21.08.15
5.	Quality fruit production in Pomegranate.	Sonyal ,Tal-Koregaon, Dist-Satara	26 farmers	18.07.15
6.	Pomegranate production and value addition opportunities.	Daund, Dist Pune	76 farmers	31.08.15
7.	Hands on Training and Pruning of New orchard for skill Development of tribal farmer	Kashipura, Dt. Raigada, Odisha	38 farmers	05.03.16
8.	Training programme for farmers at Koppal, Karnataka	Koppal, Karnataka	100 farmers	25.02.16
9.	Training programme for farmers of Bagalkot, Karnataka	Bagalkot, Karnataka	100 farmers	26.02.16
10.	Training programme for farmers of Hosadurga, Chitradurg Dt, Karnataka	Hosadurga, Dt, Chitradurg Karnataka	100 farmers	14.12.15
11.	Training programme on Skill development in pomegranate	Barshitakali, Telhara, Murtijapur, Akola	50 farmers	04.11.15-06.11.15
12.	Training programme on Plant protection measures in pomegranate	Bagalkot, Koppal	100 farmers	25.02.16-26.02.16
13.	Skill development on water management in pomegranate for tribal farmers of Sironcha taluk of Gadchiroli District	Sironcha Taluk, Gadchiroli Dt.	25 farmers	22.03.16-25.03.16
14.	Foundation day- cum- 1st Dr. G.S. Cheema Lecture, ICAR-NRCP, Solapur	ICAR-NRCP, Solapur	25 farmers	25.09.15

Glimpses of training programmes and workshops participated

Training programme for staff of Yuva Mitra, Sinnar, Nashik

Hands on training on skill development in pruning of pomegranate for tribal farmers of Kashipura, Raigada, Odisha

Training programme on quality pomegranate production at Sonyal, Tal-Koregaon Dist- Satara,

Training programme on pomegranate production and value addition opportunities Daund, Pune, MS

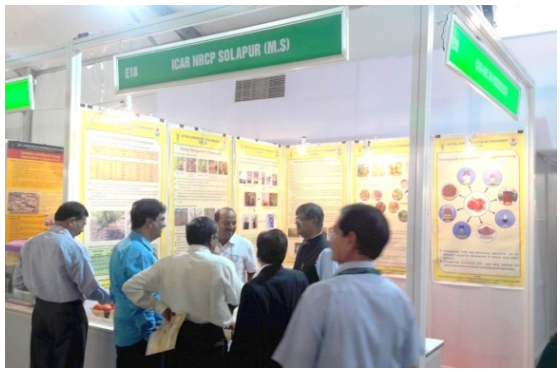
Skill development on water management in pomegranate for tribal farmers of Sironcha taluk of Gadchiroli District

A small gathering of farmers on the eve of Foundation day of ICAR- NRCP

8.3. Exhibitions Participated

Sl.No.	Name of Exhibition	Venue	Date
1.	International exhibition on Agriculture 2015	Baramati, District Pune	06.11.15-09.11.15
2.	Unnat Krishi National Agricultural Fair	ICAR-IARI, New Delhi	19.03.16-21.03.16
3.	Horti Krishi Mela	UAHS, Shimoga, Karnataka	04.10.15-06.10.15
4	Horticultural Mela	UHS, Bagalkot	19.12.15-21.12.15

Glimpses of Exhibitions Participated



ICAR-NRCP participated in Unnat Krishi National Agricultural Fair

ICAR-NRCP participated in International exhibition on agriculture

Participation in Krishi Mela held at UAHS, Shivamogga, Karnataka, Oct 4-6,2015

Participation in Horticultural Mela held at UHS, Bagalkot, Karnataka, Dec 19-21, 2015

8.4. Pomegranate Growers/Visitors visited ICAR-NRCP, Solapur

Sr.No	Date	Region	No. of Visitors
1	01.04.15	Vijapur District, Karnataka	45
2	26.06. 15	Bidar District, Karnataka	25
3	26.06.15	Bellary District, Karnataka	55
4	26.07.15	Bidar District, Karnataka	45
5	08.09.15	Daund District, Pune	25
6	10.09.15	Gujarat women farmers, Gujarat	25
7	15.09.15	Gulbarga District, Karnataka	55
8	18.09.15	Gulbarga District, Karnataka	16
9	01.10.15	Students from Lokmangal college of Biotechnology, Wadala, Solapur	54
10	01.10.15	Students from Shri. PrakashYelgulwar College of Science and Arts, Solapur	94
11	05.11.15	Kiramgaon, District Ahemadanagar, Maharashtra	50
12	11.12.15	Students of University of Agriculture, Dapoli	36
13	18.12.15	Akola District of Maharashtra	48
14	06.01.16	Students of Agriculture School, Solapur	48
15	08.01.16	Raichur District, Karnataka	54
16	11.01.16	Students of Horticulture College, Mysore District, Karnataka	45
17	18.01.16	Farmers from Yadgir District, Karnataka	90
18	19.01.16	Bagalkot District, Karnataka	47
19	27.01.16	Students of Walchand College of Arts and Science, Solapur	50
20	29.01.16	KVK, Mohol	75
21	06.02.16	ATMA , Deesa District, MP	54
22	09.02.16	Vijapur District, Karnataka	54
23	12.02.16	Shrigonda, District Ahmedanagar, Maharashtra	16
24	15.02.16	Students from Lokmangal college of Biotechnology Wadala, Solapur	54
25	19.02.16	Bidar District Karnataka	25
26	29.02.16	Students of Shri Mohitepatil College of Science, Akluj, District Solapur	20
27	01.03.16	Gadag District, Karnataka	22
28	14.03.16	Students of Botany Dayanand College, Solapur	33
29	18.03.16	Agriculture Women's Self Help Group Sangola District, Solapur	21
30	22.03.16	Ramnagar Tahasil of Bangluru, Karnataka	56
31	24.03.16	Koppal District, Karnataka	24
32	28.03.16	Nalgonda District, Karnataka	71
33	29.03.16	Kolar District, Karnataka	45
34	31.03.16	Sinnar Taluk of Nasik District, Maharashtra	12
		Total visitors	1489

8.5. Mera Gaon Mera Gaurav

Baseline survey of six villages adopted under MGMG has been completed. These are Waghdari (Akkalkot), Karkambh (Pandharpur), Nimgaon (Madha), and Nandgaon, Tk. Naldurga (Osmanabad) in Maharashtra and Jambga B., and Ambalga in Kalburgi (Karnataka) all between 70-100 km. distance from NRCP, Solapur. In addition a farmer-scientist interface was also organized in Feb. 2016, by group of 1 technical and 4 Scientists from the discipline of Plant Protection, Horticulturist, Soil Nutrition and/or Water Conservation / Post Harvest Technology/Breeder. Water scarcity and dependence of farmers on few annual crops was the major problem. Limited farmers growing pomegranate was advised on plant protection measures with respect to diseases in their orchards.

