ICAR-NRCP

(An ISO 9001:2015 Certified Institute)

वार्षिक रिपोर्ट

Annual Report 2017-18

भा.कृ.अनु.प.–राष्ट्रीय अनार अनुसंधान केंद्र

ICAR-National Research Centre on Pomegranate

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Solapur - 413 255 (M.S.)

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वार्षिक रिपोर्ट

Annual Report

2017-18

भाकृ अनुप
ICAR

राष्ट्रीय अनार अनुसंधान केंद्र, सोलापुर
National Research Centre on Pomegranate, Solapur
औषधी रसपरीपूर्णम्।
दाडिमम सु-वर्णम्।

भा.कृ.अनु.प.– राष्ट्रीय अनार अनुसंधान केन्द्र

ICAR- National Research Centre on Pomegranate

(भारतीय कृषि अनुसंधान परिषद)

(Indian Council of Agricultural Research)

सोलापूर – 413 255

Solapur - **413 255**

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PREFACE

The ICAR-National Research Centre on Pomegranate, Solapur is about to complete 13 years of its existence in coming months. The Centre has made several remarkable accomplishments during this short span. Tremendous increase in pomegranate area under cultivation (122.91%), production (279.15%), productivity (70.12%) and export (382.17%) during last 15 years endorses the role this Centre has played in promoting pomegranate cultivation. Noteworthy contributions by the Centre during 2017-18, include, release of promising varieties 'Solapur Lal' and 'Solapur Anardana', a novel bio-formulation for potassium supplementation for which patent has been filed, amino acid based micronutrient formulations for better fruit size and quality of pomegranate and value added products including Sparkling Pomegranate wine, Virgin Seed oil and Hi-fibre cookies from de-oiled seed cake are ready for commercialization.

ICAR-NRCP effectively disseminated its technologies all over India, through several in-house and on-site training programmes and National Seminar-cum-Farmers' Fair, consultancy etc..Pomegranate cultivation has played a significant role in doubling farmers' income hence tribal areas in Anuppur district of MP and Koriya district of Chhattisgarh have been adopted under TSP to improve farmers' income. The Centre also took various activities under 'Swachh Bharat"and 'Mera Gaon Mera Gaurav' schemes.
The 'Trainees' Hostel' became functional from September 2018 and is in great demand since then. New mobile App 'Solapur Anar' has been launched in April 2017 in 6 languages with more than 5000 downloads within a year.

With tremendous increase in area and productivity of pomegranate the Centre has a challenging task ahead to improve export through breeding large size variety and pesticide residue free production; work on these aspects have already been initiated. I am sure we will continue to move forward with confidence to achieve new milestones.

I wish to place on record my sincere gratitude to Dr. T. Mohapatra, Secretary, DARE and Director General, ICAR for his constant guidance and encouragement to face the challenges. I also wish to express my sincere thanks to the Hon'ble DG for entrusting me with the responsibility of heading this Centre. It is a matter of great privilege to serve the institute-with which I have been associated since it came into existence-as Acting Director. I am obliged to Dr. AK Singh, DDG (HS) for his support and guidance. Kind cooperation and support rendered by all the staff members of SMD (HS) to this Centre is

thankfully acknowledged. I place on record my sincere gratitude to Dr. RB Deshmukh, former Vice Chancellor MPKV and Chairman, RAC for his guidance and keen interest in improving the research activities of the institute.

I express my sincere thanks to our former Director Dr. RK Pal, for increasing the visibility of this Centre during his tenure till December 31, 2018. The Centre could not have achieve its targets without constant support and cooperation of all scientific, administrative, technical and supporting staff as well as senior research fellows, young professionals in various research projects. I am indebted to one and all for their unflinching support and place on record my sincere thanks to them with the hope for their constant co-operation in future, for the betterment of this dynamic Centre.

Jyotsana Sharma
Director (Acting)

INTRODUCTION

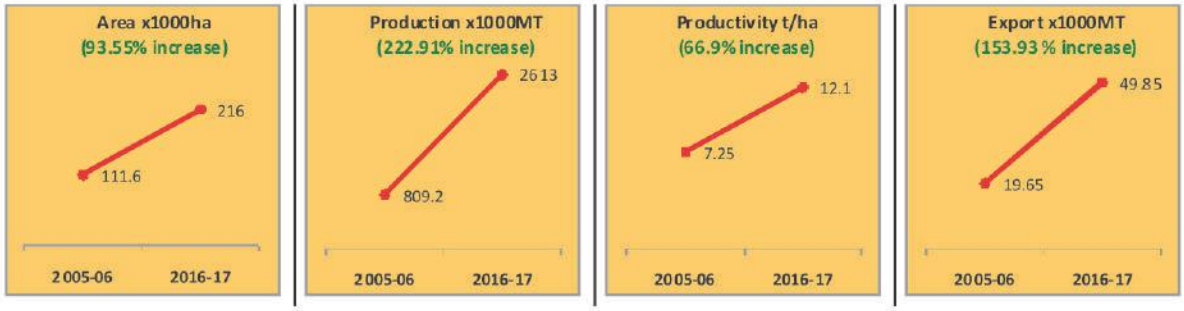
Pomegranate (*Punica granatum* L) attracted mankind since time immemorial, earlier due to its magical therapeutic use and now due to alluring returns as well as consumer awareness towards its innumerable health benefits. Demand in the international market has enhanced the scope for earning higher dividends from this crop. Moreover, it is an ideal crop for the sustainability of small holdings because of its adaptability to topography, soil and agro-climatic condition prevailing in arid and semi-arid regions of India. Climate change has resulted in lower productivity of some high value crops like apple, forcing the growers to shift to alternative crops like pomegranate, dragon fruit, etc. for mitigating the challenges of high temperatures and water scarcity. Fascinated by its innumerable health and monetary benefits, people from not only rural areas but also employed urban youth, having uncultivated ancestral land are venturing into pomegranate cultivation to taste the benefits of the fruit of paradise. It is considered an ideal crop for doubling the farmers' income.

In order to tap the vast potential of quality pomegranate production in the country, both for domestic and export market and to cater the needs of the pomegranate growers facing challenging biotic problems, the Indian Council of Agricultural Research, New Delhi established ICAR-National Research Centre on Pomegranate (ICAR-NRCP) at Kegaon, Solapur (Maharashtra) during the Tenth Five Year Plan.

The Centre since its inception in 2005 is working with the objective to develop technologies for pomegranate production and processing through genetic improvement, plant protection, resource management and biotechnological tools, ensuring food and environmental safety as well as economic development. The major achievements made by the ICAR-NRCP during the decade include, successfully managing the bacterial blight disease of pomegranate through research and widespread demonstrations, collection of 375 germplasm lines from indigenous and exotic sources; development of protocols for production of tissue culture plantlets and hardwood cuttings, and their bio hardening as well as commercialization; release of two promising varieties of pomegranate viz. 'Solapur Lal' and 'Solapur Anardana'; development of integrated disease and insect-pest management (IDIPM) schedule (with constant modifications depending on promising research results); developing nutrient norms and biofertilizer for pomegranate, mapping of pomegranate growing areas in the country; development of novel value-added products with the concept of total utilization; transfer of technology through demonstrations, trainings and supply of extension material throughout India. Further, ICAR-NRCP has developed

infrastructure and farm facilities with state-of-the-art facilities for conducting research, extension and administration. ICAR-NRCP is a proud recipient of ISO 9001:2008 Certification in 2014 and ISO 9001:2015 in 2018.

The pomegranate cultivation in India has steadily picked up during the last decade. The impact of research in handling major issues in pomegranate cultivation and popularity of this crop can be witnessed through tremendous increase in pomegranate area, production, productivity and export since 2005 when the centre was established.



Increase in pomegranate area, production, productivity and export from 2005-06 to 2016-17 in India (Source: *http://nhb.gov.in*)

The Centre is moving forward confidently to fulfill its mandate, mission and vision.

Mandate

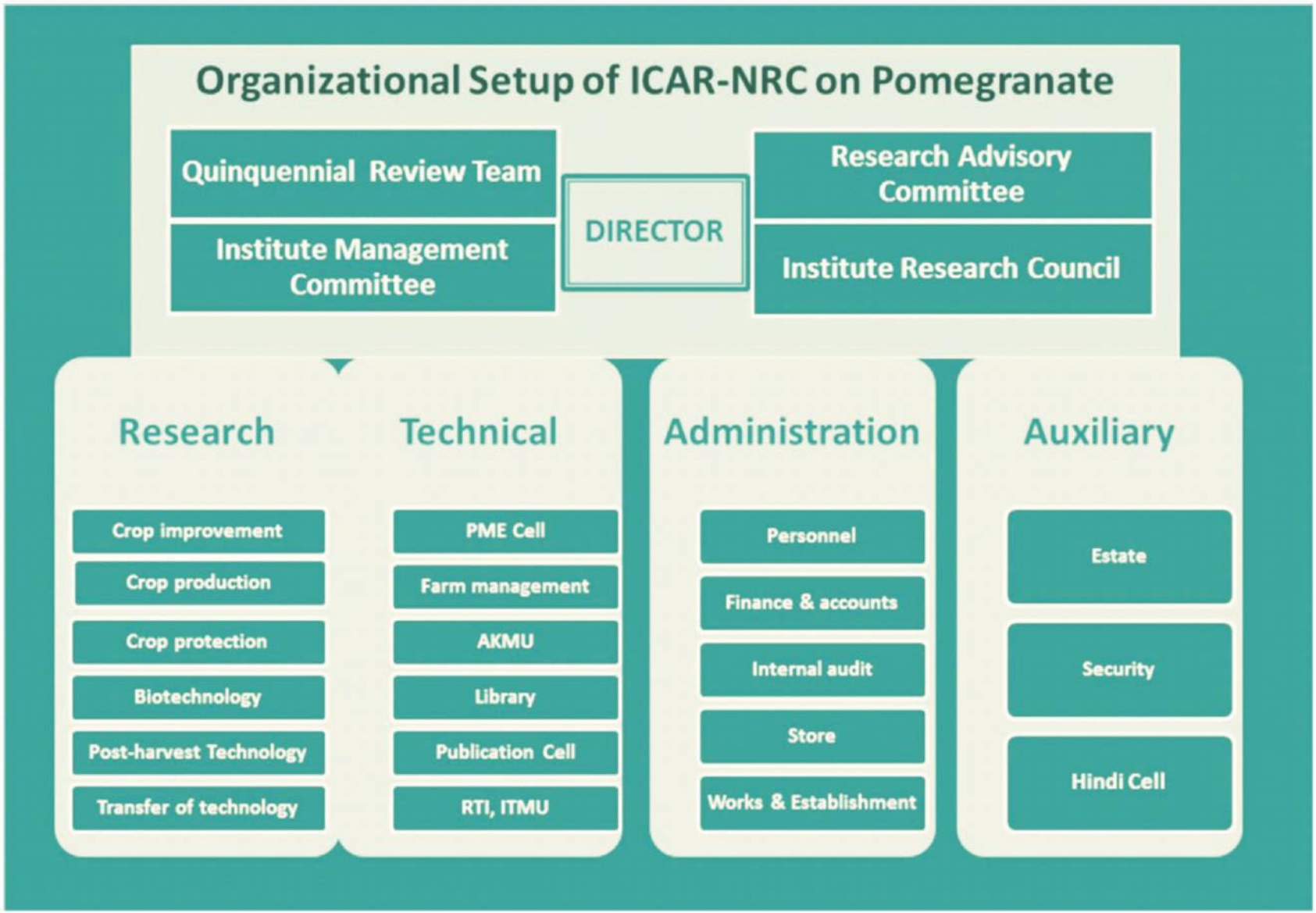
- Basic, strategic and applied research on genetic resource management, crop improvement, production and protection technology for enhanced and sustained productivity of pomegranate
- Transfer of technology and capacity building of stakeholders for enhancing and sustaining productivity of pomegranate

Mission

- To establish an international repository of genetic resources, develop suitable technologies for pomegranate production and to improve economic status of farmers in different regions

Vision

- To transform the ICAR-National Research Centre on Pomegranate to an International Centre for Pomegranate Research


Organizational Setup of ICAR-NRC on Pomegranate
Quinquennial Review Team
Institute Management Committee
DIRECTOR
Research Advisory Committee
Institute Research Council
Research
Crop improvement
Crop production
Crop protection
Biotechnology
Post-harvest Technology
Transfer of technology
Technical
PME Cell
Farm management
AKMU
Library
Publication Cell
RTI, ITMU
Administration
Personnel
Finance & accounts
Internal audit
Store
Works & Establishment
Auxiliary
Estate
Security
Hindi Cell

कार्यकारी सारांश

भारत में अनार (पुनिका ग्रेनेटम) की खेती पिछले दशक के दौरान लगातार बढ़ी है, जिस मेंअनार क्षेत्र (93.55%), उत्पादन (222.9 1%), उत्पादकता (66.9%) और निर्यात (49.65%) में भारी वृद्धि हुई है। अनार की फसल किसानों की आय को दोगुना करने और किसानों की आर्थिक स्थिति में सुधार के लिए लोकप्रियता प्राप्त कर रही है। केंद्र इस लोकप्रिय फसल की चुनौतियों का सामना करने के लिए विभिन्न पहलुओं पर शोध लेने में महत्वपूर्ण भूमिका निभाता है। रिपोर्ट के तहत वर्ष के दौरान भा. कृ. अनु. प.- राष्ट्रीय अनार अनुसंधान केन्द्र ने 10 संस्थान परियोजनाओं, 15 बाहरी रूप से वित्त पोषित परियोजनाओं, 2 सहयोगी परियोजनाओं और आदिवासी उप-योजना के तहत 2 परियोजनाओं पर काम किया। इन में से 3 संस्थान परियोजनाओं और 4 बाहरी रूप से वित्त पोषित परियोजनाओं को सफलतापूर्वक पूरा कर लिया गया है। प्रमुख उपलब्धियों का सारांश यहां दिया गया है।

जर्मप्लाज्म संसाधन

अनार के जर्मप्लाज्म संसाधनों का संरक्षण केंद्र की प्रमुख गतिविधियों में से एक है। एक अच्छी तरह से स्थापित 'फील्ड जीन बैंक' में स्वदेशी और विदेशी 375 जर्मप्लाज्म लाईन शामिल हैं। जनवरी 2018 में भा.कृ.अनु.प.- एन.बी.पी.जी.आर., नई दिल्ली के माध्यम से फ्रांस से नई जर्मप्लाज्म (45 जीनोटाइप) लाइनें शामिल की गई हैं।

अनार का बीस जर्मप्लाज्म 34 DUS लक्षणों के लिए चित्रित किया गया। अनुक्रमण जीनोटाइपिंग तकनीक के माध्यम से कुल 106 SNP मार्कर बैक्टीरियल ब्लाइट (बी.बी) संक्रमण और 971 मार्कर बी. बी. गंभीरता के लिए विशिष्ट पाये गए।

कुल 45 जंगली और कृषिकरण अनार जीनोटाइप (क़िस्म) का उपयोग करके 35 SSR मार्करों का स्क्रीनिंग किया गया, 20 SSR मार्कर पॉलीमोर्फिक पाए गए और PGKVR 08 तथा PgSSR 70 अत्यधिक जानकारीपूर्ण पाए गए। दूसरे अध्ययन में PgSSR 25, PgSSR 44, PgSSR 55, PGKVR 129 और PgSSR 56 अत्यधिक पॉलिमॉर्फिक पाए गए तथा जीनोटाइप को तीन क्लस्टर में समूहीकृत किया गया। एक अलग अध्ययन में, 280 SSR प्राइमरों का चयन कर, मैपिंग कार्य के लिए NRCP श्रृंखला SSR प्राइमर्स के रूप में संश्लेषित और नामित किया गया। NRCP श्रृंखला SSR प्राइमरों के नए सेट को प्रमाणित करने के लिए, कुल 120 NRCP-SSR प्राइमरों को 8 अनार जीनोटाइप (वाणिज्यिक किस्म) पर प्रदर्शित किया गया। इनमें से 66 प्राइमर्स वालिदैन भगवा और दारू-17 को छोड़कर, 6 अनार की किस्मों में विशेष रूप से बहुरूपी थे।

जीनोम अनुक्रमण और युग्मित अंत पुस्तकालयों की असेंबली, स्वच्छ पठन के साथ अनुक्रम संरेखण, और भारतीय अनार के जीनोम के पुणिका ग्रेनाटम 30 के उपलब्ध संदर्भ जीनोम के साथ जीनोम अनुक्रम का संरेखण 80% चीनी संदर्भ अनुक्रम (Dabenzi GCA_002201585.1ASM220158 v1genomic.fna) के समान पाया गया, जहां 96% पठन मैप किए गए। कुल SNV/InDels 559045 थे, जिनमें से 491094 SNVs और 67951 InDels हैं। Illumi पर, 10 X, PacBio और फिर ऑप्टिकल मैप्स का व्यापक रूप से उपयोग एवं विलय करहाइब्रिड असेंबली बनाई गई। इसके अलावा, बेंचमार्किंग यूनिवर्सल सिंगल कॉपी ऑर्थोलोग्स (BUSCO) का उपयोग करके पठन की विशिष्टता के लिए मचानों (scaffolds) का मूल्यांकन किया गया है, 1257 मचान पूर्ण और एकांगीपठन हैं जो नवीन हैं।

बैक्टीरियल ब्लाइट प्रतिरोध की जेनेटिक मैपिंग पर काम शुरू किया गया है। भगवा (S) x दारू-17 (R) क्रॉस के F1मैपिंग आबादी (83 पौधों) का प्रयोग दारू-17 में जीवाणुरोधी प्रतिरोध को नियंत्रित करने वाले जीन/QTL मैप किया जा रहा है। मैपिंग वालिदैन भगवा x दारू-17 के बीच वालिदैनके बहुरूपता का सर्वेक्षण 108 नए डिजाइन किए गए हाइपर-वेरिएबल SSR प्राइमरों का उपयोग करके किया गया। इनमें से 75 पॉलिमॉर्फिक थे और 33 वालिदैन के बीच मोनोमोर्फिक थे।

फसल सुधार

अनार की दो किस्में 'सोलापुर लाल' और 'सोलापुर अनारदाना' को अप्रैल 2017 में जारी करा गया। 'भगवा' की तुलना में 'सोलापुर लाल' गहरा लाल है, इसकी परिपक्वता 15 दिन जल्दी है, उच्च टी.एस.एस (17.6 AmoB), मोटे दानों के साथ फल उपज, लौह, जिंक, एंथोसाइनिन और विटामिन-सी तत्वभी अधिक हैं, और इसलिए प्रसंस्करण और खाने, दोनों के लिए उपयुक्त है। 'अम्लिदाना' की तुलना में अनार की किस्म'सोलापुर अनारदाना' में उच्च अम्लता (4.8%), टी.एस.एस., एंथोसाइनिन, विटामिन-सी और अधिक उपज के साथ लाल वर्ण है, जो अनारदाना उद्देश्य के लिए उपयुक्त है।

अनार प्रवर्धन

पॉलीहाउस परीक्षणों अर्बस्क्यूलर मायकोर्ज़िज़ल कवक के उपयोग से अनार के पौधों ने बेहतर ऊंचाई और कुल फेनोलिक सामग्री का प्रदर्शन किया। सभी जैव-कठोर पौधों के सापेक्षिक पत्ते का पानी और क्लोरोफिल '-' काफी बेहतर पाए गए। एक फील्ड

ट्रायल में, विभिन्न प्रवर्धन तरीकों के माध्यम से प्रचारित पौधों, के फल के छिलके की मोटाई, टी.एस.एस, अम्लता और औसत फल वजन सांख्यिकीय रूप से एक समान पाए गए। सार्वजनिक रूप से उपलब्ध 90 SSR, 26 RAPD और 38 ISSR मार्करों में से, हमने पाया कि 28 SSR और 12 RAPD अत्यधिक पॉलिमॉर्फिक थे और इन्हें 'भगवा' क्लोन के इन विट्रो पौधों में निष्ठा (fidelity) परीक्षण में उपयोग किया जा सकता है।

फसल उत्पादन

अनार में पोषक सामग्री की मौसमी गतिशीलता एक अविरोधी पैटर्न साझा करते हैं: मौसम की शुरुआत में वुडी ऊतकों से पोषक तत्वों का स्थानांतरण सक्रिय रूप से बढ़ते अंगों में दर्ज किया गया था और बाद में पोषक तत्व परिपक्वता चरण में वुडी ऊतक में पाय गए। किसी अन्य मैक्रो-तत्वों की तुलना में अधिकतम अपतटीय (uptake)उरका था। प्रमुख और मामूली सूक्ष्म पोषक तत्व अपतटीय पैटर्न क्रमश: Ca>N>K>Mg>S>P और Fe>Cu>B>Mn>Zn था। फ़ास्फ़रोस (P) को छोड़कर, मैक्रो-तत्वों का बहुमत अपतटीय विश्रान्ति अवधि सेपुष्पण के दौरान हुआ था। इसके अलावा, पूर्ण खिलने के 0-60 दिन बाद और पूर्ण खिलने के 121-180 दिन बाद पोषक तत्वों की महत्वपूर्ण बढ़ोतरी हुई।

सब सरफेसड्रिप सिंचाई (SDI) प्रणाली 30 सेमी गहराई और 30 सेंटीमीटर पृथकपर डबल इनलाइन लेटरल के साथ पौधे के अनुकूलतम विकास के लिए सबसे अच्छी पाई गई। ड्रिप सिंचाई प्रणाली में दो लेटरल के साथ चार ड्रिप्पर,पौधों के विकास के लिए सबसे अच्छा पाया गया। विभिन्न आर्गेनिक और अकार्बनिक मल्च में, गन्ना बगास (कार्बनिक मल्च) और व्यापक मल्च (अकार्बनिक) ने फूल और फल उपज के लिए सर्वोत्तम परिणाम दर्ज किए। चार स्टेम ट्रेनिंग प्रणाली (फल उपज 18.1 किग्रा/पौध) तथा तीन स्टेम ट्रेनिंग प्रणाली (फल उपज १७.७ किग्रा/पौध) उच्चतम ट्रेनिंग प्रणाली पाए गये, इसलिए अनार में सर्वोत्तम उपज के लिए 3-4 स्टेम ट्रेनिंग प्रणाली की सिफारिश की जा सकती है।

फसल संरक्षण

फल बोरर आबादी ने तापमान, वर्षा (0.82) के साथ सकारात्मक सहसंबंध (0.82), और RH (-0.61) के साथ नकारात्मक सहसंबंध दिखाया। थ्रिप्स ने सभी मौसम मानकों के साथ नकारात्मक सहसंबंध दिखाया। नौफेरोमोन यौगिकों ने आकर्षण के स्रोत की ओर फल चूसनेवाले नरपतंगों की अच्छी प्रतिक्रिया और दोहराव वाले व्यवहारिक अभिविन्यास को दिखाया और आगे मूल्यांकन किया जा रहा है। स्पिनेटोरम 12% SCw/v 2 मिलीलीटर / लीटर ने थ्रिप्स का सर्वोत्तम नियंत्रण (90.32%) दिया।

ICAR-CIPHET, लुधियाना में तैयार सरसों पर आधारित फॉर्मूलेशन प्रयोगशाला परीक्षण में जैंथोमोनास अक्सोनोपोडिस पीवी. पुनिकै को अवरुद्ध करने में प्रभावी पाया गयातथा पॉलीहाउस और फील्ड परीक्षणों में रस चूसने और बोरर कीटों के खिलाफ प्रभावी रहा।

रहिजोक्टोनिआ स्पीशीज के कारण अनार के फल पर एक नया फंगल स्पॉट की पहचान की गई है। हेक्साकोनाज़ोल और डिफ़ेन्कोनाज़ोल फल स्कैब को पूरी तरह से रोकने में सबसे प्रभावी थे।

सेराटोसिस्टिस फिम्ब्राइटा के कारण कवक मुर्झान को बायोफॉर्म्यूलेशन (एस्पर्जिलस नाइजर ए.एन. 27 और वी.ए.एम कवक) के निवारक उपयोग के साथ रोका जा सकता है। रासायनिक में प्रोपेनिकोनोजोल के साथ, फोसिटाइल AI+ टेबुकोनाज़ोल चिकित्सकीय उपचार में प्रभावी थे। नेमाटोड उपद्रव के लिए, कार्बोलिक एसिड फॉर्मूलेशन सुज़ान सबसे अधिक आशाजनक था। बेयर का एलीएट और प्रोफाइलर प्रोटोकॉल 100% नियंत्रण के साथ सेराटोसिस्टिस मुर्झान की रोकमें प्रभावी था।

स्वस्थ और बैक्टीरियल ब्लाइट प्रभावित ऊतकों से ट्रांसक्रिप्टोम अध्ययनों के लिए अच्छी गुणवत्ता वाले आर.एन.ए. के पृथक्करण के लिए सात प्रोटोकॉल का मूल्यांकन किया गया। फिनॉल क्लोरोफॉर्म विधि सभी सात प्रकार के ऊतकों से अच्छी गुणवत्ता वाले कुल आर. एन.ए. के पृथक्करण के लिए अन्य तरीकों से बेहतर पाया गया तथा सबसे कम अवधि के साथ सबसे सस्ता था। अतिसंवेदनशील और मामूली प्रतिरोधी अनार जीनोटाइप के ट्रांसक्रिप्टोमिक डेटा से R जीन की अलग-अलग संख्या का पता चला। इन सिलिको (in silico) विश्लेषण और जैंनथोमोनस के पूरे जीनोम में सरल अनुक्रम दोहराने (SSR) प्रारूपों के खनन में 419 SSR प्राइमरों की पहचान और डिजाइनिंग कीगई।

कॉपर नैनो कण (CuNP) ने 56.21% कम बैक्टीरियल ब्लाइट (बी.बी) दर्ज किया जब कि स्ट्रेप्टोसाइटलाइन ने इलाज न किए गए चेक की तुलना में 89.73% कम बी.बी. दर्ज करा। औषधीय पौधों से तीस एंडोफाईट अलग किए गए और बी.बी. रोगजनक के खिलाफ मूल्यांकन किया गया। एक पॉलीहाउस परीक्षण में 2 बैक्टीरियल एंडोफाईट्स BE-2 और BE-4 (बैसिलस सबलिटिस) और १ एक्टिनोबैक्टरीआ-AE-5 और 1 कवक एन्डोफाइट FE-8 (ट्रायकोडर्मा एस्पेरेलम) बैक्टीरियल ब्लाइट को 30 दिनों तक 40-68% तक कम कर देता है और Xap स्प्रे के 40 दिनों तक 32-51% तक बी. बी. कम कर देता है। इन एंडोफाईट्स का उपयोग फील्ड मूल्यांकन के लिए किया जाएगा।

अनार के फाइलोस्फीयर पर Xap विरोधी बैक्टीरिया पाएगए, जिन मे वाष्पशील यौगिकों की योगिता है, जिनकी पहचान की जा रही है। फिनाइल प्रोपेनोइड पाथवे रोग-प्रतिरोधक

प्रेरक,जैसे् बीटा अमीनो ब्यूटिरिक एसिड (BABA) और गॅमा अमीनो ब्यूटिरिक एसिड (GABA) बैक्टीरियल ब्लाइट के प्रबंधन के लिए प्रभावशाली पाये गये। फलों के रूपात्मक, जैव-रासायनिक और पोषण संबंधी पैरामीटर के साथ बी.बी. रोग की संवेदनशीलता का सहसंबंध देखा गया। फल आकार, एंटी ऑक्सिडेंट्स, pH, N, P तथा K की मात्रा का बी.बी. संवेदनशीलता केसाथ सकारात्मक सहसंबंध मिला;जब कि TSS, अम्लता, कुल फिनोल, बीज की मुलायमता तथा रेडुसिंग शुगर के साथ महत्वपूर्ण नकारात्मक सहसंबंध पाया गया।

संशोधित एकीकृत रोग प्रबंधन (IDM) शेड्यूल (बायोफॉर्म्यूलेशन, SAR एजेंटों और आवश्यकता अनुसार कीटनाश कों का छिड़कव-बिनाजीवाणुनाशक के) का उपयोग दूसरे वर्ष मेंकेंद्र पर किया गया। इस शेड्यूलने 11.45 किग्रा/पौधा (8.47 टन/हेक्टेयर) की उपज दी जो 100% ब्लाइट फ्री थी। और फंगल स्पॉट/रोट्स से नुकसान 2% से नीचे था।

कटाई उपरांत प्रबंधन और मूल्यवर्धन: केंद्र अनार उत्पादन के पूर्ण उपयोग की अवधारणा को कार्यान्वित कर रहा है; इसलिए अनार के बीज (रस निष्कर्षण के बाद) का उपयोगकर उच्च मूल्य वाले उत्पादन तैयार किये गए हैं। 1.5% पेक्टिनेज + 1.5% सेलूलोज़ के साथ अनार के बीज का पूर्व उपचारकर२ घंटे की सबसे कम अवधि में 29% की उच्चतम तेल वसूली प्राप्त की गई। मध्यम कैप्सूलीकरण दक्षता वाले बबूल गोंद का उपयोग कर स्प्रे शुष्क तकनीक द्वारा अनारके बीज कातेल का कैप्सूलीकरण किया गया। अग्रगामी अनुसंधान प्रगति पर है। कम तापमान और एम्बरवर्ण की बोतलों में भंडारण से उच्च लिनोलेनिक एसिड सामग्री और निम्न पेरोक्साइड बना रहता है। अनार के व्यर्थ बीज केक से उच्च फाइबर कुकीज़ बनाने के लिए इष्टतम स्थितियों का मानकीकरण कर कूकीज तैयार करी गईं।

जनजातीय उप-योजना

केंद्र ने गडचिरोली जिले के सिरोनचा तालुक, पश्चिम बंगाल के बांकुरा और पुरुलिया जिले, मध्य प्रदेश के अनुपपुर और छत्तीसगढ़ के कोरिया, जिले के जनजातीय किसानों को अपनाया है और 4 प्रशिक्षण भी प्रदान किए हैं।

अन्य गतिविधियां

केंद्र के कर्मचारियों ने स्वच्छता अभियान, मेरा गांव मेरा गौरव, सतर्कता (विजिलेंस) सप्ताह आदि के तहत सक्रिय रूप से भाग लिया। 1 राष्ट्रीय कार्यशाला और किसान मेले, 3 कार्यशालाओं/फील्ड दिवस, किसानों के लिए 5 प्रशिक्षण और कॉलेज के छात्रों के लिए 2 प्रशिक्षण आयोजित किये। साथ ही साथ अलग-अलग हितधारकों को विकसित प्रौद्योगिकियों का प्रसार करने के लिएकेंद्र के सहयोग से विभिन्न संगठनों द्वारा आयोजित 11 प्रदर्शनियों, 14 प्रशिक्षण, कार्यशालाओं और संवादात्मक/इंटरैक्टिव मीटिंग में भी भाग लिया। केंद्र की प्रौद्योगिकियों को 2 उद्यमियों को हस्तांतरण करा गया। किसानों और अन्य हितधारकों समेत 1500 से अधिक आगंतुकों ने सूचना के लिए केंद्र का दौरा किया। कुल 24 कर्मचारियों में से 38% ने मानव संसाधन विकास के तहत प्रशिक्षण लिया और क्षमता निर्माण गतिविधियों के तहत ११ कार्यशालाओं में भाग लिया।

केंद्र के वैज्ञानिकों ने सहकर्मी समीक्षा पत्रिकाओं में 16 शोध पत्र प्रकाशित किए, जिनमें से 10 NAAS रेटिंग 6 से ऊपर वाले जर्नल में प्रकाशित हुए। इसके अलावा 1 पुस्तक, 17 पुस्तक अध्याय, 14 लोकप्रिय लेख और 7 विस्तार बुलेटिन/फ़ोल्डर्स भी प्रकाशित किए गए। वैज्ञानिकों को व्यवसायी सोसाइटी पुरस्कारों के साथ-साथ मौखिक व्याख्यान और सर्वोत्तम पोस्टर अवार्ड से भी पुरस्कृत किया गया।

भा.कृ.अनु.प.- रा.अ.अनु.के. की नई पहल में मोबाइल ऐप के नए संस्करण 'सोलापुर अनार' का लॉन्च शामिल है,जो छह भाषाओं (अंग्रेजी, हिंदी, मराठी, कन्नड़, गुजराती और तेलुगू) में लॉन्च किया गया और जिसके साल भर में 5000 डाउनलोड हैं; इस के अतिरिक्त 43 बिस्तर प्रशिक्षु छात्रावास का उद्घाटन, दो वीडियो फिल्म (अंग्रेजी और हिंदी भाषाओं में)'अनार कुलीन रोपण सामग्री' और 'उद्यमिता विकास के लिए अनार का प्रसंस्करण'शामिल है।

भा.कृ.अनु.प.-राष्ट्रीय अनार अनुसंधान केन्द्र के उल्लेखनीय योगदान में बॉयोफोर्टिफाइड किस्म'सोलापुर लाल' और प्रोसेसिंग के लिए किस्म'सोलापुर अनारदाना' जारी करना, पोटेशियम उर्वरक पूरक के लिए एक नवीन जैव-निर्माण का अस्थायी पेटेंट दाखिल करना,बेहतर फल आकार और अनार की गुणवत्ता के लिए एमिनो एसिड आधारित सूक्ष्म पोषक तत्व फार्मूलेशन, मूल्यवर्धित उत्पादों के अलावा वर्जिन बीज का तेल तथा बीज केक से हाय-फाइबर कुकीज़ बनाना शामिल हैं।

EXECUTIVE SUMMARY

Pomegranate (*Punica granatum*) cultivation in India has steadily picked up during the last decade, with tremendous increase in pomegranate area (93.55%), production (222.91%), productivity (66.9%) and export (49.65%). Pomegranate crop is gaining popularity as a crop for doubling farmers' income and improving economic status of the farmers. The Centre is instrumental in taking research on various aspects to meet the challenges of this popular crop. During the year under report ICAR-NRCP handled 10 institute projects, 15 externally funded projects, 2 collaborative projects and 2 projects under tribal sub-plan. Out of these 3 institute projects and 4 externally funded projects have been successfully completed. The major achievements are summarized here.

Germplasm Resources

Conservation of pomegranate germplasm resources is one of the major activities of the Centre. A well established 'Field Gene Bank' has 375 germplasm lines including indigenous and exotic lines. New germplasm (45 genotype) lines have been introduced from France through NBPGR, New Delhi in Jan, 2018.

Twenty pomegranate germplasm were characterized for 34 DUS traits. In all 106 SNP markers were found specific to bacterial blight (BB) incidence and 971 markers specific to BB severity through Genotyping-by-sequencing technique.

Out of 35 SSR markers screened using 45 wild and cultivated pomegranate genotypes, 20 SSRs were found polymorphic and PGKVR 08 and PgSSR70 were found highly informative. In the second study, PgSSR25, PgSSR44, PgSSR55, PGKVR129 and PgSSR56 were found highly polymorphic and genotypes were grouped into three clusters. In a separate study, 280 SSR primers were selected, got synthesized and named as NRCP series SSR primers for mapping work. In order to validate the new set of NRCP SSR primers, Total 120 NRCP SSR primers were screened on 8 pomegranate genotypes (commercial cultivars). Out of these, 66 primers were exclusively polymorphic among 6 pomegranate cultivars excluding mapping parents Bhagwa and Daru 17.

Genome sequencing and assembly of the paired end libraries, sequence alignment with clean reads and alignment of genome sequence with available reference genome of *Punica granatum* 30x of the Indian pomegranate genome was found to be 80% similar to the Chinese reference sequence(Dabenzi GCA_002201585.1_ASM220158v1_genomic.fna) where 96% reads mapped. SNV/InDels were 559045, of which 491094 are SNVs and 67951 are InDels. The Hybrid assembly was created by merging the Illumina, 10X, PacBio and then using Optical Maps comprehensively.

Further, scaffolds have been evaluated for uniqueness of reads by using Bench marking Universal Single Copy Orthologs (BUSCO), 1257 scaffolds were found complete and single reads which are novel.

Work on genetic mapping of bacterial blight resistance has been initiated. The F1 mapping populations (83 individuals) of cross Bhagwa (S) x Daru 17(R) was used to map genes/QTLs governing resistance to bacterial blight in Daru 17. Parental polymorphism between mapping parents Bhagwa x Daru17 were surveyed, using 108 newly designed hyper-variable SSR primers. Out of this, 75 were polymorphic and 33 were monomorphic between the parents.

Crop Improvement

Two pomegranate varieties 'Solapur Lal' and 'Solapur Anardana' were released in April 2017. 'Solapur Lal' in comparison to commercial cultivar 'Bhagwa' is darker red, has15 days early maturity, has high TSS (17.6°B), fruit yield, iron, zinc, anthocyanin and Vitamin C content with bold arils and hence suitable for both processing and table purpose. The pomegranate variety 'Solapur Anardana' in comparison to 'Amlidana' has red arils with higher acidity (4.8%), TSS, anthocyanins, Vitamin C and more yield, making it suitable for anardana purpose.

Plant Propagation

Arbuscular Mycorrhizal Fungi inoculated plants exhibited significantly better height and total phenolic content in comparison to non-inoculated control in polyhouse trials. Relative leaf water content and chlorophyll 'a' of all the bio-hardened plants were found significantly better than control. In a field trial, plants propagated through different propagation methods exhibited at par fruit features for rind thickness, TSS, acidity and average fruit weight. Among 90 publicly available SSRs, 26 RAPDs and 38 ISSR markers, we found 28 SSRs and 12 RAPDs were highly polymorphic and can be utilized in fidelity testing of *in vitro* raised 'Bhagwa' clones.

Crop Production

Seasonal dynamic of nutrient content in pomegranate share a consistent pattern: translocation of nutrients from woody tissues to actively growing organs was recorded at the beginning of the season and nutrients moved to woody tissue at the maturity stage. Maximum uptake was of Ca than any other macro-elements. The major and minor micronutrient uptake pattern followed the order of Ca>N>K>Mg>S>P and Fe>Cu>B>Mn>Zn respectively. Except P, majority uptake of macro-elements took place during rest period to flowering. Besides this, other two windows i.e. 0-60 DAFB and 121-180 DAFB have been identified where considerable uptake of nutrients took place.

Subsurface drip irrigation (SDI) system with double inline lateral at 30cm depth and 30 cm apart was found to be best for optimum growth of plant. In drip irrigation

system two laterals with four drippers was found best for plant growth and development. Among various organic and inorganic mulches, sugarcane baghas (organic mulch) and pervious mulch (inorganic) recorded best results for flowering and fruit yield. Training system with four stem recorded highest fruit yield (18.1 kg/plant) followed closely by three stem training system (17.7 kg/plant), hence 3-4 stem training system can be recommended for best yields in pomegranate.

Crop Protection

Fruit borer population, showed positive correlation with temperature, rainfall (0.82) and negative correlation with RH(-0.61). Thrips showed the negative correlation with all-weather parameters. Nine pheromone compounds showed good response and repetitive behavioral orientation of the male fruit sucking moths towards the source of attraction and are being evaluated further. Mustard based formulation formulated at CIPHET, Ludhiana was found effective in inhibiting *X. axonopodis* pv. *punicae* in dual culture tests and against sap sucking and borer pests in polyhouse and field trials.

A new fungal spot on pomegranate fruits caused by *Rhizoctonia sp.* has been identified. Hexconazole and Difenconazole were most effective in completely checking fruit scab incidence.

Fungal wilt due to *Ceratocystis fimbriata* could be checked with preventive use of bioformulations *Aspergillus niger* AN27 and VAM fungi, whereas chemical treatments with propiconazole, Fosetyl-Al + Tebuconazole were effective therapeutic treatments. For nematode infestation, carbolic acid formulation, Suzaan® was most promising with 11.11 knots/g root in comparison to control with average 59.23knots/g root. Bayer's Aliette and profiler protocol was effective in checking *Ceratocystis* wilt with 100% control.

Seven protocols were evaluated for isolation of good quality RNA for transcriptome studies from healthy and blight affected tissues. Phenol Chloroform method was found to be superior over other methods for isolation of good quality total RNA from all the seven types of tissues and was cheapest with shortest duration. Prediction of R genes among blight susceptible and moderately resistant pomegranate genotypes revealed varying number of R genes from the transcriptomic data. *In silico* analysis and mining of simple sequence repeat (SSR) motifs in the whole genome of *Xanthomonas* resulted in identification and designing of 419 SSR primers.