Interface meeting with farmers at Nandgaon under Mera Gaon Mera Gaurav (MGMG), 03.02.16

Interface meeting with farmers at Wagdhari, Akkalkot, Solapur under MGMG, 03.02.16

Mera Gaon Mera Gaurav and Swachh Bharat Abhiyan programme conducted at Ambalaga village of Aland Taluka, Kalaburgi District on 04.02.2016

Filed visit of scientist during the Mera Gaon Mera Gaurav and Swachh Bharat Abhiyan programme conducted at Ambalaga village of Aland Taluka, Kalaburgi District of Karnataka on 04.02.2016

Mera Gaon Mera Gaurav and Swachh Bharat Abhiyan programme conducted at Jambaga B. village of Tq/District Kalaburgi , Karnataka on 04.02.2016

Filed visit of scientist during the Mera Gaon Mera Gaurav and Swachh Bharat Abhiyan programme conducted at Jambaga B. village of Tk. & Dist. Kalaburgi, Karnataka on 04.02.2016

Training programme organized by State Horticulture Department at Mahaboobnagar, Telangana

Field visit to organic pomegranate orchard, Kasegaon, Pandharpur

9. INSTITUTIONAL ACTIVITIES

The following events concerned with R & D activities of ICAR-NRCP were conducted during the year 2015-16.

a. RAC meeting

The IXth Research Advisory Committee (RAC) meeting was held on 09.06.2015 at ICAR-NRCP, Solapur under the Chairmanship of Dr. C.D. Mayee, Former chairman, ASRB, New Delhi. The RAC members Dr. O.P. Pareek, Former Director, CIAH, Bikaner, Dr. V. Rajagopal, Former Director, CPCRI, Kasargod and Dr. R.K. Jain, Jt. Director (Education) & Dean, IARI, New Delhi could not attend the meeting.

Sl. No.	Name	Designation
1.	Dr. C.D. Mayee – Chairman, Former Chairman, ARSB, New Delhi	Chairman, RAC
2.	Dr. B.B. Vashistha - Member, Former Director, NRCS S, Ajmer	Ex-officio Member, RAC
3.	Dr. R.K. Pal, Director, ICAR-NRCP	Ex-officio Member, RAC
4.	Dr. T. Janakiram, ADG (Hort.1), ICAR, New Delhi	Ex-officio Member, RAC
5.	Shri. Baburao Ramchandra Gaikwad, Progressive Grower, Sangola, Dist. Solapur	Non-official member, RAC
6.	Dr.(Mrs). Jyotsana Sharma - Member Secretary	Member Secretary, RAC
7.	Dr. K. Dhinesh Babu	Pr. Scientist (Hort.- Fruit Sc.)
8.	Dr. D.T. Meshram	Sr. Scientist (S&WCE)
9.	Dr. A. Maity	Scientist (Soil Science)
10.	Dr. N.V. Singh	Scientist (Hort.- Fruit Sc.)
11.	Dr. Nilesh Gaikwad	Scientist (AS &PE)
12.	Dr (Mrs.). Shilpa Parashuram	Scientist (Gen. & PB)

The members of RAC along with the Director and Scientists of ICAR-NRCP visited newly established small demonstration on protected cultivation, evaluation of seedling population, newly established pilot plant for processing, tissue culture unit, etc and interacted with scientists. The Committee appreciated for the developmental activities. Dr. R.K. Pal, Director welcomed the RAC team followed by presentation by Member Secretary, RAC on Action Taken Report of eighth RAC meeting held on April 29, 2014 and individual presentation by scientists under 7 ongoing projects. The chairman and members of the committee complemented Director and Scientists for taking action on all recommendations of previous RAC and appreciated the progress made during last three years. The recommendations of VIIIth RAC approved by ICAR are summarized below.

Recommendations

- Research on physiology of pomegranate should be taken up on priority

- Improvement of varieties should receive top priority and new variety better than Bhagwa having resistance / tolerance to major biotic stresses should be released in 5 years
- All valuable pomegranate germplasm at ICAR-IIHR, Bangalore, MPKV, Rahuri and other organizations in India should also be maintained at ICAR-NRCP field gene bank.
- Research on cropping system should be planned and initiated within 2 years keeping in view the availability of scientific man power and irrigation water resources.

b. IRC meeting

The Xth Institute Research Council (IRC) meeting of ICAR-NRCP, Solapur was held on 15.09.2015 and was attended by the following members.

Participants of Tenth Institute Research Council Meeting

Sl.No.	Participant	Designation
1.	Dr. R.K. Pal, Director, NRC on Pomegranate, Solapur	Chairman
2.	Dr. Ajit Kumar N. Deshpande , Former Head, Dep. Soil Science and Agril. Chemistry, MPKV Rahuri	Expert, Soil Science and Agril. Chemistry
3.	Dr. V.I. Benagi, Director of Extension, University of Agril. Sciences, Dharwad	Expert, Pl. Pathology
4.	Dr. (Mrs) Indu Sawant, Principal Scientist, Plant Pathology, NRC for Grapes, Pune	Expert, Pl. Pathology
5.	Dr. Jyotsana Sharma, Pr. Scientist, NRCP, Solapur	Member Secretary IRC
6.	Dr. K Dhinesh Babu, NRCP, Solapur	Sr. Scientist (Hort.-Fruit Sc.i)
7.	Dr. DT Meshram, NRCP, Solapur	Sr. Scientist (S & WCE)
8.	Dr. Ashis Maity, NRCP, Solapur	Scientist (Soil Science)
9.	Dr. NV Singh, NRCP, Solapur	Scientist, (Hort.-Fruit Sc.)
10.	Dr. Nilesh N Gaikwad, NRCP, Solapur	Scientist (AS & PE)
11.	Dr.(Mrs.). Shilpa Parashuram NRCP, Solapur	Scientist (Gen. & Pl. Breeding)
12.	Mr. Mallikarjun, NRCP, Solapur	Scientist (Entomology)

At the outset Dr. RK Pal, Director, ICAR-NRCP, Solapur extended a warm welcome to the invited experts and all scientists. This was followed by introduction of all participants. Dr. K Dhinesh Babu, In-charge PME cell presented the status report of the ongoing and completed projects. This was followed by the research report presentations by the Principal Investigators of the projects. The experts have given their valuable suggestions in focusing the research approach.

c. IMC meeting

The XIIth Institute Management Committee (IMC) meeting of ICAR-NRCP, Solapur was held at the institute on 11.08.2015 and was attended by the following members.