Copper nano particles (CuNP) recorded 56.21% less bacterial blight (BB) whereas streptocycline recorded 89.73% less BB than untreated check. Thirty endophytes were isolated from medicinal plants and evaluated against BB pathogen. In a polyhouse trial 2 bacterial endophytes BE2 (*Bacillus subtilis*) and BE-4 (*Bacillus subtilis*) and 1 actinomycete isolate AE-5 and 1 fungal

endophyte FE-8 (*Trichoderma asperellum*) reduced BB by 40-68% up to 30 days and 32-51% upto 40 days after *Xap* sprays. These endophytes will be used for field evaluation.

Pomegranate phyllosphere bacteria, highly antagonistic to *Xap* have been found to produce promising volatile compounds which are being identified. Phenyl propanoid pathway defence inducers namely, β-amino butyric acid (BABA) and γ-amino butyric acid (GABA) were found promising agents for management of bacterial blight. Correlation of BB susceptibility with morphological, biochemical and nutritional fruit parameters revealed positive correlation of BB susceptibility to fruit size, antioxidants, pH, N, P and K content while a significant negative correlation was found with TSS, acidity, total phenol, seed texture and reducing sugar.

The modified integrated disease management (IDM) schedule (using bioformulation, SAR agents and need based pesticides without bactericides) at NRCP was tested in second year. The schedule gave 100% blight free yield of 11.45kg/plant (8.47t/ha). The incidence of fungal spots/ rots was below 2%.

Post-harvest management and value addition

The Centre is implementing the concept of total utilization of the produce; hence use of pomegranate seed, a byproduct after juice extraction, has resulted in high value products. Pretreatment of pomegranate seeds with 1.5 % pectinase+1.5% cellulose gave highest oil recovery of 29% in shortest duration of 2 hrs. Pomegranate seed oil was encapsulated by spray drying technique using gum acacia with moderate encapsulation efficiency. Further studies are in progress. Amber coloured bottles stored in low temperature, maintain higher linolenic acid content and lower peroxide. Optimum conditions were standardized for preparation of high fibre cookies from deoiled seed cake of pomegranate.

Tribal Sub-Plan

The Centre has adopted tribal farmers in Sironcha Taluk of Gadchiroli District, Bankura and Purulia district of West Bengal, Anuppur, Madya Pradesh and Koriya, Chhattisgarh and also imparted 4 trainings.

Other Activities

The staff actively participated in ativites under Swachh Bharat Abhiyan, Mera Gaon Mera Gaurav, Vigilance Awareness Week etc. The Centre organized one National Workshop cum Farmer's Fair, three workshops/field day, five trainings for farmers, two for college students as well as participated in 11 exhibitions, 14 trainings, workshops and interactive meets organized by different organizations in collaboration with ICAR-NRCP to disseminate the technologies developed to different stake holders. ICAR-NRCP technologies were transferred to 2 entrepreneurs. More than 1500 visitors including farmers and other stakeholders

visited the Centre for information. In addition out of total 24 staff, 38% underwent trainings under HRD and attended 11 workshops under capacity building activities.

The Centre published 17 research papers in peer reviewed Journals, out of which 10 were in Journals with NAAS rating ≥ 6.0. In addition 1 book, 17 book chapters, 14 popular articles and 6 extension bulletins/ folders were also published. The scientists also got recognitions from professional Societies as well as oral presentation and best poster awards.

The new initiatives of ICAR-NRCP include New version of mobile-app: 'Solapur Anar' launched in six languages (English, Hindi, Marathi, Kannada, Gujarati and Telugu) with >5000 downloads within a year; inauguration of 43 bed trainees hostel with furnishing, production of two video films *viz*., Pomegranate elite planting material and Pomegranate processing for entrepreneurship development, in English and Hindi languages.

The noteworthy contributions of ICAR-NRCP include, release of promising varieties 'Solapur Lal' for table purpose and 'Solapur Anardana' for processing (Anardana) purpose, filing of provisional patent for a novel bio-formulation for potassium fertilizer supplement, amino acid based micronutrient formulation for better fruit size and quality of pomegranate besides value added products including Virgin Seed oil, Hi-fibre cookies from de-oiled seed cake.

RESEARCH PROGRAMMES AND PROJECTS

Institute Research Projects

S. No.	Project Title	Principal Investigator	Co-PIs	Status
1	Conservation, characterization and sustainable use of diversity in pomegranate (01/04/2013 to 31/03/2018)	Dr. Shilpa Parashuram	Dr. Jyotsana Sharma, Dr. K. Dhinesh Babu, Dr. D. T. Meshram, Dr. N. V. Singh, Dr. Ashis Maity, Dr. Nilesh Gaikwad, Ms. Roopa Sowjanya P, Mr. Mallikarjun	Completed
2	Genetic improvement of pomegranate (01/04/2013 to 31/03/2018)	Dr. K. Dhinesh Babu	Dr. N. V. Singh, Dr. Jyotsana Sharma, Dr. Shilpa Parashuram, Ms. Roopa Sowjanya, P. Dr. A.Maity,Dr.N.Gaikwad	Completed
3	Development and refinement of integrated production technologies for improved productivity (01/04/2013 to 31/03/2018)	Dr. D.T. Meshram	Dr. Ashis Maity Dr. K. Dhinesh Babu	Completed
4	Propagation, bio-hardening and mass multiplication of elite planting material in pomegranate (*Punica granatum* L.) (01/10/2014 to 30/09/2019)	Dr. N.V. Singh	Dr.K. Dhinesh Babu, Dr. Jyotsana Sharma, Dr. Shilpa Parashuram, Ms. Roopa Sowjanya	Ongoing
5	Development and refinement of integrated crop protection technologies for improved productivity of pomegranate (01/04/2013 to 31/03/2020)	Mr. Mallikarjun	Dr. Jyotsana Sharma, Dr. U. R. Sangle	Ongoing
6	Post-harvest management value addition and improving knowledge of stakeholders for increasing production and marketing of pomegranate (01/07/2014 to 30/06/2019)	Dr. Nilesh N. Gaikwad	Dr. K Dhinesh Babu Dr. R K Pal	Ongoing
7	Biological control of wilt complex problem in pomegranate (01/12/2016 to 30/11/2021)	Dr. U. R. Sangle		Ongoing

8	Draft genome sequencing and *de novo* assembly of pomegranate (*Punica granatum* L.) (01/02/2017 to 30/11/2022)	Ms. Roopa Sowjanya P.	Dr. N.V. Singh, Dr. Shilpa Parashuram Dr. Prakash G Patil	Ongoing
9	Flagship project on integrated approach to eradicate bacterial blight (01/03/2013 to 31/03/2020)	Dr. Jyotsana Sharma	Dr. Ashis Maity, Dr. N. V. Singh, Dr. Shilpa Parashuram, Dr. K. Dhinesh Babu, Dr. Prakash G. Patil Dr. Aundy Kumar, Dr. K.K. Mondal, ICAR-IARI New Delhi Dr. Manjunath, Dr. R.K. Mestha UHS Bagalkot	Ongoing
10	Genetic mapping of bacterial blight and fruit quality traits in pomegranate (01/01/2018 to 31/12/2022)	Dr. Prakash G.Patil	Dr. Jyotsana Sharma Dr. Shilpa Parashuram Dr. N.V. Singh Dr. K. Dhinesh Babu	Ongoing

Externally Funded Projects

S. No.	Funding Agency	Project Title	PI/Co-PIs	Status	Amount Rs. in Lakhs
1	RKVY	Horticultural crop pest surveillance and advisory project for mango, pomegranate &banana	Dr. Jyotsana Sharma, Sh. Mallikarjun	Ongoing	10.76
2	ICAR-IPTM	Intellectual property management and transfer/commercialization of agriculture technology scheme	Director, ICAR-NRCP Dr. Nilesh Gaikwad	Ongoing	6.40
3	PPV&FRA, GoI	Establishment of DUS centre at NRC on Pomegranate	Director, ICAR-NRCP Dr. Shilpa Parashuram Ms. Roopa Sowjanya,P	Ongoing	6.0
4	Bayer Crop Science Ltd., Mumbai	Contract research project on Performance evaluation of Fosetyle –Al 80WP (Aliette) and other protection range chemicals on pomegranate health and productivity	Dr. Jyotsana Sharma, Mr. Mallikarjun	Ongoing	11.0

S. No.	Funding Agency	Project Title	PI/Co-PIs	Status	Amount Rs. in Lakhs
5	NHB, Gurugram, GoI	Mechanization in pomegranate cultivation and its demonstration	Dr. N.V. Singh	Completed	41.62
6	NHB, Gurugram, GoI	Standardization and demonstration of propagation and production technologies for protected cultivation of pomegranate (*Punica granatum* L.)	Dr. N. V. Singh Mr. Mallikarjun Dr. Nilesh N. Gaikwad Dr. D. T. Meshram	Ongoing	16.84
7	NMPB, Ministry of AYUSH, GoI	Utilization of pomegranate for development of functional medicinal ingredients	Dr. R.K.Pal Dr. Nilesh N. Gaikwad	Ongoing	41.77
8	M/s. MOSCOS Food processing Pvt. Ltd., Nashik.	Technical consultancy for establishment of minimal processing and packaging unit for pomegranates	Dr. R.K.Pal Dr. Nilesh N. Gaikwad	Ongoing	6.90
9	M/s.Sanjeevni Fertilizers and Chemicals (P) Ltd.Bhognipur, Kanpur	Implementation of total orchard management practices for pomegranate plantation	Dr. N.V. Singh Dr. Jyotsana Sharma	Completed	2.50
10	ICAR CRP on Water	Response of pomegranate to deficit irrigation and partial root zone drying	Dr. D.T. Meshram	Ongoing	56.00
11	ICAR	All India Coordinated Research Project on Arid Zone Fruits	Dr. K. Dhinesh Babu Dr. N.V. Singh Mr. Mallikarjun	Ongoing	1.50
12	ADMA India Pvt. Ltd	Evaluation of MCW-2 (2% GR) against Root Knot Nematode (*Meloidogyne incognita*) in Pomegranate	Mr. Mallikarjun Dr. Jyotsana Sharma	Ongoing	13.55
13	Dow Agro Sciences India Pvt. Ltd	Field Evaluation of the bio-efficacy of Spinetoram 12% SC against Thrips and fruit borer in pomegranate	Mr. Mallikarjun	Ongoing	10.40

S. No.	Funding Agency	Project Title	PI/Co-PIs	Status	Amount Rs. in Lakhs
14	Nagarjuna Fertilizers and Chemicals Limited	Effect of Zetol Select water soluble fertilizer grades and ProRise solutions of Nagarjuna Fertilizers and Chemicals Limited on Pomegranate yield and quality	Dr. Ashis Maity Dr. R.K. Pal Dr. Jyotsana Sharma	Ongoing	9.45
15	ICAR Network Project	Micronutrient management in horticultural crops for enhancing yield and quality.	Dr. Ashis Maity	Completed	20.76
16	ICAR-extramural project	SNP markers based mapping of bacterial blight genes in pomegranate	Dr. Shilpa Parashuram Dr. N. V. Singh Dr. B. N. S. Murthy, ICAR-IIHR	Completed	37.09

Tribal Sub-Plan

S. No.	Project Title	Principal Investigator	Status
1	Introduction of pomegranate cultivation to tribal farmers of Gadchiroli Dt., MS, Anuppur Dt., M.P. & Koriya Dt., Chhattisgarh for livelihood security of tribal population	Dr. R. K. Pal, Dr. D. T. Meshram Dr. Ashis Maity Dr. N.V. Singh	Ongoing

Inter-institute Collaborative Projects

S. No.	Project Title	Collaborative Institutes	PI / Co-PI	Status
1	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
2	Development of a smart sprayer for young pomegranate orchard	ICAR-CIAE, Bhopal	Dr. Nilesh N. Gaikwad ICAR-NRCP (Co-PI)	Ongoing
3	Development and evaluation of eco-friendly mustard based antimicrobial formulation using other botanicals for control of bacterial blight problem and insect pests of pomegranate	ICAR-CIPHET, Ludhiana	Dr. Jyotsana Sharma, Mr. Mallikarjun Dr. K. Dhinesh Babu	Ongoing

RESEARCH ACHIEVEMENTS

1. GENETIC RESOURCES

Project: Conservation, characterization and sustainable use of diversity in pomegranate

In addition to 375 indigenous and exotic germplasm lines in the Field Gene Bank of the centre, hardwood cuttings of 45 new genotypes of pomegranate were introduced from France through NBPGR, New Delhi during January, 2018. It is under quarantine check for survivability and presence of quarantined insect pests and diseases.

1.2. Germplasm characterization

1.2.1 Assessment of genetic diversity in pomegranate germplasm for various horticultural traits

Forty pomegranate germplasm were evaluated for 32 morphological and physico-chemical traits during *mrig bahar,* 2017-18. Highly significant differences were observed for all the traits except for petiole length (mm), petiole width (mm), petal length (mm) and rind thickness (mm). The study indicated the presence of adequate variability among the genotypes for the significant characters.

Genetic variation for various horticultural traits among 40 pomegranate germplasm

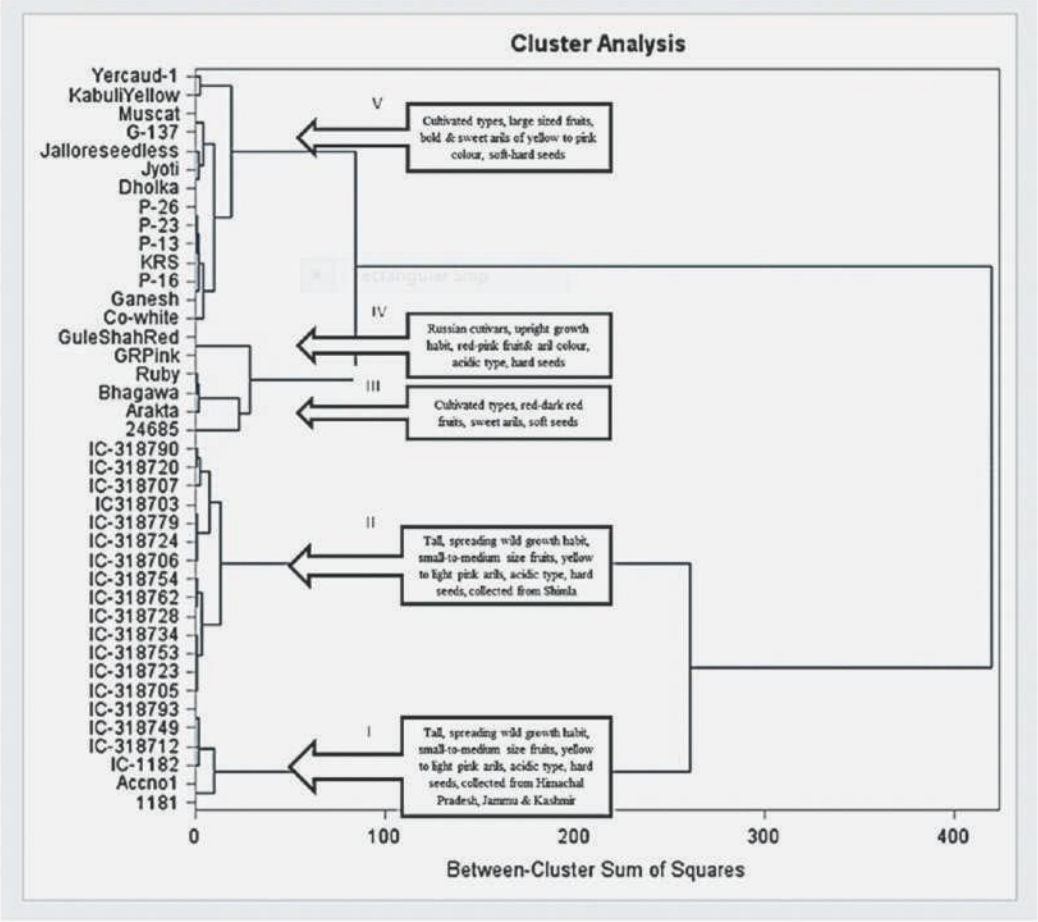
Traits	Mean	Min	Max	CV%	LSD	Traits	Mean	Min	Max	CV%	LSD
Tree height (m)	3.26	2.10	4.37	8.98	0.48	100 aril weight (g)	37.59	17.72	62.33	17.28	10.56**
Tree spread (m)	3.61	1.08	4.93	10.44	0.61	100 aril dry weight (g)	8.00	4.36	10.32	8.63	1.12**
Leaf blade length (cm)	5.03	4.02	10.08	22.20	1.81	Rind thick ness (mm)	3.41	2.37	7.15	38.38	2.13
Leaf blade width (cm)	1.49	1.31	1.79	4.30	0.10	Aril length (mm)	10.56	8.29	11.81	3.64	0.62**
Petiole length (mm)	4.36	3.56	7.06	18.54	1.31	Aril width (mm)	7.25	5.91	8.30	4.58	0.54**
Petiole Width (mm)	0.92	0.73	1.55	25.08	0.38	TSS (^{o}Brix)	17.03	14.92	20.89	2.14	0.59**
Calyx length (mm)	36.12	25.68	50.75	4.68	2.25	Acidity (%)	1.33	0.27	3.40	9.34	0.20**
Calyx width (mm)	12.66	8.76	14.82	4.78	0.98	100 Seed wight (g)	2.06	1.15	2.78	2.43	0.08**

Traits	Mean	Min	Max	CV%	LSD	Traits	Mean	Min	Max	CV%	LSD
Petal length (mm)	24.69	16.36	144.63	134.39	53.95	Seed length (mm)	6.30	4.85	7.14	4.12	0.42**
Petal width (mm)	16.66	12.12	19.32	8.32	2.25	Seed width (mm)	2.70	2.21	3.05	5.12	0.22**
Fruit weight (g)	267.82	81.53	417.24	17.36	75.57	Fruit colour (L*)	62.94	12.77	82.61	6.89	7.05**
Fruit length (cm)	7.40	5.01	9.02	6.83	0.82	(a*)	23.48	4.19	42.54	10.24	3.91**
Fruit diameter (cm)	7.77	5.36	9.23	6.79	0.86	(b*)	32.93	14.56	47.58	7.31	3.91**
Fruit volume(ml)	217.53	58.17	344.00	23.47	82.99	Aril colour (L*)	46.29	19.15	58.35	1.92	1.45**
Crown length(mm)	12.58	9.00	18.35	14.30	2.92	(a*)	16.59	4.82	32.97	7.52	2.03**
Aril (%)	58.46	27.45	70.89	5.14	4.88	(b*)	19.09	11.41	25.65	6.56	2.04**
Fruit Juiciness (%)	36.86	15.27	49.27	9.38	5.62	Bioyield (N)	6.50	4.00	9.55	13.97	1.48**
No of arils per fruit	439.69	150.53	985.17	31.82	227.44	Seed rupturing point (N)	67.46	29.24	100.92	7.98	8.75**

** Significant at 1% L*+ indicate lightness of sample color;
a*indicates red colour; b*indicates a yellow colour

The Ward's Minimum Variance Cluster Analysis grouped 40 genotypes into five clusters at 22.83 similarity coefficient. The highest numbers of genotypes were grouped in cluster II and V with 14 genotypes in each, followed by cluster I (6 genotypes). Clusters- III and IV were found to have 4 and 2 genotypes respectively.

Maximum similarity was observed between KRS and P-13 (0.97) followed by 0.96 similarity coefficient between P -23 & P-26, IC-318779 & IC-318703, IC-318728 & IC-318753, IC-318728 & IC-318762, IC-318723 & IC-318753, IC-318720 & IC-318724, Gul-e-Shah Red & Gul-e-Shah Rose Pink, 1181 and Acc.-1. Minimum similarity was recorded between Gul-e-Shah Rose Pink and IC-318749 (0.40).



Dendrogram showing similarity coefficient of 40 pomegranate genotypes

1.2.2. Correlation analysis for horticultural and biochemical traits

In cultivated types the TSS, acidity, total phenol, ascorbic acid, reducing sugar, total sugar and non-reducing sugar, were found in lower quantity than that in wild types. Higher antioxidant activity and anthocyanin concentration were found in cultivated types. The following important horticultural and biochemical traits have shown significant positive correlation in pomegranate.

Horticultural traits

- **Fruit weight** vs Leaf blade length, Leaf blade width, petiole length, petiole width, Calyx length, Calyx width, Petal width
- **Fruit length** vs Leaf blade length, Leaf blade width, petiole length, petiole width, Calyx length, Calyx width, Petal width, Fruit weight
- **Fruit diameter** vs Leaf blade length, Leaf blade width, petiole length, petiole width, Calyx length, Calyx width, Petal width, Fruit weight, Fruit length
- **Fruit volume** vs Leaf blade length, Leaf blade width, petiole length, petiole width, Calyx length, Calyx

width, Petal width, Fruit weight, Fruit length, Fruit diameter

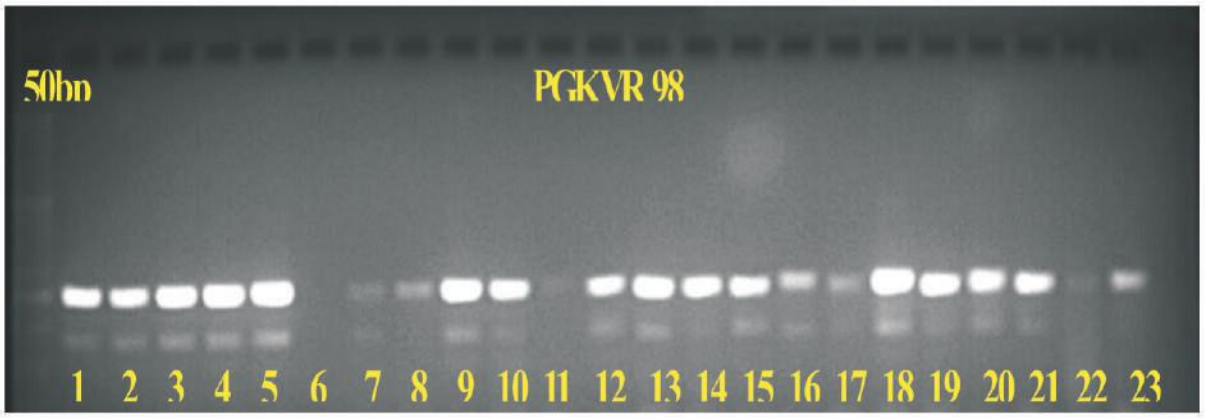
- **Aril %** vs Petiole length, Calyx length, Calyx width, petal width, Fruit weight, Fruit length, Fruit diameter, Fruit volume
- **Fruit juiciness** vs Leaf blade width, petiole length, petiole width, Calyx length, Calyx width, Petal width, Fruit weight, Fruit length, Fruit diameter , fruit volume, Aril %
- **Number of arils per fruit** vs Leaf blade length, Leaf blade width, Calyx length, Calyx width, Petal width, Fruit weight, Fruit length, Fruit diameter, fruit volume, aril %, Fruit juiciness
- **100 arils weight** vs Petiole length, Calyx length, Calyx width, Petal width, Fruit weight, Fruit length, Fruit diameter, fruit volume, crown length, aril %, Fruit juiciness, Number of arils per fruit
- **Bioyield / Aril rupturing point** vs Fruit juiceness
- **Seed rupturing point** vs tree height, tree spread, TSS, acidity, 100 seed weight, seed width, Fruit colour (*L), Aril colour (*b), bioyield

Biochemical traits

- **TSS** vs tree height, tree spread
- **Acidity** vs tree height, tree spread, TSS
- **pH** vs Fruit weight, Fruit length, Fruit diameter, 100 aril weight, aril length, aril width
- **Phenol** vs TSS, Acidity
- **Reducing sugar** vs Rind thickness, TSS, acidity
- **Non-Reducing sugar** vs Rind thickness
- **Total sugar** vs Rind thickness, TSS, acidity

1.2.3. Molecular diversity analysis in pomegranate

Nineteen SSR primers reported from the previous study were screened across the 23 cultivated varieties and wild pomegranate genotypes to understand their diversity pattern at molecular level. Out of 23 varieties, 19 were found to be polymorphic and 8 were monomorphic. Eleven polymorphic primers have generated 43 SSR marker alleles, with 3.9 average number of alleles per locus. The maximum number of alleles was observed for PGKVR 08 and minimum for PGKVR 83. Polymorphic information content (PIC) values ranged from 0.79 to 0.27 with an average of 0.54. Among 19 Polymorphic primers, SSR primers PGKVR 08 and PgSSR70 were found to be very informative and highly polymorphic. These PGKVR 08 & PgSSR70 informative primers could be used in future crop breeding programme to aid in marker-assisted selection of desirable genotypes.



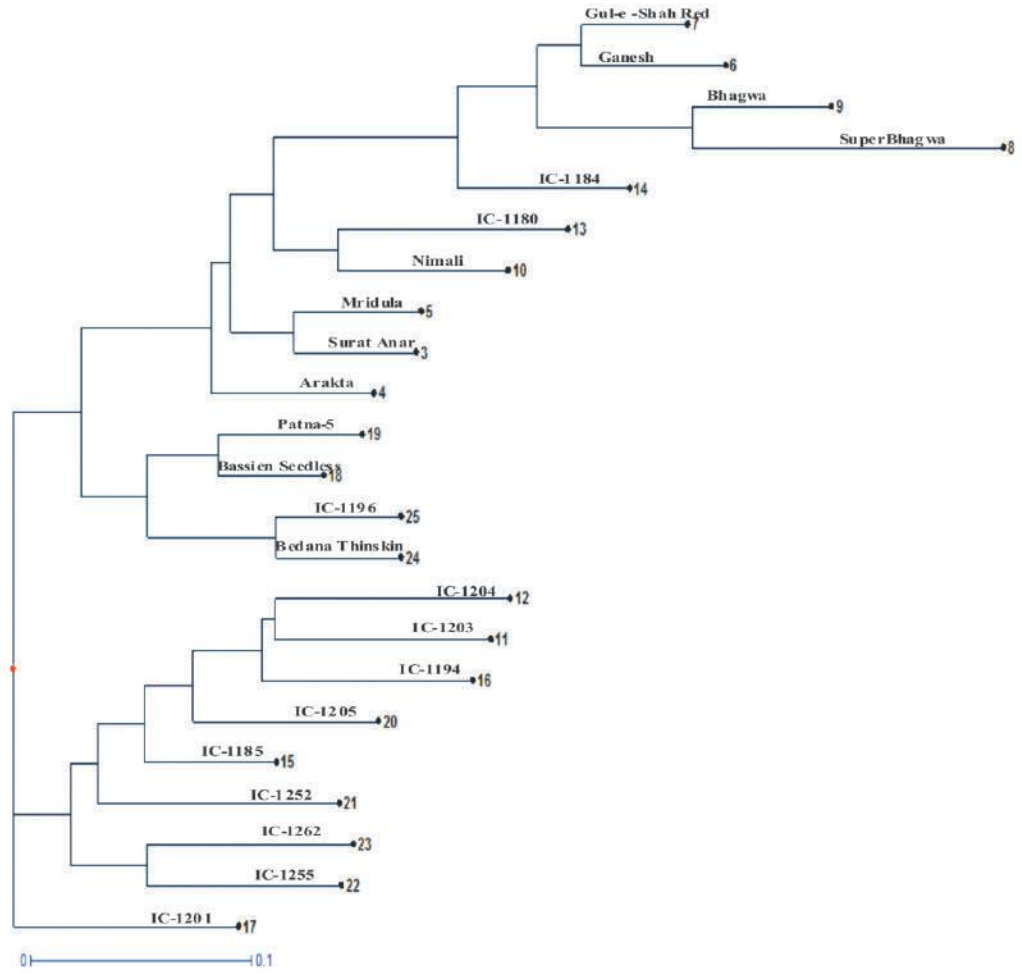
Amplification of germplasm by using PgSSR primer

(1) Bhagwa (2) Arakta (3) Mridula (4) Ganesh (5) Gul- e- Shah Red (6) Super Bhagwa (7) Surat Anar (8) Nimali (9) IC-1203 (10) IC-1204 (11) IC-1180 (12) IC-1184 (13) IC-1185 (14) IC-1194 (15) IC-1201 (16) Bassien Seedless (17) Patna-5 (18) IC-1205 (19) IC-1252 (20) IC-1255 (21)IC-1262 (22) Bedana Thinskin (23) 1196

Polymorphic Information content (PIC) and heterozygosity values of polymorphic SSR markers

Markers	No.of Marker alleles	Het	PIC
PGKVR 154	3	00.410	0.3586
PGKVR 83	2	0.3299	0.2755
PGKVR 98	4	0.6706	0.6158
PGKVR 08	7	0.8182	0.7945
PgSSR 24	3	0.4821	0.4282
PGKVR 151	3	0.6040	00.520
PGKVR 75	3	0.4953	00.421
PgSSR 73	5	0.7438	0.7006
PgSSR 74	4	0.7423	0.6944
PGKVR 88	3	0.5975	0.5113
PgSSR 70	6	0.7912	0.7577

The binary data derived from amplified bands of SSR primers were used to create dissimilarity matrix to estimate genetic dissimilarity among pomegranate accessions. Maximum genetic dissimilarity (0.73) was observed between the variety ' Super Bhagwa' and 'IC 1194'. Hierarchical cluster analysis separated genotypes into three major clusters I cluster II and cluster III. Cluster I consisted of fourteen genotypes and cluster II consisted of eight genotypes and cluster III was the solitary cluster with only one genotype (IC-1201).

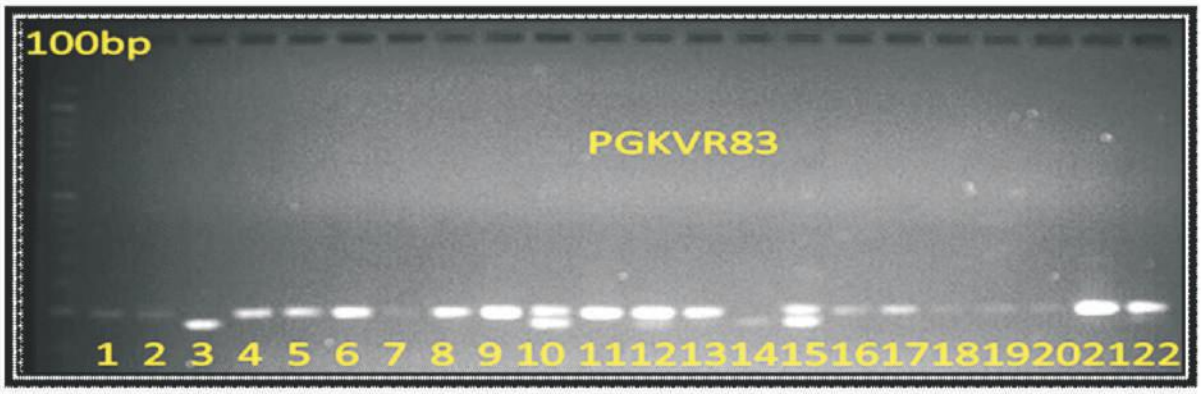


Dendrogram showing phylogenetic relationship among 23 genotypes generated from eleven SSR marker analysis

In another study genetic diversity among 22 wild pomegranate genotypes were assessed using 16 simple sequence repeat (SSR) markers. Out of 16 SSR markers selected from the previous reports, 12 were found polymorphic which were able to distinguish the selected genotype and five (Primer No. PgSSR25, PgSSR44, PgSSR55, PGKVR129 & PgSSR56) were found to be very informative and highly polymorphic. These markers can be used in future crop breeding programme to aid in marker-assisted selection as desirable genotypes. The genetic variability among twenty two pomegranate genotypes was assessed at 29 polymorphic SSR marker loci.

The maximum genetic dissimilarity was observed between IC-318712 and IC-318718 as well as IC-318712 and Acc-8, while non-significant/lower dissimilarity was observed between Acc-11 and IC-318707, Acc -12 and IC-1181.

Based on genetic dissimilarity indices, the genotype were grouped into three major clusters (cluster I, cluster II, cluster III). Cluster I consisted of maximum number of genotypes (11 numbers) with two sub-clusters (sub-cluster I with 5 and sub-cluster II with 6 genotypes).



Molecular polymorphism among 22 pomegranate genotypes showed by PGKVR83 primer

(1) Acc-11 (2) Acc-12 (3) Acc-10 (4) Acc-02 (5) IC-318718 (6) IC-318720 (7) Acc-04 (8) IC-318793 (9) IC-318716 (10) Acc-09 (11) IC-318766 (12) IC-318744 (13) IC-318735 (14) Acc-09 (15) Acc-09 (16) IC-1181 (17) IC-318764 (18) IC-318712 (19) IC-318740 (20) IC-318706 (21) IC-318707 (22) IC-318702

Polymorphic Information content (PIC) and heterozygosity values of polymorphic SSR markers

Markers	No. of marker alleles	Het	PIC
PgSSR02	2	0.32	0.268
PgSSR13	2	0.498	0.374
PgSSR25	5	0.710	0.662
PgSSR28	2	0.50	0.375
PgSSR44	3	0.617	0.543
PgSSR55	4	0.609	0.536
PgSSR56	3	0.611	0.540
PGKVR64	2	0.244	0.214
PGKVR83	2	0.355	0.292
PGKVR98	2	0.48	0.364
PGKVR120	2	0.260	0.226
PGKVR129	3	0.571	0.501

The clustering analysis was well supported by Principal Component Analysis (PCA). The first two axes of PCA with positive Eigen values were able to account 46.71% of the total variations.

1.2.4. Reaction of Seedling population of exotic and indigenous lines/hybrids to bacterial blight:

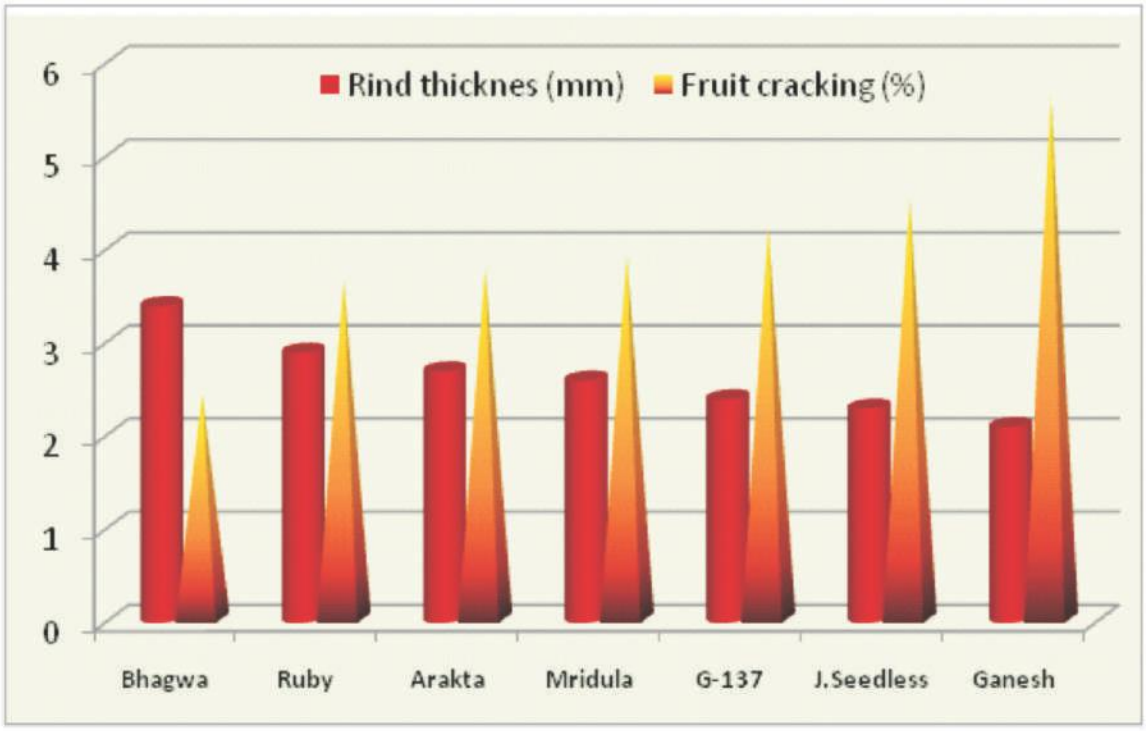
Seedling population of 4 EC accessions, one ACC13 and 8 Hybrid lines were screened using challenge inoculation with *Xanthomonas axonopodis* pv. *punicae* isolate *Xap*130. All the seedling population of 12 germplasm accessions (indigenous and exotic collections) were found highly susceptible to BB under challenge inoculation with incidence ranging from 79.28% to 100.00% and severity grade of 3.25 to 5.00 on a scale of 1-5.

Reaction of seedling population of different genotypes

Germplasm line	Bacterial Blight	
	Incidence (%)	Severity Grade (Scale 1-5)
ACC 13	91.88	3.25
EC-676964	89.44	4.11
EC-676981	79.28	4.22
EC-676991	83.14	3.86
EC-81839	100.00	5.00
NRCPH-07	92.20	3.60
NRCPH-09	94.29	4.40
NRCPH-08	89.88	3.55
NRCPH-06	93.50	4.17
NRCPH-04	92.47	3.93
NRCPH-12	95.00	4.00
NRCPH-10	87.00	4.00

1.2.5. Fruit cracking in relation to fruit rind thickness

The incidence of fruit cracking in seven commercial cultivars was assessed during the *mrig bahar* crop of eight year old orchard. Cracking was lowest in Bhagwa (2.40%) having highest rind thickness (3.4 mm) and highest in Ganesh (5.60%) with lowest rind thickness (2.1mm).



Fruit cracking in relation to rind thickness in commercial cultivars of pomegranate

1.2.6. Determination of heat unit requirement of pomegranate germplasm

Total growing degree days (GDD) requirement of twelve pomegranate varieties viz., Bhagwa, Patna-5, P-13, P-16, IC-1201, IC-318753, IC-318779, IC-318740, IC-318702, IC-318707, Acc-1 and IC-318712 was quantified. The total GDD, photo-thermal index and heat use efficiency was estimated for in *mrig bahar*. Total days for new leaf initiation to harvesting ranged from 136 to 188 days. Total GDD accumulations of all the varieties ranged from 2390.30 to 3575.10°D from defoliation to harvesting period. The growing degree days ranged from 932.80 to 1753.20°D at flowering stage and 284.90 to 903.50°D at reproductive stage. The lowest and highest GDD from defoliation to harvesting period build up of 2390.20°D for IC-318707 and 3575.10°D for Bhagwa. Photo-Thermal Index (PTI) and Heat Use Efficiency (HUE) of twelve varieties ranged from 18.20 to 19.9°D/day and 0.70 to 73.60 kg ha^{-1} $degree^{-1}$ at flowering and reproductive stages respectively. The water used, yield and water use efficiency ranged from 3330 to 5580 L $bahar^{-1}$, 1.88 to 26.90 t ha^{-1} and 0.5 to 6.1 kg m^{-3} respectively.

2. CROP IMPROVEMENT

Project: Genetic improvement of pomegranate

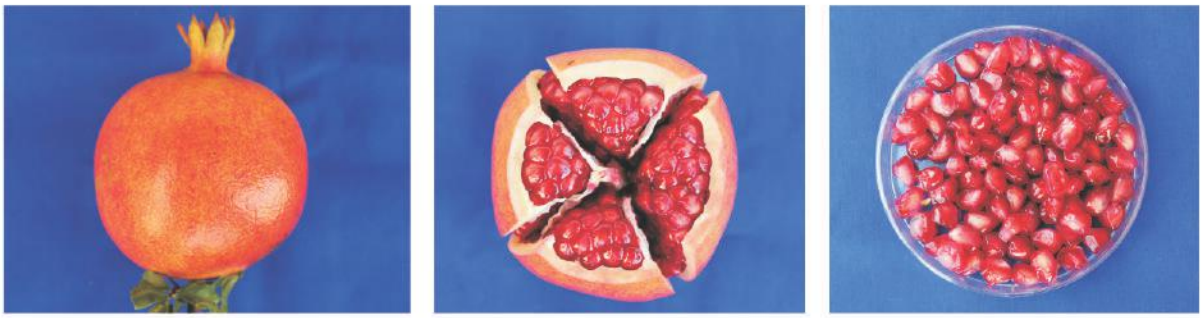
2.1. Hybrids developed at NRCP

2.1.1. Field evaluation of hybrids for quality fruits

Fruit quality and size of four pomegranate hybrids developed using Bhagwa, Ganesh, Kalpitya and Nayana was compared with ruling variety Bhagwa during third year. Hybrid Ganesh x Kalpitiya recorded highest fruit weight, number of fruits, yield, TSS with red colour; however it had smallest arils. Hybrid Bhagwa x Nayana had bold arils and dark red colour with big size fruits but TSS was lower.