Sl. No	Name	Designation
1.	Dr. R. K. Pal, Director, ICAR-NRCP, Solapur	Chairman, IMC
2.	Director of Horticulture, Govt. of Maharashtra	Member, IMC
3.	Director of Horticulture, Govt. of Rajasthan	Member, IMC
4.	Dr. D.P. Waskar, Director of Research, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani	Member, IMC
5.	Sh. Prabhakar Chandane, Ekhatpur, Sangola Tk, Solapur Dt.	Member, IMC
6.	Sh. Baburao Ramchandra Gaikwad, Ramkrishna Niwas, Shivaji Nagar A/p, Sangola, Solapur	Member, IMC
7.	Dr. (Mrs.) J. Sharma, Principal Scientist, ICAR-NRCP, Solapur	Member, IMC
8.	Dr. R.G. Somkuwar, Principal Scientist, ICAR -NRC for Grapes, P.B. No.3, Manjari Far, Pune-412 307	Member, IMC
9.	Dr. S. Sriram, Principal Scientist, Division of Plant Pathology , ICAR-IIHR, Bangalore	Member, IMC
10.	Dr. Prabhakar, Principal Scientist, Centre on Rabi Sorghum (IIMR), NH-9, Bypass Road, Shelgi, Solapur	Member, IMC
11.	ADG (Hort.-I), ICAR, KAB-II, Pusa, New Delhi-12	Member, IMC
12.	FAO, National Institute of Abiotic Stress Management, Malegaon, Baramati-413115	Member, IMC
13	Sh. R.B. Rai, AAO, ICAR-NRCP, Solapur	Member Secretary, IMC

d. Hindi Chetna Saptah

ICAR-NRC on Pomegranate has celebrated "*Hindi Chetna Saptah*" from 15 to 25th September, 2015 by conducting various competitions viz., elocution, writing, translation, quiz etc. To mark the end of these competitions, a prize distribution ceremony was organized on 25 September, 2015. Dr. R. K. Pal, Director, ICAR-NRCP attended the ceremony as a chief guest. In his speech, honorable chief guest highlighted the importance of Hindi in bringing social integrity and the event was managed by Dr. D. T. Meshram, Hindi officer in cooperation with all the Scientific, Technical, Administrative and Supporting staff of ICAR- NRCP, Solapur.

Hindi Chetna Saptah

e. Foundation day celebration

The Foundation day celebration of ICAR-NRCP was coordinated by Dr. Nilesh Gaikwad and Dr. K. Dhinesh Babu.

25.09.2015. This synchronized with the inauguration of the 1st G.S. Cheema Lecture, which was delivered by the invited expert, Retd. Prof. Dhotre, MPKV, Rahuri on porous pipe irrigation. Besides, Dr. Abhay Shendye also delivered a lecture on the aspects of identification of bacterial blight disease of pomegranate. A small group of farmers and some staff of KVK, Solapur and KVK, Mohol attended the meeting.

Foundation day celebration of ICARNRCP

f. Swachh Bharat Abhiyan

Swachh Bharat Abhiyan (Clean India Mission) was observed at ICAR-NRCP, Solapur on 02.10.2015. On this occasion, various laboratories, nursery area, experimental block in the premises were cleaned and maintained neat.

g. One day National Workshop on Fruit cracking and soil health management

One day National Workshop on "Fruit cracking and soil health management" was organized by ICAR-NRCP and coordinated by Dr. N.V. Singh, Scientist (Hort.- Fruit Science) and Dr. A. Maity, Scientist (Soil Science) on 03.10.2015. Dr. N.K. Krishnakumar, DDG (HS) acted as the Chairman of the workshop. There were 2 sessions viz., Fruit cracking and Soil health management. Invited speakers from different institutes including ICAR-NRCP, Solapur have delivered lecture addressing these aspects.

National Workshop on fruit cracking & soil health management

National Workshop on fruit cracking & soil health management

h. Infrastructure created

An interactive touch screen kiosk to provide information on pomegranate has been installed at the ATIC, ICAR-NRCP, Solapur. The pilot plant for processing of pomegranate has been equipped with recently procured machineries for processing and packaging of pomegranate juice and Ready-to serve (RTS) beverage.

Interactive touch screen kiosk installed in the ATIC

A view of pilot plant for pomegranate processing

Cold press

Pomegranate processing line for juice and RTS beverage

10. TRAINING AND CAPACITY BUILDING

Participation of scientist/ Staff in Conference/Meetings/Symposia/Workshop/Training

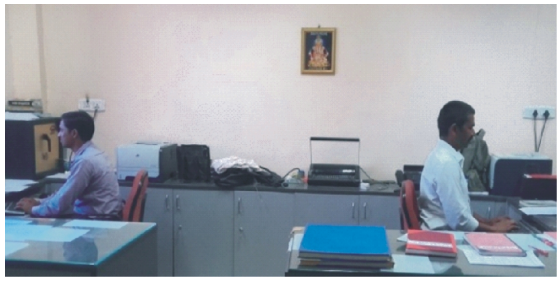
S.No.	Title	Date	Venue	Participants
1	Seminar on Basics of chromatography and water products	21.12.15	Walchand College of Arts and Science, Solapur	Dr. Nilesh Gaikwad
2	Annual review meeting of ITMU of south zone	08.02.16	ICAR-IIHR, Bangalore	Dr. Nilesh Gaikwad Mrs. S. Suryavanshi
3	One day workshop on fruit cracking and soil health management in pomegranate', organized by SARP, ICAR -NRCP, Solapur	03.10.15	ICAR-NRCP, Solapur	Dr.R.K.Pal, Director & all scientists
4	XX Research workers Group Meeting of AICRP-AZF, 4-6 Feb 2016	04.02.16-06.02.16	S.K. Rajasthan Agril. University, Bikaner	Dr. R.K. Pal, Director Dr. K. Dhinesh Babu
5	Review meeting of Flagship project on Integrated approach to eradicate pomegranate bacterial blight, Jan 30, 2016 at ICAR-NRCP, Solapur	30.01.16	ICAR-NRCP, Solapur	Dr.R.K.Pal, Director Dr.(Mrs). J. Sharma, Dr. K. Dhinesh Babu Dr. A. Maity Dr. N.V. Singh Dr.(Mrs).H.B. Shilpa
6	Pomegranate Meeting organized by Akhil Maharashtra Dalimb Utpadak Sanshodhan Sangh with the Scientists of NRCP	11.12.15	ICAR-NRCP, Solapur	Dr. D.T. Meshram
7	Meeting with members of Maharashtra pomegranate growers research association	07.05.16	Phaltan, Satara	Dr. D.T. Meshram
8	Geospatial technologies in mapping, monitoring and management of natural resources	05.08.15-25.08.15	ICAR-NBSS&LUP, Nagpur	Dr. D.T. Meshram
9	User's training workshop on ICAR Krishi Geoportal	28.03.16-30.03.16	ICAR-NBSS&LUP, Nagpur	Dr. D.T. Meshram
10	One day National Seminar on Rajbasha	09.11.15	NASC Complex, New Delhi	Dr. D.T. Meshram
11	Technical Committee meeting of Maharashtra pomegranate growers research association	08.07.15	MPKV, Rahuri	Dr. D.T. Meshram
12	Recent advances in next generation sequencing data analysis	08.01.16-18.01.16	IASRI, New Delhi	Dr. N.V. Singh
13	National Trainers Training Workshop on Natural farming and rural economy	29.01.16-31.01.16	Kolhapur	Dr. N.V. Singh
14	One day workshop on Pomegranate cultivation – good management practices opportunities for value addition & exports	21.08.15	Telangana	Dr. N.V. Singh

S.No.	Title	Date	Venue	Participants
15	Short course training on Modern integrated crop breeding tools-breeding management system	18.01.16-27.01.16	ICAR-IIRR, Hyderabad	Dr (Mrs). H.B. Shilpa
16	Awareness cum training program on PPV & FRA Act and interface with Nodal Officers of MGMG initiative	28.03.16	ICAR-CRIDA, Hyderabad	Dr (Mrs). H.B. Shilpa
17	India Germany bilateral cooperation in seed sector : DUS workshop	23.11.15-24.11.15	ICAR-IARI, New Delhi	Dr (Mrs). H.B. Shilpa
18	CRP-AB review meeting	28.10.15	ICAR-NRCG, Pune	Dr (Mrs). H.B. Shilpa
19	Meeting : Round table discussion on semiochemicals	31.07.15	NBAIR, Bangalore	Mr. Mallikarjun
20	Research project review meeting	15.09.15	ICAR-NRCP, Solapur	Dr. R.K. Pal, Director & All Scientists
21	ICAR-NRCP Foundation day cum 1st Dr. G.S. Cheema Lecture	25.09.15	ICAR-NRCP, Solapur	Dr. R.K. Pal, Director & All Scientists
22	Annual Review meeting of the project Out-Reach Programme on management of sucking pests in horticultural crops	12.02.15-14.02.15	ICAR-IIHR, Bangalore	Mr. Mallikarjun
23	Annual Review meeting of the project HORTSAP	24.02.16	State Dept of Horticulture, Pune	Mr. Mallikarjun
24	IXth RAC meeting	09.06.15	ICAR-NRCP, Solapur	Dr. R.K.Pal, Director, Dr. (Mrs.).J. Sharma, MS & all scientists
25	Xth IRC meeting rd	15.09.15	ICAR-NRCP, Solapur	Dr. R.K.Pal, Director, Dr. (Mrs.).J. Sharma, MS & all scientists
26	State level 43rd Joint Agresco -2015	28.05.15	MPKV, Rahuri	Dr. (Mrs.).J. Sharma (as Director's representative)
27	Pomegranate growers- Scientists interaction	07.07.15	ICAR-NRCP, Solapur	Dr. R.K. Pal, Director & All Scientists
28	Meeting of stakeholders for promoting export through cluster development	20.07.15	APEDA, Mumbai	Dr. (Mrs.).J. Sharma
29	Review meeting of vigilance officers of ICAR	18.11.15	ICAR-NAARM, Hyderabad	Dr. (Mrs.).J. Sharma
30	Meeting with farmers of Maharashtra under Mera Gaon Mera Gaurav	03.02.16	Nandgaon, Naldurg & Wagdhari, Akalkot	Dr. (Mrs.).J. Sharma, Dr. A. Maity, Dr. Mallikarjun Mr. M.S. Gogaon
31	6th International conference on Plant, pathogens and people with mission challenges in plant pathology to benefit humankind	23.02.16-27.02.16	NASC Complex, N. Delhi	Dr. (Mrs.).J. Sharma

S.No.	Title	Date	Venue	Participants
32	Meeting of HRD Nodal Officers of ICAR institutes	10.01.16-12.01.16	ICAR-NAARM, Hyderabad	Dr. (Mrs.).J. Sharma
33	Training workshop on competency	10.02.16-	ICAR-NAARM,	Dr. (Mrs.).J. Sharma
34	Typing in Microsoft word and acquaintance with routine computer operation for technical and supporting staff	14.03.16-03.04.16	ICAR-NRCP, Solapur	G.A. Salunkhe Shylas S. Bayas

Glimpses of training programme on capacity building

Training attended by Dr. Mallikarjun on Regional Plant Health Systems Analysis at NIPHM, Hyderabad from 23.11.15 to 07.12.15



Training programme on computer typing for technical staff of ICAR-NRCP, Solapur, 14.03.16