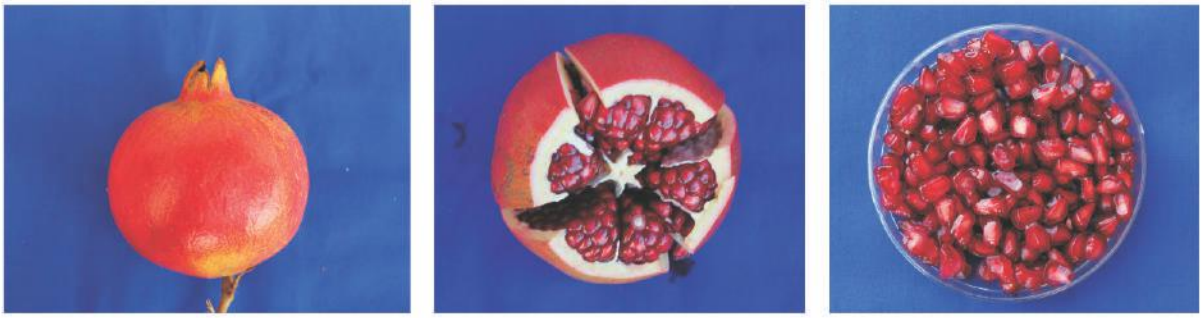
Evaluation of pomegranate hybrids

Hybrid	Fruit weight (g)	No. of fruits/ plant	Fruit yield (kg/tree)	Fruit yield (t/ha)	100 aril weight (g)	TSS (°B)	Acidity (%)	Fruit colour	Aril colour
Bhagwa	250.4	52.5	13.14	9.72	35.2	15.9	0.48	Red	Red
Bhagwa x Kalpitiya	260.2	51.0	13.27	9.82	36.5	15.8	0.42	Red	Red
Bhagwa x Nayana	270.5	53.0	14.33	10.60	37.5	15.9	0.45	Red	Dark red
Ganesh x Kalpitiya	273.5	60.0	16.41	12.14	30.0	16.2	0.40	Red	Red
Ganesh x Nayana	273.2	55.0	15.02	11.11	30.5	16.1	0.42	Red	Pink



Bhagwa x Kalpitiya

Bhagwa x Nayana



Ganesh x Kalpitiya

Ganesh x Nayana

Evaluation of new pomegranate hybrids

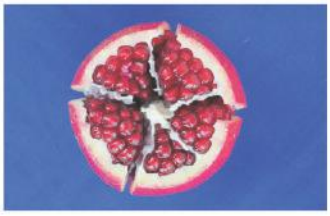
2.1.2. Solapur Lal vs. Bhagwa

Evaluation of pomegranate variety Solapur Lal in comparison to ruling variety Bhagwa during the third year of planting in *mrig bahar* recorded 15 days early maturity, 3.4 t/ha higher yield over Bhagwa besides better fruit colour with bolder arils.Fruit quality was also superior to Bhagwa as it recorded higher TSS (17.6°B), vitamin C (19.4 mg/100g) and anthocyanin (390 mg/100g) content.

Solapur Lal	Characters	Bhagwa
1.65 Medium	Tree height (m)	1.51 Medium
165.0	Calyx colour	180.0
13.12	Fruit maturity (days)	9.72
236.4	Fruit weight (g)	250.4
Red	Fruit colour	Red
3.3 Medium	Rind thickness (mm)	3.4 Medium
40.0	100 Aril weight (g)	36.5
Dark Red	Aril colour	Red
Medium	Seed Texture	Soft
44.5	Juice %	45.0
17.6	TSS (°Brix)	15.9
19.4	Vitamin-C*	14.60
390.0	Anthocyanin *	360.0
0.61	Iron*	0.32
0.64	Zinc*	0.50
*(mg/100g of fresh arils)		








Comparative evaluation of Solapur Lal vs Bhagwa during third year of planting

2.1.3 Solapur Anardana vs Amlidana

Evaluation of pomegranate variety Solapur Anardana in comparison with Amildana during third year of planting in *mrig bahar* revealed higher yield (12.25 t/ha), acidity (4.8%), vitamin C (18.2 mg/100g) and anthocyanin (460.5 mg/100g) showing its superiority over Amlidana.

Solapur Anardana	Characters	Amlidana
	Medium 1.65	Tree height (m)	Small 1.35	
	Red	Calyx colour	Red	
	148.0	Fruit maturity (days)	150.0	
	12.25	Yield (t/ha)	7.81	
	240.2	Fruit weight (g)	220.1	
	Red	Fruit colour	Yallow	
	3.3	Rind thickness (mm)	2.0	
	Medium	100 Aril weight (g)	Thin	
	34.0	Aril colour	33.5	
	Red	Seed Texture	Light-pink	
	Medium	TSS (°Brix)	Medium	
	45.0	Juice %	43.0	
	16.6	TSS (°Brix)	15.7	
	18.2	Vitamin-C (mg/100g)	14.2	
	460.5	Anthocyanin (mg/100g)	55.0	
	4.8	Acidity (%)	4.2	






Comparative evaluation of Solapur Anardana vs. Amlidana during third year of planting

2.1.4. Screening seedling population of hybrids

Seedling population of 31 hybrids screened under challenge inoculation for bacterial blight reaction, recorded high susceptibility to bacterial blight with incidence of 70.00 to 92.80% except Daru seedlings which recorded tolerant reaction with 13.44% incidence, except one with 90% severity.

Susceptibility of seedling population of pomegranate hybrids

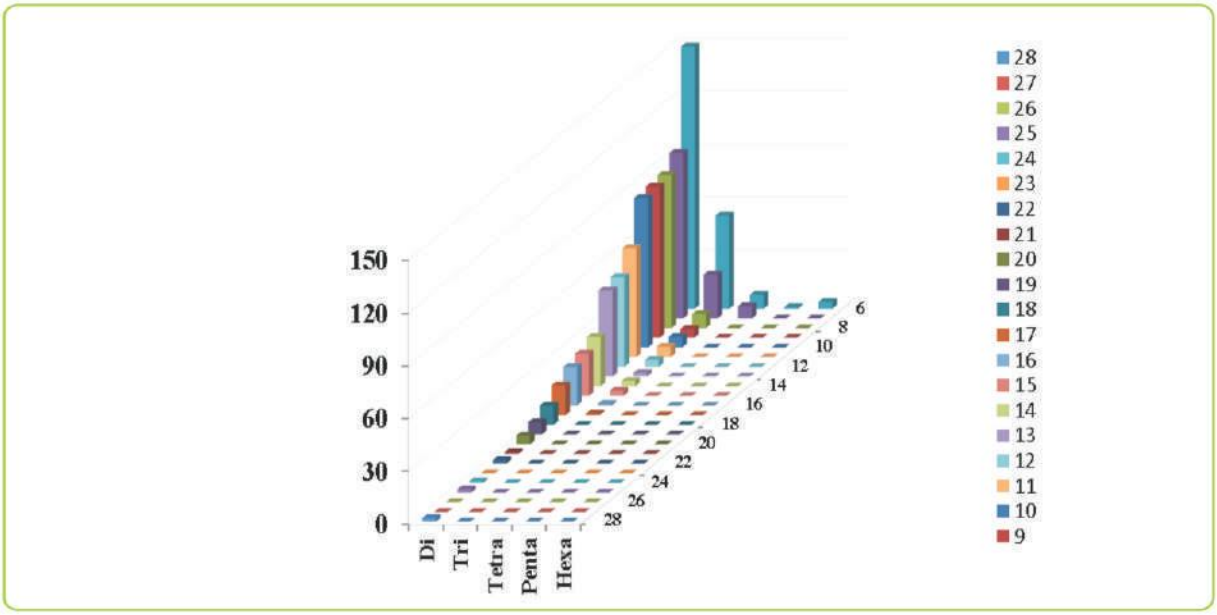
Hybrid lines	Bacterial Blight		Hybrid lines	Bacterial Blight	
	Incidence (%)	Severity Grade on scale of 1-5)		Incidence (%)	Severity Grade on scale of 1-5)
Bhagwa	92.80	4.60	BxH-28	87.52	3.53
Daru	13.44	2.00	NxR	87.56	3.78
ACC-51	65.00	4.00	KRSxB	88.56	3.11
H-14	68.00	3.00	HA-1	89.00	3.80
KxR	70.00	4.00	1194xG	89.25	4.00
HA	70.40	3.20	H-12	90.00	5.00
KxR	72.30	3.60	7/10	90.00	4.00
ACC-50	75.00	4.00	H-4	90.00	4.00
ACC-15	78.00	4.00	H-24	90.67	4.22
Bx318712	79.32	2.90	Arakta	90.80	3.00
Amlidana	79.80	3.60	Nayana-1	91.00	4.60
Nayana-3	83.00	4.20	H-4	92.73	4.55
BxPatna-5	84.56	3.52	(NxR)xB	93.30	3.70
BxNana	85.70	3.20	RxKRS	94.50	3.50
H-14	86.20	4.20	KxRxB	94.67	4.00
BxKRS	87.00	3.59	Jalore Seedless	97.40	4.00

(One plant in Daru showed highly susceptible reaction with incidence of 90% and severity grade of 4. One plant in H-24 showed moderately susceptible reaction with incidence of 30% and severity grade of 2. B-Bhagwa, K-Kalpitya, R- Ruby, N- Nayana, G-Ganesh)

Project: Genetic mapping of bacterial blight and fruit quality traits in pomegranate

2.2.1. *In silico* analysis, development of hyper variable SSR markers and validation

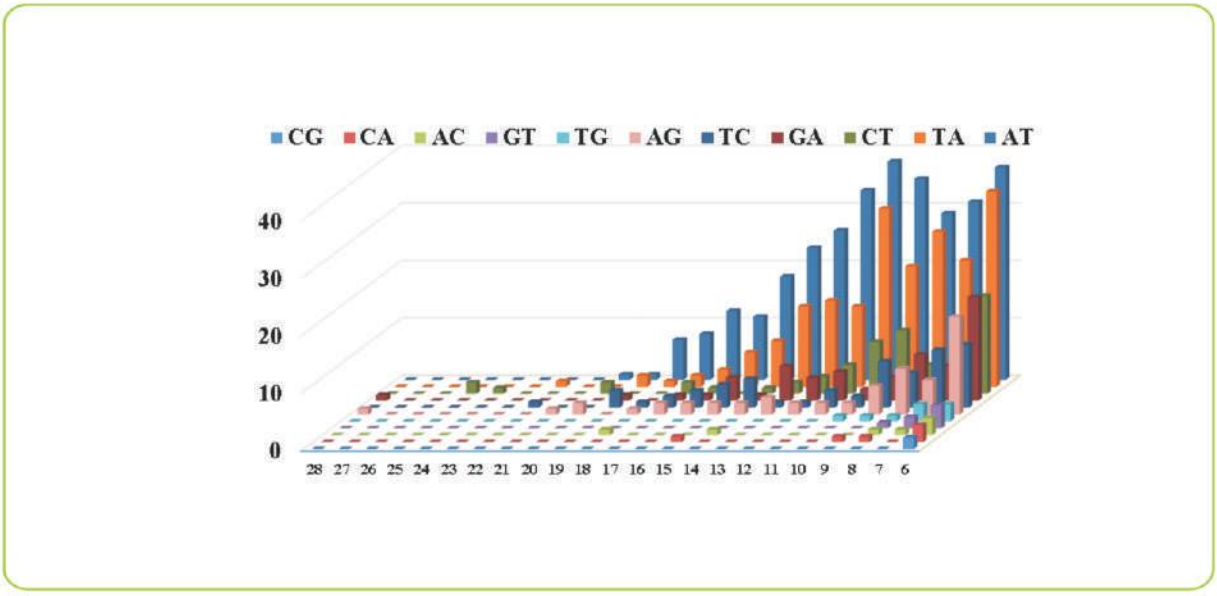
Draft genome sequence of pomegranate variety Dabenzi was retrieved from the NCBI database and it was surveyed for microsatellite motifs in 530 (MTKT010000010.1-MTKT01000530.1), pomegranate whole genome shotgun sequences representing 36 scaffolds. Designed, 1009 SSR primers specific to 79% (Di), 11% (Tri), 1% (Tetra), 0.39% (Hexa), and 8% (Compound) repeat motifs using Primer 3 tool. The analysis of SSR motif types, repeat length and their distribution pattern in these shotgun sequences revealed dinucleotide repeats were most frequent (79%) followed by trinucleotide repeats (11.0%)



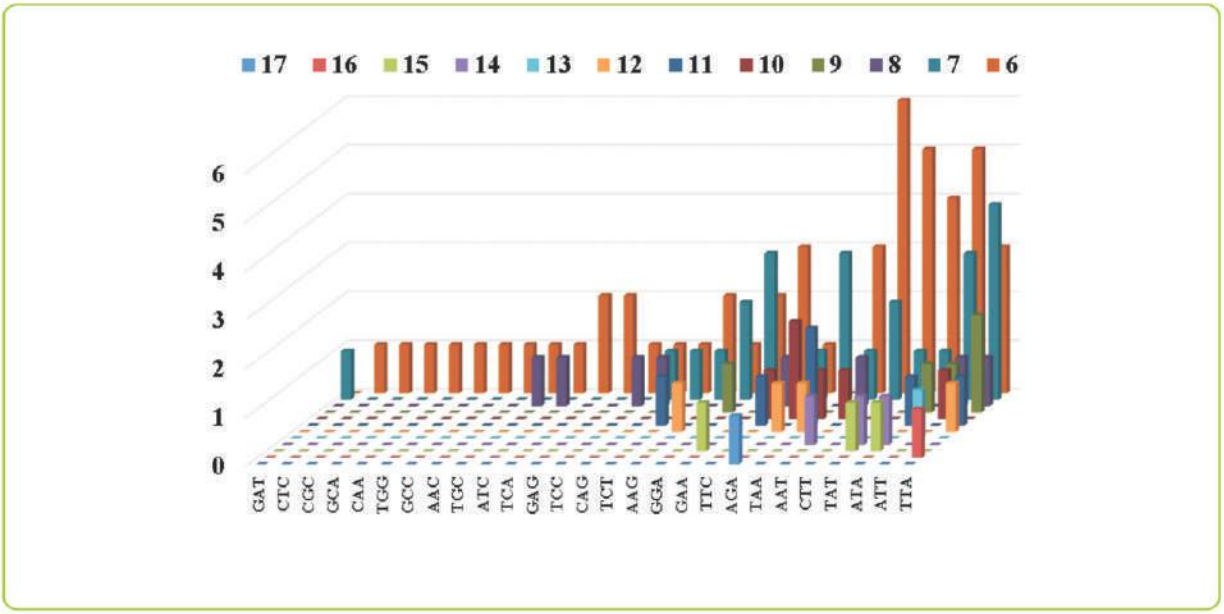
Motif types, repeat length and their distribution pattern

Relative frequency and number of selected microsatellite repeat-motif types in the pomegranate contigs

The frequency distribution graph for dinucleotide and trinucleotide repeats revealed AT/TA and TTA/ATT repeats types are more prominent in these pomegranate shotgun sequences. Finally based on track length (>25bp), total 280 SSR primers were selected, got synthesized and named as NRCP series SSR primers for mapping work.

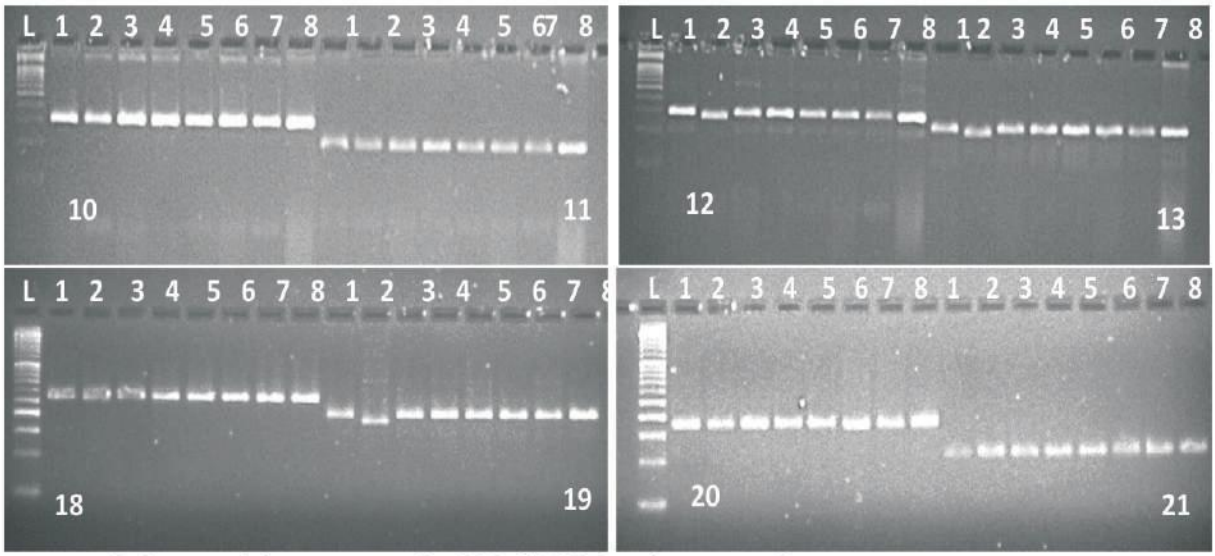


Frequency distribution of classified di-nucleotide repeats with number of selected microsatellite repeat-motif types.



Frequency distribution of classified tri-nucleotide repeats with number of selected microsatellite repeat-motif types

In order to validate these new set of NRCP SSR primers, the genomic DNA was isolated from 8 pomegranate genotypes *viz*., Bhagwa, Daru-17, G-137, Ganesh, Arakta, Dholka, Jodhpur Red and Solapur Lal. Total 120 NRCP SSR primers have been screened on 8 pomegranate genotypes. Out of these, 66 primers (55%) were exclusively polymorphic among 6 pomegranate cultivars excluding mapping parents Bhagwa and Daru-17.

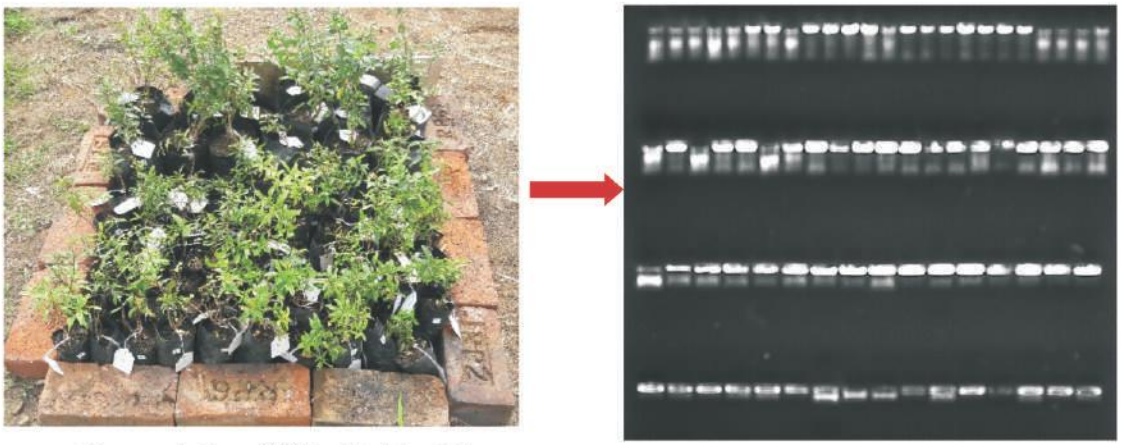


Polymorphism survey for NRCPSSR primers on 8 pomegranate genotypes

(L-50bp ladder, Lanes 1-8- pomegranate genotypes as mentioned in the text, primer number 10,11,12,13,18,19,20 and 21mentoined in each gel)

2. 2. 2. Genetic mapping of bacterial blight resistance

With objective to map genes/QTLs governing resistance to bacterial blight in Daru 17, the F1 mapping populations (83 individuals) of cross Bhagwa (S) x Daru 17(R) was used. The leaf samples of these 83 F1 individuals were collected and genomic DNA was isolated. The quality and concentration of DNA was checked on 0.8% agarose. In order to locate genomic regions for resistance to bacterial blight in pomegranate constructing saturated linkage map is a prerequisite. So far there is no report available in pomegranate on construction of saturated linkage map using SSR markers. The possible regions may be limited information on polymorphic SSRs in pomegranate. Now the availability of two draft genome sequences for pomegranate varieties n public database, has opened the scope for increasing the SSR markers repository in pomegranate for genetic mapping. We surveyed the parental polymorphism between mapping parents Bhagwa x Daru17 using 108 newly designed hyper-variable SSR primers. Out of 108 primers screened, 75 were polymorphic and 33 were monomorphic between the parents on 3% agarose gel. The remaining 172 SSRs primers are being screening for parental polymorphism.



F_1 population (83 individuals) of cross Bhagwa (S) x Daru-17 (R)

Genomic DNA of 83 F_1 individuals

Isolation of genomic DNA from Nursery raised F_1 mapping population

Project : Genome sequencing of pomegranate cv. Bhagwa

2.3 Genome sequence information through *de novo* assembly of pomegranate

DNA sample was isolated from cultivar Bhagwa. Sequencing libraries were generated using Truseq Nano DNA HT Sample preparation Kit. The genomic DNA was randomly fragmented to a size of 350 bp by

Covaris cracker, then DNA fragments were end polished, A-tailed, and ligated with the full-length adapter for Illumina sequencing with further PCR amplification. At last, PCR products were purified by AMPure XP system and libraries were analyzed for size distribution by Agilent 2100 Bio analyzer and quantified using real-time PCR.

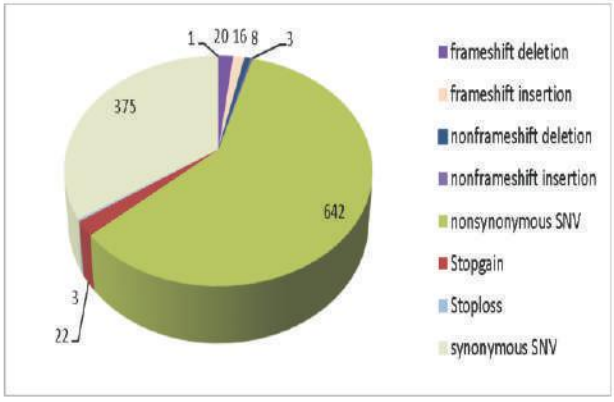
Mapping and annotation

Using Variant Calling (SNV, InDels, SV and CNV) mapped back all the clean reads from the multiple libraries to the reference genome of Dabenzi Cultivar genome.

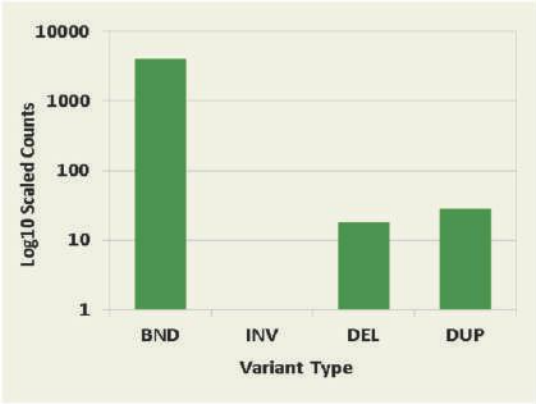
Reference genome of Dabenzi Cultivar genome parameters

Reference Sequence Statistics Sample	%GC	No. of Scaffolds	Length of Genome(Mb)	N50
MTKT00000000.1	38.5	17405	296.383	82,310

The variants were then annotated based on the Dabenzi Cultivar using Annovar. Raw variant counts including SNV/InDels were: 559045 of which 491094 are SNVs and 67951 are InDels.



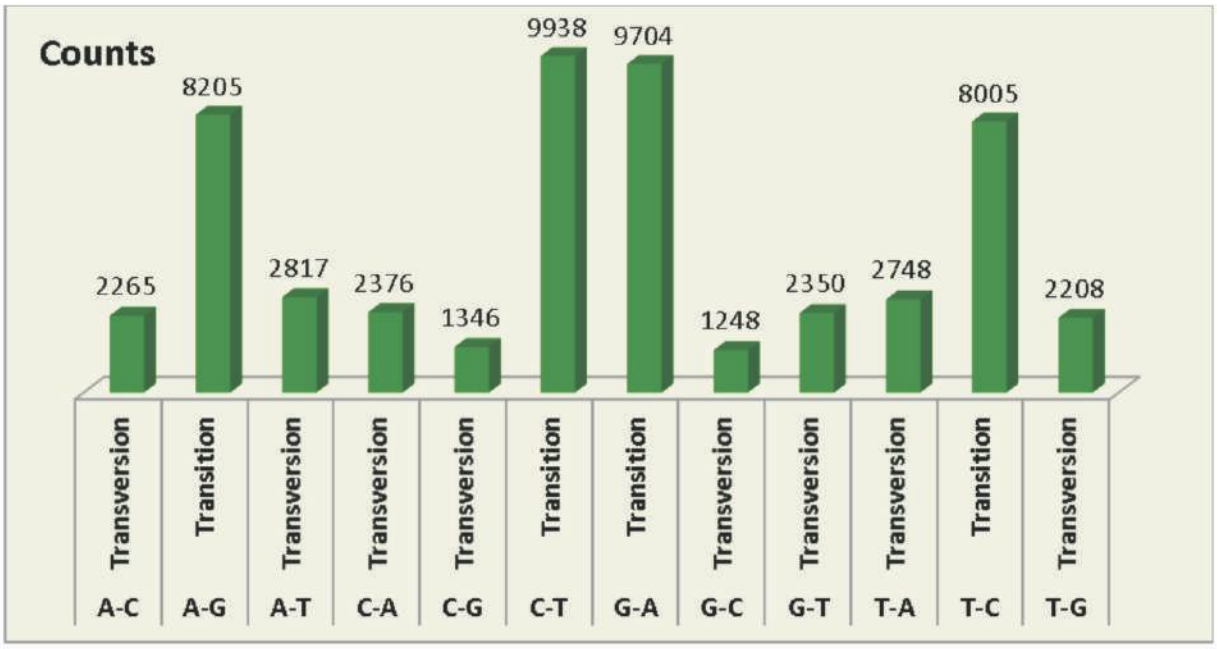
Pie Chart of the Exonic Variants



Structural variant types

Genome Assembly

The reads from all the three insert libraries were passed on to SPAdes v3.10.1 SPAdes is a de Bruijn. This was chosen based on the smaller genome size of the pomegranate genome (~340Mb). The assembly was done using the Auto-module which performs the assembly based on the following kmers: 21, 33, 55, 77 after the reads are error corrected based on the kmer-profiles. Then the contigs are corrected for mismatches and then merged/extended to form scaffolds, using the pairing information, thus creating a scaffold level assembly.



Base Changes and their counts (Ts/Tv ratio: 2.065)

Assembly Statistics at Contig/Scaffold level Assembly

Parameters	Contigs	Scaffolds
N50	4294	8666
#bases	411987014	312914239
#contigs/scaffolds	445232	113677
Maximum size	101145	101144
Minimum Size	200	500
%GC	45.27	42.23

Assembly Statistics for contigs > 1000bp

Parameters	Statistics
#Contigs	2847
#Bases	348667523
N50	542601
N90	34995
Maximum Contig length	7248178

The Hybrid assembly was created by merging the Illumina, 10X, PacBio and then using Optical Maps to create a comprehensive assembly for the genome. The statistics values are furnished below.

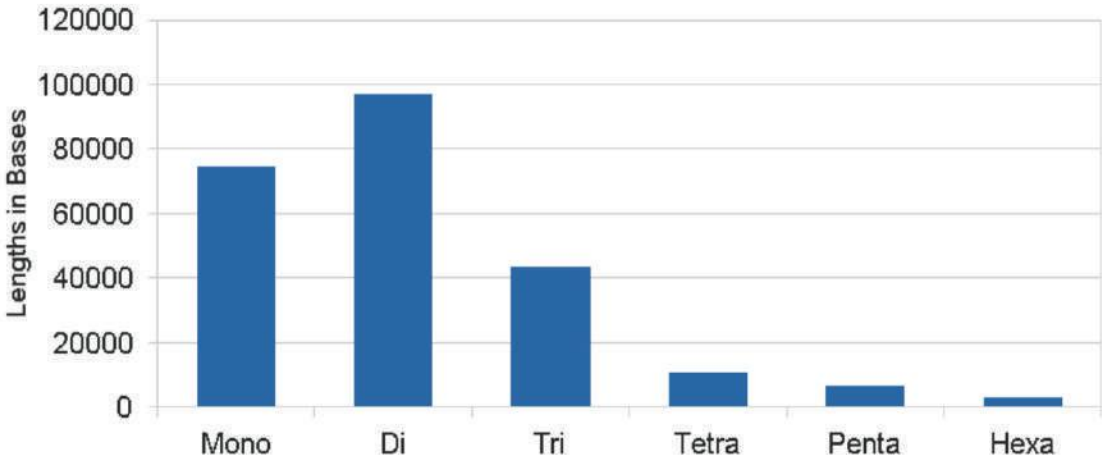
Identification of SSR from Assembly

Microsatellites are regions, in which a unit repeats for a large sequence tract. These regions are generally abundant in mutations leading to high genetic diversity, so these are most useful genetic resources. Here we have used MISA tool to identify the microsatellites, to report the microsatellite's nature.

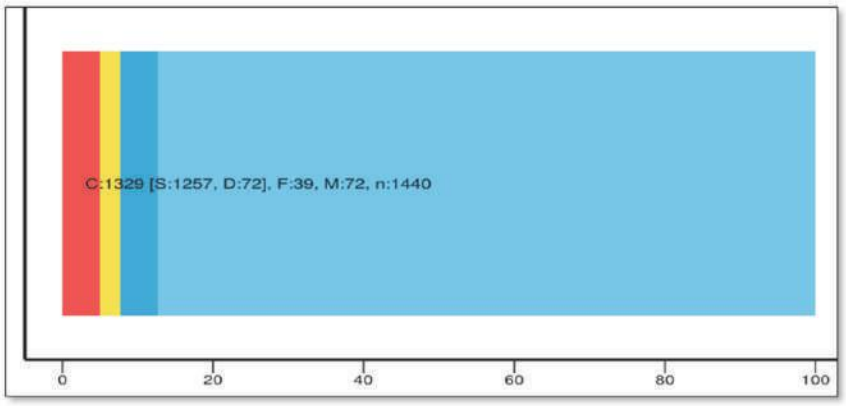
Misa Statistics	
Total length of Sequence examined (bp) (MISA)	113677
Total number of SSR (MISA)	142304
Total length of SSR (bp)	34531
Relative abundance (SSR/Mb)	454.77
Relative density (bp/Mb)	753.37

Busco Evaluation of Genome Scaffolds on Hybrid Datasets

Category	No. of Scaffolds
Complete BUSCOs (C)	1329
Complete and single-copy BUSCOs (S)	1257
Complete and duplicated BUSCOs (D)	72
Fragmented BUSCOs (F)	39
Missing BUSCOs (M)	72
Total (n)	1440



Microsatellite length Distribution



BUSCO core gene-set analyses at embryophyta lineage resulted in 92.3% conserved gene

3. PLANT PROPAGATION

Project: Propagation, bio-hardening and mass multiplication of elite planting material in pomegranate (*Punica granatum* L.)

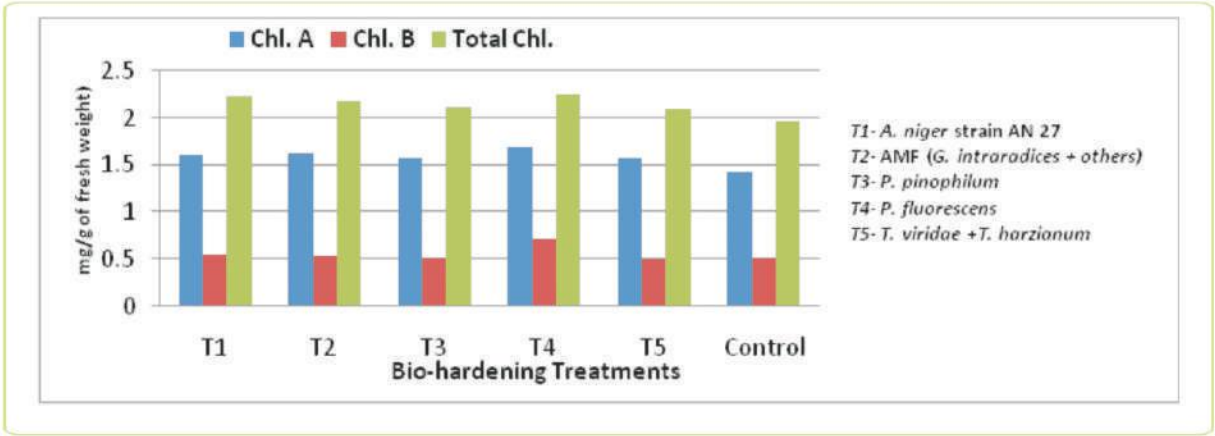
3.1. Bio-priming of *in vitro* raised plants

Five beneficial microbial agents were utilized for bio-priming of *in vitro* raised pomegranate plants through rhizospheric application. Microbial treatments were found effective in improving most of the attributes of *in vitro* raised pomegranate plants. Plants inoculated with Arbuscular Mycorrhizal Fungi (AMF) exhibited significantly better height (84.66 cm) when compared to un-inoculated control (62.66 cm). Relative leaf water content (RWC) of all the bio-hardened plants ranged from 86.093 to 84.48 %) was found significantly better than the un-inoculated control (80.66%). The maximum phenolic content was estimated in plants inoculated with AMF (61.33) and was significantly higher than the *Aspergillus niger* strain AN 27 and *Trichoderma* treated plants and control. Though, chlorophyll 'b' and total chlorophyll content of the leaves did not show significant variations among various treatments and control but chlorophyll 'a' varied significantly. All the treatments resulted into enhanced leaf chlorophyll 'a' content (1.696 to 1.578 mg/g of fresh weight) when compared to control (1.423 mg/g of fresh weight).

The increased water uptake by increasing exploration of soil volume, rapid colonization by the microbes, improved plant nutrition and/or regulating stomatal opening through hormonal biosynthesis, improved water transport because of reduced root resistance owing to increased uptake of phosphorus by AMF, enhanced absorbing area for water uptake due to growth of fungal hyphae, thereby reducing or eliminating 'dry zones', which surrounds the slow growing rootlets during low moisture period are major factors responsible for the improved performance of the bio-hardened/bio-primed plants.

Morphological, physiological and biochemical performance of *in vitro* raised bio-hardened plants

Treatment	Plant height (cm)	RWC (%)	Total phenols content (mg/100 g of FW)	SPAD Value
T1- *Aspergillus niger* strain AN 27	69.00	85.87(67.92)	42.00	42.00
T2- AMF (*Glomus intraradices* + others)	84.66	85.45(67.59)	61.33	61.33
T3- *Penicillium pinophilum*	77.00	84.48(66.80)	52.66	52.66
T4- *Pseudomonas fluorescens*	81.66	85.54(67.67)	55.33	55.33
T5- *Trichoderma viridae+T. harzianum*	79.00	86.09(68.15)	41.33	41.33
Control	62.66	80.66(63.95)	26.00	26.00



Chlorophyll 'a', 'b' and total chlorophyll content of pomegranate leaves

3.2. Comparative evaluation of fruits in plants propagated through different methods

Qualitative and quantitative evaluation of fruits raised on plants propagated through different propagation methods has been carried out for the third year in 2017-18. The ANOVA results confirmed at par fruit features for rind thickness, TSS, acidity and average fruit weight in all the four types of planting material used for comparative evaluation.

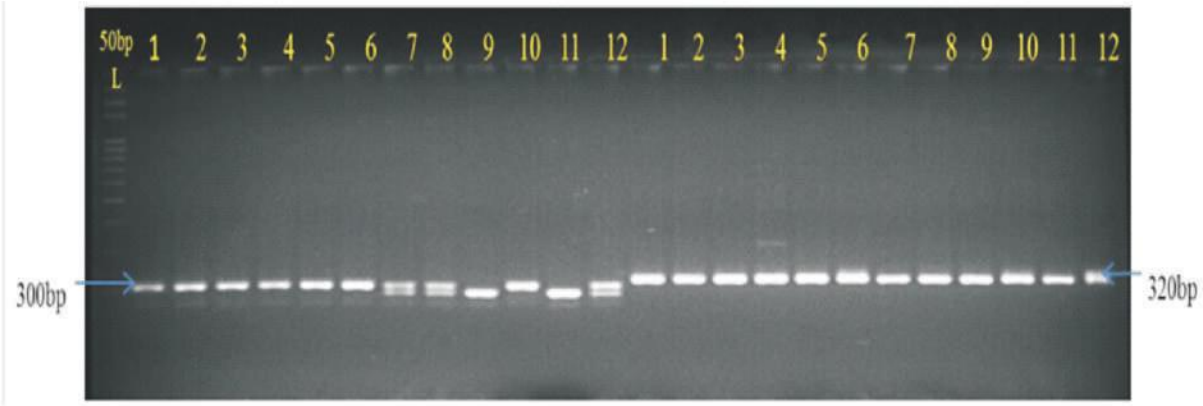
Qualitative and quantitative evaluation of fruits from plants propagated through different methods

Sapling type	Rind Thickness (mm)	Av. Fruit Weight *(g)	TSS (°Brix)	Acidity (%)
TC Plants under High Density Planting	3.40	348.46	15.31	0.46
Hard Wood Cutting	3.62	319.51	15.50	0.55
Air Layer	3.34	294.56	15.42	0.57
Tissue Culture Plant	3.12	303.25	15.19	0.56
CD (p=0.05)	NS	NS	NS	NS

*Average of randomly selected fruits

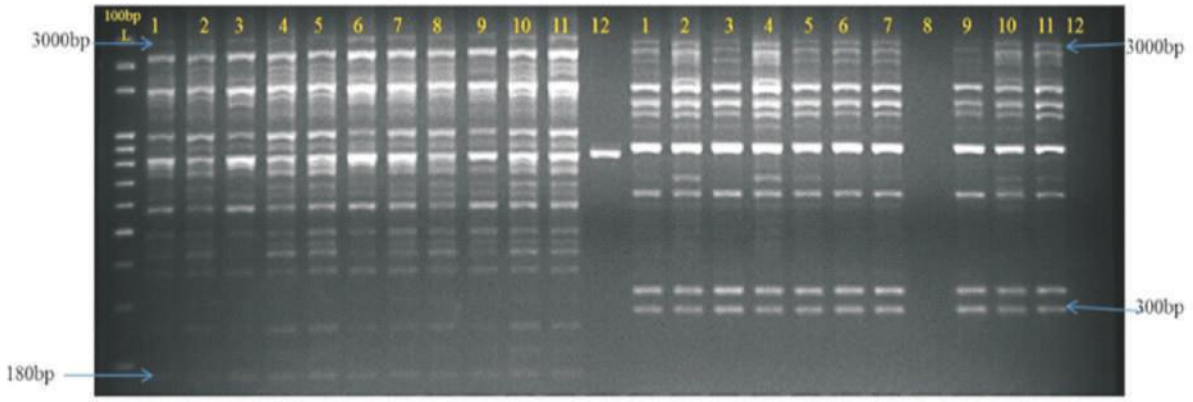
3.3. Clonal fidelity testing of tissue culture raised plants

In our quest to find out highly polymorphic and reliable markers for their utilization in clonal fidelity testing of *in vitro* raised 'Bhagwa' clones, we screened 90 publicly available SSRs, 26 RAPDs and 38 ISSR markers and found 28 highly polymorphic SSRs and 12 RAPDs for their further utilization in clonal fidelity testing of *in vitro* raised 'Bhagwa' clones.



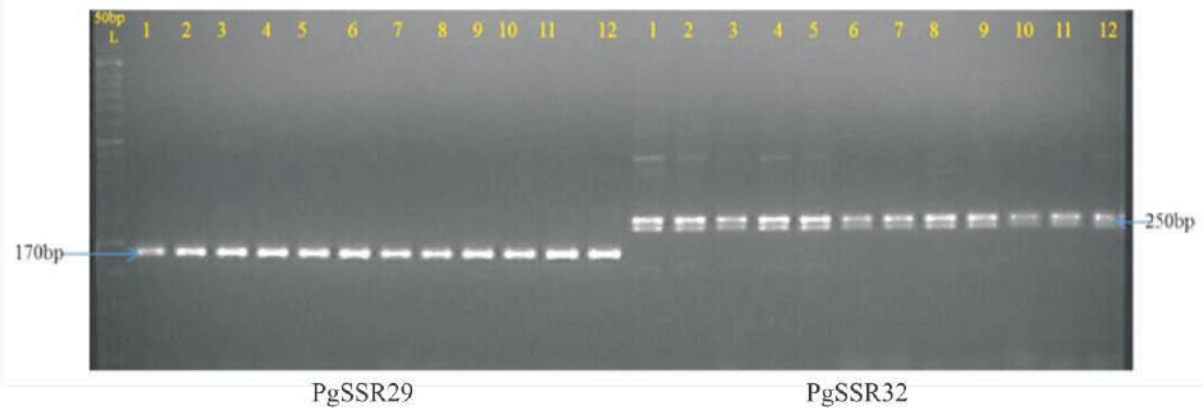
Gel electrophoresis images of amplicons using SSR Markers

1. Bhagwa, 2. Super Bhagwa, 3.Bhagwa-1, 4.AnkoliBhagwa, 5. IndapurBhagwa,6. Seedling Bhagwa, 7.Arakta, 8.Mridula, 9.Ganesh, 10. Gul-e Shah Red, 11. Ruby, 12. IC-318720



Gel electrophoresis images of amplicons using RAPD Markers

1. Bhagwa 2. Super Bhagwa 3. Seedling Bhagwa 4.Ankoli Bhagwa 5. Indapur Bhagwa 6. Bhagwa-1 7.Arakta 8. Mridula, 9. Ganesh, 10. Gul-e Shah Red, 11. Ruby, 12. IC-318720



PgSSR29 PgSSR32

Monomorphic bands obtained using polymorphic markers

(1:Mother Plant Bhagwa, 2-12: *In vitro* raised Bhagwa clones)

4. CROP PRODUCTION

Project: Propagation, bio-hardening and mass multiplication of elite planting material in pomegranate (*Punica granatum* L.)

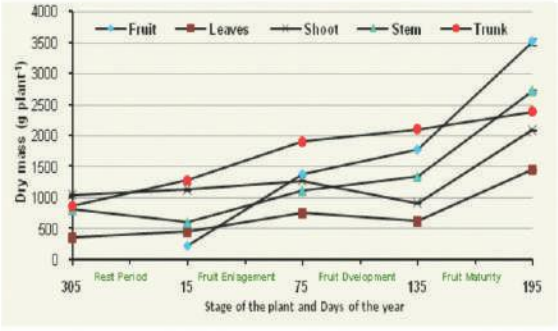
4.1. Nutrient management

4.1.1. Seasonal nutrient uptake and partitioning in mature pomegranate plants

Understanding nutrient dynamics within the pomegranate plant on a temporal scale is critical to the development of sound nutrient management practices. This study investigated the seasonal patterns of nutrient uptake and redistribution in whole pomegranate plant of cv. Bhagwa. The study was conducted in a 4 years old pomegranate orchard. Six plants were excavated at before pruning, flowering, fruit enlargement, fruit development stages and harvest. Each plant part was separated, dried and weighed to determine biomass and then ground and analyzed for nutrients. The results are described below.

4.1.1.1. Dry matter

Above-ground biomass of pomegranate plant increased gradually from rest period to flowering, followed by gradual increase upto fruit enlargement stage i.e. 0-60 days after full bloom (DAFB), remained almost constant during 61-120 DAFB and then again increased sharply towards fruit maturity. The highest biomass was recorded at harvest which is about 3.9 times of that at rest period. The annual growth from shoots, leaves and fruits contributed significantly (58.02%) towards total above-ground biomass of plant at harvest. Maximum growth took place during fruit maturity period i.e. 121-180 DAFB followed by fruit enlargement period i.e. 0-60 DAFB. The least growth occurred during fruit development period i.e. 61-120 DAFB. While maximum fruit growth took place during fruit enlargement stage followed by fruit maturity stage. The growth of trunk occurred at two distinct phases, viz. initially at rapid rate upto 60 DAFB, then at gradual rate towards maturity of the fruits. The stem biomass remained almost stable upto 120 DAF and then it increased sharply during fruit maturity stage. Shoots and leaves biomass got diminished during fruit development stage, but they grew rapidly during maturity stage.



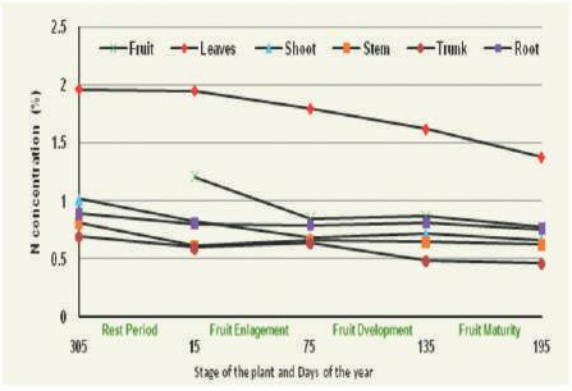
Seasonal changes in dry weight of mature pomegranate plant cv. Bhagwa

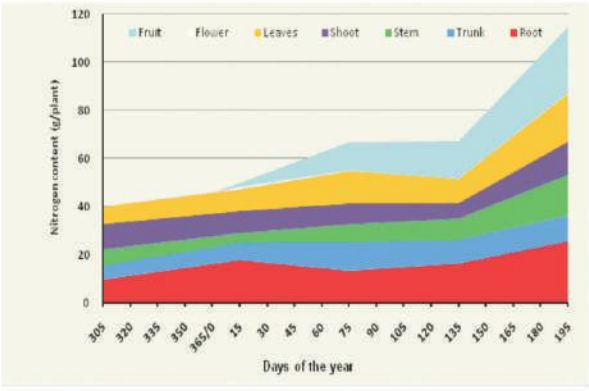
4.1.1.2. Seasonality of macro-nutrients uptake and partitioning

Nitrogen

Nitrogen concentrations in various plant parts decreased from bloom to harvest of fruits. Higher N concentrations were found in leaves and fruits, while lower N concentrations were noted in trunk and stem throughout the growing period. Fruit N concentration dropped rapidly during bloom to fruit enlargement stage (0-60 DAFB) and then remained almost stable during development and maturity stage. Woody tissue *viz*., shoot, stem and trunk N concentrations initially decreased from rest period to bloom thereafter it remained almost constant during late growth stage. Nitrogen concentration in the phloem vessels was higher than those recorded in the xylem during rest period while it was reversed during fruit growth period, xylem N concentrations was higher than those recorded in the phloem.

Nitrogen content of pomegranate plant increased slowly from rest period to bloom and then at moderate rate during fruit enlargement stage, remained constant during fruit development stage and then again increased sharply during fruit maturity stage. Highest amount of N uptake (43.61% of the total) occurred during rest period to bloom followed by that took place during fruit maturity (41.28% of the total) and then during fruit enlargement stages (14.84% of the total). Nitrogen uptake rate was high during fruit maturity stage than during fruit enlargement stage. Very meager amount of N was taken up during fruit development stage.



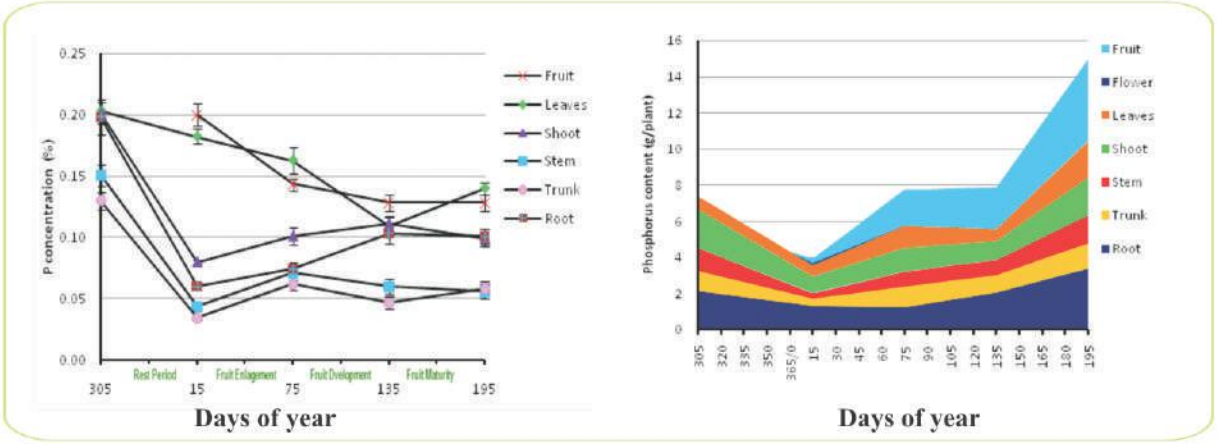


Seasonal change in concentrations and contents of nitrogen in various organs of mature pomegranate plant

During rest period to bloom N content in woody tissue *viz*. trunk, stems and shoots changed little with the exception of cognizable increase of N content in fruits, leaves and stems during fruit enlargement stage, while its content decreased in roots and shoots during the same period. Nitrogen content continued to increase in fruit and began to increase in roots while its content decreased in leaves, shoots and trunk during fruit development stage. During maturity stage, N content increased in all the plant parts except in trunk, however the extent of increase was much higher in shoots and leaves. At harvest highest content of N was recorded in fruits (20.15 kg N ha^{-1}) followed by in roots (18.87 kg N ha^{-1}). The total amount of N found in different parts of fully grown pomegranate plant (4 year old) was 84.58 kg ha^{-1}. Approximately, half of N in plant was found to confine in fruits, leaves and shoots (45.12 kg ha^{-1}).

Phosphorus

Phosphorus concentrations in woody tissue viz. shoots, stems, trunk and roots were highest at rest period and decreased to the lowest level at bloom. After that P concentrations in shoots and roots increased up to fruit development stage and remained constant thereafter, while in stem and trunk its concentration increased up to fruit enlargement stage, thereafter again declined towards maturity stage.



Seasonal change in concentrations and contents of phosphorus in various organs of mature pomegranate plant

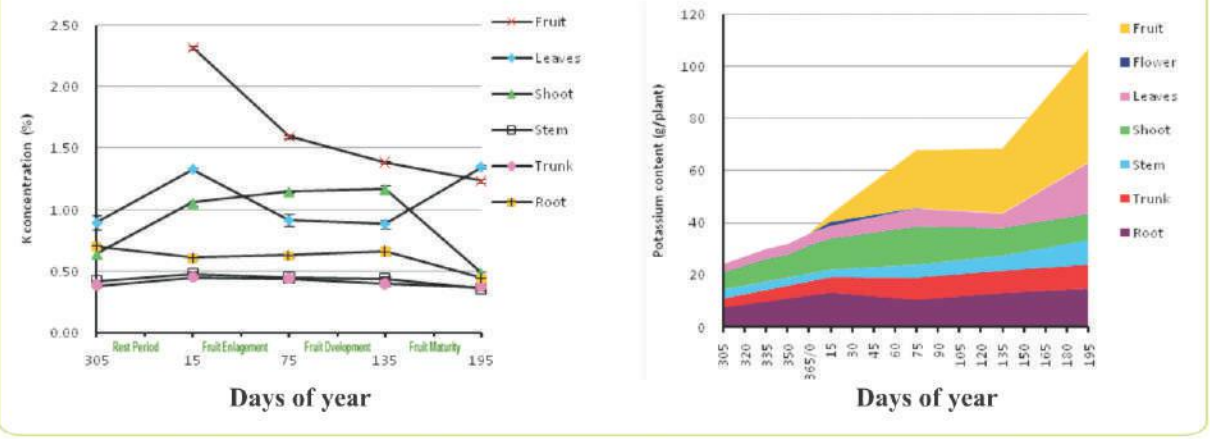
Like N, higher P concentrations were recorded in fruits and leaves while lower P concentrations were noted in stem and trunk throughout the fruit growth period. Phosphorus concentration was highest in fruits at bloom and declined sharply during fruit enlargement stage then gradually during maturity stage. Decreasing trend of P concentration was noticed in leaves with highest concentration observed during rest period and lowest concentrations at 120 DAFB i.e. end of fruit development stage. It was also observed that P concentrations in all organs except fruits got elevated during fruit enlargement stage (0-60 DAFB).

Unlike N, phosphorus content decreased from rest period to bloom and then increased during fruit enlargement stage, remained constant during development stage and again increased sharply during maturity stage. Majority uptake of P took place during fruit maturity stage (47.18% of the total) followed by that occurred during rest period to bloom (26.46% of the total) and fruit enlargement stage (25.67% of the total). Phosphorus uptake rate during fruit maturity stage was almost 1.4 times of that recorded during fruit enlargement stage. Phosphorus content declined in shoots, stems, trunk and roots during rest period to bloom, while its content in leaves remained constant. After bloom, P content increased in fruits, leaves, shoots and trunk while it continued to decrease in roots during fruit enlargement stage. Very little changes in P content were noticed in leaves (decreased) and roots (increased) during fruit development stage. During maturity stage P content increased in all parts except in trunk. At harvest, highest P content was recorded in fruits (3.33 kg P ha^{-1}) followed by in roots (2.52 kg P ha^{-1}), while total P content of fully grown plant was found to be 11.07 kg P ha^{-1}.

Potassium

At bloom higher potassium (K) concentration was found in fruits and lower K concentration was recorded in stem and trunk. Potassium concentration in fruits declined sharply during fruit enlargement stage followed by more gradual decrease during development and maturity stages, while leaves K concentration remained almost constant up to development stage and then increased during maturity stage. In shoots, K concentration increased up to fruit development stage (120 DAFB) followed by sharp decline during maturity. There was not much change in woody tissues (stems, trunk and roots) K concentration with time of season.

Potassium content in plant followed similar pattern as that observed with N content throughout the growing season. Here, also highest amount of K (40.61% of the total) was taken up during rest period to bloom and it was followed by that took place during fruit maturity (35.78% of the total) and fruit enlargement (23.60% of the total) stages. Uptake rate of K was found to be higher during fruit maturity stage than fruit enlargement stage. Negligible uptake of K took place during fruit development stage. Potassium content in roots, trunk and shoots increased while it decreased in stems and remained constant in leaves during rest period to bloom. After bloom, K content increased in fruits, leaves and shoots while it decreased in roots up to fruit enlargement stage.

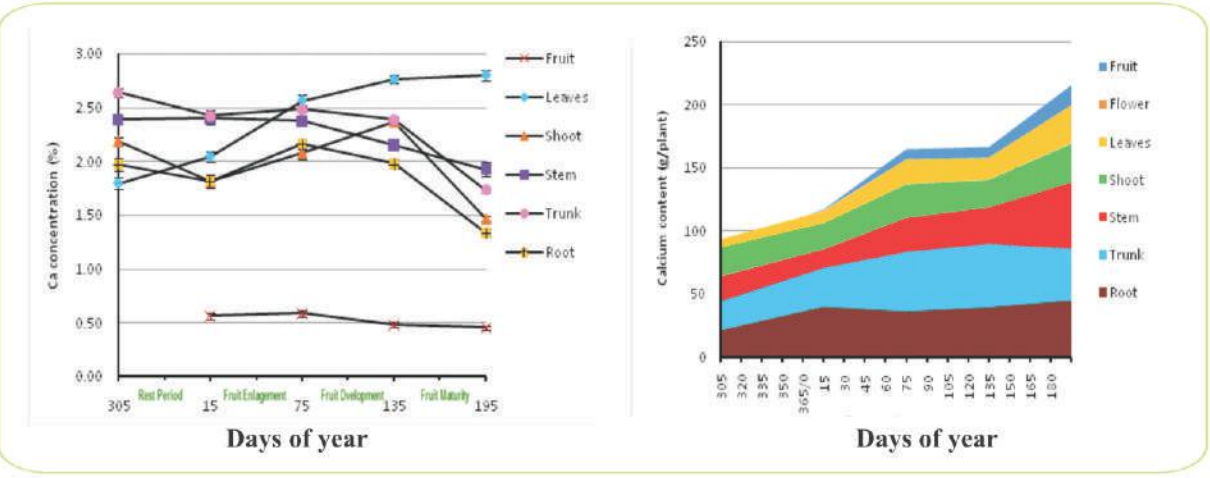


Seasonal change in concentrations and contents of potassium in various organs of mature pomegranate plant

The K content in different plant parts remained almost constant up to 120 DAFB and then again increased during fruit maturity stage. Enhancement of K content in fruits and leaves were predominant during this stage. At harvest highest amount of K was confound in fruits followed by in leaves. The total K content of full grown plant was 78.97 kg ha^{-1} which closely followed the N content of plant.

Calcium

Calcium was the most concentrated nutrient in stem and trunk at bloom. Its concentration in shoot and leaves significantly increased from bloom to fruit development stage, and then declined sharply during maturity, while fruit Ca concentration declined gradually until the end of the season. Unlike N, P and K, higher Ca concentrations were recorded in woody tissue (stem and trunk) and lower concentration was found in fruits.



Seasonal change in concentrations and contents of calcium in various organs of mature pomegranate plant

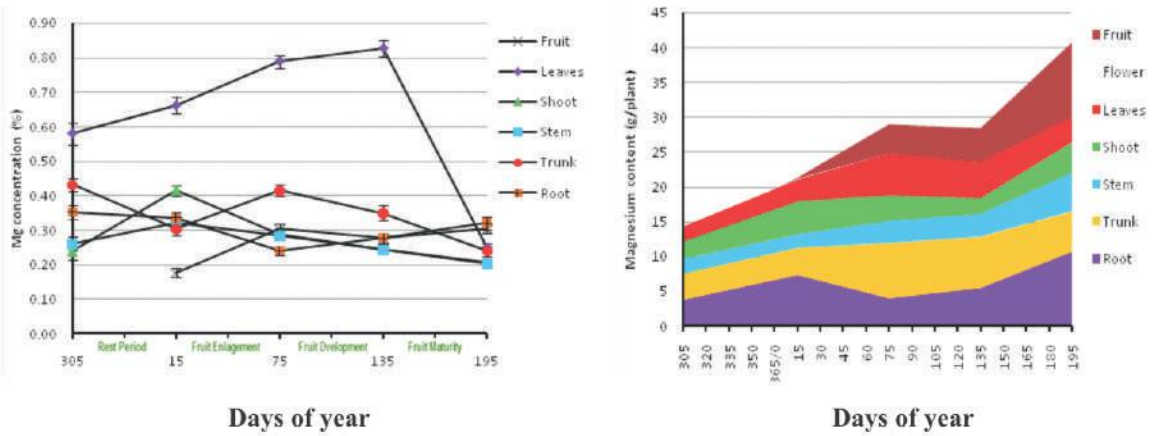
Like N and K, calcium content of plant increased slowly during rest period to bloom and then rapidly during fruit enlargement stage, remained stable during fruit development stage and then again increased slowly during maturity stage. Majority Ca uptake occurred during rest period to bloom (61.10% of the total) and rest of the uptake took place during fruit enlargement (24.95% of the total) and fruit maturity stages (13.04% of the total). Highest Ca uptake rate was recorded during fruit enlargement stage which was followed by that during fruit maturity stage. Calcium content increased in leaves, trunk and more prominently in roots and decreased in stem during rest period to bloom. After bloom it increased in all plant parts except roots where it remained constant during fruit enlargement stage. Contents of Ca were much higher in woody tissues, particularly in trunk and stem than in leaves and fruits. It again increased in stem, shoots and fruits and decreased in leaves and trunks during maturity stage. Unlike, N, P and K, higher Ca contents were recorded in stems (38.82 kg ha^{-1}), roots (33.21 kg ha^{-1}) and trunk (30.69 kg ha^{-1}) than fruits, the eatable part (11.78 kg ha^{-1}) at harvest. The total amount of Ca content recorded in full grown plant was 141.91 kg ha^{-1} which was much higher than primary nutrients like N and K content recorded in this study.

Magnesium

Magnesium concentrations was higher and most dynamic in leaves, whereas its concentrations in other plant parts viz. shoots, stem, trunk and roots were much lower and showed little changes throughout the growing season. Like Ca, magnesium concentration in leaves increased up to fruit development stage and then declined sharply towards maturity. While its concentration in fruits increased during initial growth period (i.e. up to 60 DAFB) and then remained almost constant during development and maturity stages. However, in shoot Mg concentration increased up to bloom and then continued to decline throughout the fruit growth period.

Magnesium content in plant increased from rest period to the end of fruit enlargement stage (60 DAFB), remained constant during fruit development stage and then again increased during fruit maturity stage. More than half of the Mg uptake occurred during rest period to bloom and rest of the uptake took place during fruit maturity (28.57% of the total) and fruit enlargement stage (18.62% of the total). Among the three fruit growth stages, Mg uptake rate was highest during fruit maturity stage followed by that during fruit enlargement stage. During rest period to bloom, Mg content increased in leaves, shoots and roots and decreased in stem. After bloom, it increased in fruits, leaves, stems and trunk while decreased in roots during fruit enlargement stage. Subsequently, Mg content increased in roots and fruits, while decreased in trunk, shoot and leave and thus maintained a stable Mg content in plant during fruit

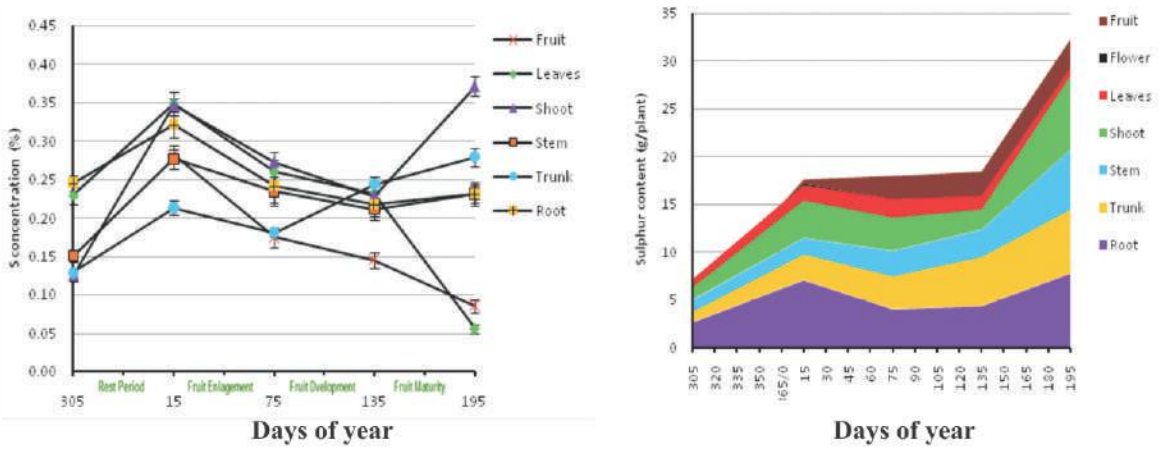
increased in all plant parts, more prominently in fruits except in leaves and trunk during fruit maturity stage. Significantly higher Mg contents were recorded in fruits (7.92 kg ha^{-1}) and roots (7.97 kg ha^{-1}) at harvest sharing more than half of the Mg content of plant. The total Mg content of a full grown plant was 30.15 kg ha^{-1} at harvest. and fruits, while decreased in trunk, shoot and leave and thus maintained a stable Mg content in plant during fruit development stage. Further, Mg content increased in all plant parts, more prominently in fruits except in leaves and trunk during fruit maturity stage. Significantly higher Mg contents were recorded in fruits (7.92 kg ha^{-1}) and roots (7.97 kg ha^{-1}) at harvest sharing more than half of the Mg content of plant. The total Mg content of a full grown plant was 30.15 kg ha^{-1} at harvest.



Seasonal change in concentrations and contents of magnesium in various organs of mature pomegranate plant

Sulphur

Sulphur concentrations in shoot and leaves were much higher than in fruits. Its concentration increased from rest period to bloom and then declined during fruit enlargement and development period and again increased in shoot while sharply decreased to very low level in leaves during maturity. Fruit S concentration initially dropped rapidly followed by more gradual decrease during fruit maturity. Sulphur concentrations in stem and roots increased during rest period and then declined gradually after bloom, while its concentration in trunk showed somewhat rising trend throughout the growth period.



Seasonal change in concentrations and contents of sulphur in variousorgans of mature pomegranate plant.

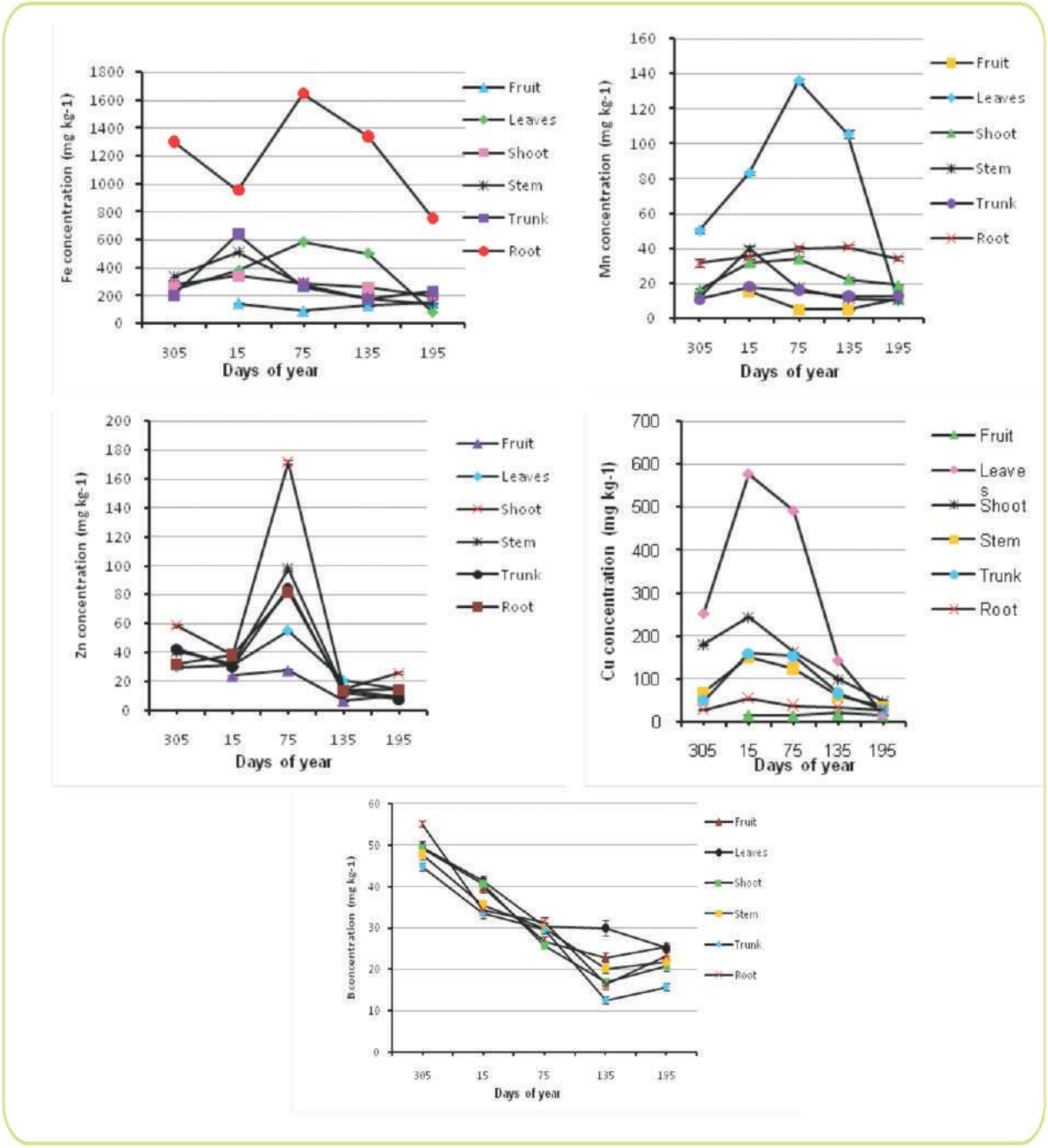
Unlike other macro-elements, S content of plant increased from rest period to bloom, remained almost constant during fruit enlargement and development stages and again increased during fruit maturity stage. Majority uptake of S occurred during rest period to bloom (54.93% of the total) and during fruit maturity stage (42.54% of the total). Sulphur uptake rate was found to be highest during fruit maturity stage. Sulphur content increased in all plant parts during rest period to bloom. After bloom it continued to increase in leaves, stem, trunk and fruits but decreased in roots and shoots during fruit enlargement stage. However, during fruit development stage S content increased in trunk and decreased in shoots while remained almost constant in other plant parts. Subsequently, it again increased in all plant parts except in leaves during fruit maturity stage. Unlike other macro-elements, majority S content was confound in shoots (5.75 kg ha^{-1}, equivalent to 24% of the total) and roots (5.75 kg ha^{-1}, equivalent to 24% of the total), while only 9.34% of S was found in fruits at harvest. Total S content of a fully grown plant at harvest was 23.96 kg ha^{-1}.

4.1.1.3. Seasonality of micronutrient concentration

The concentration of micronutrients (Fe, Mn, Zn, Cu and B) within various plant parts changed significantly over time. Iron concentration in fruit decreased during fruit enlargement stage and then gradually increased during rest of the fruit growth period. While in leaves it increased up to fruit enlargement stage and then continued to decrease during fruit development and maturity stage. Iron concentrations in stem and trunk increased during rest period to bloom and then declined throughout the fruit growth

period, while in roots it initially decreased and then increased during fruit enlargement stage followed by declining during rest of the fruit growth period. Highest Fe concentrations were recorded in roots while lowest Fe concentrations were noted in fruits throughout the growth period. Manganese concentration in fruits, leaves, shoots, stem and trunk followed similar trend as that of Fe. In contrast, Mn concentration in roots continued to increase from rest period to fruit development stage and then declined gradually during fruit maturity stage. Highest Mn concentrations were recorded in leaves while lowest concentrations were noted in fruits throughout the growth period. Unlike Fe and Mn, zinc concentration in fruits and leaves increased during fruit enlargement stage and then declined during fruit development stage followed by slight elevation in fruit and reduction in leaves during fruit maturity stage. Zinc concentrations in woody tissues viz. shoots, stem, trunk and roots also followed similar trend as that recorded in leaves. Highest Zn concentrations were found in shoots while lowest concentrations were recorded in fruits during the growth period. Copper concentration in fruit remained almost constant during fruit growth period while in other parts, it increased during rest period to bloom and then declined during fruit growth period. Like Mn, highest Cu concentrations were noted in leaves while lowest concentrations in fruits.

The studies on seasonal nutrient uptake and partitioning in mature pomegranate plants have shown that seasonal dynamic of nutrient content in pomegranate share a consistent pattern i.e. translocation of nutrients from woody tissues to actively growing organs was observed at the beginning of the season and movement of nutrients to woody tissues at maturity. Pomegranate takes up more of Ca than any other macro-elements. The uptake pattern follow the order of Ca>N>K>Mg>S>P, and micronutrient uptake pattern follow the order of Fe>Cu>B>Mn>Zn. Except P, majority uptake of macro-elements takes place during rest period to flowering. Beside this, other two windows i.e. 0-60 DAFB and 121-180 DAFB have been identified where considerable uptake of nutrients takes place. Unlike other micronutrients, boron concentrations in various plant parts decreased from bloom to fruit development stage and then increased slightly in all parts except leaves where it continued to decrease during fruit maturity stage. However, changes in the concentration of B in various plant parts did not show any clear differentiation. The fully grown plants were found to have highest content of Fe (3348.32 g ha^{-1}) followed by Cu (322.45 g ha^{-1}), B (255.75 g ha^{-1}), Mn (198.76 g ha^{-1}) and Zn (149.42 g ha^{-1}) at harvest.



Seasonal change in concentrations of micronutrients (Fe, Mn, Zn, Cu and B) in various organs of mature pomegranate plant

(Days of Year: Stage of Crop= 305 to15:Rest Period; 15-75: Fruit Enlargement; 75-135:Fruit development; 135-195: Fruit Maturity)

4.2. Water management

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

The experiment was conducted to compare the performance of various irrigation methods with sub-surface drip irrigation (SDI) system and to evaluate its effect on the growth performance of 5th year pomegranate orchard. Six treatments were replicated four times in RBD during 2017-2018. Various micro-irrigation treatments promoted 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 at 30*30 cm followed by double laterals at 40*40 cm, 50*50 cm, drip irrigation(DI) with double laterals (4Drippers), SDI with single laterals at 30 cm depth) and DI with single lateral (2D). Soil moisture holding capacity was also higher in the SDI with double laterals (30*30 cm). Root distribution pattern wasalso recorded.

SDI at 30 cm x30 cm spacing

Ring type DI with six drippers

Plant canopy

An experiment with 3 main treatments and 6 sub-treatments on lateral geometry in split plot design was conducted to find out its effect on five year old pomegranate orchard during 2017-18. The seasonal values of water requirement to be applied to pomegranate tree ranged from 1281.25 to 2989.30 liters/year/tree for 5 year pomegranate tree. The 0.50*ETr is the best treatment having double laterals with 4 drippers followed by ring type and single lateral (2D) and maximum plant height, flowers, branches and stem diameter was recorded at 0.50*ETr. Monthly shaded area (m^2), wetted area (%), total area leaves (m^2) and leaf area index at solar noon hours were recorded and shown below in the table.

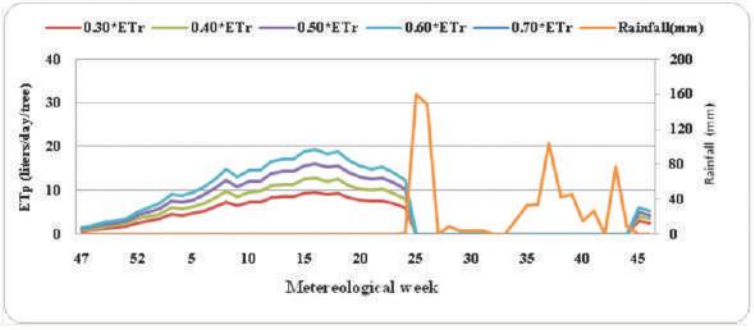
Cumulative growth performance, water use and root distribution pattern in various micro-irrigation methods (Dec, 2017 – Mar, 2018)

Treatments	Water use (litre/ tree/season)	Plant height (cm)	Plant spread (cm)		Stem dia. (cm)	RDP LHS (g)	RDP RHS (g)	Flowers (Nos.)
			EW	SE				
SDI Single lateral (30 cm)	1493	128	112	115	2.3	463.53	82.11	139
SDI Double laterals (30*30 cm)	2986	138	125	130	3.2	508.85	469.72	166
SDI Double laterals (40*40 cm)	4479	136	130	132	2.5	484.78	440.40	147
SDI Double laterals (50*50 cm)	4972	135	124	120	2.9	444.05	381.25	141
DI with single lateral (2D)	3313	126	115	113	2.4	384.71	85.21	128
DI with double laterals (4D)	5627	130	130	125	2.7	337.54	342.88	143

Cumulative growth performance in lateral geometry experiment (Dec, 2017 to Mar, 2018)

Treatments (0.20 to 0.70 * ETr)	Plant height (cm)	Plant spread (cm)		Stem diameter (cm)	Stem girth (cm)	Flowers (Nos.)
		EW	SE			
Single lateral (2D)	130	130	120	2.8	3.2	130
Double laterals (4D)	142	140	132	4.2	3.6	155
Ring type (6D)	132	120	115	3.1	2.9	140

(Plant spacing- 4.5 x 2 m)



Pomegranate evapotranspiration, ET_p (litre/day/tree) at various irrigation levels

Monthly shaded area, wetted area and leaf area index

Months	APP(m^2)	SA (m^2)	WA (%)	TA (m^2)	LAI_{SN}
December 2017	9.0	1.65	28.30	6.60	3.25
January 2018	9.0	1.95	30.20	7.65	3.45
February 2018	9.0	2.10	32.26	7.70	3.56
March 2018	9.0	2.45	31.22	7.90	3.88

(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))
(Plant Spacing-4.5 x 2 m)

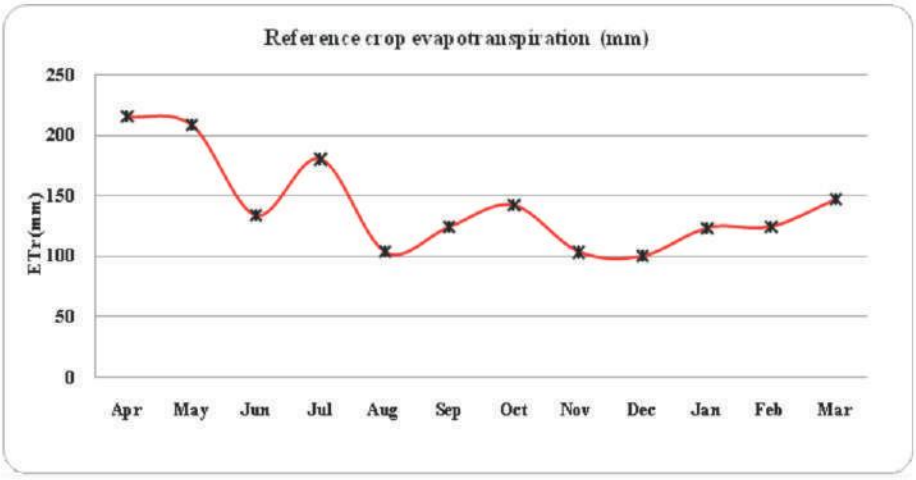
4.2.2. Effect of mulches and irrigation level on yield, quality and WUE of pomegranate

Climatic Parameters at Experimental site

The daily climatic parameters concerned with estimation of ETr, are recorded.

Estimation of Reference Crop Evapotranspiration (ETr, mm)

Reference crop evapotranspiration (ETr, mm) wasused to describe the atmospheric "demand" for water. The daily climatic data for the period of Dec, 2017 to Mar, 2018 were used to determine daily, weekly and monthly reference crop evapotranspiration (ETr) by using Penman-Monteith Method. Figure below shows the trend of variation of average ETr values over the year. The yearly reference crop evapotranspiration (ETr) obtained is 1711.89 mm. The ETr was maximum in May (19-21 SMW) and minimum in December (49-52 SMW). The monthly minimum and maximum ETr ranged from 100.37 to 215.96 mm.



Monthly ET_r (mm) values from April, 2017 to March, 2018 at experimental site

Development of wetted area(WA) and crop coefficient (Kc) values

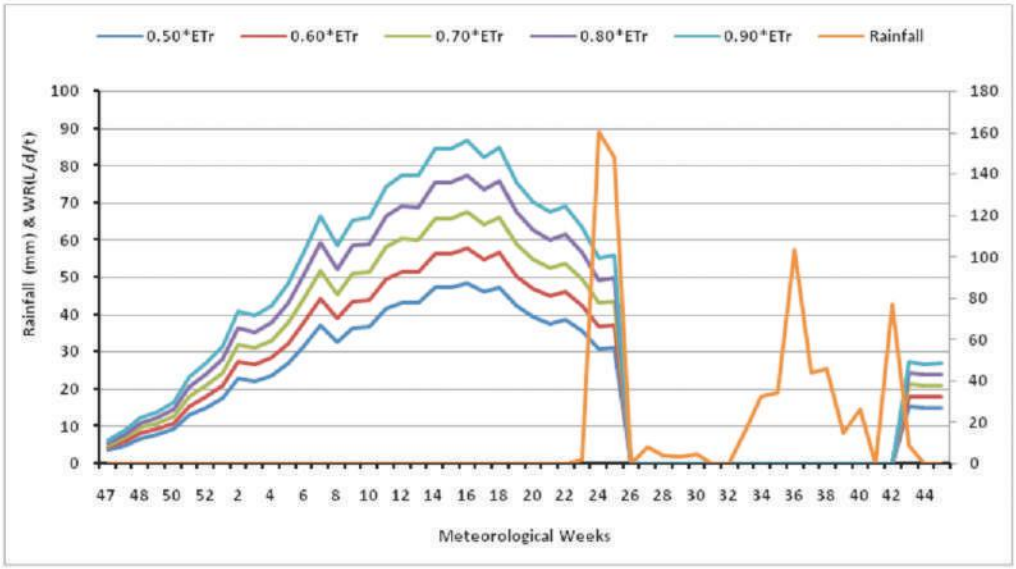
Wetted area and crop coefficients are needed to estimate pomegranate evapotranspiration (ETp) with reference crop evapotranspiration (ETr). Stage-wise crop coefficient values were computed and converted on weekly basis. The stage-wise wetted area and crop coefficient values for pomegranate tree in 6 year plants are presented in the table below. Table shows that the values of wetted area increases from 0.45 to 0.60 and crop coefficient from 0.32 to 0.95 from new leaf inititation to maturity, due to increased number of leaves, foliage, water sprout, flowers and fruits of the tree during 6th year. The WA and Kc values increases linearly from new leaf initiation to maturity phase due to increases in number of leaves, water sprout, luxors, flowers, fruits and shaded area as observed from the representative trees and decreases from maturity to harvesting phase due to removing of water sprout and leaf drop.