11. PUBLICATIONS

I) Papers in research journals

1. Awachare, C., Singh, N.V., Mundewadikar, D. M., Shilpa, H. B., Pal, R. K., Nimbolkar, P. K. and Murthy, B. N. S. 2016. Biochemical profiling in pomegranate (*Punica granatum* L.) cultivar 'Bhagwa'. *Res. on Crops* 17(3): XX (In press).
2. Dhinesh Babu, K., N.V. Singh, Ram Chandra, J. Sharma, A. Maity and P.C. Sarkar. 2015.Improvement in keeping quality of pomegranate fruits during storage (*Punica granatum* L). *Res. on Crops* 16 (2) : 281-287.
3. Marathe, R.A. and K.D. Babu. 2015. Determination of sampling period and leaf position for critical nutrient analysis in pomegranate cv. Bhagwa. *Indian J. Hort.* Dec, Vol No. 72 (4).:562-565
4. Marathe, R.A. J. Sharma and K.D. Babu. 2016. Identification of suitable soils for cultivation of pomegranate (*Punica grantum* L.) cv. Ganesh. *Indian J. Agric. Sciences* 86 (2):227-33
5. Meshram DT and SD Gorantiwar. 2015. Evaluation of pan coefficient for estimating reference crop evapotranspiration in Solapur station, Maharashtra. *Mausam* 66 (2):205-210.
6. Meshram DT, NV Singh and RK Pal. 2016. Improvement of water use efficiency in Pomegranate (*Punica granatum* L.) cv. Bhagwa under micro-irrigation system. *Indian Journal of Agricultural Sciences* 86(2):192-196.
7. Meshram DT, SD Gorantiwar, HK Mittal and HK Jain. 2015. Forecasting of pomegranate (*Punica granatum* L.) evapotranspiration by seasonal ARIMA model. *Indian Journal of Soil Conservation* 43 (1):255-259.
8. Saminathan, T., Bodunrin, A., Singh, N. V., Devarajan, R., Nimmakayala, P., Jeff, M., Aradhya, M. and Reddy, U.K. 2015.Genome-wide identification of microRNAs in pomegranate (*Punica granatum* L.) by high throughput sequencing. *BMC Plant Biology*16:122 DOI 10.1186/s12870-016-0807-3
9. Singh, N. V., Sharma, J., Chandra, R., Babu, K.D., Shinde, Y. R., Mundewadikar, D. M. and Pal, R. K. 2016. Bio-hardening of *in-vitro* raised plants of Bhagwa pomegranate (*Punica granatum* L.). *Indian J. Agric. Sci.* 86 (1): 132–136
10. Singh, N.V., Saminathan, T., Chandra, R., Awachare, Babu, K. D., Mundewadikar, D.M. and Pal, R.K. 2015. RNA isolation from high polyphenol containing tissues of pomegranate. *Indian J. Hort. 72(2): 273-277.*
11. Singh, N.V., Singh, S., Chandra, R., Babu, K. D. and Pal, R.K. 2016. Comparative evaluation of seed germination and parameters of seedling growth in pomegranate genotypes (*Punica granatum* L.). *Res. Environ. Life Sci.* 9(3): 282-284.

II. Book Chapters

1. Ahuja DB, Niranjan Singh, Jyotsana Sharma, CN Rao, AK Das, R Thangavelu, KS Raghuvanshi, Suresh Pardeshi, Sachin Suroshe, SK Godse, Pushpa D Patil, AY Munj, SS Mane, Suresh Dadmal, BV Bhede, BBBhosle, BD Shinde and Makarand S Joshi. 2015. Implementation of electronic –pest (e-pest) surveillance. In: *Pests of Fruit Trees (Citrus, Banana, Mango, Pomegranate and Sapota) E-Pest Surveillance and Pest Management Advisory* (DB Ahuja and C Chattopadhyay Eds.): Publ. ICAR-National Research Centre for Integrated Pest Management, New Delhi and State Department of Horticulture, Commissionerate of Agriculture, Pune, Maharashtra, pp.85-101.

2. Sharma Jyotsana, Sachin Suroshe, KS Raghuvanshi, SG Borkar and SR Kulkarni. 2015. Pomegranate. In: *Pests of Fruit Trees (Citrus, Banana, Mango, Pomegranate and Sapota) E-Pest Surveillance and Pest Management Advisory* (DB Ahuja and C Chattopadhyay Eds.): Publ. ICAR-National Research Centre for Integrated Pest Management, New Delhi and State Department of Horticulture, Commissionerate of Agriculture, Pune, Maharashtra, pp.56-70.
3. Sharma Jytosana, Sachin Suroshe, K. S. Raghuwanshi, S.G. Borkar and S. R. Kulkarni. 2014. Pest management advisory for pomegranate. In: Pests of Fruit Trees (Citrus, Banana, Mango, Pomegranate and Sapota) E-Pest Surveillance and Pest Management Advisory (DB Ahuja and C Chattopadhyay Eds.): Publ. ICAR-National Research Centre for Integrated Pest Management, New Delhi and State Department of Horticulture, Commissionerate of Agriculture, Pune, Maharashtra, pp.107-110.
4. Sharma KK, Jyotsana Sharma and VT Jadhav. 2015. Recent Developments in Bacterial Blight of Pomegranate and its Management. In : *Recent Advances in the Diagnosis and Management of Plant Diseases* (Ed. LP Awasthi). Publ. Springer (India) Pvt. Ltd.119-126.
5. Singh NV, Jyotsana Sharma and RK Pal, 2015. Biological control of pre and post disease of fruits. In:*Microbial empowerment in agriculture-a key to sustainability and crop productivity* (Ed. B.K Sharma). Biotech Books, New Delhi (ISBN 978-81-7622-331-7). pp. 141-172

III. Popular articles

1. J. Sharma. 2015. Garpeetwa Bemausmi Pawasamule Nuksan Dalimb Pikasathi Salla. *Dalimbwrut* . July-Sep. 2015: 39-40 (*Marathi*).
2. J. Sharma. 2015. Agrochemicals recommended for control of various diseases and insect pests for export of pomegranate. *Dalimbwrut.* Jan. –Mar, 2016: 36-39 (*Marathi*)
3. Meshram, D.T., Pal, R.K. and Singh, N.V. 2015. More pomegranates per drop of water. *Indian Horticulture*. 19-21.
4. Meshram, D.T., R.K. Pal and R.T. Khopde. 2016. Dalimbache Rajniye Shetr Utpadhan Utpadakta. Dalimbwrut. 51-52 (Marathi)
5. Singh, N.V., Singh, S. and Singh, A. 2016. Paudhshala (Nursery) Kesthapana Ki Taiyari. *Vindhya Krishi.* 10 (2): 113-119 (*Hindi*)

IV. Presentation in conference/ symposia/ seminars/ workshop/ other fora

1. Babu, K. D. 2015. Physiological, genetical and biochemical basis of fruit cracking. 'One day workshop on fruit cracking and soil health management in pomegranate', 3rd Oct, 2015.organized by SARP, Solapur (Invited Presentation)
2. Manjunatha, G. Jyotsana Sharma and J Venkatesha. 2015. Biological formulation for pomegranate bacterial blight management. 21-22nd August 2015, *National Seminar on "Biological products for crop, animal and human health -Problems and Prospects*" held at University of Mysore, Mysore.
3. Pavan Kumar, B. Aravind, Abhishek Gowda, V. Lokesh, Jyotsana Sharma and G. Manjunath. 2016. Bioformulations for enhanced disease tolerance against Bacterial Blight and fungal wilt of Pomegranate, 5-6 th January 2016, "National Symposium (IPS, South Zone) on Recent Trends in Plant Pathological Research and Education" held at University of Agricultural Sciences, Raichur.
4. Pavan Kumar, B. Aravind, V. Lokesh, Jyotsana Sharma and G. Manjunath. 2015. Development of bioagents inventory for management of pomegranate diseases, 21-22nd August 2015, *National Seminar on*

"Biological products for crop, animal and human health -Problems and Prospects" held at University of Mysore, Mysore.

5. Sharma Jyotsana, KK Sharma, Aundy Kumar, KK Mondal, Sunil Thalor, A. Maity, Ramakant Gharate, Shivakumar Chinchureand VT Jadhav. 2016. Symptomatology, standardization of inoculation method and mode of infection of *Xanthomonas axonopodis* pv. punicae in pomegranate. Sharma Jyotsana. 2016. Challenges in the management of bacterial blight of pomegranate. In *Abstracts 6th International Conference on "Plant, Pathogens and People" with mission "Challenges in Plant Pathology to benefit humankind'* Org. by Indian Phytopathological Society, at NASC complex New Delhi from Feb. 23-27, 2016. pp 242. (Poster presentation)
6. Sharma Jyotsana. 2016. Challenges in the management of bacterial blight of pomegranate. In *Abstracts 6th International Conference on "Plant, Pathogens and People" with mission "Challenges in Plant Pathology to benefit humankind'* Org. by Indian Phytopathological Society, at NASC complex, New Delhi from Feb. 23-27, 2016. Pp 84-85. (Oral Presentation)

V. Technical/ Extension Bulletins& Folders

1. Mallikarjun, HB Shilpa, Jyotsana Sharma and R.K. Pal. 2015. Dalimbe Beleya Pramuka Keetagalu Haagu Avugala Nirvahane. *NRCP/Extension-2015/03 (Major insect pests of pomegranate crop and their management - Kannada language Folder).*
2. Meshram, D. T., V. T. Jadhav, S. D. Gorantiwar and Ram Chandra. 2016. Modeling of Weather Parameters using Stochastic Methods in Climate Change Modeling, Planning and Policy for Agriculture. Springer publisher.
3. Pal, R.K., Singh, N.V., Sharma, J., Babu, K.D., Maity, A., and Chaudhary, D.T. 2015. Anar: Utpadan, Vipnanavem Upyogita. Technical Bulletin No. NRCP/2015/2. 97p. (in Hindi)
4. Shilpa HB, Jyotsana Sharma and RK Pal. 2015. Dalimbeya Soragu Roga Mattu Adara Nirvahana Kramagalu. *NRCP/Extension-2015/02 (Pomegranate wilt disease and its management schedule - Kannada language Folder)*
5. Shilpa HB, Jyotsana Sharma, Mallikarjun and RK Pal.2015. Dalimbeyalli Samagra Roga Mattu Keeta Badegala Nirvahana Velapatti. *NRCP/Extension-2015/01 (Integrated Diseases and Insect Pest Management - Kannada language Folder)*

VI. Annual Report

1. Pal, R.K., Babu, K.D., Maity, A., Singh, N.V., Gaikwad, N. and Meshram, D.T. 2015. ICAR-NRCP Annual Report 2014-15, National Research Centre on Pomegranate, Solapur, 117p.

VII. Manual / Compendium

1. D.T. Meshram, R.K. Pal, R. Chandra, J. Sharma, K.K. Sharma, K.D. Babu, A. Maity, N.V. Singh, Mallikarjun and H.B. Shilpa. 2016. Compendium on "Skill Development on Water Management in Pomegranate" for Tribal Farmers of Sironcha taluk of Gadchiroli District, Maharashtra." 22-25 Feb, 2016, ICAR-NRCP, Solapur , 81p
2. H. B. Shilpa, Nilesh N. Gaikwad, R.K. Pal, Jyotsana Sharma, K. Dhinesh Babu, D. T. Meshram N.V. Singh., Ashis Maity and Mallikarjun. 2015. Training manual on Awareness cum Training on Protection of Plant Varieties, Farmers Rights and Model Pomegranate Production for Karnataka Farmers. 21st-23rdSeptember, 2015, ICAR-National Research Centre on Pomegranate, Solapur, Maharashtra, India.

3. NV Singh, HB Shilpa, Ram Chandra, Jyotsana Sharma, KD Babu, DT Meshram, Ashis Maity, NN Gaikwad, PrativaSahu, Mallikarjun and RK Pal. 2015. Training Manual on Propagation, model production practices and value addition in pomegranate. 8-10th December, 2015, ICAR-NRC on Pomegranate, Solapur, Maharashtra, India. Training manual no. NRCP/2015/6, 93p.
4. Pal, R.K., Chandra, R., Sharma, J., Babu, K. D., Meshram, D.T., Maity, A., Singh, N.V., Gaikwad, N.N., Sahu, P. and Shilpa, H.B. 2015. Awareness cum Training Programme on PPV&FR Act, 2001 and Model Pomegranate Production. Training manual no. NRCP/2015/3, 91 p.
5. Singh, N.V., Chandra, R., Sharma, J., Babu, K. D., Meshram, D.T., Maity, A., Gaikwad, N.N., Sahu, P., Shilpa, H.B. and Pal, R.K. 2015. Propagation, model production practices and value addition in pomegranate. Training manual no. NRCP/2015/7, 57p.
6. Nilesh Gaikwad, R.K. Pal, J.Sharma, K.Dhinesh Babu, D.T. Meshram, N.V. Singh, Shilpa H.B. and Mallikarjun. 2015. 'Compendium of Lectures in Training Programme on Skill Development in Pomegrante Production and Value addition for staff of Yuvamitra, Sinner, Nashik' (19-21st Jan. 2016), National Research Centre on Pomegranate, Solapur, Maharashtra, India.