Wetted area and Crop coefficient values for 6th year pomegranate tree

Plant Stage	Phenophase Indicators	Period	Wetted area	Crop coefficient
I. New leaf Initiation	Start of new leaves to 10% ground cover	25 days from first irrigation	0.45	0.32
II. Development	10% ground cover to effective full cover, about 60-70% coverage crops	65 days after stage I	0.50	0.75
III. Maturity	Effective full cover to maturity, indicated by yellowing of leaves, leaf drop and browning of fruit	85 days after stage II	0.55	0.95
IV. Harvesting	Maturity to harvest indicated ripe fruits start falling on the ground	65 days after stage III	0.60	0.85

Estimation of pomegranate Evapotranspiration (ETp, litres/day/tree)

The daily water to be applied through drip irrigation system at 90 % efficiency from December, 2017 to March, 2018 ranged from 10–50 litres/day/tree for 6 year old pomegranate tree at 0.70*ETr. It gradually increased or decreased during different development stages of pomegranate tree due to the variation of reference crop evapotranspiration, pan coefficient, wetted area and crop coefficient values. The four months pomegranate evapotranspiration are 9657 litres/tree/season and water to be applied to pomegranate tree ranged from 980 to 1763 liters/month/tree based on different irrigation levels from 0.50 to 0.90*ETr. The critical stage wise water requirement for pomegranate Bhagwa cv. (i.e. new leaf initiation, crop development and maturity) have been worked out and tabulated.



Pomegranate evapotranspiration (liters/day/tree) of 6 year old tree

Critical pomegranate plant stages for irrigation in Hasta Bahar

S. No.	Critical stage for Irrigation	Nos. of days	WR (lit. stage^{-1}tree^{-1})
1	New leaf initiation	22-25	154-275
2	Crop development (Flowering-fruit Setting)	70-80	1500-2200
3	Mid (Fruit development)	60-70	1800-2400

Pomegranate evapotranspiration for inorganic and organic mulches (ETp, litres/day/tree)

An experiment with different organic (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. Various mulching treatments promoted plant growth, reduced moisture evaporation loss and also regulated soil temperature. Depletion of soil moisture was very high in untreated plants. Maximum number of fruits was recorded in sugarcane and pervious mulches at 0.70*ETr, followed by safflower. Wheat mulch and black inorganic mulches. Soil moisture retention was also high under black mulch treated plants. Development of wetted area(WA) and crop coefficient (Kc) values.

Organic mulch

Inorganic mulch

Growth performance of six year old pomegranate plants under different mulches

Mulch	Plant height (cm)	Plant spread (cm)		Stem diameter (cm)	Stem girth (cm)	Thorn length (cm)	Bisexual flower (No.)	Fruits/plant (No.)
		EW	SE					
Organic mulch (0.40 to 0.80*ET_r)								
Wheat	130	130	120	3.8	3.1	3.0	160	50
Safflower	140	132	142	4.1	3.3	3.8	185	65
Sugarcane baggas	156	149	142	4.9	3.5	4.2	235	89
Control	142	135	138	4.6	2.9	4.0	195	57
Inorganic mulch (0.40 to 0.80*ET_r)								
Black and White	132	156	136	3.9	3.2	2.9	196	49
Black	154	166	144	4.1	3.5	3.3	160	60
Pervious	173	178	142	4.7	3.8	4.0	252	65
Control	144	150	140	4.4	3.9	4.3	158	56

4.3 Crop Management

4.3.1 Evaluation of pomegranate under different training systems

Evaluation of pomegranate cv. Bhagwa under different training systemsviz., single, double, triple, four, five stem and more than five stems/plant during firth year of planting revealed that the fruitset ranged from 45.6 to 58.6%. Fruitset percent was highest under single stem training system (58.6%).The yield was highest in four stem training system (18.1 kg/plant).

Evaluation of pomegranate under different training systems

Training system (Stem/plant)	Total bisexual flowers (No./plant)	Total fruits (No. /plant)	Fruit set (%)	Axillary flowers (No./plant)	Axillary flowering (%)	Fruit yield (kg/plant)
1 Stem	101.5	59.5	58.6	60.5	59.6	14.8
2 Stem	121.3	68.0	56.0	66.5	54.8	16.6
3 Stem	137.0	74.3	54.1	70.0	51.0	17.7
4 Stem	143.3	76.5	53.4	71.2	49.7	18.1
5 Stem	149.5	72.5	48.4	67.2	44.9	16.3
>5Stem (Control)	154.0	70.3	45.6	63.5	41.2	14.7

Single stem

Double stem

Triple stem

Four stem

Five stem

>5 stem (Control)

Evaluation of pomegranate under different training systems

5. CROP PROTECTION

Project : Development and refinement of integrated crop protection technologies for improved productivity of pomegranate

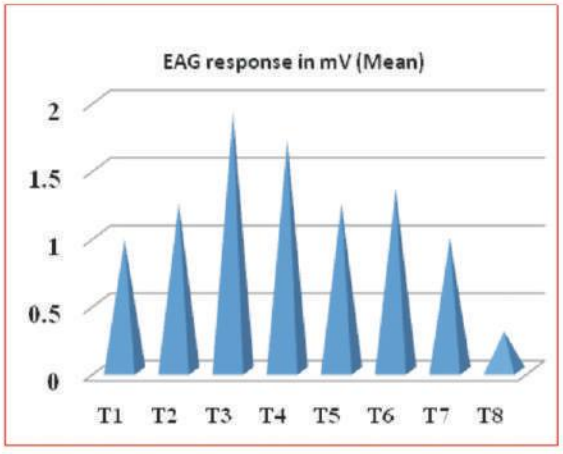
5.1. Insect pests

5.1.1 Survey of borer and sucking pest of pomegranate

Survey was conducted in eight different taluks of Solapur District in 53.4 ha area, to record the incidence and infestation by various borer and sucking pests on pomegranate. Infestation of thrips varied from to 1.90-70.34 %, aphids 2-8%, whiteflies and mealy bugs 1.2- 4.7 %, fruit borer incidence varied from 12-15 % and shot hole borer and stem borer incidence varied from 1.15-2%.

5.1.2 *In vitro* evaluation of sex pheromone compounds against fruit sucking moth

Nine sex pheromone compounds identified and procured were tested for individual response to 5 male moths (Antennae) both for Electro-antennography (EAG) and wind tunnel bioassay. Among the 9 pheromone, the compounds which showed good response and repetitive behavioral orientation of the male moths towards the source of attraction were further tested in different ratios to have improved response. Among the 6 different ratio treatments, the treatments T3 and T4 were found promising compared to control and standard.



T1	Z-9-23H: E-9-23H: Z-9-25H: E-9-25H (100:50:100:75)
T2	Z-9-23H: E-9-23H: Z-9-25H: E-925H (100:30:100:30)
T3*	Z-9-23H: E-9-23H: Z-9-25H: E-9-25H:1-12C:1-16C (100:50:100:75:100:100)
T4*	Z-9-23H: E-9-23H: Z-9-25H: E-9-25H:1-12C:1-16C (100:30:100:75:100:100)
T5	Z-9-23H:Z-9-25H (100:100)
T6	Z-9-23H:E-9-23H:Z-9-25H (100:100)
T7	Hexane (Control)
T8	Honey (Standard)

* Z-9-23H–Z-9-Tricosene; Z-9-25H–Z-9- Pentacosene; E-9-23H–E-9-Tricosene; E-9-25H–E-9- Pentacosene; 1-12C– 1- Dodecene; 1-16C – 1- Hexadecene

EAG responses of male FSM antenna to different ratio of pheromone compounds

5.1.3. Population dynamics of insect pests in relation to weather conditions

Population dynamics of insect pests was studied in relation to weather conditions on cv. Ganesh and Bhagwa. Fruit borer population showed positive correlation with temperature, rainfall (0.82) and negative correlation with relative humidity (-0.61). Thrips showed negative correlation with rainfall and positive correlation with RH and Temperature. Mealybugs showed positive correlation with temperature and relative humidity (0.78).

5.1.4. Evaluation of six combi- insecticide formulation against borer and sucking pests

Among the six products evaluated against the borer and sucking pests of pomegranate the treatment T5 (Chlorantraniliprole 8.80 %+Thiamethoxam 17.5%) provided the best control of thrips with 53.04 % over control followed by T6 (52.52%),T2 (50.51%), T1(50.17%) and least reduction over the control was observed in T3 (48.89%) and T4 (41.89%). The incidence of the fruit borer and other sucking pest of pomegranate was too low during the experimental period hence could not be evaluated.

Formulations tested against borer and sucking pests

S. No.	Formulation	Dose (ml/l) *
1	Chlorpyriphos 16% +Alphacypermethrin 1% EC	0.75
2	Profenophos 40%+Cypermehtrin 4% EC	0.75
3	Thiamethoxam 12.6% +Lambda cyhalothrin 9.5 % ZC	0.75
4	Lambda cyhalothrin 4.6 %+Chlorantraniliprole 9.3%	0.75
5	Chlorantraniliprole 8.80 %+Thiamethoxam 17.5%	0.75
6	Chlorpyriphos 50% +Alphacypermethrin 5% EC	0.75
7	Control	0.75

* along with spreader sticker @ 0.25 ml/l

5.1.5.Evaluation of bio-efficacy of new insecticide molecules against pest complex in pomegranate

Among the 4 insecticides and two different doses of Cyantroniliprole 10.26 % OD and Lambda cyhalothrin5% EC evaluated against borer and sucking pests of pomegranate the Treatment T2 provide the best control of thrips with 60.67 % over the control followed by T4 (58.21%) and least reduction over the control was observed in T6 (50.32%) and T5 (50.40%). The incidence of the fruit borer and other sucking pest of pomegranate observed was too low during the experimental period for satisfactory evaluation.

Formulationstested against thrips and fruit borer

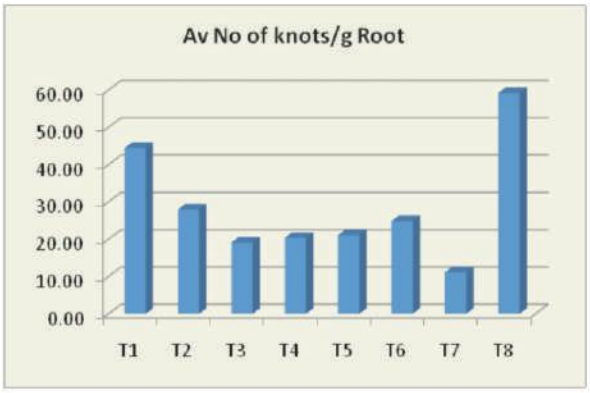
T. No.	Treatments details	Dose (ml/l)*
T-1	Cyantroniliprole 10.26 % OD	0.20
T-2	Cyantroniliprole 10.26 % OD	0.30
T-3	Lambda cyhalothrin 5% EC	0.50
T-4	Lambda cyhalothrin 5% EC	1.00
T-5	Fipronil5% SC	1.00
T-6	Spinosad 45% SC	0.25
T-7	Control	Water

* along with spreader sticker @ 0.25 ml/l

5.2. Wilt Management

5.2.1. Nematode wilt

Seven formulations were tested for nematode wilt. In all 4 applications were made at monthly intervals. Carbolic acid formulation Suzaan® was most promising with 11.11 knots/g root in comparison to control with average 59.23knots/g root. Formulations having *Aspergillus niger*-Kalisena® SA, VAM Fungi- Josh Super®, *Trichoderma harzianum* and fipronil were also promising with more than 50% reduction in knots in comparison to control.



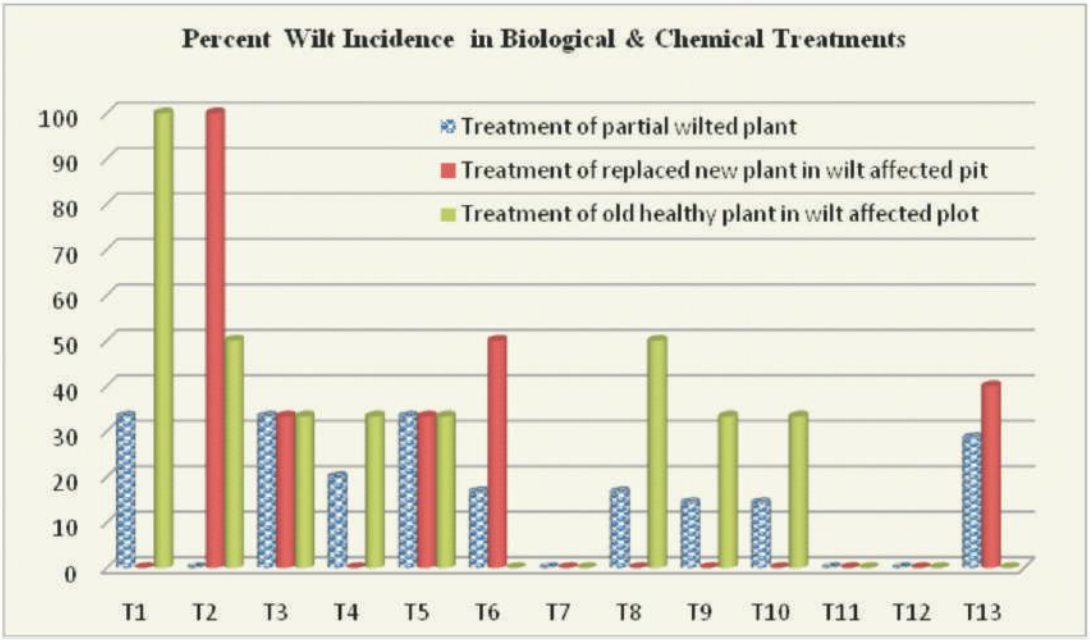
T1: ASOP Prophite® @4 g/l
T2: *T. harzianum*@ 10g/plant
T3: *A.niger* Kalisena® @ 10g/plant
T4: VAM fungi Josh Super® @10g/plant
T5: T4+T5
T6: Fipronil 0.36 @30g/plant
T7: Thiocarbonic Acid Suzaan® @2ml/l
T8: Control

Effect of various formulations on nematode control

5.2.2. Ceratocystis wilt

In vitro efficacy of 10 fungicides was evaluated using poisoned food technique against C. fimbriata. All inhibited C. fimbriata growth above 50% but carbendazim, propineb, metalaxyl, difenconazole, hexaconazole, propiconazole and tebuconazole completely inhibited in vitro growth of the wilt pathogen. Formulations evaluated in pot culture trials for Ceratocytis fimbriata wilt revealed that bioformulations based on Aspergillus niger and Trichoderma were effective as preventive and Chemical formulations like propiconazole, tebuconazole, fosetyl-Aluminium were effective as preventive as well as curative treatments.

In field evaluation of different chemical and bio-formulations, treatments were given to (i) partial wilted plants, (ii) replaced new plants in wilt affected pits and (iii) old healthy plants in wilt affected pits. Bioformulations were promising as preventive where as chemical treatments with propiconazole, Fosetyl-Al + Tebuconazole checked wilt 100% both as preventive and therapeutic treatments. It was also observed that in wilt affected plants treatment T12 with first treatment of chemical propiconazole followed after a month with biological treatments of Aspergillus niger Kalisena® and Aspergillus niger Kalisena® checked wilt completely as no plant wilted in 9 months of observations.



Effect of different biological and chemical control treatments in management of *Ceratocystis* wilt

T1-*Aspergillus niger* Kalisena® @ 5g/plant with 2 kg FYM/plant
(2 applications, 1 month interval)
T2- AMF Josh Super® @ 25g/plant with 2kg FYM/plant (2 applications, 1 month interval)
T3- T1+T2
T4- *Trichoderma spp.* (UHS Bagalkot) @ 100g/plant with 2kg FYM/plant
(2 applications 1 month interval)
T5-FE-8 (Fungal endophyte *Trichoderma sp.*) 3 plates culture with 2kg FYM/plant
(2 applications 1 month interval)
T6- *Penicillium pinophilum* @ 100g/plant with 2kg FYM/plant
(2 applications 1 month interval)
T7- Tilt (Propiconazole 25%) @2ml/l+Chlorpyriphos @ 2ml
(3 drenching at 20 days interval)
T8- Bavistin (Carbendazim 50%WP) @2g/l+Chlorpyriphos @ 2ml
(3 drenching at 20 days interval)
T9- [Tilt @2ml/l+Chlorpyriphos @ 2ml (5l solution)] + [Bavistin @2g (5l solution)]
(3 drenching at 20 days interval)
T10-[1st drenching TILT (Propiconazole 25%) @2ml/l+Chlorpyriphos @ 2ml (10l solution)] [2nd drenching Bavistin (Carbendazim 50%WP) @2g/l+Chlorpyriphos @ 2ml (10l solution)] [1st drenching Tilt @2ml/l+Chlorpyriphos @ 2ml (10l solution)] (20 days interval)
T11-[1st drenching Fosetyl Al 80% WP @6gm/plant (10l solution)] [2nd drenching (Tebuconazole 25.9% w/w EC) @3ml/plant (10 l solution)] [3rd Fosetyl Al 80% WP @6gm/plant (10 l solution)] [4th drenching Folicur @3ml/plant (10l solution)] (20 days interval)
T12-[(1st drenching Tilt @2ml/l+Chlorpyriphos @ 2ml (10l solution). After 30 days of first application 2nd drenching Kalisena @ 5gm/plant with 2kg FYM/plant after 30 days of 2nd application -Josh @ 25g/plant with 2kg FYM/plant
T13- Untreated Control

5.3. Fruit spots and Rot

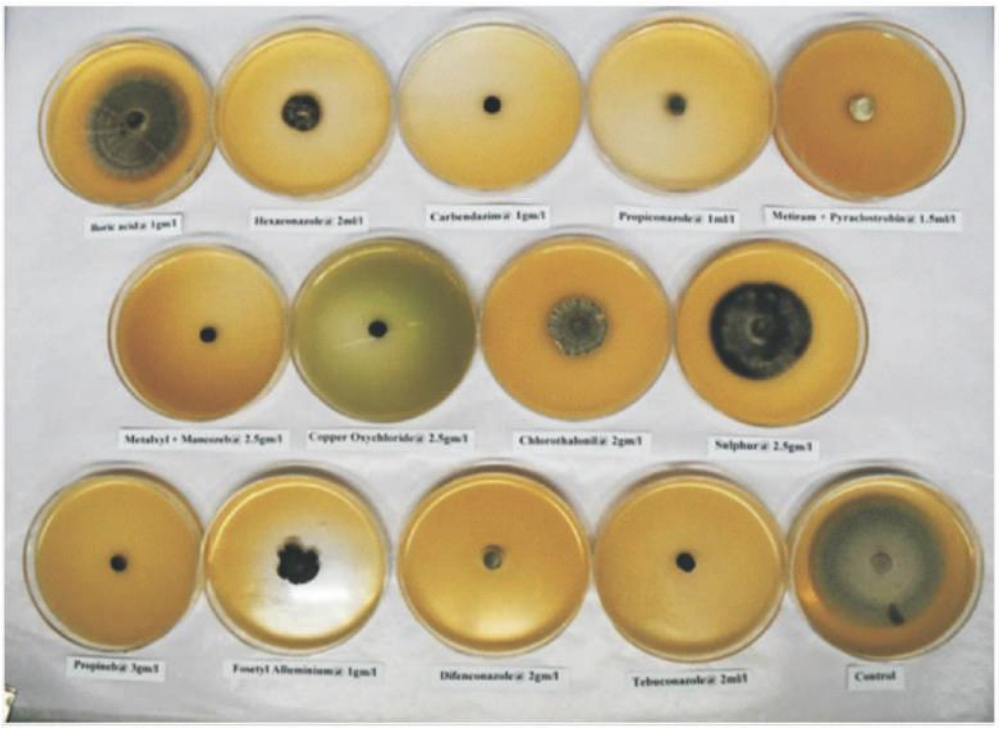
5.3.1. *Rhizoctonia* diseases in pomegranate

A new fungal spot on pomegranate fruits caused by *Rhizoctonia sp.* has been identified. The fruit samples having symptoms of greenish white spreading patches with necrotic patches in later stage were found associated with fungus *Rhizoctonia* based on Koch's postulates.

In addition to this *Rhizoctonia sp.* was found to be associated with fruit, root and stem rots. In all 6 *Rhizoctonia* isolates (RH-1 to RH-6) have been collected during the year from Solan (HP), and different districts of Maharashtra. The incidence and prevalence was extremely low.

***Rhizoctonia* fruit spot**

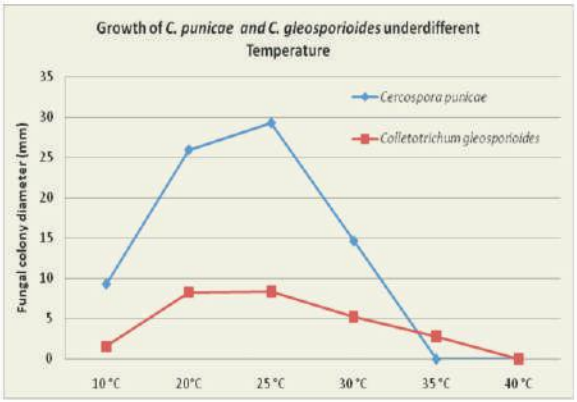
In order to find effective chemicals against *Rhizoctonia* among 13 chemicals tested, carbendazim, propineb, metalaxyl, difenconazole, hexaconazole, propiconazole and tebuconazole completed inhibited in vitro growth of fruit spot pathogen *Rhizoctonia sp.* in poisoned food technique.



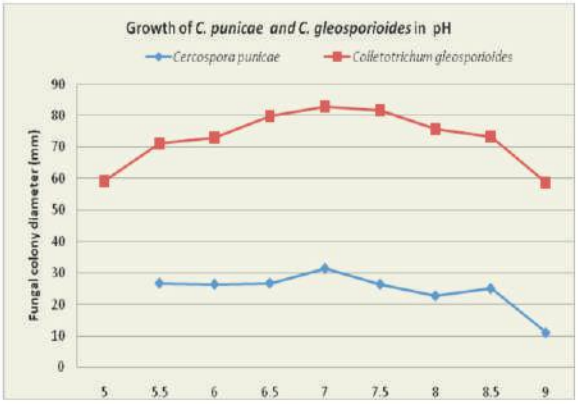
Effect of different chemicals on growth of *Rhizoctonia sp.*

5.3.2. Factors affecting growth of *Colletotrichum* and *Cercospora*

Fruit spots and rot caused by *Cercospora punicae* and *Colletotrichum gleosporioides* have been responsible for qualitative and quantitative losses during last few years hence efforts to identify environmental factors responsible for increased incidence need to be studied. In vitro studies were conducted with pure cultures. Growth of pure cultures of *Cercospora punicae* and *Colletotrichum gleosporioides* causing fruit spots and rots was recorded on PDA at different temperatures and pH. Temperatures of 25 ^{O}C was most congenial for the growth of both the fungi, however they recorded faster growth from 20-30 ^{O}C while no growth of *Cercospora* was observed at 35 ^{O}C and of *Colletotrichum* at growth at 40 ^{O}C. Both the fungi *C. punicae* and *C. gleosporioides* were able to grow at all pH tested 5 to 8.5, but pH of 7 was optimum for both though pH 5.5 to 7.5 was favourable for growth of both the fungi.



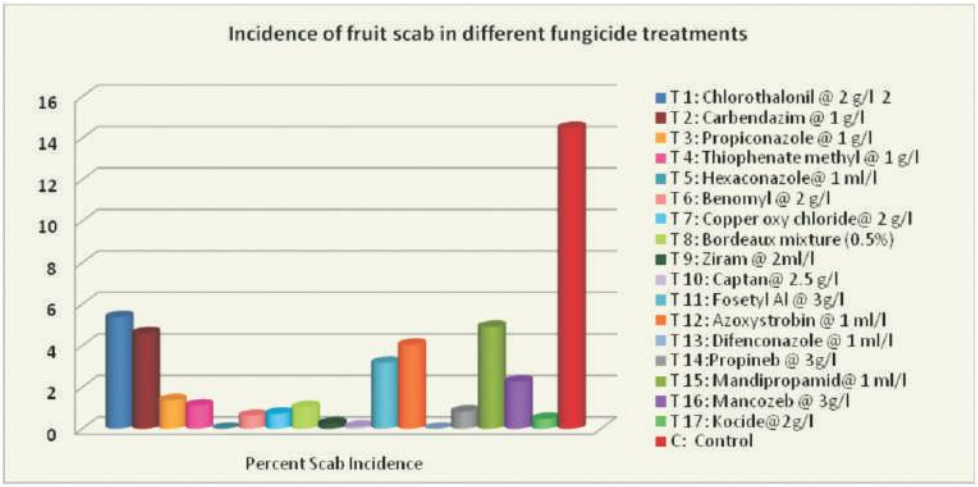
Effect of different Temperatures on Growth of *C. punicae* and *C. gleosporioides*



Effect of pH on Growth of *Cercospora punicae* and *Colletotrichum gleosporioides*

5.3.3. Management of fungal fruit spots

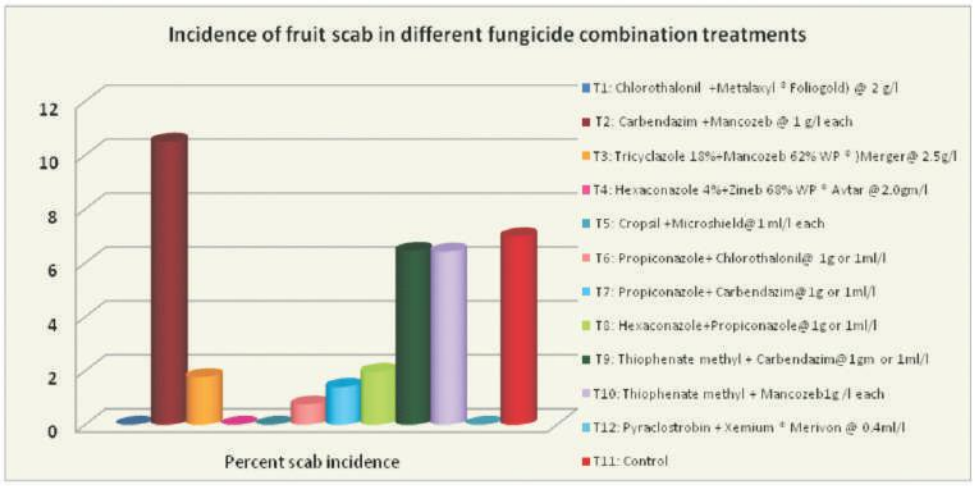
In a field trial out of 17 fungicides tested against various fruit spots and rots, systemic fungicides Hexconazole and Difenconazole were most effective in completely checking fruit scab incidence. Fungicides propiconazole, thiophanate methyl, benomyl, ziram, propineb, copper fungicides -copper hydroxide, copper oxy chloride and Bordeaux mixture reduced scab between 90-98%. All other fungicides were also effective with 61-84% control. The other fungal disease incidence was too low in control hence, could not be evaluated.



Effect of fungicide sprays on control of fruit scab

5.3.4. Combi-products in fungal disease management

In a field trial 10 combi-product fungicides were tested for management of various fungal spots and rots. Combi-products chlorothalonil + metalaxyl, mexaconazole 4%+zineb 68% WP, cropsil +microshield and pyraclostrobin + xemium recorded no incidence of scab, however incidence in control was only 6.99%, which is too low for evaluation.



Effect of fungicide combinations on control of fruit scab

5.3.5. Molecular diversity in *Colletotrichum gloeosporioides* and *Cercospora punicae*

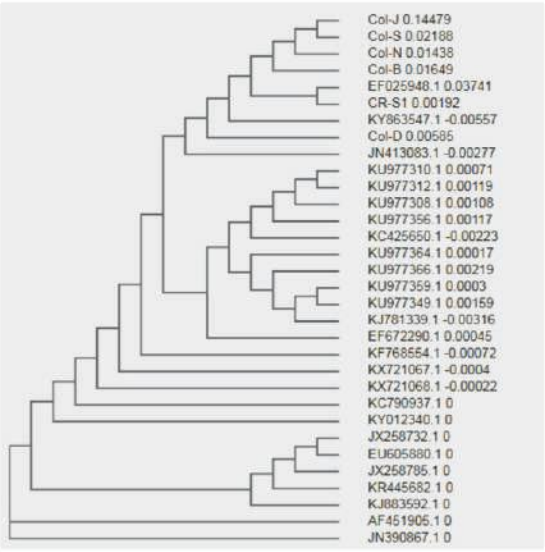
Molecular confirmation of fungal pathogens *Colletotrichum gloeosporioides* and *Cercospora punicae* culture was done using Internal Transcribed Spacer (ITS) primers from two different sources

A multiple-sequence alignment were performed with similar reference sequences of other *Colletotrichum* and *Cercospora* isolates available in the GenBank database using CLUSTAL X and a BLAST similarity test were performed. This study indicated that no diverse groups existed in *C. gloeosporioides* and *Cercospora punicae* populations associated respectively with fruit rot and fruit spot on pomegranate grown in different states and districts.

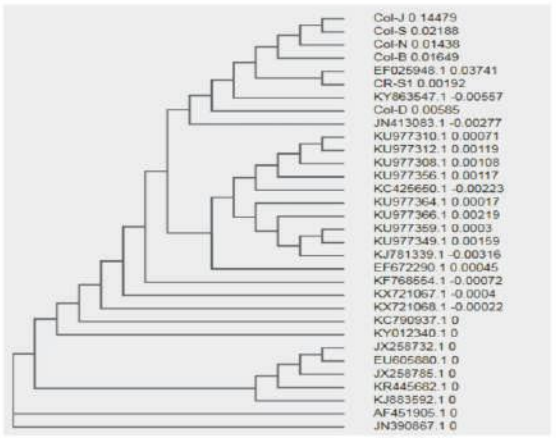
Based on phylogentic trees generated using sequences of ITS 1and ITS 2 regions, two clusters were evident that corresponded to the two subgroups previously identified by morphological and restriction digestion patterns of ITS region in *C. gloeosporioides* where as in *Cercospora*, all the isolate were clustered in one group. The results of the present study show that, *C. gloeosporioides* and *Cercospora* isolates from pomegranate and same geographical locations of Solapur district, there is no considerable variation in restriction digestion patterns and sequencing of ITS region of r- DNA and phylogenetic analysis, which mostly correlated with morphological groups based on different colony and conidia characteristics.

Isolates of Colletotrichumgleosporioides causing fruit rot

Isolate No.	Place of collection
Col-N	Kegaon, Solapur (MS)
Col-B	Beghampur,Mohol (MS)
Col-D	Degaon, Solapur (MS)
Col-J	Jat, Sangli (MS)
Col-S	Sangli (MS)



Phylogenetic tree generated using neighbor joining method, showing the relationship of present fungal pathogenic isolates from pomegranate (*C. gleosporioides*) with some other pathogenic *Colletotrichum spp.* published in genebank.



Isolates of *Cercospora punicae* causing black spot on fruits

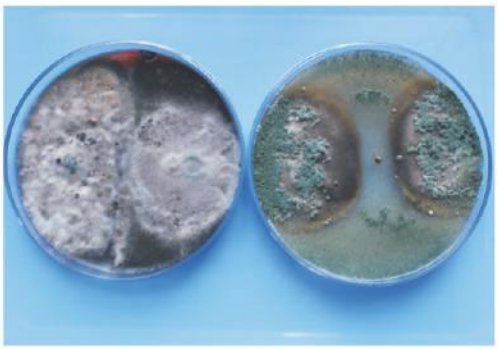
Isolate No.	Place of collection
CR-23	Bhoganipur (UP)
CR-24	Jalana (MS)
CR-30	Sirohi (Rajasthan).
CR-31	Malshirus, (MS)
CR-H25	Kegaon, Solapur (MS)

Phylogenetic tree generated using neighbor joining method, showing the relationship of present fungal pathogenic isolates from pomegranate with some other pathogenic *Cercospora spp.* published in genbank.

5.3.6. In-vitro evaluation of bioagents against leaf/fruit spot of Pomegranate

The competitive ability of antagonists against *Alternaria alternata* was studied by dual culture technique. Maximum reduction in colony of A. alternata was observed with n *Trichoderma virens* (46.25%) followed by *T. harzianum* (40.25%) over control which was significantly superior over all other bioagents within 3 days inoculation of bioagents.

After 3 days



After 7 days

Inhibition of *A. alternata* by *T. virens*

5.3.7. Fungal culture collection

In all 40 new fungal isolates including 13 *Ceratocystis fimbriata* isolates (Cf-39 to Cf-50) causing wilt, 6 *Sphaceloma punicae* isolate (SB34-SB39) causing scab, 13 *Colletotrichum agloeosporioides* (CR32-CR44) causing fruit rot and 2 *Alternaria alternata* isolates (Alt-5 to Alt-6) causing heart rot and 6 *Rhizoctonia solani* (RH-1to RH-6) causing spots on pomegranate fruits have been

added to collection from West Bengal, Himachal Pradesh, Karnataka and Maharashtra.

5.4. Biological control of wilt complex problem in pomegranate

Survey was carried out in western Maharashtra. Maximum wilt incidence (33.06%) was noticed in Jalgaonmahi, Ahmednagar district in 10 years old plantation. Lowest incidence was in Ichgaon (8.36%). Older orchards recorded more wilt.

Status of wilt in Maharashtra

S. No.	Place	Age of orchard	Percent Wilt incidence
1	Jalgaonmahi, Dist. A. Nagar	10	33.06
2	Ichgaon, Mohol, Dist. Solapur	1	8.36
3	Kamathi, Mohol, Dist. Solapur	7	21.39
4	Karkumbh, Dist. Solapur	5-10	22.80
5	Anudur, Dist. Osmanabad	7	21.39

5.4.1 Effect of neem products on the growth of bioagents *Trichoderma spp.*

Neem products were mixed with PDA to get final concentrations of 0.1, 0.5, and 1 per cent. Poured plates were inoculated with *Trichoderma harzianum* and *T. viride* and observations recorded after 48 hrs. Among all the treatments maximum effect on growth and sporulation of *Trichoderma spp.* was recorded in neem oil at 0.5-1%

Effect of neem products on the growth of bioagent

Treatments	Colony diameter(mm)		Sporulation ($x10^{10}$ spores /ml)	
	T. harzianum	*T. viride*	*T. harzianum*	*T. viride*
T1 Neem cake (1g/l)	65.70	71.66	1.93	1.27
T2 Neem cake (5g/l)	58.50	60.83	2.13	2.37
T3 Neem cake (10g/l)	54.00	65.16	2.77	4.33
T4 Neem powder (1g/l)	70.50	72.66	2.83	1.97
T5 Neem powder (5g/l)	70.83	67.00	2.63	1.50
T6 Neem powder (10g/l)	59.33	60.50	2.27	2.47
T7 Neem oil (1ml/l)	69.50	62.00	2.10	1.50
T8 Neem oil (5ml/l)	63.50	62.83	1.80	1.27
T9 Neem oil (10ml/l)	53.83	53.50	1.57	1.27
T10 Control	79.66	69.66	2.53	2.00

5.4.2 Antifungal evaluation of potential bioagents against *Ceratocystis fimbriata*

Fungal and bacterial bioagents were evaluated against *C. fimbriata* in dual culture. Allbioagents were found effective except *B. subtilis*. Total inhibition of *C. fimbriata* was recorded with *T. harzianum,* T. reesei, *T. hamatum, Penicillium* sp. and actinobacteria, whereas 32.33% inhibition was recorded with with *P. fluorescens.*

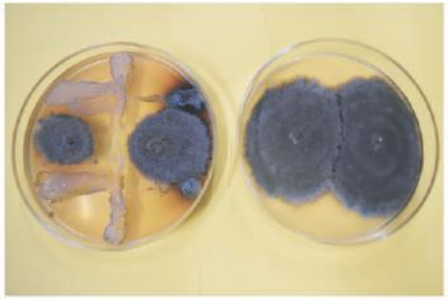
Per cent inhibition of the mycelia growth of *Ceratocystis fimbriata* by different bioagents

S. No.	Bioagents	Percent inhibition over control
1	*Trichoderma harzianum*	100
2	*T. viride*	100
3	*T. reesei*	100
4	*T. hamatum*	100
5	*Pseudomonas fluorescens*	32.33
6	*Penicillium sp.*	100
7	*Bacillus subtilis*	0.00

T. hamatum

T. reesei

Penicillium sp.



P. fluorescens

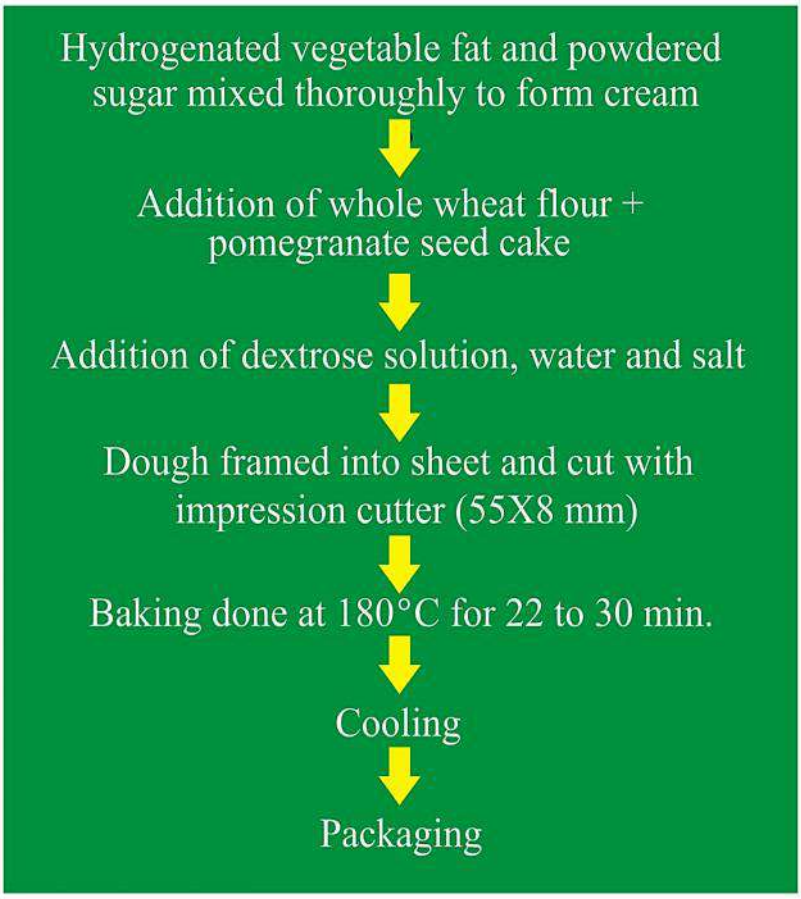
Inhibition of *C. fimbriata* growth by fungal bioagents
(left-treated, right-control)

6. POST HARVEST MANAGEMENT AND VALUE ADDITION

Project: Post harvest management, value addition and improving knowledge of stakeholders for increasing production and marketing of pomegranate

6.1. Development of pomegranate de-oiled Seed cake based cookies

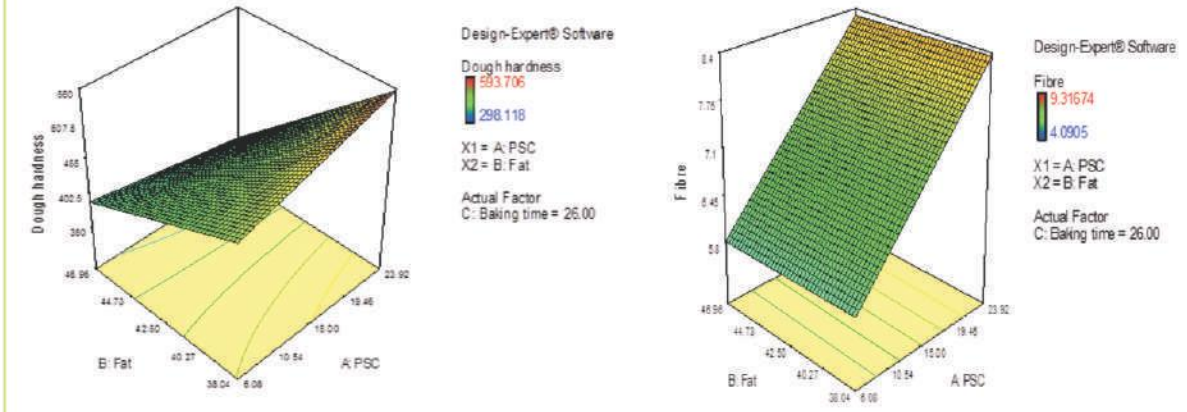
Pomegranate de-oiled seed cake is the byproduct of oil extraction process and is a good source of proteins, fats and fibers. The process for development of nutritious cookies was optimized by replacement of whole wheat flour with de-oiled pomegranate seed cake (PSC). Standard method of American Association of Cereal Chemist (AACC) with modifications was followed for preparation of cookies. The process flow chart for preparation of cookies is depicted.



Flow chart for preparation of pomegranate de-oiled seed based cookies

6.1.2. Process parameters affecting quality of cookies

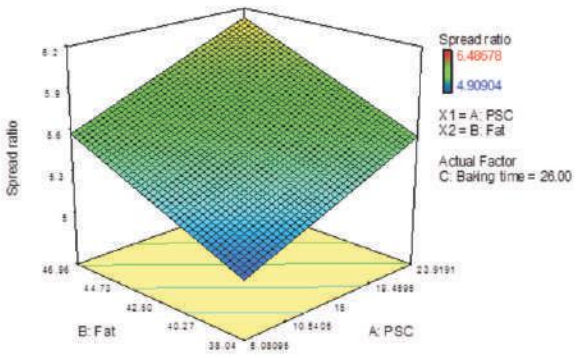
The results of the experiment were recorded and also plotted as three dimensional graphs. It revealed process parameters and response parameters fitted with suitable models. The effect of fat and PSC on dough hardness revealed that the increase in fat content decreased hardness or increased softness. The increased PSC lead to increased hardness due to absorption of water by fibre in PSC and consequently making it readily available for absorption by wheat flour. The contribution of fat from higher PSC may be very negligible as it may not be available in released form. It was also found that the increase in PSC increased the fibre content significantly in cookies. The effect of PSC, fat and baking time on spread ratio, cookies hardness and color (lightness) was recorded. The spread ratio of cookies was positively related to fat content and PSC. Fat from PSC might contribute to increase in spread ratio of cookies. Cookies hardness was reduced with increase in fat content. The increased PSC was seen to increase hardness of cookies.



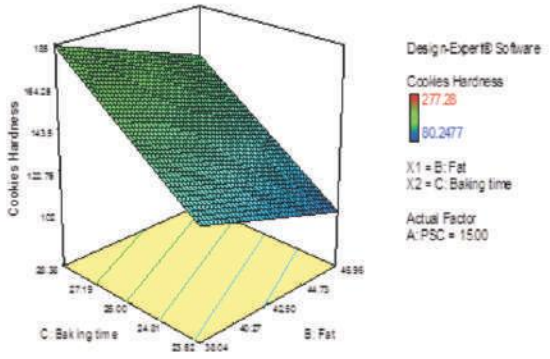
Dough hardness as affected by fat and PSC

Fiber as affected by fat and PSC

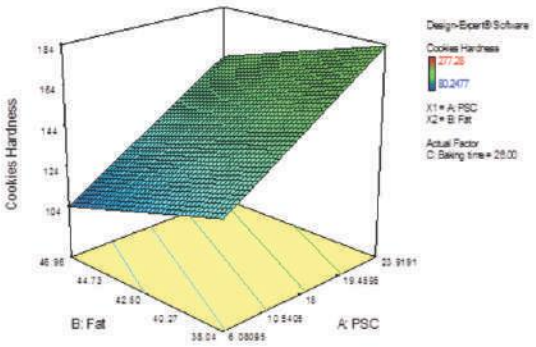
Effect of fat and PSC on dough hardness and Cookies fiber content



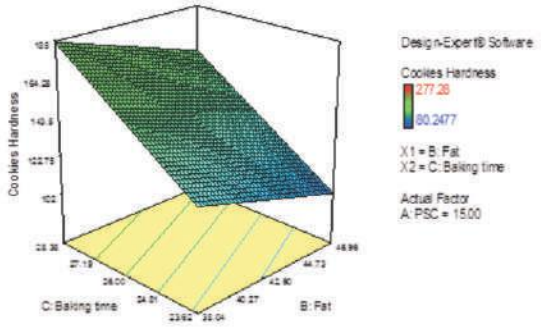
Spread Ratio as affected by fat and PSC



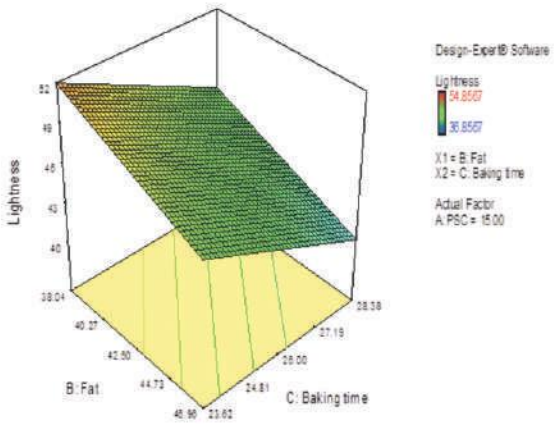
Spread Ratio as affected by Baking time &Fat



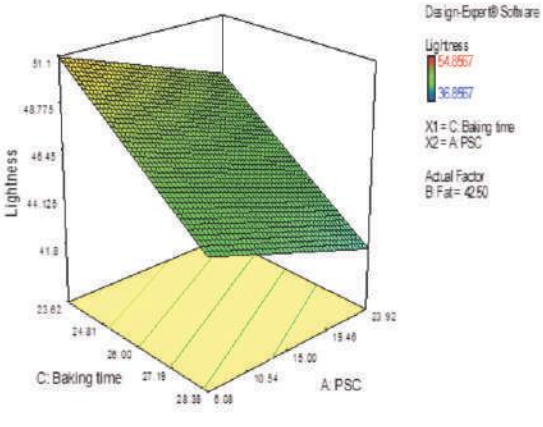
Cookies Hardness as affected by fat &PSC



Cookies Hardness as affected by Baking time & fat

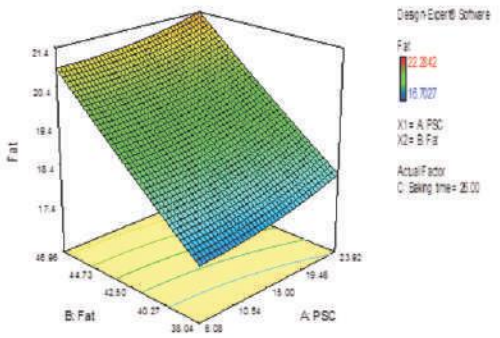


Cookies Lightness (L*) as affected by fat & Baking time

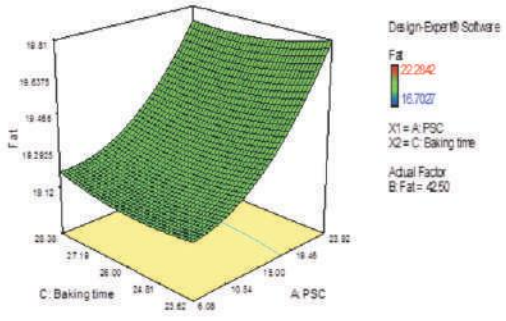


Cookies Lightness (L *) as affected by Baking time& PSC

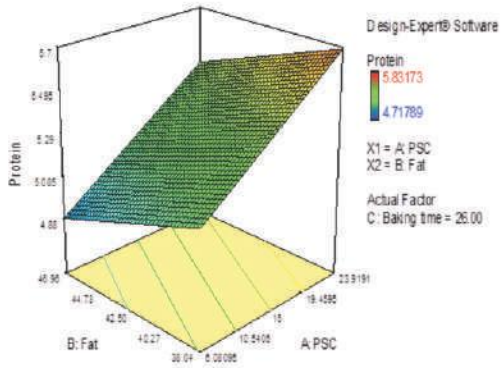
Spread ratio, cookies hardness and color (lightness) as affected by PSC, fat and baking time



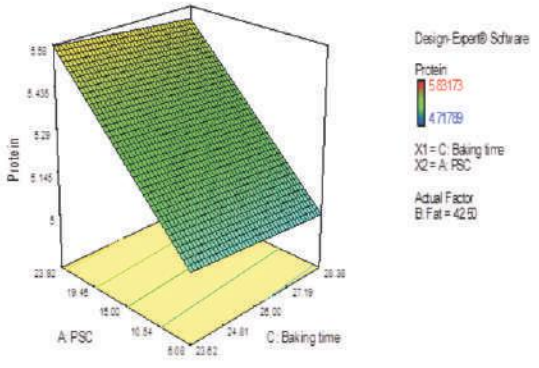
Cookies fat as affected by fat and PSC



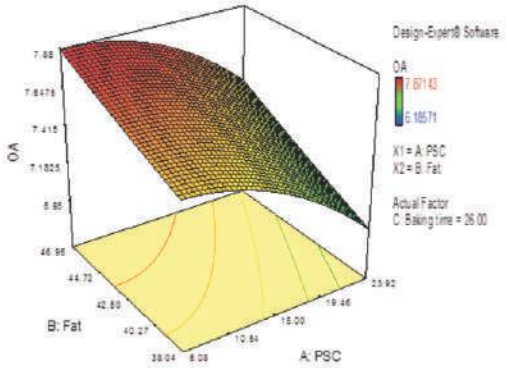
Cookies fat as affected by Baking time and PSC



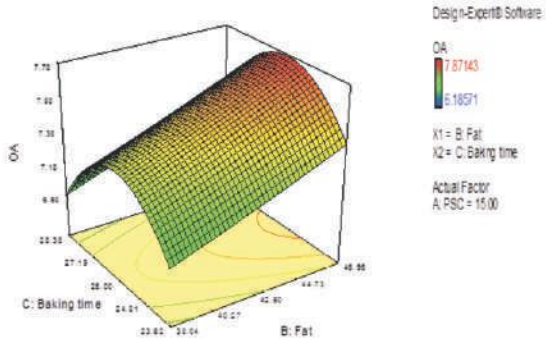
Cookies protein as affected by fat and PSC



Cookies protein as affected by PSC and Baking time



Overall acceptability as affected by fat and PSC



Overall acceptability as affected by Baking time & PSC

Cookies fat, protein and overall acceptability as affected by PSC, fat and baking time

6.1.3. Optimum conditions and quality parameters for cookies preparation

The L* value i.e. lightness decreases with increased baking time. Further, increase in fat and PSC both reduced lightness value of cookies. Increased PSC lead to higher fat in cookies as it may be contributed from seed cake. Increase in PSC also lead to increased protein in the cookies. As fat increased the overall acceptability increased. The increased PSC improved overall acceptability up to certain extent and thereafter it decreased. It was found that 23.92% PSC,45.27 g fat and 26 minutes of baking time were optimum conditions for preparation of cookies.

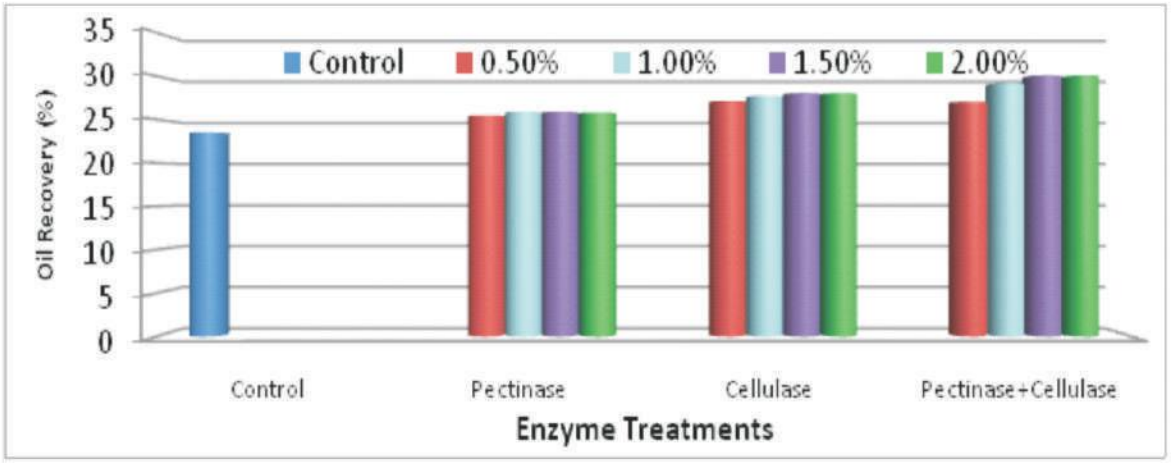
Cookies developed at optimized conditions

6.2. Effect of enzymatic pretreatment on pomegranate seed oil extraction

The experiments were conducted to study the enzyme assisted extraction of pomegranate seed oil. Effect of two enzymes viz., pectinase and cellulase was studied individually and in combination on the yield and quality of oil. The enzymes were used at four concentrations (0.5, 1.0, 1.5 & 2.0%).

6.2.1. Effect of enzyme treatment on oil recovery

Enzyme treated seeds of pomegranate showed higher oil yield (25.48-30.06%) at all concentrations tested, in comparison to untreated sample with only 23.5% recovery. Oil recovery was higher in cellulase enzyme treated samples in comparison to pectinase at all concentrations. However, samples treated with combination of both enzymes cellulase and pectinase were found superior to individual enzyme treatments, with highest oil recovery at 1.5% and 2.0% concentrations. Enzymatic hydrolysis as pretreatment of seeds was found to be effective for quick softening of seed coat which opened up oil cell walls. It has been found that the use of enzymes like cellulase and pectinase improves release of oil during solvent extraction.



Effect of enzyme treatment on oil recovery from pomegranate seeds

6.2.2. Effect of enzyme treatment on biochemical parameters

Effect of enzyme treatment on biochemical parameters of pomegranate seed oil is given in the table. Statistical analysis shows non-significant difference in the biochemical content of the pomegranate seed oil except the peroxide value. Peroxide value of the enzyme treated sample was significantly lower than the control sample.

Effect of enzyme treatment on biochemical properties of pomegranate seed oil

Treatment	Acid value (mg KOH/g)	Iodine value (no. of Iodine/100g)	Saponification value (mg KOH/g)	Peroxide value (meq /1000g)	Antioxidant activity (%)	Antioxidant Capacity (mg/ml AAE)	Total phenol (mg/ml GAE)
Control	0.45	187.42	113.14	6.3	19.84	107.35	13.78
Range in different enzymes	0.45 0.47	184.17- 187.42	113.6- 115.94	4.6-4.8	18.74 20.67	107.35- 107.69	13.50- 13.97
CD @ 5%	NS	NS	NS	0.248	NS	NS	NS

6.2.3. Effect of enzyme concentration on extraction time

Enzyme pretreatment with optimum pretreatment combination of 1.5 % pectinase and 1.5% cellulase reduced the extraction time to 2 hours in comparison to control where highest recovery was in 5 hrs. Thus oil is subjected to extraction process and consequent higher temperature for shorter period.

Effect of enzyme concentration on extraction time

Treatment	Per cent oil recovery with extraction time (hours)			
	2	3	4	2
Control	18.50	20.75	22.25	23.50
1.5 % pectinase + 1.5% cellulase	29.00	3.0.05	30.00	30.10

(C.D.: Extraction time 0.106, Treatment 0.15)

7. EXTERNALLY FUNDED / COLLABORATIVE PROJECTS

Project : Establishment of DUS Centre at ICAR-NRCP, Solapur
(Funded by PPV&FRA, New Delhi)

DUS characteristics of twenty pomegranate germplasm were recorded for plant, leaf, flower and fruit morphological and physico-chemical properties during *mrig bahar* 2017-18 as per the DUS guidelines. In total, 34 characters were recorded in each accession. All the accessions were found to have spreading growth habit except in IC-444204, IC-444201, IC-524027, IC-444200 which have upright habit. Patna-5 and Bedana Thins kin showed long leaf blade length. Leaf blade width and calyx length was found medium in all the accessions. Broader calyx width was observed in Surat Anar and Patna-5.Patna-5showed elliptic lanceolate leaf blade shape, while other accessions had lanceolate shape. Most of the germplasm showed low level of petiole coloration except in seven germplasm *i.e.* Surat Anar, Bedana Thinskin, IC-524027,IC-444200,IC-524031,IC-0599595 and IC-0599597 showed medium level of petiole coloration. Calyx and corolla of all the accessions were orange in colour with single corolla type.

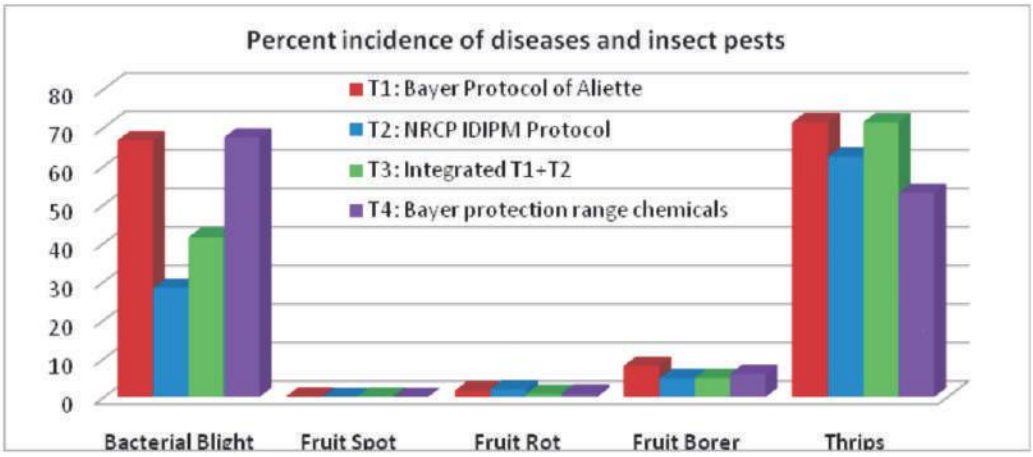
Shorter fruit length was recorded in IC-524027, IC-524030, IC-524031, IC-444200, IC-444201, IC-444204, IC-444208, IC-0599595, IC-0599597, IC-318716, IC-318766 and longer length in G-137,KRS,Patna-5 and Surat Anar. Fruit diameter was found large in Bedana Shri, Bedana Thin skin, G-137, KRS, Patna-5 and IC-318707. Fruit colour varied from yellow, yellow with red tinge, yellow with pink tinge to pink colour. Thin rind was observed in Bedana Thin skin and IC-444208. IC-0599597 showed medium crown length while others had shorter crown. Aril colour varied from light pink, pink to dark red color. Except G-137 and KRS other accessions seeds were found to be hard. TSS (Total Soluble Solids) was recorded high in all germplasm except Patna-5which has medium. Acidity percentage was low in Bedana Shri, Bedana Thin skin, G-137 and KRS, while medium in Patna-5 and Surat Anar. Fruit juiciness percentage was low in all accessions except in Surat Anar which showed medium percentage.

Project : SNP marker based mapping of bacterial blight genes in pomegranate
(ICAR-extramural project)

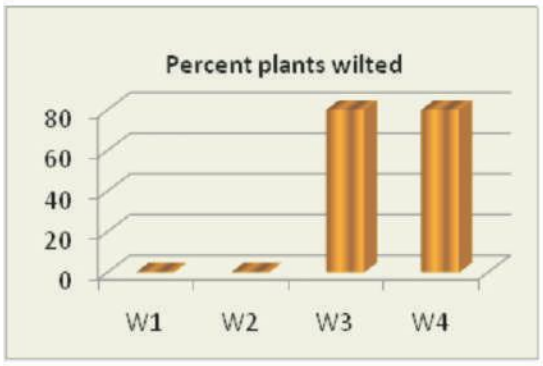
In total, 192 germplasm accessions were selected for identification of SNPs associated with bacterial blight disease based on their bacterial blight reaction under field and challenge inoculation conditions. These included highly susceptible, susceptible, moderately susceptible and moderately resistant genotypes. Genomic DNA was extracted from the leaf samples of all the accessions. DNA purity, integrity and quantity was monitored by agarose gel electrophoresis, Nanodrop and Qubit® 2.0 Flurometer (Life Technologies, CA, USA). The genomic DNA of samples was digested by using double restriction enzymes, and the obtained fragments were ligated with barcodes, and then amplified by PCR. Subsequently, the samples were pooled and choosing the required fragments for library construction. To check the prepared DNA libraries, Qubit® 3.0 Fluorometer was firstly used to determine the concentration of the library. After dilution to 1 ng/ul, the Agilent® 2100 Bioanalyzer was used to assess the insert size. Finally the quantitative real-time PCR (qPCR) was performed to detect the effective concentration of each library. The qualified DNA libraries were pooled according to their effective concentration as well as the expected data production. Pair-end sequencing was performed on Illumina HiSeq 2500 platform using SBS V4 Chemistry, with the read length of 144 bp at each end. Out of 192, 171 samples libraries have qualified the criteria and hence were considered for further processing. Totally 48.387GB raw data were sequenced from this run, with 48.385GB clean data after filtering low-quality data with the Q20 and Q30 reached 93.96% and 85.66%, respectively. The effective sequencing data was aligned with the reference pomegranate genome data available in NCBI database (https://www.ncbi.nlm.nih.gov/assembly/GCA_002201585.1/) to discover SNPs. Total SNPs were discovered from Upstream, Exonic (Stop gain, Stop loss, Synonymous, Non-synonymous), Intronic, Splicing, Downstream, Intergenic, Upstream/Downstream regions of the genome. These SNPs were associated with pomegranate bacterial blight and identified novel SNP markers for the trait under consideration. As many as about 5111 and 5980 SNP markers associated with incidence and severity of BB disease in pomegranate were identified from 171 genotypes through Genotyping-by-sequencing technique. Among these 106 and 971 markers were found to be specific to BB incidence and severity. Further markers can be converted into SNP chips or gel based markers to aid in marker breeding programmes in pomegranate.

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)

In a field trials conducted at NRCP during *ambe bahar* 2017, Bayer protection range chemicals and Alliete protocols were found ineffective in checking BB, however Bayer protocol was effective in reducing, thrips and borer infestation though to limited extent. Marketable fruit yield was significantly higher in NRCP-IDIPM or Integrated protocol of Bayer protection range chemicals+NRCP-IDIPM.



Effect of BCS protection range chemicals on pomegranate diseases, insect pests and disorders: *Ambe bahar* season



W1: NRCP Propiconazole-carbendazim protocol
W2: Bayer Aliette-Folicur protocol
W3: Bayer profiler protocol
W4: Control

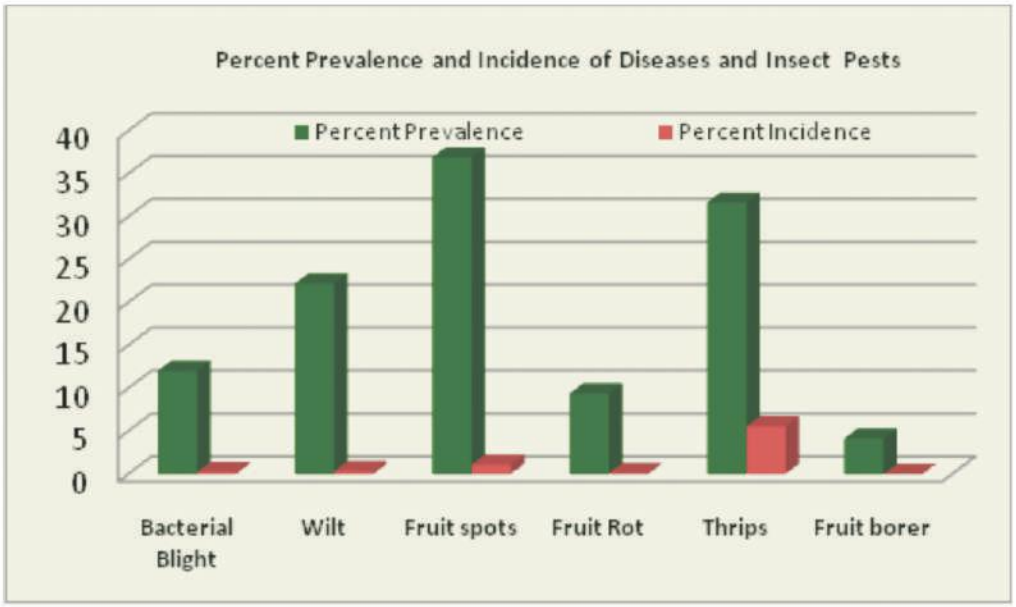
Performance of various wilt management protocols

Bayer's Aliette and profiler protocol was effective in checking *Ceratocystis* wilt with 100% control, however profiler protocol was ineffective, both in NRCP field and pot culture trials.

Project : Horticulture 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 covering 220 acres area of pomegranate orchards in Pune, Solapur, Nagpur, Sangli and Ahmednagar districts of Maharashtra with prevalence of wilt (22.22%) and bacterial blight (12%), fungal spots (36.9%), fruit rot (9.38%), Thrips (31.63%) and fruit borer (4.13%) Thrips were prevalent in all orchards in fruiting but not in those in stress period. Incidence was however low as either orchards were in flowering/fruit setting stage or rest period.



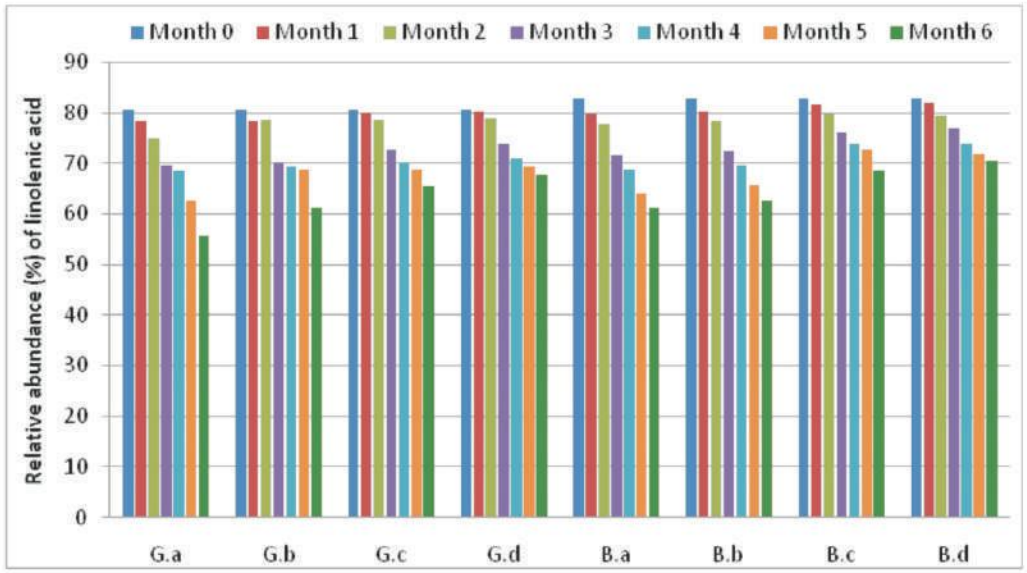
Status of pomegranate diseases and insect pests in surveyed orchards of Maharashtra

Project : Utilization of pomegranate for development of functional medicinal ingredients
(Funded by NMPB, Ministry of AYUSH, Govt. of India)

Storage study of pomegranate seed oil

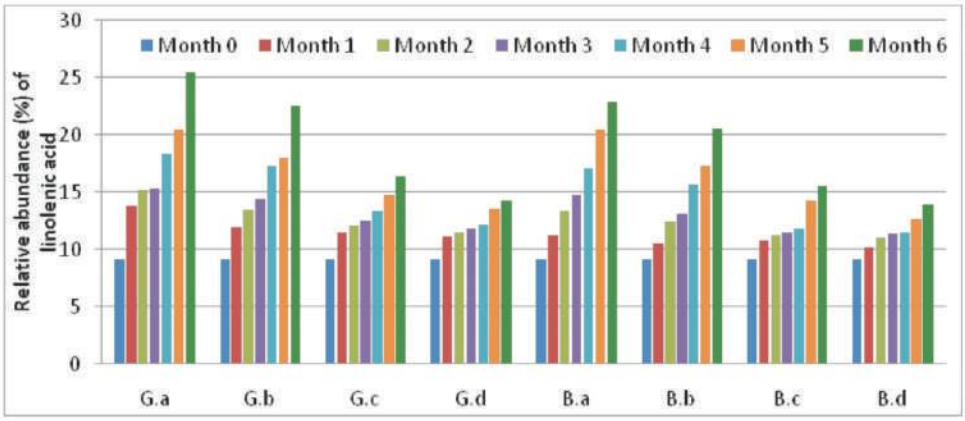
In order to understand the storage conditions on quality of pomegranate seed oil, the oil of Bhagwa and Ganesh cultivars was extracted and stored in two types of glass bottles (transparent and amber colored), two storage conditions (refrigerated 5ºC+1 and Room temperature). The storage studies were carried out for six months duration. Effect of storage was recorded on linolenic acid and peroxidase value.

The studies revealed that linolenic acid content decreased during storage and higher decrease in linolenic acid content was observed at room temperature and in transparent bottle storage. Amber coloured bottles stored in low temperature maintain higher linolenic acid content.



Effect of storage conditions on Linolenic Acid Content
(G-Ganesh and B-Bhagwa; a- Room temperature transparent bottle: b- Room temperature amber bottle; c- Low temperature transparent bottle; d- Low temperature amber bottle)

Peroxides have been shown to occur when oil is exposed to oxygen and/or light, particularly at elevated temperatures. Although peroxides are not directly responsible for the taste and odour of rancid fats, their concentration as represented by the peroxide value (PV) is useful in assessing the extent to which the rancidity has advanced. Peroxide value increased rapidly at room temperature and in transparent bottles than at low temperature and amber coloured bottles.



Effect of storage conditions on peroxide value

(G-Ganesh and B-Bhagwa; a- Room temperature transparent bottle: b- Room temperature amber bottle; c- Low temperature transparent bottle; d- Low temperature amber bottle)

Microencapsulation of pomegranate seed oil by spray drying

Freshly extracted pomegranate (cv. Bhagwa) seed oil was used for encapsulation experiment using facilities at MPKV, Rahuri. Maltodextrin and gum acacia were used as wall material. Initial studies show pomegranate seed oil can be encapsulated by spray drying technique. Gum acacia yielded low encapsulated powder with moderate encapsulation efficiency. Further studies are required with different encapsulation agent, considering all the aspects such as emulsion viscosity, emulsion droplet size, particle size distribution of the powder etc.

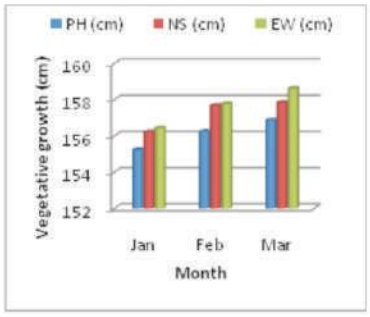
Project : Response of Pomegranate to Deficit Irrigation and Partial Root Zone Drying

(Funded by ICAR, CRP on Water)

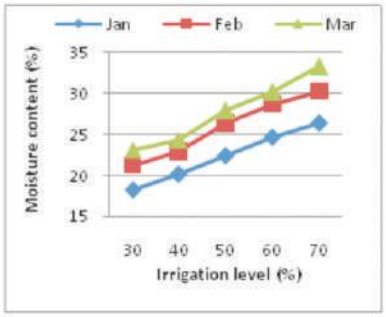
Field experiment was conducted during 2017-18 on light texture soil at National Research Centre on Pomegranate, Solapur to assess the deficit and partial root zone drying irrigation system at different phenological stages (i.e. new leaf initiation, development, maturity and harvesting period) of pomegranate. The soil of the experimental site is light texture soil throughout the soil profile. Experiments were laid out at 4.5 X 2.0 m; 4.5 X 3.0 m and 4.5 X 4.0 m spacing.

Effect of deficit irrigation

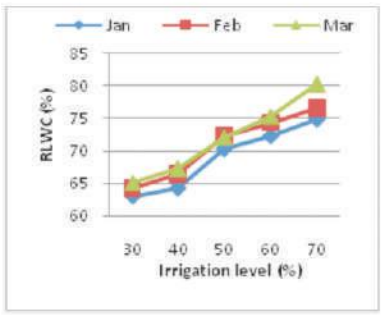
The performance evaluation of deficit irrigation (DI) systems at different plant spacing and wetted soil volume at 50, 60, and 70 % for 4, 5 & 6 year old pomegranate orchards was studied. Soil moisture content varied from 18.30 to 33.35% and relative leaf water content from 63.10 to 80.26 %.



Vegetative plant growth



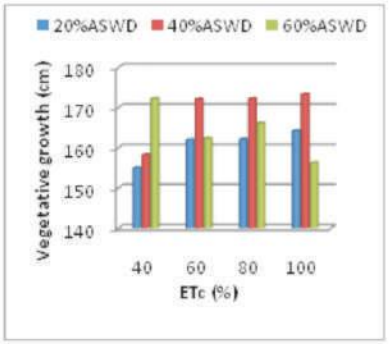
Soil moisture (%)



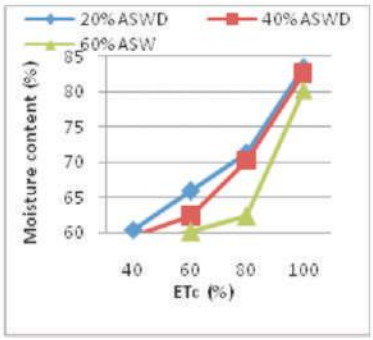
RLWC (%)

Effect of partial root zone drying irrigation system

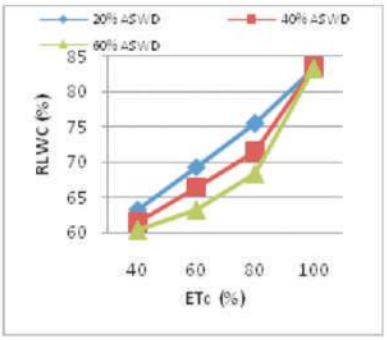
The performance evaluation of PRZDI systems at 40 %*ETc, 60 %*ETc, 80 %*ETc and 100 %*ETc (control) having 20, 40, and 60 % ASWD (Available Soil Water Deficit) at drying side showed that less water produced good performance of vegetative growth, no water shoot and luxury growth. PRZDI reduced moisture content with maximum plant height, branches and flowers at water soil volume (WSV) 100 % * ETc with 20% ASWD. Soil moisture content and relative leaf water content under deficit irrigation were recorded. The moisture content and relative leaf water content varied between 25.6 to 33.5 and 64.5 to 81.4 % respectively.



Vegetative plant growth



Soil moisture (%)



RLWC (%)

Effect of root geometry

Observations on root geometry was recorded and results showed that, the highest root length, weight and density (79.40 cm, 90.25 g and 1.57 kg/m3) were recorded at 100 % *ETc.

Root Geometry at 100 % *ETc

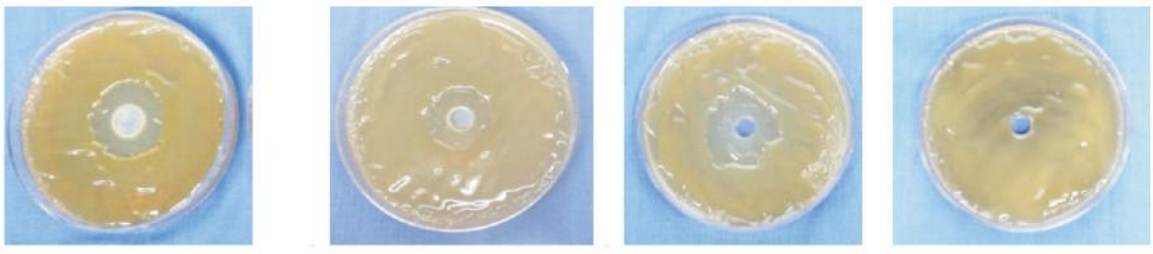
Project: Effect of Zetol Select water soluble fertilizer grades and ProRise solutions of Nagarjuna Fertilizers and Chemicals Limited on Pomegranate yield and quality
(Funded by Nagarjuna Fertilizers and Chemicals Limited, Hyderabad)

A field trial was conducted with Zetol select water soluble fertilizer grades I (comprising of 6-45-6, 8-21-21 and 8-6-38), grade II (comprising of 6-40-10, 9-17-21 and 5-10-35) and ProRise package consisting of Actin, Durmalin and Multi-C of NFCL to evaluate their effect on pomegranate fruit yield and quality applied in the fertigation programme. The results of the trial indicated that fertigation of pomegranate plants with Zetol select water soluble fertilizer grade II at 75% of the recommended dose of fertilizers (RDF)along with ProRise package significantly increased pomegranate fruit yield over the farmers fertilization practices. It also improved fruit quality viz. aril percent, ascorbic acid and anthocyanin content but it significantly reduced phenol concentration of fruit. This combination led to the production of higher yield (19.23 kg/plant) which is even higher than that obtained with the application of same at 100% of RDF. Low pH grade of the same did not result any additional yield benefit over the Zetol select water soluble fertilizer grade II.

Project: Development & evaluation of eco-friendly mustard based antimicrobial formulation using other botanicals for control of bacterial blight problem and insect pests of pomegranate
(Collaborative project lead by CIPHET, Ludhiana)

Effect of Mustard Formulations on Bacterial Blight

Black mustard formulation was tested in vitro for inhibition of Xap at 25%, 20%, 15% and 5% concentrations. Mustard formulation inhibited Xap with maximum inhibition zone of of 29.67mm at 25% concentrations. The zone at 25% concentration was equivalent to that of Streptomycin sulphate 90% + Tetracycline hydrochloride (Streptocycline) and 2-bromo-2-nitro-propane 1,3-diol at 0.05% (Bactronol-100).

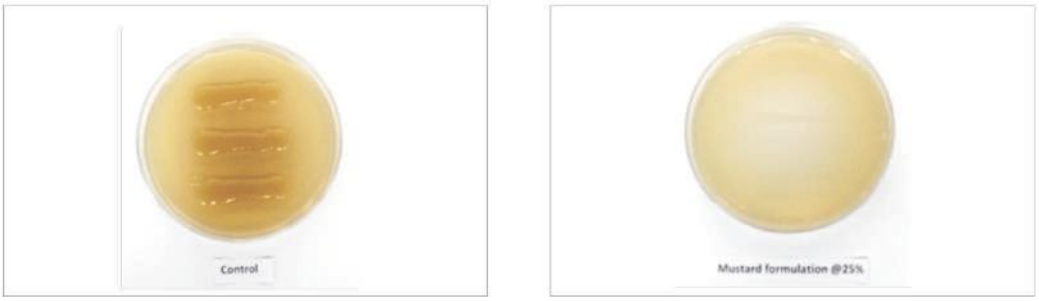


Mustard Formulation 25% | Streptocycline 0.05% | Bactronol-100 0.05% | Control (Sterile water)

Effect of mustard formulation on inhibition of *X. axonopodis* pv. *punicae*

Bactericidal activity of mustard based formulation

In another trial the pure culture of Xap was dipped in 25% concentration and streaked on NGA plates at 1 hour interval starting at 0 hours to see bactericidal and bacteriostatic activity. There was no growth of Xap even at 0 hours even after incubation for 7 days, thereby indicating bactericidal activity.



Bactericidal activity of mustard based formulation at 25%

Performance of mustard based formulation in pot culture trials under polyhouse conditions

The formulation was not found effective in checking bacterial blight in preliminary polyhouse trials however, the trial has been repeated in polyhouse and field in current season with new formulation sent by CIPHET for bacterial blight.