VIII. TV Talk

1. N.V. Singh. 2016. A TV talk was delivered on show on 'Anar me Hard Wood Cutting se Pravardhan' Television Programme telecast on Jan,2016 on DD Kisan in Khet Khalyan (9 minutes)
2. Sharma Jyotsana. 2016. Anarke bagicheki, Uske utpadanki aur rogon Se Mukthkarneki vidhyonke Bare Me' Television Programme telecast on Feb 4, 2016 on DD Kisan in Khet Khalyan (9 minutes).

IX. Patent

1. Nilesh Gaikwad and Pal. R.K. 2016. A process of extraction of virgin pomegranate seed oil, patent filed (provisional), Application No. 201611011366 TEMP/E-1/10196/2016-DEL.

X. Others

1. Kumar Pavan,J. Manjunatha G., Aravind B., Abhishek Gowda, Lalithya KA, Jyotsana Sharma. Submitted a total of 21 gene sequences of Pseudomonas spp to NCBI-GenBank (KT157591.1, KT157592.1, KT159287.1, KT159286.1, KT159288.1, KT159289.1, KT156645.1, KT159290.1, KT156646.1, KT156646.1, KT157591.1, KU572479, KU572480, KU572481, KU572482, KU572483, KU572484, KU977458, KU977459, KU977460 and KU977461) (Gene sequence)
2. Sharma. J. 2016. Compiled, 'Pre harvest Package of Practices for export of pomegranate to European Union and update Annexure 5, 'Pesticides Recommended for the Control of Various Diseases and Insect Pests of Pomegranate for Export to the European Union' for APEDA (compilation).

12. BUDGET ESTIMATE

Financial Outlay 2015-16

Head of Account	Rupees in lakhs			
	2015-16			
	Plan		Non-Plan	
	RE	Expenditure	RE	Expenditure
A. Recurring				
Estt.Chargs	0.00	0.00	236.03	188.17
T.A.	2.20	2.20	4.00	4.00
Other Charges	120.80	108.80	234.28	231.99
Total A	123.00	111.00	474.31	424.16
B.Non-Recurring				
Equipment	40.00	39.82	5.00	4.75
Major Work	312.00	310.00	0.00	0.00
Library	0.00	0.00	4.14	1.79
Furniture	0.00	0.00	2.00	0.15
Total B	352.00	349.82	11.14	6.69
C. Loans &Advances	0.00	0.00	2.55	2.55
D. Pension	0.00	0.00	9.55	7.19
E. Vehicles & Vessels	0.00	0.00	0.00	0.00
Grand Total (A+B+C+D)	**475.00**	**460.82**	**497.55**	**440.59**

Revenue Receipts 2015-16

SI. No.	Items	Amount (Rs.)
1.	Income from farm produce	369657/-
2.	Income from royalty and publications	284765/-
3.	Income from other sources	607191/-
4.	Interest on loans and advances	5383/-
5.	Interest earned on short term deposits	297551/-
6.	Recovery of loans and advances	533450/-
7.	Training programmes	10000/-
	Total revenue receipt	**2107997/-**

13. STAFF POSITION

Category	Sanctioned during XIIth Plan	Staff position	Vacant
RMP	01	01	00
Scientific	14	10	04
Technical	06	06	00
Administrative	11	05	06
Supporting	02	02	00
Total	**34**	**24**	**10**

14. AWARDS / RECOGNITION / JOINING / PROMOTION / RELIEVING

Awards

- Dr. N. V. Singh, Scientist (Hort.- Fruit Science) was awarded Young Scientist Associate Award by BRIATS, Allahabad for contribution in the field of Horticulture - Fruit Science
- Dr. N. V. Singh, Scientist (Hort.- Fruit Science) was conferred with the Fellow of the International College of Nutrition for the year 2015
- Dr. (Mrs.) Jyotsana Sharma was awarded 'Anar Ratna Award' by the Pomegranate Growers and Research Foundation, Maharashtra
- Mr. Mallikarjun, Scientist (Agril. Entomology) was awarded 'Junior Scientist of the Year Award' (2015) by National Environmental Science Academy, New Delhi.

Recognition

- Dr. N.V. Singh and Dr. A. Maity acted as Organizers for the One day National Workshop on Fruit cracking and soil health management in pomegranate, jointly organized by SARP and ICAR-NRCP on 03.10.15.

Joining

- Mr. Mallikarjun, joined as Scientist (Entomology) at ICAR - NRCP on 10.04.2015
- Dr. Sangle U. R. joined as Sr. Scientist (Pl. Pathology) at ICAR - NRCP on 04.03.2016

Promotion

- Dr. K. Dhinesh Babu, Sr. Scientist (Hort.- Fruit Science) promoted to Principal Scientist (Hort.- Fruit Science) w.e.f. 25.11.2014
- Shri Yuvraj Shinde, promoted from Technical Assistant to Sr. Technical Assistant w.e.f. 04.06.2015
- Shri Govind Salunke, promoted from Technician to Sr. Technician w.e.f. 12.11.2013
- Shri Vijay Lokhande, promoted from Technician to Sr. Technician w.e.f. 03.06.2015

Relieving

- Shri A. A. Goswami, AO, relieved on 31.05.2015 upon transfer from this centre to NBSSLUP, Nagpur
- Dr. K. K. Sharma, Pr. Scientist (Pl. Pathology) relieved on 27.07.2015 upon transfer from this centre to IIMR, Solapur
- Mrs. Prativa Sahu, Scientist (Hort.- Fruit Sc.) relieved on 06.05.2015 upon transfer from this centre to Directorate of Water Management, Bhubaneswar, Odisha

Appendix I
Institute Management Committee of ICAR-NRCP
(As on 31.03.2016)

Chairman

Dr. R.K. Pal, Director
ICAR-NRCP, Solapur

Dr (Mrs.) J. Sharma, P.S.
ICAR-NRCP, Solapur

Members

Director of Horticulture
Govt. of Maharashtra

Dr. R.G. Somkuwar, P.S.
ICAR-NRCG, Pune

Director of Horticulture
Govt. of Rajasthan

Dr. S. Sriram, P.S.
ICAR-IIHR, Bangalore

Dr. D.P. Waskar
Dirctor of Research
VNMKV, Parbhani

Dr. Prabakar, P.S.
Centre on Rabi Sorghum, IIMR,
Shelgi, Solapur

Sh. Prabhakar Chandane
PO. Ekhatpur, Sangola

ADG (Hort.-I), ICAR, KAB
KAB-II, New Delhi

Sh. Baburao R. Gaikwad
Ramkrishna Niwas, Shivaji Nagar
Sangola

F & AO
National Institute of Abiotic Stress Management
Malegaon, Baramati

Sh. R.B. Rai, AAO
ICAR-NRCP, Solapur

Appendix II

Research Advisory Committee of ICAR-NRCP

(As on 31.03.2015)