7.8.2. Evaluation of mustard based formulation against insect pests

7.8.2.1. In vitro evaluation

Thrips

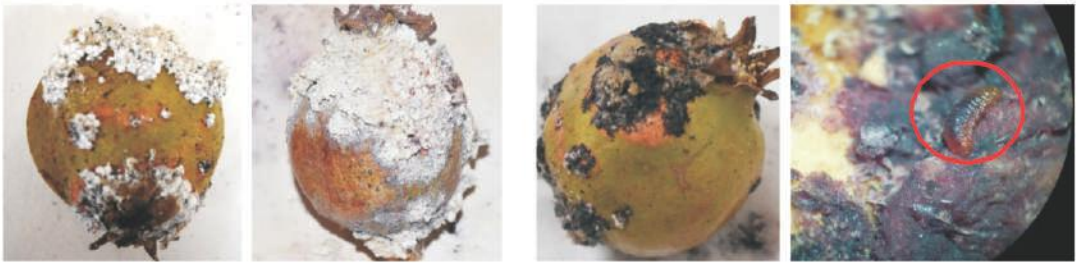
Fresh twigs with thrips infestation were used for the experiment and formulation was sprayed in 0.1 to 1.0 g/l doses and data on dead and alive thrips recorded after 1 hour and 21 hours. Concentrations from 0.4g/l to 1.0 g/l were found effective in killing 50-80% of the population within 1 hour.

Dead thrips on tender leaf

Dead thrips - magnified image

Mealy bugs and scale insects

Formulation was sprayed in 1.0 to 5.0 g/l doses on mealy bug infested fruits and data on dead and alive bugs recorded after 1 hour. Concentrations from 3 g/l was found effective in killing 100% of the mealy bugs population within 1 hour and 5g/l for scale insects. Mortality of Mealybugs was observed after overnight treatment.



Before treatment **After treatment**

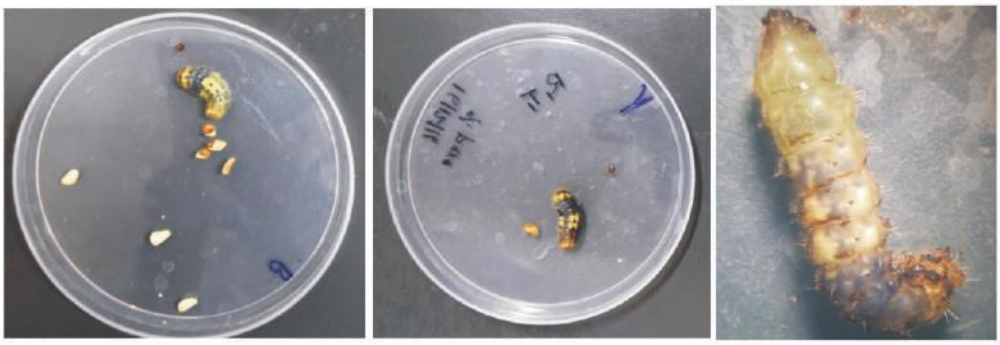
Mealy bugs and scale insects

Pomegranate fruit borer

Mortality of fruit borer larval stage was observed after15 minutes of treatment.

Aphids

Formulation was sprayed in 0.1 to 1.0 g/l doses on 10 aphids per leaf and data on dead and alive thrips recorded after 1 hour. Concentrations from 0.1to 1.0 g/l doses were found effective in killing 10-50% of the population within 1 hour. However, 1.0 g/l dose was most effective with 50% mortality.



Treated larvae **Dead larva** **Fruit borer**

Field efficacy of mustard based formulation against insect pests

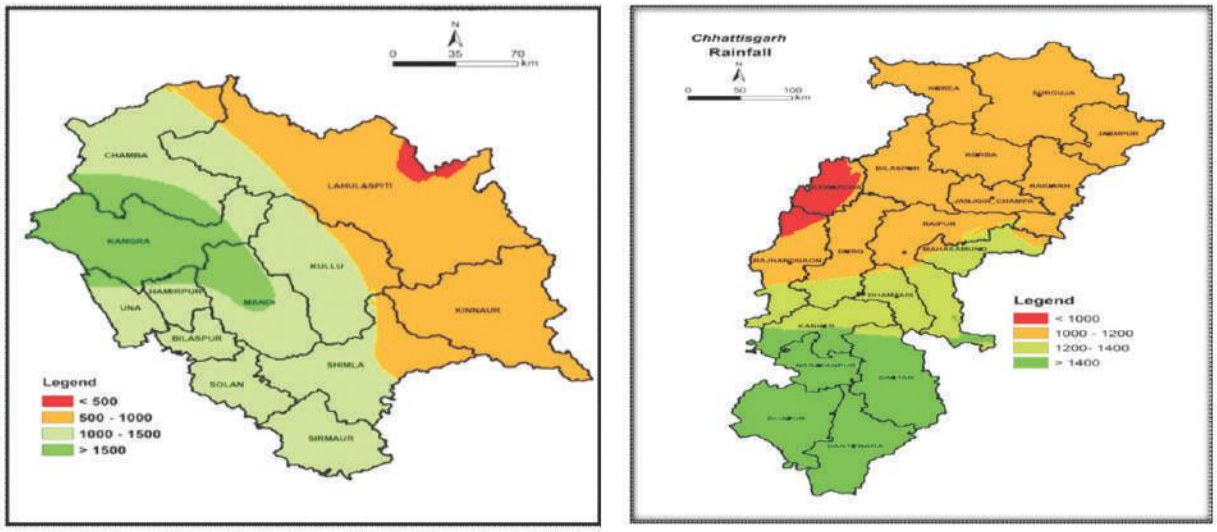
Field evaluation of mustard based formulations was done for the management of fruit borer and sucking pests which were found infesting pomegranate organic block. Mustard formulation was sprayed in different doses however, 3.0 g/l dose alone or 1g/l dose in combination with other organic formulations were found effective.

It was found that thrips damage was lowest (4%) in treatment combination mustard formulation (1g/l) +Neem oil (3ml/l) + Mustard oil (3ml/l) in comparison to control with 75% damage; Fruit borer damage was lowest (1.98%) in combination treatment of mustard formulation (1g/l) + Neem oil (3ml/l) where as in control damage was 11.32% and highest damage was in combinations where along with mustard formulation pongamia, mustard or castor oil was also used. Highest percentage (74%) of healthy fruits was in treatment combination with mustard formulation (1g/l) +Neem oil (3ml/l) + Mustard oil (3ml/l) in comparison to control having only 13.20% healthy fruits.

Project : Delineation of potential areas for pomegranate cultivation in H.P. and Chhattisgarh states using Remote Sensing and GIS Techniques

(Collaborative project with NBSSLUP, Nagpur Nodal Institute ICAR-NRCP, Solapur)

The potential areas for pomegranate cultivation in Himachal Pradesh and Chhattisgarh states of India have been identified with respect to different categories in highly suitable, moderately suitable, marginally suitable and not suitable for Himachal Pradesh and Chhattisgarh states, India based on rainfall distribution pattern.



Himachal Pradesh **Chhattisgarh**

Potential areas for pomegranate cultivation based on rainfall

(Rainfall <500mm: Highly suitable; 500-1000mm: moderately suitable;1000-1500mm: marginally suitable; >1500mm: unsuitable)

Anuppur, Madya Pradesh and Koriya, Chhattisgarh

Planting material was distributed through SRIJAN to tribal farmers of 14 villages of Anuppur, Madhya Pradesh and 2 villages of Koriya, Chhattisgarh for planting after rains.

Tribal farmers adopted by ICAR-NRCP

S. No	State	District	Sub-District	Village	ST population Benefited	Year of adoption	Status as on 31.03.18
1	Maharashtra	Gadchiroli	Sironcha	Bamani, Ranggapalli, Mukallikonda, Pochanpalli Venkatpura	12 farmers (100% Tribal)	2014-15	First crop regulated
2	West Bengal	Bankura	Sironcha	Bamunpatri	13 farmers (100% Tribal)	2015-16	First crop regulated in one orchard
			Onda	Baliguma Makaijuri Ramsagar Ratnpur	57 tribal family	2015-16 & 2016-17	
			Simlapal Ranibandh Bankura 1 Sonamukhi Indapur Chhatna	Bamunpatri Borgora Puramouli Panchal Raghunathpur Chhatna II Ghosergram			
		Purulia	Puncha Kashipur Balarampur	Bahadurpur Tilabani Kumar kanan	100 Tribal Family	2016-17	
3	Chhattisgarh	Koriya	Manendragarh	Gudru and Bharatpur	*200 farmers (100% Tribal)	2017-18	Planting material distributed
4	Madhya Pradesh	Anuppur	Kotma and Budhar,	Bahiyatola, Kharuha,Urtan, Baskhala, Baskhala,Chaka Dhurvasin, Chouhari,Reula Chapani, Kadmaha, Reula, Jaminiya, Baskhala, Baskhali and Thoudha	*200 farmers (100% Tribal)	2017-18	Planting material distributed

*Adopted in collaboration with Self Reliant Initiative through Joint Action (SRIJAN), Madhya Pradesh

ACTIVITIES UNDER TRIBAL SUB-PLAN

Pomegranate cultivation in tribal areas Gadchiroli District, Maharashtra

Ten tribal farmers were adopted under TSP in Sironcha Taluka of Gadchiroli District in the year 2014-15 where each of the farmer was given 325 plants of pomegranate variety 'Bhagwa'. Technical support was provided during the year for various cultural operations. Pomegranate plantation now 2 years old was regulated for *ambe bahar* crop and the plants are now in fruit bearing stage. Two new farmers were given planting material for establishing new orchards Bankura and Purulia district of West Bengal

The pomegranate planation in both Bankura and Purulia district of West Bengal are two years old and have been regulated for ambe bahar crop. Plant in Bankura district is at flowering. In Purulia District due vegetative growth, flowering was low or absent.They were advised for heavy pruning from which they produced 10000 pomegranate saplings. Measures like nipping of tips on new growth and spraying of ethrel @ 250 ppm have been suggested to induce flowering in pomegranate orchards at Purulia district, West Bengal.

Two years old plantation of tribal farmer at Sironcha of Maharashtra

Orchards established under TSP in Bankura and Purulia, West Bengal

Trainings and Visits

In all, 4 trainings were given to 46 tribal farmers from Sabarkantha District, Gujarat; Gadchiroli District, Maharashtra; Tikamgarh District, Madhya Pradesh and tribal farmers of Anuppur District, Madhya Pradesh and Koriya District, Chhattisgarh. Details are given in the chapter on transfer of technology.

Tikamgarh Dist., Madhya Pradesh

Gadchiroli Dist. Maharashtra

Trainings imparted on pomegranate cultivation at ICAR-NRCP, Solapur to tribal farmers from various states

On-site visit of pomegranate orchards of tribal areas at Tikamgarh

A team of scientists visited ten (10) tribal framers of Tikamgarh and surrounding areas for onsite advice to pomegranate farmers. Advise on various diseases and pest problems faced by them were addressed and intercultural operations like pruning, staking, fertilizer applications, slurry preparation, Fertigation etc. were demonstrated. After the visit one interaction with tribal farmers was also arranged by SRIJAN, MP.

Nematode infestation problem being addressed

Demonstration of pruning technique

Interaction with farmers

Onsite visit of ICAR-NRCP staff to Tikamgarh, Madhya Pradesh

OUTREACH ACTIVITIES

Trainings / workshops

Several trainings, workshops and interactive meets were organized by different organizations in collaboration with ICAR-NRCP, where several scientists of ICAR-NRCP participated as resource persons to disseminate the technologies developed to different stake holders. These outreach activities are summarized below.

S. No	Name of the training / workshop	Venue	Date	Participants
1	Nutrient Management in Pomegranate for Quality Fruit Production	Krishi Utpanna Bazar Samittee, Pandharpur	18.05.17	100 farmers
2	Workshop on Export oriented Pomegranate Production.	Sangola, Solapur	20.06.17	40 farmers
3	Krishi Divas Mela	Yeshwantrao Chavan Sabhagruh, Solapur	01.07.17-07.07.17	110 farmers
4	Training Programme on Pomegranate Cultivation	Akhil Maharashtra Dalimb Utpadak Sangh Saha Sanskriti Bhawan, Indapur	22.08.17	100 farmers of Pune
5	Workshop on Processed Products From Pomegranate and Their Marketing	Sangamner, Maharashtra	29.08.17	500 farmers
6	Training on Farm Level Stress and Innovations- Farm Innovators Meet' jointly being organized by ICAR-ATARI, Pune; ICAR-IARI, New Delhi and Agricultural Development Trust, Baramati	KVK Baramati	07.10.17-08.10.18	50 farmers and staff
7	Kisn Aadhar Sammelon	MPKV, Rahuri	25.10.17-29.10.18	50 farmers
8	Stakeholders Meet on Pomegranate Value chain	NASC Complex, New Delhi	30.10.17	53 delegates of processing industry, academician and export houses
9	Model Training Course (MTC) on Climate Smart Agriculture for Enhancing Crop and Water Productivity under Abiotic Stress Conditions.	ICAR-NIASM, Baramati	21.12.17	50 participants

S. No	Name of the training / workshop	Venue	Date	Participants
10	Winter School on Understanding Flowering Mechanism and Management of Bearing in Sub-Tropical Fruit Crops	ICAR –NRCL, Muzaffarpur	01.12.17-21.12.17	70 participants
11	Training to Students on Food Processing Technology	TC College Baramati	02-02-2018	80 students and staff of TC College Baramati
12	Workshop on Pomegranate Processing and Value Addition	APMC, Sangli Jat, Maharashtra	4.02.18	50 farmers
13	Technology Week of KVK	KVK Dhule	17.02.18	30 farmers and staff
14	Advances in Pomegranate Processing In National Conference on Advanced Trends in Agricultural and Food Engineering (ATAFE).	Maharashtra Institute of Technology (MIT) Aurangabad	07.04.18	150 delegates for workshop
15	Meeting on Finalization of modified weather triggers for *mrig bahar* crop of pomegranate	ICAR-NRCP, Solapur	22.03.18	25 delegates

Consultancy

Consultancy was provided by ICAR-NRCP to M/s. MOSCOS Food Processing Pvt. Ltd for the MOU signed on "Technical consultancy for establishment of minimal processing and packaging unit for pomegranate at Nashik for export of minimally processed arils with an outlay of approximately 6.00 crores. The institute received Rs. 6.90 lakh as consultancy fees for providing consultancy for establishment of this business startup. The scientists, Dr. Nilesh Gaikwad and Dr. R.K.Pal were the expert consultants.

Scientific agro advisories

In response to the queries of farmers, information was provided to the farmers through e-mail and mobile phone. Scientific agro-advisories were sent to about 1200 pomegranate growers through the "m-Kisan portal" during the period under report.

TRANSFER OF TECHNOLOGY

Trainings

ICAR-NRCP, Solapur organized eight in-house training/workshop/interactive meet, for farmers and field staff to promote pomegranate cultivation and livelihood in different states. These are tabulated below.

S.No	Name of Training Programme	Participants	Date
1	Model Pomegranate Production and Post-Harvest Management Practices	25 Farmers of Mandi, Himachal Pradesh	18.09.17-21.09.17
2	Pomegranate Cultivation for Improving the Livelihood Security	17 Tribal Farmers of Tikamgarh Regions, Madhya Pradesh.	04.10.17 -07.10.17
3	Canopy Management in Pomegranate	35 Tribal farmers of Sabarkantha Gujarat	05.10.17- 08.10.17
4	Skill Development in Water Management for Improving the Livelihood Security	25 Tribal farmers of Gadchiroli dist., Maharashtra	19.02.18- 22.02.18
5	Propagation, Model Production Practices and Value Addition in Pomegranate	28 Tribal farmers of MP and Chhattisgarh and Staff of SRIJAN, India.	19.03.18- 22.03.18

Workshop/ Field day

S.No	Name of Training Programme	Participants	Date
1	Interactive Meet for Promotion of Export of Pomegranate	37 Heads of APEDA, MSAMB, ICAR-NRCG, Dept. of Horticulture, GoM, AIPGRA, Pune, ICAR-NRCP Scientists and Exporters.	09.0717
2	Pomegranate filed day and planting material distribution of new variety 'Solapur Lal'.	100 Representative from KVK, Growers Association, State Dept., progressive farmers	26.12.17
3	Workshop on Handling Major Issues in Pomegranate Export Jointly Organized by ICAR-NRCP, Solapur & APEDA, New Delhi	100 Progressive farmers, exporters, State Dept. officials, etc.	17.03.18

Technology of transfer agreement Entrepreneurs

The ICAR-NRCP technologies were transferred to 2 entrepreneurs during the period through memorandum of understanding (MoU).

S.No	Technology Transferred	Beneficiary	Date	Revenue received (Rs)
1	Minimal processing and shelf life extension of minimally processed pomegranate arils	M/s. Ananya Agro Products, At/Post Shevate, Taluka Pandharpur, Solapur 413 315, MS	03.05.2017	1,15,000/-
2	Biohardening of *In vitro* propagated pomegranate plants	M/s.H. U. Gugle Biotech Pvt. Ltd., Devanahalli - 562110, Bengaluru Dist., Karnataka.	11.05.2017	43,125/-

Technology transfer agreement with M/s. Ananya Agro Products, Pandharpur, Solapur

Students

S. No	Programme	Beneficiary	Date
1	Guidance for Students Project work	Students of SVG Shivdare College of arts, commerce & science, Solapur	29.12.17
2	Guidance for Students Project work	Students of TC College of Engineering Baramati, Pune.	22.02.18

MoU with SVG Shivdare college of arts, commerce & science, Solapur, Maharashtra

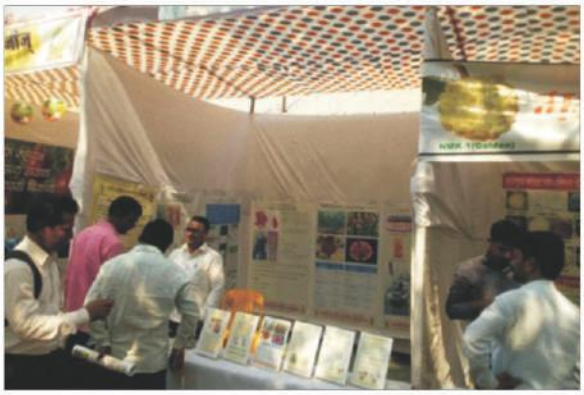
MoU with TC College of Engineering Baramati, Pune, Maharashtra

Exhibition

S.No.	Name of the Exhibition	Organizer	Venue	Participants (No.)	Date
1	2nd National Seminar-cum farmers fair – Pomegranate for health, growth and prosperity	ICAR-NRCP and SARP, Solapur	ICAR-NRCP Solapur	4400	28.04.17-30.04.17
2	Exhibition of biodiversity conservation	PPV&FRA, Pune	College of Agriculture, Pune , MS	350	20.05.2017
3	Science Centre Exhibition	Solapur Science Centre	Solapur , MS	430	14.08.2017
4	Grapes Pomegranate Krishi Exhibition	Agrowon news net, Solapur	Home Maidan Solapur	1500	15.09.17
5	Krushithon Agriculture Exhibition 2017	Media Exhibition Pvt Ltd	Thakkars Dome, Nashik , MS.	3200	23.11.17-27.11.17
6	Kisan Agrishow 2017	Kisan Forum Pvt Ltd	Moshi, Pune, MS	4800	13.12.17-17. 12.17
7	National Seminar cum Exhibition	ZARS, MPKV, Solapur	ZARS,Solapur, Mulegaon Farm, MS.	470	09.01.18
8	Siddheshwar Devsthan Fair cum Exhibition	Siddheswar Devasthan Samithi	Home ground, Solapur, MS.	170	12.01.18
9	ICAR-NIASM Foundation day and Exhibition	ICAR-NIASM, Baramati	ICAR-NIASM, Baramati, Pune,	70	21.02.18
10	Solapur Krishi Mohotsav Exhibition 2018	State Dept. of Agri., Solapur	Home Maidan, Solapur	370	11.03.18
11	National Horticulture Fair	ICAR-IIHR, Bengaluru	ICAR-IIHR, Bengaluru	3000	15.03.18-17.03.18

National Seminar-cum-Farmers fair at ICAR-NRCP, Solapur

Krushithon Agriculture Exhibition 2017, Nasik



National Seminar cum Exhibition at Mulegaon farm, ZARS, Solapur

Krushi Mahostav 2018 Exhibition, Home ground, Solapur

ICAR-NRCP Stalls at various Exhibitions

Pomegranate growers/ visitors to ICAR-NRCP, Solapur

During the year, the following visitors involving 1692 beneficiaries visited this centre and the details are given below.

Women Farmers from Raichur, Karnataka at NRCP

Farmers from Shivmoga, Karnataka at NRCP

Visitors to ICAR-NRCP, Solapur

Visits of farmers and students

During the year, the following visitors involving 1692 beneficiaries visited this centre and the details are given below.

S. No.	Date	Organization/Place of visitors	Category	Beneficiary (No.)
		Farmers		
1.	03.04.2017	Podali Andra Pradesh	Farmers	18
2.	03.04.2017	Bidar, Karnataka	Farmers	35
3.	05.04.2017	Kalburgi, Karnataka	Farmers	45
4.	03.05.2017	Davangere, Karnataka	Farmers	38
5.	13.07.2017	Haveri, Karnataka	Women Farmers	44
6.	15.07.2017	Zuari fertilizers Pvt. Ltd, Solapur	Farmers	16
7.	27.07.2017	JD, SDA-Dharwad Karnataka	Farmers	47
8.	11.08.2017	Food tech. college, Mohol, Solapur	Farmers	40
9.	20.09.2017	Yavati village, Mohol, MS	Farmers	38
10.	21.09.2017	Khandala of Satara, MS	Farmers	160
11.	22.01.2018	Telangana state	Farmers	20
12.	30.01.2018	Bellary, Karnataka	Farmers	30
13.	12.02.2018	Raichur, Karnataka	Women Farmers	44
14.	23.02.2018	Chickmangluru, Karnataka	Farmers	30
15.	23.02.2018	SAO, Penukonda, Andhra Pradesh.	Farmers	22
16.	27.02.2018	Yadgir of Karnataka	Farmers	48
17.	22.03.2018	Shivmoga of Karnataka	Farmers	46
		Students		
18	01.04.2017	SVG Shivdare college of Arts, Commerce and Science, Solapur	Students	18
19	05.04.2017	Department of Agriculture, Govt. of Karnataka, Bellary	Students	49
20	03.05.2017	Department of Agriculture, Govt. of Karnataka, Shivamogga	Students	44
21	11.05.2017	Department of Agriculture, Govt. of Karnataka, Shivamogga	Students	49
22	12.07.2017	Arabhavi, Karnataka	Students	60

S. No.	Date	Organization/Place of visitors	Category	Beneficiary (No.)
23	20.09.2017	College of Agriculture.Pune, MS	Students	06
24	20.09.2017	Lokamangal college of bioteh. Wadala, MS	Students	74
25	27.09.2017	Department of Agriculture, Govt. of Karnataka, Gadag	Students	49
26	27.09.2017	Department of AgriAculture, Govt. of Karnataka, Shivamogga	Students	06
27	10.10.2017	College of Agriculture, Pune	Students	12
28	11.10.2017	College of Agriculture Junagad, Gujarat	Students	18
29	12.10.2017	Jat, Aatpadi, Sangli, MS	Students	09
30	29.11.2017	Department of Agriculture, Govt. of Karnataka, Chikkamagalur	Students	100
31	07.12.2017	Department of Agriculture, Govt. of Karnataka, Davanagere	Students	47
32	19.01.2018	Oyester international school, Solapur	Students	44
33	19.01.2018	College of agriculture Udgir, Latur	Students	50
34	19.01.2018	College of agriculture Udgir,Latur	Students	50
35	20.01.2018	College of Agriculture Umerkhed , Yeotmal	Students	70
36	20.01.2018	Shivdare College of Biotech. Solapur, MS	Students	150
37	31.01.2018	College of Agriculture Dhule, MS	Students-Ph.D	14
38	01.02.2018	Solapur University MS	Students-PG	17
39	12.02.2018	College of Horticulture Shivmoga, Karnataka	Students	60
40	22.02.2018	Lokmangal College of Agriculture Wadala Solapur, MS	Students	22
41	23.02.2018	TC of college engineering Baramati, Pune, MS	Students	54
42	24.02.2018	Sangmeshwar college of Arts and Science Solapur	Students	84

S. No.	Date	Organization/Place of visitors	Category	Beneficiary (No.)
43	26.02.2018	Walchand college of Arts and Science, Solapur, MS	Students	70
44	27.02.2018	Walchand college of Arts and Science, Solapur	Students	70
45	20.03.2018	College of Agriculture, Pune, MS	Students	193
46	24.03.2018	VNMKV University, Parbhani,MS	Students	52
47	28.03.2018	College of Agriculture Dhule	Students	15

INSTITUTIONAL ACTIVITIES

1a. RAC meeting

The meeting of the eleventh Research Advisory Committee (RAC) of ICAR-National Research Centre on Pomegranate was held on December 23, 2017 at ICAR-NRCP, Kegaon, Solapur under the Chairmanship of Dr. R.B. Deshmukh, Former Vice Chancellor, MPKV Rahuri. The committee visited experimental sites at ICAR-NRCP farm and also in polyhouse. They interacted with concerned scientists and gave valuable suggestions to improve the experimental output. They also visited the block at Hiraj to see newly released variety, 'Solapur Lal'. The RAC members were briefed on the developments at the Centre during 2012-17 by Dr. RK Pal, Director. The committee appreciated the infrastructure developments and research efforts made by the Centre under the dynamic leadership of Dr. RK Pal, Director during his tenure of 5 years.

Research Advisory Committee of ICAR-NRCP

Chairman			
1	Dr. R. B. Deshmukh Former Vice Chancellor MPKV, Rahuri	5	Dr. K.S. Mohan, * Former Biotechnologist, Monsanto Research Centre, Bangalore
Member			
2	Dr.Vitthal Benagi, Director of Extension, UAS, Dharwad	6	Dr. R. K. Pal Director, ICAR-NRC on Pomegranate, Solapur
3	Dr. D. P. Waskar,* Director of Research,VNMKV, Parbhani	7	Shri BaburaoRamchandraGaikwad, RamkrishnaNiwas, Shivaji Nagar, At. Post. Sangola, Dist. Solapur
		Member Secretary	
4	Dr. W. S. Dhillon, ADG (HS-I) (Fruits and PI Crop) ICAR, KAB-II, Pusa,New Delhi	8	Dr. (Mrs.) Jyotsana Sharma Principal Scientist, ICAR-NRC on Pomegranate, Solapur 413255 (MS)

*Not attended the meeting

Recommendations

- The Pomegranate seed oil and de-oiled cake for use in the production of fibre rich cookies should be commercialized on priority.
- One project should be proposed to address farmers" problems related to sudden climatic changes (untimely rains, drought, temperature fluctuations etc.) on flower/fruit drop, pests and disorders in pomegranate.
- In future, breeding programmes should be focused to breed varieties for (i) resistance to bacterial blight (ii) Earliness in popular commercial varieties (iii) fruit size above 500 g for export.
- Standardize training (including Trellis & Y system.) and pruning techniques in pomegranate *vis-a-vis* plant spacing.

1b. IRC meeting

The meeting of the twelfth Institute Research Council (IRC) of ICAR- National Research Centre on Pomegranate was held on December 28, 2017, at NRCP, Kegaon, Solapur under the chairmanship of Dr. RK Pal, Director, ICAR-NRCP, Solapur. All the Scientists of the Centre attended the meeting. The RAC suggestions and recommendations were included in respective projects for timely action.

Institute Research Council of ICAR-NRCP

Chairman			
1	Dr. R. K. Pal (till 31.12.17) Dr. (Mrs.) Jyotsana Sharma (wef.01.01.18) Director, ICAR-NRCP		
Member			
2	Dr. K. Dhinesh Babu Principal Scientist (Hort.-Fruit Science) ICAR-NRCP, Solapur	7	Dr. N. N. Gaikwad Scientist (AS & PE) ICAR-NRCP, Solapur
3	Dr. U. R. Sangle, Principal Scientist (Plant Pathology) ICAR-NRCP, Solapur	8	Dr. (Mrs.) Shilpa Parashuram Scientist (Gen. & Pl. breeding) ICAR-NRCP, Solapur
4	Dr. D. T. Meshram Senior Scientist (L & WME) ICAR-NRCP, Solapur	9	Mr. Mallikarjun Scientist (Entomology) ICAR-NRCP, Solapur
5	Dr. Ashis Maity Scientist (Soil Science-Pedology) ICAR-NRCP, Solapur	10	Ms. Roopa Sowjanya Scientist (Gen. & Pl. breeding) ICAR-NRCP, Solapur
Member			
6	Dr. N. V. Singh Scientist (Hort.-Fruit Science) ICAR-NRCP, Solapur	11	Dr. (Mrs.) Jyotsana Sharma Principal Scientist (Plant Pathology) ICAR-NRCP, Solapur

RAC Meeting

RAC Meeting

IRC Meeting

RAC / IRC meeting of ICAR-NRCP, Solapur

1c. IMC meeting

The 14th Institute Management Committee (IMC) meeting of ICAR-NRCP, Solapur was held on 01.07.2017. The members of the IMC team interacted and discussed on several issues concerned with institute management aspects.

Institute Management Committee of ICAR-NRCP

Chairperson			
1	Dr. R. K. Pal (till 31.12.17) Dr. (Mrs.) Jyotsana Sharma (wef.01.01.18) Director, ICAR-NRCP, Solapur		
Members			
2	Dr. (Mrs.) J. Sharma Principal Scientist, ICAR-NRCP, Solapur	8	Dr. Prabhakar, Principal Scientist, Centre on Rabi Sorghum (DSR) NH-9, Bypass Road, Shelgi, Solapur 413 006
3	Director of Horticulture Govt. of Maharashtra	9	Sh. Prabhakar Chandane Po. Ekhatpur, Tal. Sangola, Dist. Solapur (MS)
4	Dr. R. G. Somkuwar, Principal Scientist, ICAR-NRC for Grapes, Post Box No. 3, Manjari Farm, Pune 412 307 (MS)	10	Dr. W.S. Dhillon, The Assistant Director General (HS-I) Indian Council of Agricultural Research Krishi Anusandhan Bhavan, Phase II, Pusa, New Delhi 110 012
5	Director of Horticulture, Govt. of Rajasthan	11	Sh. Baburao Ramchandra Gaikwad Ramkrishna Niwas, Shivaji Nagar A/p., Sangola, Solapur
6	Dr. S. Sriram, Principal Scientist Division of Plant Pathology, ICAR- IIHR Bangalore	12	The Finance and Accounts Officer Indian Institute of Rice Research, Rajendranagar, Hyderabad
		Member Secretary	
7	Dr. D. P. Waskar Director of Research, VNMKV Parbhani	13	Sh. R. B. Rai Assistant Administrative Officer ICAR-NRCP, Solapur

1d. IJSC Meeting

The Institute Joint Staff Council (IJSC) meeting of ICAR-NRCP, Solapur was held regularly with the following members.

Chairperson			
1	Dr. (Mrs.) Jyotsana Sharma Director (Acting) ICAR-NRCP, Solapur		
Member (Official Side)		**Member (Staff side)**	
2	Dr. (Mrs.) Jyotsana Sharma, Pr. Scientist, ICAR-NRCP	8	Sh. R. B. Rai, Member (CJSC) AAO, ICAR-NRCP
3	Dr. N. V. Singh, Scientist, ICAR-NRCP	9	Sh. Y. R. Shinde, Secretary (IJSC) Sr. Tech. Asstt. ICAR-NRCP
4	Dr. D. T. Meshram, Sr. Scientist, ICAR-NRCP	10	Sh. Kiran Khatmode, LDC, ICAR-NRCP
5	Dr. Nilesh Gaikwad, Scientist, ICAR-NRCP	11	Sh. S. S. Bayas, SSS, ICAR-NRCP
6	Officer I/c Accounts ICAR-NRCP	12	Sh. V. S. Gangan, SSS, ICAR-NRCP
7	Officer I/c Admin, ICAR-NRCP		

2. Mera Gaon Mera Gaurav

Under 'Mera Gaon Mera Gaurav' (MGMG) programme, two different teams involving scientists and technical staff along with SMS from KVK, Solapur visited the adopted villages at 2-3 months interval for conducting training and demonstration programme.

The programmes were organized in association with NGO and direct contact of farmers in different adopted villages. Interface meetings and demonstration for the farmers were organized in collaboration with KVK and NGOs in different adopted villages organized. In general 25-40 farmers participated in the meetings. Farmers were very much interested to adopt new agricultural technologies, especially for diseases. In the villages with severe water shortage, the farmers were advised to shift to pomegranate and other arid zone crops instead of sugarcane which requires large quantity of water.

Baseline survey was conducted for six villages viz.,Waghdari (Akklakot Tk.), Karkamb (Pandharpur Tk.) Nimgaon (Madha Tk.) in Solapur District, Nandgaon (Nalduraga Tk.) in Osmanabad District of Maharashtra and Jambaga B., Ambalaga in Kalburgi District of Karnataka states. All between 70-100 km distance from the institute. About 218 farmers were benefited in Farmers Scientist interface and demonstration was organized in

every month in difference adopted villages in the all discipline. Many farmers was motivated for cultivation of pomegranate for their livelihood. Many farmers became aware on the various schemes of National Horticulture Board, GOI for establishment of new orchards and enlightened about importance of cleanliness and Swachh Bharat Mission of GOI. Famers were advised not to burn wheat stubble/straw through this training program and taught soil conservation measures and practices for soil health improvement. All specific and general questions and queries of farmers related to the agriculture were answered by concerned scientists.

In the every meeting and training programme, farmers in the villages were also highlighted about importance of cleanliness and also administered 'Swachta Shapath' under Swachha Bharat Mission of GOI.

Distrubution of technical bulletins to the farmers at adopted village, Waghdari

Guidance of farmers at Waghdari village for management pomegranate crop

Demonstration on Management of pomegranate 6 months old crop at Ichgaon

Interaction of NRCP Scientists with the farmers at adopted village Karkhamb

Demonstration of the technology for management of pomegranate field at Nimgaon

Visit to farm of Shri Baburao Patil. 4 ha sugarcane grower

Field visits/demonstration/ interaction of ICAR-NRCP Scientists with the farmers at different adopted villages

3. Hindi Pakhwada

Dr.(Mrs). Jyotsana Sharma addressing the staff during inaugural programme

The NRCP Hindi competition

Mrs. Surya Jahagirdar being facilitated on the eve of Hindi PakhwadaCeremony

Hindi Pakhwada celebrations at ICAR- NRCP

ICAR-NRCP celebrated 'Hindi Pakhwada' from 14.09.17 to 28.09.17 by conducting various competitions viz., elocution, essay writing, translation, quiz, etc. for staff members. The importance of Hindi language in bringing social integrity was highlighted. Dr. D.T. Meshram, Hindi Officer coordinated the successful conduct of the events.In the concluding ceremony, Dr. R.K.Pal, Director, ICAR-NRCP distributed the certificates to the active participants.

4. Swachh Bharat Abhiyan

Swachh Bharat Abhiyan (Clean India Mission) was observed at the institute from 15.09.17-02.10.17 under the theme "Swachhtha Hi Sewa". As part of the programme, cleaning of the premises and other places were done. Apart from this, various activities like vermicomposting, tree plantation, cleaning of stores, laboratories etc., were taken throughout the year.

Date	Events conducted under Swachhtha Hi Sewa
16.09.17	Weeding of block B2
17.09.17	Cleaning premises of ICAR-NRCP
18-09.17-23.09.17	Weeding other blocks at Kegaon,
24.09.17	Samagra Swachhta Divas at Shivajinagar Tanda
25.09.17	Sarvaytra Swachhta Diwasby cleaning near by bus stop
26.09.17	Drawing competition for School children
27.09.17	Essay competition for School children
28.09.17	Cleaning of rooms
29.09.17	Cleaning of Laboratories
30.09.17	Weeding at NRCP premises
01.10.17	Swachhta of nearby tourist spot - Siddheswar Temple
02.10.17	Award ceremony to the winners of drawing, essay competition

ICAR-NRCP Staff takes Swachhata Pledge

ICAR-NRCP staff cleans office premises

Dr. (Mrs.) Jyotsana Sharma) Nodal Officer ICAR-NRCP, Solapur, administered Swachhata pledgeto the farmers participating in an Exhibition organised by Sakal - Agrowon daily News paper at Home Maidan, Solapur

Mr. VA Shinde AFAO briefing the staff on the use of Swachhata-Mohua the official mobile-app of Ministry of Housing and Urban Affairs (Mohua), GOI.

Swach Bharat Abhiyan activities at ICAR-NRCP

5. Vigilance Awareness Week

ICAR-NRC on Pomegranate, Solapur observed the vigilance awareness week from 30.10.17 - 04.11.17. Dr. R.K. Pal, Director, ICAR-NRCP administered the pledge- 'Rashtriya Ekta Shapat' to uproot corruption in the office. Dr. Jyotsana Sharma, Vigilance Officer demonstrated the procedure for online pledge, all the staff took online pledge and submitted the certificate. One day elocution contest was also organized for the staff. Dr. Arun Deokar, DySP, Anti Corruption Bureau, Solapur, interacted with the staff and replied on their queries related to office corruption and on line frauds.

Dr. Arun Deokar, DySP, Anti-Corruption Bureau, Solapur interacting with NRCP Staff

Dr. Arun Deokar, DySP, Anti-Corruption Bureau, Solapur interacting with NRCP Staff

Vigilance awareness week observed at ICAR-NRCP, Solapur

6. Second National Seminar-Cum Farmers Fair

Second National Seminar cum Farmers Fair–Pomegranate for health, growth and prosperity was conducted jointly by ICAR-NRCP and SARP, Solapur from April 28-30, 2017 at ICAR-NRCP, Solapur. Pomegranate varieties viz., Solapur Lal and Solapur Anardana were released. Besides, Trainees Hostel with a capacity of 43 beds was inaugurated. A book on pomegranate and Souvenir of the seminar were also released on this occasion. On this occasion, an Exhibition was organized with participation of more than 35 renowened agri-input companies and Government organizations from private sector, about 3000 delegates, farmers, students and other stakeholders attended the seminar and visited exhibition stalls.

Padma Shri Dr. K.L. Chadha at ICAR-NRCP on the occasion of National Seminar

Inaugural Ceremony of 2nd National Seminar on Pomegranate

Farmer-Scientist interactive session

Exhibition stall of ICAR-NRCP

2nd National Seminar on Pomegranate for Health, growth and prosperity

7. Infrastructure Created

7a. Mobile-app

An improved version of the mobile app "Solapur Anar" was launched by Hon'ble Director General, ICAR, Dr. Trilochan Mohapatra on April 28, 2017. The App is in six languages viz., Hindi, English, Marathi, Kannada, Gujarati and Telugu. It has all information related to pomegranate cultivation.The App downloadable from google play store works both online and offline. The App has a rating of 4.3 out of max 5, with more than 5,000 downloads during the year.

Screen Shots of ICAR-NRCP Mobile App 'Solapur Anar' in 6 languages

7b. Trainees' Hostel

A well-furnished trainees' hostel constructed with 43 bed facility was inaugurated by Shri. Subhash Deshmukh Hon'ble Cabinet Minister, Maharashtra on April 30, 2017. The hostel is in great demand since its inception in October 2017 and had 264 visitors since Dec 2017.

7c. Video Films

Two video films in Hindi and English languages have been prepared on 'Pomegranate Elite Planting Material- Nurturing Prosperity' and 'Pomegranate Processing for Entrepreneurship Development' for the benefit of farmers and entrepreneurs.

Pomegranate Elite Planting Material- Nurturing Prosperity

Pomegranate Processing for Entrepreneurship Development

Video films prepared

8. Distinguished visitors

Dr. S.K. Chaudhari, ADG Soil Science interacting with the Scientists on his visit at ICAR-NRCP on 31.03.2018

Padma Shri GenabhaiDargabhai Patel at ICAR-NRCP, Solapur

Distinguished visitors at ICAR-NRCP during 2017-18

HUMAN RESOURCE DEVELOPMENT

1.Trainings attended

During the year under report, 5 scientists, 2 technical staff, 2 administrative & finance staff have undergone need based training as a part of the capacity building. The details of trainings undergone by different categories of staff are given below.

S.No	Training programme	Date	Venue	Participants
		a. Scientific Staff		
1	DST SRB School in chemical ecology	03.07.17-16.07.17	NCBS, Bangalore	Mr. Mallikarjun
2	Recent Advances in Abiotic Stress Management for Climate Smart Agriculture	08.09.17-28.09.17	ICAR-NIASM, Baramati.	Dr. N V Singh
3	Recent advances of Bioinformatics in Agriculture :A Practical Perspective	01-12-17-21.12.17	ICAR-IASRI, New Delhi	Ms. RoopaSowjanya P.
4	One day awareness training programme on Protection of Plant Variety & Farmers' Rights	06.12.17	ICAR-NIASM, Baramati	Dr. Shilpa Parashuram
5	CAFT training on Recent Developments in Conservation and Characterization of Horticulture Plant Genetic Resources	04.01.18-24.01.18	CoH- UHS campus, GKVK, Bengaluru	Ms. Roopa Sowjanya, P.
6	Advances in Microscopy	17.01.18-19.01.18	ICAR-CIRCOT Mumbai	Mr. Mallikarjun
7	Analysis of experimental data	19.02.18-24.02.18	ICAR-NAARM, Hyderabad	Dr. K Dhinesh Babu
8	Training on ISO 2009:2015	22.03.18	ICAR-NRCP, Solapur	Mr. Mallikarjun
		b. Technical Staff		
1	Application of Remote Sensing and GIS in Natural Resource Management'	17.09.17 - 28.09.17	IISWC, Dehradun	Mr. Yuvraj Shinde
2	Selection, Adjustment, Operation and Maintenanceof Agricultural Implements for Field and Horticultural Crops' from	01.08.17 – 10.08.17	ICAR- CIAH, Bikaner	Mr. Diwakar Sawaji

S.No	Training programme	Date	Venue	Participants
		c. Administrative Staff		
1	Public Financial Management System,GEM,GFRworks	11.09.17 - 15.09.17	ICAR-CPRI, Shimla	Mr. R.B. Rai
2	Public Financial Management System	17.01.18- 24.01.18	Ministry of Finance, Fort Mumbai	Mr. R.B. Rai
3	Organization specific programme on "General Financial Rules-2017" for ICAR Officers	21.08.17 - 23.08.17	ISTM, New Delhi	Mr. VA. Shinde

2. Conferences, Workshops and Meetings attended

The scientists of the Centre participated in conferences / workshops and meetings conducted by different organizations in India in addition to the meetings mentioned in the chapter on institutional activities. Workshop/conference and important meetings attended during the year are tabulated below.

S.No	Title	Date	Venue	Participants
		Conferences / Workshop/Meetings		
1	Meeting on "Processing characteristics of agricultural produce and animal and fisheries breeds"	16.06.17.	Ministry of Agriculture, New Delhi	Dr. Nilesh Gaikwad
2	Workshop on Export Quality Pomegranate Production	09.07.17	WariPariwar ATMA and Mahaanar, Mangalwedha, Maharashtra	Ms. RoopaSowjanya, P
3	QRT meeting of AICRP-AZF scheme	08.08.17	MPKV, Rahuri	Dr. Jyotsana Sharma, Dr. K. DhineshBabu
4	N. D. Krishi Sanjivni Project Workshop	18.08.17	VAMNICOM, Pune, Maharashtra	Dr. Nilesh Gaikwad
5	Stering committe meeting of HORTSAP 2016-17&2017-18	05.05.17	VAMNICOM, Pune, Maharashtra	Dr. Mallikarjun

6	National Symposium on "Innovative Approaches for Detection, Diagnosis and Management of Plant Diseases"	15.09.17	UHS, Bagalkot	Dr. Jyotsana Sharma
7	Stakeholders meet on pomegranate Value Chain	31.10.17	IARI, New Delhi	Dr. R. K. Pal, Dr. Nilesh Gaikwad, Sh. Yuvraj Shinde
8	International Seminar on Global Climate Change: Implications for Agriculture and Water Sectors	14.12.17 - 16.12.17	WALMI, Aurangabad Maharashtra	Dr. Jyotsana Sharma
9	National Conference on Biodiversity and conservation of nature and natural resources	11.01.18-12.01.18	MPKV, Rahuri.	Dr. U. R. Sangle
10	National Seminar on Recent Trends in Plant Science and Agricultural Science	11.01.18-12.01.18	ZARS Solapur	Dr. Nilesh Gaikwad, Dr. D.T. Meshram Mr. Mallikarjun
11	22nd Research Workers Group Meet of AICRP on Arid Zone Fruits	16.02.18-18.02.18	HRS, Dr.YSRHU, Ananthapuram	Dr. K Dhinesh Babu Mr. Mallikarjun
12	National Conference on Conservation Agriculture	22.02.18-23.02.18	ITM University, Gwalior, Madhya Pradesh	Dr. N V Singh
13	National workshop on Revisiting FOCARS : Reflections and feedbacks of trained Scientists	15.03.18-6.03.18	ICAR- NAARM, Hyderabad	Ms. Roopa Sowjanya, P
14	National Seminar on sustainable Pomegranate production during adverse conditions	07.01.18	Maharashtra Pomegranate Growers Association, Pune	Dr. Jyotsana Sharma, Dr. Nilesh Gaikwad
15	Farmers workshop on pomegranate and grapes cultivation	04.02.18	APMC, Jat, Sangli, Maharashtra	Dr. Jyotsana Sharma, Dr. Nilesh Gaikwad
16	Research Programme Planning Meeting 2018-19 in Horticulture Crops	13.03.18	MPKV, Rahuri	Dr. Jyotsana Sharma
17	Intl.Conf. on advances in Agri. & allied ST for sustainable devt.	10.01.18-11.01-18	GUARD Hyderabad	Dr. Mallikarjun

PUBLICATIONS

Papers in research journals

S. No.	Research papers	NAAS Rating
1	Babu. K.D., Singh, N V., Gaikwad, N., Maity, A., Suryawanshi, S.K. and Pal, R.K. 2017. Determination of maturity indices for harvesting of pomegranate (*Punica granatum* L.). *Indian J. Agricultural Sciences* 87 (9) :1225-30	6.22
2	Gaikwad, N.N., R. K. Pal, Swati Suryawanshi, K.D. Babu, Ashis Maity and Susheel Sarkar. 2017. Effect of extraction method and thermal processing on retention of bioactive compounds of pomegranate (*Punica granatum*) (cv. Bhagwa) juice. *Indian Journal of Agricultural Sciences* 87 (11): 1445-52.	6.22
3	Gaikwad. N.N., V.H. Yedle, Govind Yenge, Swati Suryawanshi, K.D. Babu, R.K. Pal and Susheel Sarkar. 2017. Effect of microwave pretreatment on extraction yield of pomegranate seed (cv. Bhagwa) oil. *International Journal of Chemical Studies* 5(4):1291- 1294.	5.31
4	Gosavi. A.B, Deshpande. A. N and Maity. A.2017.Diagnosis of nutrient imbalance by Diagnostic and Recommended integrated system in pomegranate growing soils of south-western Maharashtra. *Indian Journal of Horticulture* 74(4): 498-504.	6.15
5	Maity, A., Jyotsana Sharma, Ananta Sarkar, Amarja K. More, R.K. Pal, and Arnab Maity. 2017. Salicylic acid mediated multi-pronged strategy to combat bacterial blight disease in pomegranate caused by *Xanthomonas axonopodis* pv. *punicae*. *European Journal of Plant Pathology*. doi: 10.1007/s10658-017-1333-3	7.48
6	Maity. A., Babu. K.D, Sarkar Ananta and Pal, R.K. 2017. Seasonality of nutrients vis-à-vis fruit quality of pomegranate cv. Bhagwa on vertisol, *Journal of Plant Nutrition*, 40:9, 1351-1363	6.62
7	Mallikarjun M.H.and Pal, R.K. 2018 Laboratory Rearing Protocol for Pomegranate Fruit Borer *Deudorixisocrates*. *International Journal of Current Microbiology and Applied Sciences*. SI-6, 883-8	5.38
8	Mallikarjun M.H., Sunil Joshi and Ram Krishna Pal.2018. Pomegranate: a new host for the invasive scale insect Lopholeucaspis japonica (Cockerell, 1897) (*Hemiptera: Diaspididae*) from Gujarat, India.*OrientalInsects*.DOI: 10.1080/00305316.2018.1451783.	6.24
9	Marathe R.A, Jyotsana Sharma, Babu, K.D. and A. A. Murkute. 2017. Bedding System: A Unique Plantation Method of Pomegranate in Arid and Semiarid Region. National Academy Science Letters ISSN 0250-541X *Natl. Acad. Sci. Lett.* DOI 10.1007/s40009-017-0567-0	6.37
10	Marathe, R.A., Babu, K.D., and D T Chaudhari. 2017. Response of pomegranate (*Punica granatum*) to drip irrigation system in light textured soils of semi-arid regions. *Indian Journal of Agricultural Sciences* 87 (1): 56–61.	6.22
11	Meshram D.T., S.D.Gorantiwar, K.D. Babu and R.K.Pal. 2018. Influence of organic mulches and irrigation level on yield and water use efficiency of pomegranate (*Punica granatum* L.). *Journal of Agrometeorology* (Accepted).	6.40

S. No.	Research papers	NAAS Rating
12	Meshram D.T.,S.D.Gorantiwar, S.R., Lad and R.K. Pal. 2018. Effect of organic mulches on yield, quality and WUE of Pomegranate (*Punica granatum* L.). *Indian Journal of Soil Conservation*, 48(1):1-8.	5.20
13	Meshram D.T.,S.D.Gorantiwar, U.R Sangale, B.K.Nagraj and R.K. Pal. 2017. ARIMA model for forecasting reference crop evapotranspiration (ET_o) of Solapur region, Maharashtra, India. *Contemporary Research in India*,7(2):286-295.	3.23
14	Sangle, U.R. and J.S. Mishra. 2017. Cultural diversity of *Trichoderma spp.* isolated from different agro-climatic regions.*Int. J. of Pure and App. Biosci*.5(2):1012-1016.	4.74
15	Sangle, U.R., S.S.Chinchure, D.T.Meshram andK.D. Babu 2017. Effect of nutrient combination of cheaper organic substrates on the mass multiplication of virulent isolates of *Trichodarma species*. *Journal of Pure and Applied Microbiology*, 11(1):359-365.	6.00
16	Shilpa P, S.N. Shendage, N. V. Singh, P. Patroti, P. Roopa Sowjanya, Prakash G. Patil, Vipul Sangnure, Daithankar, Manglaram and R. K. Pal. 2018. *In silico* development of EST-SSR Markers in Pomegranate (*Punica granatum* L.). *Contemporary Research in India*, 4: 155-161.	3.23
17	Singh, N.V., Chandra, R., Awachare, C.M., Babu, K.D. and Pal, R.K. 2017.A novel method of propagation in pomegranate: Mound Layering. *Prog. Hort.,* 49(1): 92-94 (DOI:10.5958/2249-5258.2017.00020.3).	3.53
18	Singh, N. V., Singh, S.K., Babu, K.D., Shilpa, P., Singh, S., Sharma, A., Mishra, D.C., Das, S. and Pal, R.K. 2018. Arbuscular Mycorrhizal Fungi for improving performance of cutting derived pomegranate plants. *Journal of Pharmacognosy and Phytochemistry.* SP2:204-209	5.20
19	Shilpa, P., Singh, N. V., Roopasowjanya, P., Babu, K.D., Sangnure, V., Singh, S., Sharma, J. and Pal, R.K. 2018. Germplasm conservation and phenotypic characterization of pomegranate (*Punica granatum* L.) germplasm accessions for various morphological and physico-chemical characters. *Journal of Pharmacognosy and Phytochemistry.* SP2:114-118	5.20

Book

1. Pal, R.K. and Singh, N.V. 2017. Pomegranate for nutrition, livelihood security and entrepreneurship development, Daya Publishing House (A division of Astral International Pvt. Ltd), New Delhi, 288 p.

Book Chapter

1. Babu, K.D, Chandra, R, Singh, NV, Sharma Jyotsana, Sahu, P, Pal, RK and Murthy, BNS. 2017. Crop improvement strategies in pomegranate (*Punica granatum* L.). In: Pomegranate for nutrition, livelihood security and entrepreneurship development (Eds. Pal, R.K. and Singh, N.V.), Daya Publishing House (A division of Astral International Pvt Ltd), New Delhi, ISBN 978-93-5124-852-1 (HB),p.11-19.
2. Chandra, R., Sahu Prativa, Singh, N.V., Babu, K.D. and Pal, R.K. 2017. High density planting: An approach for enhancing productivity in pomegranate (*P. granatum* L.). In: Pomegranate for nutrition, livelihood security and entrepreneurship development (Eds. Pal, R.K. and Singh, N.V), Daya Publishing House, New Delhi, p.53-58.
3. Gaikwad, N N., Pal, R.K., and Babu, K.D. 2017. Entrepreneurship development in

pomegranate through value addition. In: Pomegranate for nutrition, livelihood security and entrepreneurship development (Eds. Pal, R.K. and Singh, N.V), Daya Publishing House, New Delhi, p.243-250.

4. Gorantiwar, S.D. and DT Meshram. 2017. Water Management in Pomegranate. In: Pomegranate for nutrition livelihood security and entrepreneurship development, Daya Publishing House, New Delhi, 105-115.
5. Kumar Aundy, Mondal KK and Sharma Jyotsana. 2017. Tracing the evolutionary origin of *Xanthomonas axonopodis* pv. *punicae* causing bacterial blight of pomegranate using multilocus sequence typing. In: Pomegranate for nutrition, livelihood security and entrepreneurship development (Eds. Pal, R.K. and Singh, N.V), Daya Publishing House, New Delhi, p.157-160.
6. Maity, A., Ram Chandra, N.V. Singh, D.T. Meshram and R.K. Pal. 2017. Effect of elemental sulphur on solubility of micronutrients and their uptake by pomegranate. In: Pomegranate for nutrition, livelihood security and entrepreneurship development (Eds. Pal, R.K. and Singh, N.V.), Daya Publishing House, New Delhi, p.85-95.
7. Mallikarjun M.H., Sachin S. Suroshe, and R.K.Pal. 2017. Major sucking pests of pomegranate and their Integrated Management. In: Pomegranate for nutrition, livelihood security and entrepreneurship development (Eds. Pal, R.K. and Singh, N.V.), Daya Publishing House, New Delhi, p. 225-228.
8. Mallikarjun M.H., Sachin S. Suroshe, and R.K.Pal. 2017.Non-insect pests of pomegranate and their integrated management. Pomegranate for nutrition, livelihood security and entrepreneurship development (Eds. Pal, R.K. and Singh, N.V.), Daya Publishing House, New Delhi, p.221-224.
9. Sachin S. Suroshe, Mallikarjun M.H, and R.K.Pal. 2017. Status of major borer pests of pomegranate and their integrated management. Pomegranate for nutrition, livelihood security and entrepreneurship development(Eds. Pal, R.K. and Singh, N.V.).Daya Publishing House, New Delhi, 215-220.
10. Meshram DT, SD Gorantiwar, UR Sangale, Nagraj Bake and RK Pal.2017. Use of micro-irrigation system for optimum production of pomegranate. In: Global Hi-Tech Horticulture, Astral Intl. Pvt Ltd. New Delhi (Submitted).
11. Meshram DT, SD Gorantiwar, UR Sangale, Nagraj Bake and RK Pal. 2017. Water use efficiency in pomegranate. In: Global Hi-Tech Horticulture, Astral Intl. Pvt Ltd. New Delhi (Accepted).
12. Meshram, D.T., Ashis Maity, N.V. Singh, Ram Chandra and R.K. Pal. 2017. Effect of mulches on yield, quality and WUE of pomegranate .In: Pomegranate for nutrition, livelihood security and entrepreneurship development (Eds. Pal, R.K. and Singh, N.V.), Daya Publishing House, New Delhi, p 65-67.
13. Pal, R.K. and Babu, K.D. 2017. Post-harvest management of pomegranate. In: Pomegranate for nutrition, livelihood security and entrepreneurship development (Eds. Pal, R.K. and Singh, N.V), Daya Publishing House, New Delhi, p. 235-242
14. Sharma Jyotsana. 2017. Pomegranate wilt and its management. In: Pomegranate for Nutrition, Livelihood Security and Entrepreneurship Development (Eds. Pal, R.K. and Singh, N.V), Daya Publishing House, New Delhi, p. 209-213.

15. Sharma Jyotsana and Sharma KK. 2017. Pomegranate diseases and their management. In: Pomegranate for Nutrition, Livelihood Security and Entrepreneurship Development (Eds. Pal, R.K. and Singh, N.V), Daya Publishing House, New Delhi, p. 169-176.
16. Sharma Jyotsana. 2017. Integrated pest management in pomegranate In: IPM Handbook (Eds. Chattopadhyay C *et al.*), DKMA, ICAR, New Delhi. (Submitted the revised manuscript).
17. Singh, N. V., Babu, K.D., Chandra, R., Sharma, J., Sahu, P., Meshram, D.T. and Pal, R.K. 2017. Quality planting material production in pomegranate. In: Pomegranate for nutrition, livelihood security and entrepreneurship development (Eds. Pal, R.K. and Singh, N.V), Daya Publishing House, New Delhi p. 69-79.

Popular article

1. Sharma Jyotsana, Ramakant Gharate, Vijay Lokhande and R. K. Pal. 2017. Katekor Vyavsthapanatun Okhuya Telkat Dag Rogala. *Agrowon*. July 2017:10-11(*Marathi*)
2. Singh, N. V., Sharma Jyotsana, Babu, K. D., Kashyap, P., Chandra, R. and Pal, R.K. 2017. Pomegranate – a viable fruit crop for integration. *Indian Horticulture*, 62 (5): 59-63.
3. Meshram D.T., R.K. Pal and S.A.Lad. 2017. Dalimbacha Pani Vaprachi Karyshamta Utpadan Ani Gunvatevar Jaivik Achadanacha Honara Parinam. *Dalimbvrut*, April, 77 82.(*Marathi*)
4. Meshram D. T., R. K. Pal and S. A. Lad.2017. Dalimbacha Utpadana Ani Unvatevar Jaivik Achadanacha Honar Parinam. *Sheti patrika*. September, 3-5. (*Marathi*)
5. Meshram D.T., R.K. Pal, S.A. Lad and Wagmode B. K. 2017. Jamini Khalil Susham Ichan Padhat, *Sheti mitra*, April-Jun, 36-39 (*Marathi*)
6. Meshram D.T. and Sharma Jyotsana. 2018. Ambia Bahar Madhe Dalimbacha Jhadana Panya Che Prabhand. *Agrowon*, March 15, 2018 (*Marathi*)

Presentation in Conferences/Symposia/ Seminars/ other fora:

1. Babu, K.D., N.V. Singh, R. Chandra, J. Sharma, A. Maity, R.K. Pal, V.T. Jadhav, Shilpa, P., Jalikop, S.H, Sampthkumar, P and Murthy, B.N.S. 2017. Development and assessment of pomegranate hybrids for processing purpose. Souvenir, 2nd National Seminar – cum – Farmers' Fair: Pomegranate for health, growth and prosperity (Ed. RK Pal, Jyotsana Sharma, KD Babu, Ashis Maity, NV Singh.). ICAR-NRCP and SARP, C/o. ICAR-NRCP, Solapur, April 28-30, 2017, p.38-39.
2. Babu, K.D., N.V. Singh, R. Chandra, J. Sharma, A. Maity, R.K.Pal, V.T. Jadhav, Shilpa, P., Jalikop, S.H, Sampthkumar, P and Murthy, B.N.S. 2017. Development and evaluation of pomegranate hybrids for table purpose. Souvenir, 2nd National Seminar – cum – Farmers' Fair: Pomegranate for health, growth and prosperity. ICAR-NRCP and SARP, C/o. ICAR-NRCP, Solapur, April 28-30, 2017, p.39-40.
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AWARDS & RECOGNITION

Awards

S. No	Recipient	Award	Year	Awarding organization
Fellowship/ Associateship/ Young Scientist /Other awards				
1	Dr. R.K. Pal	Fellow of SARP (FSARP)	2017	SARP, ICAR-NRCP, Solapur
2	Dr. Prakash G. Patil	Fellow of the Indian Society of Pulses Research and Development (FISPRD)	2017	Indian Society of Pulses Research and Development (ISPRD)
3	Dr. K. Dhinesh Babu	SARP Associateship	2017	SARP, ICAR-NRCP, Solapur
4	Dr. D.T. Meshram	SARP Associateship	2017	SARP, ICAR-NRCP, Solapur
5	Dr. Ashis Maity	SARP Young Scientist Award	2017	SARP, ICAR-NRCP, Solapur
6	Dr. N.V. Singh	SARP Young Scientist Award	2017	SARP, ICAR-NRCP, Solapur
7	Dr. Nilesh N. Gaikwad	SARP Young Scientist Award	2017	SARP, ICAR-NRCP, Solapur
8	Dr. Ashis Maity	Dalimb Ratna Award	2017	Maharashtra Pomegranate Growers Research Association, Pune
9	Sh. Mallikarjun M	Young Scientist Award	2018	Genesis and Rural Development Society (GARD), Hyderabad
10	Dr. U.R. Sangle	Eminent Scientist Award	2018	Society for Educational Development and Environmental Research, BHU, Varanasi
11	Dr. D.T. Meshram	Outstanding Scientist Award	2017	5th IJTA International Conference. June 24-25, 2017, Rishikesh
12	Dr. D.T. Meshram	Best Researcher Award	2017	6th Science and Technology at Mumbai, Dec.10 , 2017
13	Ms. Roopa Sowjanya, P	Hindi Typing Award	2017	Hindi Pakwada held during 14-28 Sept, 2017 ICAR-NRCP Solapur
Best poster awards				
1	Dr. Ashis Maity	Best Poster award (2 no.)	2017	2nd National Seminar-cum-Farmers' Fair on Pomegranate, April 28-30, 2017, SARP, ICAR-NRCP, Solapur
2	Dr. K. Dhinesh Babu	Best Poster award	2017	2nd National Seminar-cum-Farmers' Fair on Pomegranate, April 28-30, 2017, SARP, ICAR-NRCP, Solapur

3	Dr. N.V. Singh	Best Poster award (3 no.)	2017	2nd National Seminar-cum-Farmers' Fair on Pomegranate, April 28-30, 2017, SARP, ICAR-NRCP, Solapur
4	Shri. Mallikarjun	Best Poster award	2017	2nd National Seminar-cum-Farmers' Fair on Pomegranate, April 28-30, 2017, SARP, ICAR-NRCP, Solapur
5	Dr. Nilesh Gaikwad	Best Poster award (3 no.)	2017	2nd National Seminar-cum-Farmers' Fair on Pomegranate, April 28-30, 2017, SARP, ICAR-NRCP, Solapur
6	Ms. Roopa Sowjanya, P	Best Poster award	2017	2nd National Seminar-cum-Farmers' Fair on Pomegranate, April 28-30, 2017, SARP, ICAR-NRCP, Solapur
7	Dr. Nilesh Gaikwad	Best Poster award (2 no.)	2018	Society For Free Radical Research India (SFRRI) 2018 at AIIMS, New Delhi

Best oral presentation award

1	Dr. D.T. Meshram	Best Oral Presentation award	2017	5th IJTA International Conference on Agricultural, Horticulture and Plant Sciences, Rishikesh, June 24-25.
2	Dr. N.V. Singh	Best Oral Presentation award	2017	2nd National Seminar-cum-Farmers' Fair on Pomegranate, April 28-30, 2017, SARP, ICAR-NRCP, Solapur
3	Dr. N.V. Singh	Best Oral Presentation award	2018	National Conference on Conservation Agriculture, ITM University Gwalior, Feb. 22-23, 2018
4	Sh. Mallikarjun	Best Oral Presentation award	2017	Intl. Conf. on Advances in Agril. and allied science technology for sustainable development Osmania University, GUARD Hyderabad Telangana, Feb 10-11, 2018.
5	Dr. Nilesh Gaikwad	Best Oral Presentation award	2017	National Conference on Advanced Trends in Agricultural and Food Engineering (ATAFE) on 7.4.2017 organized by Maharashtra Institute of Technology(MIT) Aurangabad

BUDGET ESTIMATE

Financial Outlay 2017-18

Head of Account	Rupees in lakhs	
	2017-18	
	Govt Grant	
	RE	Expenditure
A) Recurring		
Establishment Charges	250.00	250.00
T.A.	12.00	11.66
Other Charges	465.00	457.00
Total A	**727.00**	**719.29**
B) Non-Recurring		
Equipment	5.45	5.45
Minor Works	4.05	4.05
Library	0.50	0.38
Furniture	0.00	0.00
Total B	**10.00**	**9.88**
C) Loan & Adv	6.00	2.60
D) Pension	65.34	64.56
E) Vehicles & Vessels	0.00	0.00
Grand Total (A+B+C+D+E)	**808.34**	**796.33**

Revenue Receipts 2017-18

S. No.	Items	Amount (Rs)
1.	Income from farm produce	764311.49
2.	Income from royalty and publications	172857.26
3.	Income from other sources	146217.00
4.	Interest on loans and advances	217733.11
5.	Interest earned on short term deposits	312412.00
6.	Recovery of loans and advances	234188.00
7.	Training programmes	50000.00
8.	Analytical testing fees	500.00
9.	License fee / Guest house	50868.32
	Total Revenue Receipt	**1949087.18**

STAFF POSITION, PERSONNEL, JOINING / PROMOTION / RELIEVING

Staff Position

Category	Sanctioned during XIIth plan	Staff position	Vacant
RMP	1	0	1
Scientific	10	11	-1
Technical	6	6	0
Administrative	11	5	6
Supporting	2	2	0
Total	**30**	**24**	**6**

Personnel

RMP
Dr. R.K.Pal (till 31.12.17)
Dr. (Mrs.) Jyotsana Sharma (wef.01.01.18)
Director (Acting)

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

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

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

Dr. Prakash G. Patil
Scientist
(Plant Biotechnology)

Dr. Ashis Maity
Scientist
(Soil Scientist-Pedology)

Mr. Mallikarjun
Scientist
(Agri. Entomology)

Ms. Roopa Sowajanya P.
Scientist
(Genetics & Plant Breeding)

Technical Staff
Sh. D. T. Choudhari
Tech. Officer

Sh. Yuvraj Shinde
Sr. Tech. Asst.

Sh. Diwakar Sawji
Sr. Tech. Asst.

Administrative Staff
Sh. R. B. Rai
AAO

Sh. Shinde. V. A
AF& AO

Sh. Kiran Khatmode
LDC

Sh. A. S. Babar
LDC

Sh. Vipin Dagar
LDC

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

Dr. N. N. Gaikwad
Scientist
(Agril.Structures and Process Engg.)

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

Sh. M. S. Gogaon
Sr. Technician

Sh. Govind Salunke
Sr. Technician

Sh. Vijay Lokhande
Sr. Technician

Supporting Staff
Sh. Shailesh Bayas
SSS

Sh. Vishal Gangane
SSS

Joining

Dr. Prakash G. Patil, Scientist (Plant Biotechnology) joined ICAR-NRCP, Solapur on 01.07. 2017due to transfer from ICAR-IIPR Kanpur.

Promotion

Dr. U.R. Sangle, Sr. Scientist has been promoted to Principal Scientist w.e.f. 31.12.2016 through CAS.

Dr. Prakash Patil, Scientist has been promoted from RGP 6000 to RGP 7000 w.e.f. 07.01.2013 through CAS.

Sh. Shailendrasing Bayas, Skilled Supporting Staff promoted under MACP w.e.f. 07.06.2017

Sh. Vishal Gangane, Skilled Supporting Staff promoted under MACP w.e.f. 07.06.2017.

Relieving

Dr. R. K. Pal, Director ICAR-NRC on Pomegranate, Solapur retired from the service on 31.12.2017.

Presentation of momento to
Dr. R.K.Pal, Director, ICAR-NRCP

Dr. R.K.Pal with family and Staff,
ICAR-NRCP

Farewell function of Dr. R.K.Pal, Director, ICAR-NRCP, Solapur

OBITUARY

Dr.Vilas Tejrao Jadhav

Oct 02,1950- May 06, 2018

ICAR-National Research Centre on Pomegranate, Solapur mourns the sad demise of Dr. VT Jadhav, Director (Retd.), ICAR-NRC on Pomegranate, Solapur, who breathed his last on May 6, 2018 at his home town Aurangabad. NRCP shall ever remain indebted to Dr. VT Jadhav, the founder Director (Dec. 5, 2006- Oct. 31, 2012) of this newly established Centre, for his keen interest and benevolent guidance in establishing the infrastructure facilities of this Centre and handling major pathological issues in pomegranate during his tenure from 2006-2012. In a short span of 6 years, the Centre was nationally recognized for its potential in handling farmers' problems. The magnificent NRCP Office-cum-Laboratory-Building which came up during his tenure is being highly appreciated even today by visitors from all over India. Dr. VT Jadhav will always be remembered at NRCP for giving a strong foundation to this Centre.

The staff of ICAR-National Research Centre on Pomegranate, Solapur, express heartfelt condolences to the grieved family and pray the Almighty to give strength to bear the irreparable loss and vacuum created by his sudden demise.

With deepest sympathy
Staff
ICAR-NRC on Pomegranate
Solapur

Appendix I

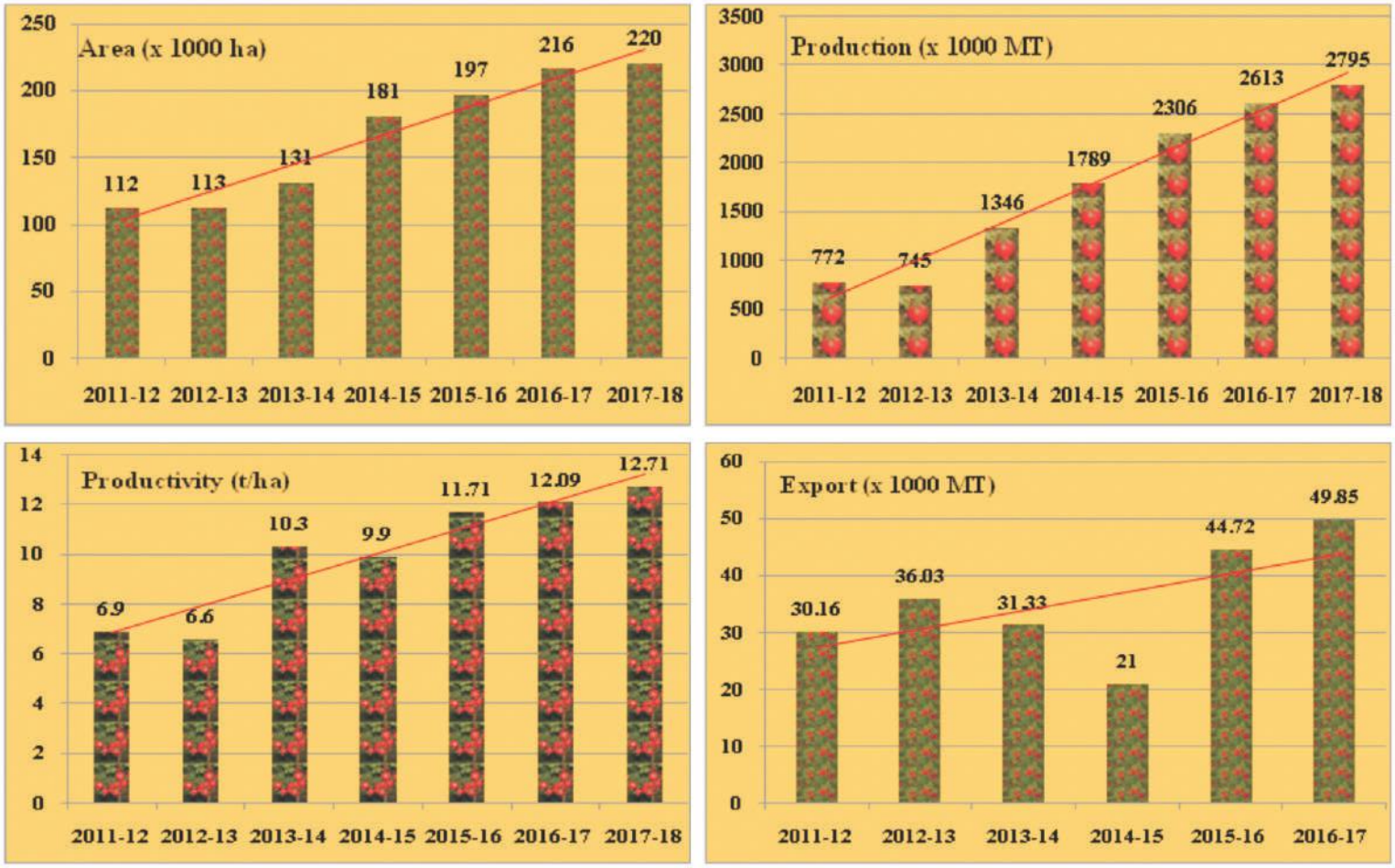
Metrological Parameters 2017-18 NRCP Solapur

Month	Temperature (°C)		Relative Humidity (%)		Wind speed (kmph)	Rainfall (mm)	Total rainy days (No.)	Sunshine (h)	Soil temp. at various depth (°C)					
									5 cm		10 cm		20 cm	
	Max.	Min.	Max.	Min.					Max.	Min.	Max.	Min.	Max.	Min.
Apr 2017	43.2	17.6	97	47	5.15	0.0	0	8.91	44.8	31.8	44.8	30.8	42.8	30.2
May 2017	42.4	22.4	96	50	6.63	0.0	0	7.92	46.8	35.4	45.8	34.2	44.8	33.8
Jun 2017	39.2	20.2	97	52	5.16	318.7	11	NA	45.8	30.8	44.8	29.8	44.8	28.4
Jul 2017	34.8	19.8	95	57	NA	11.8	3	5.25	37.8	29.6	39.8	29.8	39.2	28.4
Aug 2017	34.8	19.6	95	62	6.43	170.7	9	5.69	37.8	22.4	38.4	22.0	39.2	21.8
Sep 2017	33.6	18.8	95	62	5.77	131.4	10	6.40	37.8	24.5	36.8	25.4	35.8	25.8
Oct 2017	34.6	16.2	97	60	4.63	86.1	5	7.63	37.5	26.5	38.5	27.5	36.8	27.5
Nov 2017	39.8	13.2	93	60	5.79	0.0	0	8.68	37.5	25.5	36.5	26.5	37.5	27.5
Dec 2017	32.6	11.2	92	62	6.18	0.0	0	7.91	36.5	24.5	35.5	24.5	34.5	23.5
Jan 2018	34.4	11.2	93	55	5.36	0.0	0	8.21	38.5	26.5	37.5	27.5	38.5	25.5
Feb 2018	37.0	13.2	93	55	5.77	0.0	0	8.71	38.5	23.5	35.5	24.5	34.5	25.5
Mar 2018	37.6	17.4	93	51	6.26	0.0	0	8.32	39.5	26.5	37.5	21.5	36.5	28.5

NA- data not available

Appendix II

National Scenario of Pomegranate

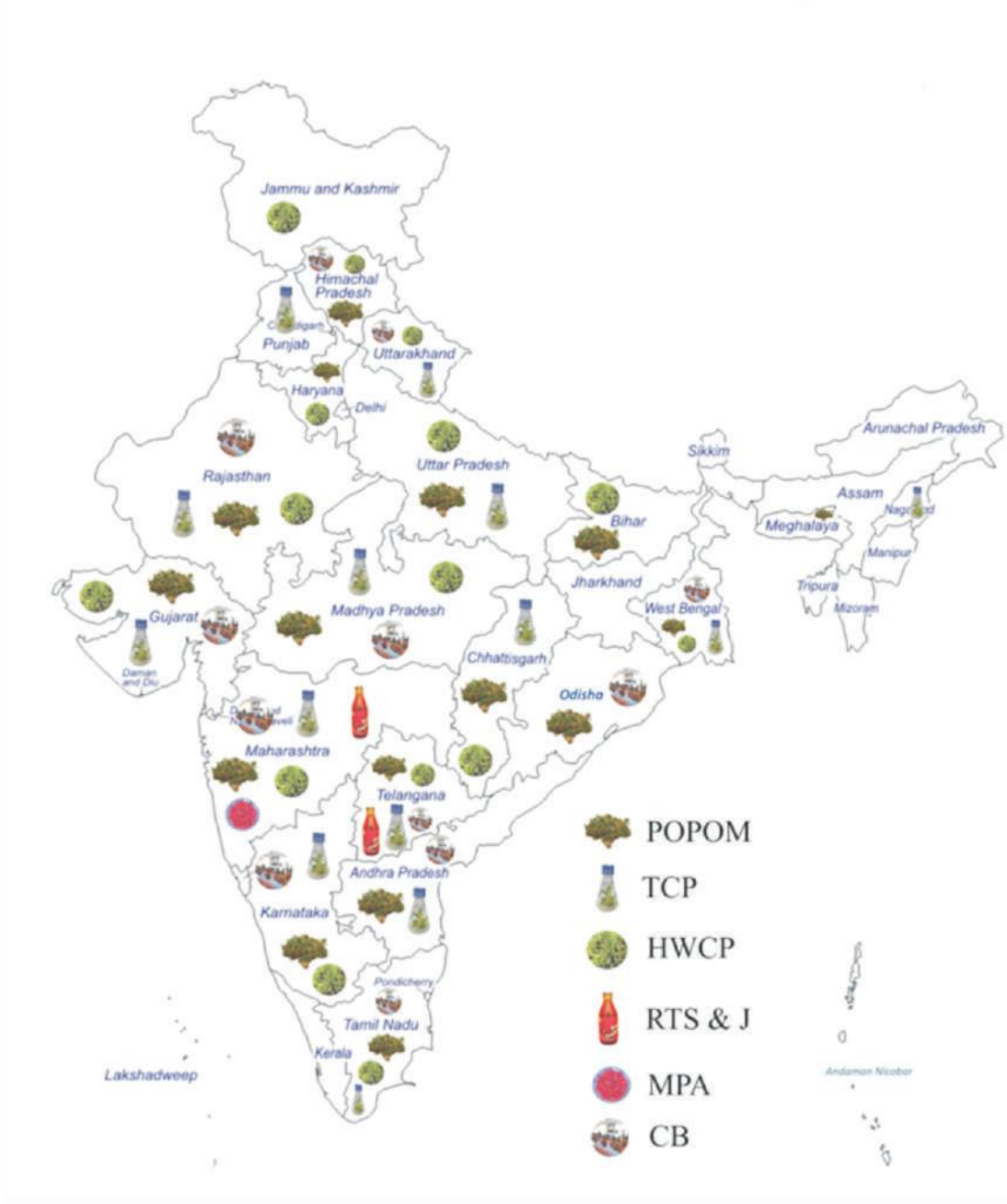


Pomegranate area, production, productivity and Export during 2011-12 to 2017-18

Note: Figures for 2017-18 are 1st advance estimate (Source: http://nhb.gov.in)

Appendix III

Outreach activities of ICAR-NRCP in India



POPOM- Package of Practices for Pomegranate Orchard Management; **TCP** – Tissue Culture Plants; **HWCP**-Hard Wood Cutting Plants; **RTS&J** – Ready to Serve Drink and Juice; **MPA** – Minimal Processing of Arils and **CB** – Capacity Building

Certificado · Sertifika · प्रमाण पत्र · Zertifikat · شهادة

CERTIFICATE OF REGISTRATION

ICAR-NATIONAL RESEARCH CENTRE ON POMEGRANATE

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

This certificate verifies that the above Organisation has been audited on the above address for scope as under and found to be in accordance with the requirements of Management system.

ISO 9001:2015

Quality Management System

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

Certificate No. : Q-18032101

UIC : MSCB-159-3113

Date of initial registration	**21-03-2018**
Date of this certificate/ Issue No.	**05-06-2018/02**
Certificate Expiry	**20-03-2019**
Recertification Due	**20-03-2021**

After successful completion of Annual Surveillance Audit, New Certificate will be issued.

This Certificate is valid as per Rules and Regulations of ECL & also the surveillance audits conducted atleast once a year.
To check the certification validity please contact -**info@theecl.com**

MSCB-159

Director

Rev: 00

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