Chairman

1. Dr. C. D. Mayee
   Formar Chairman, ASRB, New Delhi
   50 K, Bharat Nagar, Amravati Road, Nagpur - 33

Member

2. Dr. O. P. Pareek
   A-239, Kranti Nagar
   Lalgarh, Bikaner-334001

3. Dr. B. B. Vashistha
   Former Director, NRCSS
   C-107, Vidhuth Nagar
   Vaishali Nagar,
   Jaipur, Rajasthan

4. Dr. V. Rajagopal
   Former Director, CPCRI
   Flat No.102, Sreekarkasham Street
   A18-4-60, Railway Colony,
   Thirupathi-517501

5. Dr. R. K. Jain
   Head, Plant Pathology & Biotechnology
   Indian Agricultural Research Institute
   Pusa, New Delhi -12

6. Dr. R. K. Pal
   Director,
   ICAR-NRC on Pomegranate, Solapur

7. Dr. T. Janakiram
   ADG (Hort.II), ICAR
   KAB-II, Pusa, New Delhi

8. Shri Prabhakar Chandane,
   PO. Ekhatpur,
   Tal. Sangola,
   Dist. Solapur

9. Shri Baburao Ramchandra Gaikwad,
   Ramkrishna Niwas, Shivaji Nagar,
   At. Post. Sangola,
   Dist. Solapur

Member Secretary

10. Dr. (Mrs.) Jyotsana Sharma
    Principal Scientist,
    ICAR-NRC on Pomegranate,
    Solapur 413255 (MS)

Appendix III

Institute Research Coucnil of ICAR-NRCP

(As on 31.03.2016)

Chairman

1. Dr. R. K. Pal
   Director, ICAR-NRCP

Member

2. Dr. K. Dhinesh Babu
   Pr. Scientist (Hort.-Fruit Science)
   ICAR-NRCP, Solapur

3. Dr. D. T. Meshram
   Sr. Scientist (L & WME)
   ICAR-NRCP, Solapur

4. Dr. Ashis Maity
   Scientist (Soil Science-Pedology)
   ICAR-NRCP, Solapur

5. Dr. N. V. Singh
   Scientist (Hort.-Fruit Science)
   ICAR-NRCP, Solapur

6. Dr. N. N. Gaikwad
   Scientist (AS & PE)
   ICAR-NRCP, Solapur

7. Dr. Shilpa Parashuram
   Scientist (Gen. & Pl. breeding)
   ICAR-NRCP, Solapur

8. Dr. Mallikarjun,
   Scientist (Entomology)
   ICAR-NRCP, Solapur

Member Secretary

9. Dr. (Mrs.) Jyotsana Sharma
   Pr. Scientist (Plant Pathology)
   ICAR-NRCP, Solapur

Institute Joint Staff Council of ICAR-NRCP

(As on 31.03.2016)

Chairman

1. Dr. R.K. Pal
   Director, ICAR-NRCP

Members (Official Side)

2. Dr. (Mrs.). J. Sharma
   Pr. Scientist, ICAR-NRCP

3. Dr. N.V. Singh
   Scientist, ICAR-NRCP

4. Dr. D.T. Meshram
   Sr. Scientist, ICAR-NRCP

5. Dr. N. Gaikwad,
   Scientist, ICAR-NRCP

6. Officer I/c –Accounts
   ICAR-NRCP

7. Officer I/c – Admn.,
   ICAR-NRCP

Members (Staff Side)

8. Sh. R.B. Rai, Member (CJSC)
   AAO, ICAR-NRCP

9. Sh. Kiran Khatmode
   LDC, ICAR-NRCP

10. Sh. Y.R. Shinde, Secretary (IJSC)
    Tech. Asstt., ICAR-NRCP

11. Sh. D.T. Chaudhary
    Sr. Tech. Asstt., ICAR-NRCP

12. Sh. S.S. Bayas,
    SSS, ICAR-NRCP

13. Sh. V.S. Gangane
    SSS, ICAR-NRCP

Appendix IV

Personnel

(As on 31.03.2016)

RMP

Dr. R. K. Pal
Director

Scientific Staff

Dr. Ram Chandra
Pr. Scientist
(Horticulture)

Dr. (Mrs.) Jyotsana Sharma
Pr. Scientist
(Plant Pathology)

Dr. K. Dhinesh Babu
Pr. Scientist
(Hort.-Fruit Science)

Dr. D. T. Meshram
Sr. Scientist
(Land & Water Management Engg.)

Dr. U.R. Sangle
Sr. Scientist
(Plant Pathology)

Dr. Ashis Maity
Scientist
(Soil Science-Pedology)

Dr. N. V. Singh
Scientist
(Hort.-Fruit Science)

Dr. N. N. Gaikwad
Scientist
(Agrl. Structures & Process Engg.)

Dr. (Mrs.) Shilpa Parashuram
Scientist
(Genetics & Plant Breeding)

Mr. Mallikarjun
Scientist
(Agrl. Entomology)

Technical Staff

Sh. D. T. Chaudhari
Sr. Tech. Ass tt.

Sh. Yuvraj Shinde,
Sr.Tech. Asstt.

Sh. Diwakar Sawaji
Tech. Asstt.

Sh. M. S. Gogaon
Sr. Technician

Sh. Govind A. Salunke
Sr. Technician

Sh. Vijay Lokhande
Sr. Technician

Administrative Staff

Sh. R. B. Rai
AAO

Sh. V. A. Shinde
AF & AO

Sh. Kiran Khatmode
LDC

Sh. A. S. Babar
LDC

Sh. Vipin Dagar
LDC

Supporting Staff

Sh. Shailesh Bayas
SSS

Sh. Vishal Gangane
SSS

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CERTIFICATE OF REGISTRATION

Quality Management Systems

NATIONAL RESEARCH CENTRE ON POMEGRANATE

Solapur- Pune, National Highway- 65, Kegaon,
Solapur- 413255, Maharashtra, India

Equalitas Certifications Limited Certifies that the Management System of the above mentioned Company has been assessed and meets the requirements established by the following rules:

ISO 9001:2008

The Management System Includes :

Augment the Production, Productivity and Utilization of Pomegranate through Basic, Strategic and Applied Research

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