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भा.कृ.अनु.प.–राष्ट्रीय अनार अनुसंधान केन्द्र
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भाकृअनुप
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ICAR-National Research Centre on Pomegranate
(भारतीय कृषि अनुसंधान परिषद्)
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Solapur – 413 255

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Preface

ICAR-National Research Centre on Pomegranate, Solapur, completed 14 years of journey on September 25, 2019. The Centre has accomplished its objectives with visible outcomes during the period and is proud to be the driving force behind the sprawling pomegranate sector in India. The pomegranate sector has recorded constant increase in area, production and productivity since last 8 years. The pomegranate area of 2.60 lakh ha, production of 30.30 lakh MT and export of 67.89 thousand MT in 2018-19 are record figures.

It is pertinent to highlight the vital role of ICAR-NRCP in improving pomegranate scenario in India through its technologies on combating important diseases, improving fruit yield and quality, providing quality planting material, identifying suitable pomegranate growing areas in India, developing sound package of practices, acting as repository of germplasm for breeding new varieties, giving value addition technologies for complete utilization of fruit, dissemination, commercialization and transfer of technologies, imparting on-site and in-house trainings to stakeholders, etc. The Centre has implemented Government of India schemes, and introduced pomegranate cultivation in different states through Tribal Sub Plan, (TSP), Mera Gaon Mera Gaurav (MGMG) and Scheduled Cast Sub Plan (SCSP) by demonstrations, inputs, Soil Health Cards and technical guidance. The positive feedback of farmers and other stakeholders encourage us to move forward with stronger commitment.

It is also observed that states like Haryana and Uttar Pradesh which are highly or moderately suitable for pomegranate are not growing the crop except for few selected progressive farmers in last two to three years. Hence, introducing pomegranate in these areas may prove a boon in improving economic status of the farmers in these states. Though India is the largest producer of pomegranate, its export share in world trade of pomegranate is lesser (around 14%) in comparison to China (34%) and Iran (29%) with respectively 50% and 33% less area than India. The Centre has a challenging task ahead to improve export through breeding large size variety and pesticide residue free production; work on these aspects is in progress. I am sure ICAR-NRCP will continue to move forward with confidence to achieve new milestones and to fulfill the vision of our Honourable Prime Minster of Doubling farmer's income by 2022. It is a matter of great privilege to lead the institute that is working for the welfare of pomegranate growers all over India.

I wish to place on record my sincere gratitude to Dr. T. Mohapatra, Secretary, DARE and Director General, ICAR for his encouragement. I am obliged to Dr. AK Singh, DDG (HS) for his moral support and guidance, which encourages us to move forward with confidence. 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 Honourable members of RAC for guidance and keen interest in improving the research activities of the institute.

The Centre would not have achieved its milestones 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 grateful to all for their unflinching support and express my sincere thanks for the help rendered in betterment of this Centre.

ज्योत्सना शर्मा

Jyotsana Sharma
Director (Acting)

Introduction

The need for diversification to Horticulture was realized in mid-eighties. It has established its credibility in improving income through increased productivity, generating employment and in enhancing exports. Horticulture has moved from rural confines to commercial venture. Scenario of horticulture crops in India has become very encouraging in recent times. Horticulture production in 2001-02 was only 145.8 million tones, which was much lower than food grain production (212.9 million tonnes). In 2009-10 to 2011-12 both were at par. Later horticulture production remained higher than food grain production with continuous increase recording 313.85 million tonnes in 2018-19, whereas food grain production was only 283.37 million tonnes (http://agricoop.nic.in/sites/default/files/Horticulture2018) and http://nhb.gov.in/statistics/State_Level/2018-19). Today percentage share of horticulture output in agriculture has become 33%. Globally India is second largest producer of fruits and vegetables and first in Mango, Banana, lime, lemon, pomegranate, papaya and okra/ladies finger.

The pomegranate crop is considered as strategic crop in India to mitigate the future challenges like global warming, drought, alleviating the poverty by creating livelihood and improving the framers income. Therefore, in order to tap the vast potential of this crop by increasing pomegranate production, export and there by economic growth of India, Indian Council of Agricultural Research established ICAR-National Research Centre on Pomegranate during 2005 at Kegaon, Solapur (Maharashtra) a premier institute mainly for carrying out both basic and strategic research on pomegranate.

About two decades back consumer awareness towards innumerable health benefits of pomegranate increased market demand, resulting in constant increase in area and production of this crop. Alluring monetary returns from this horticulture crop were recorded, especially in India. Analysis of pomegranate statistics for last 8 years shows that, average increase in area was 133.93%, production 289.11%, productivity 67.83% and exports 55.58%. Looking into the impressive past scenario and keeping in mind the climate change and promising technologies available, it is expected that in the coming years the pomegranate can become one of the most important horticultural crops of India.

As per estimated global pomegranate acreage and production figures available on different internet sites, India is the largest producer with around 50% share globally. India in 2018-19, occupies an area of 2.62 lakh hectares with production of 30.34 lakh tonnes. The other countries after India are China (1.2 lakh ha and 12.0 lakh MT), Iran (0.75 lakh ha and 11.0 lakh MT), Turkey (0.35 lakh ha and 2.2 lakh MT). Rest of the pomegranate growing countries like USA, Tunisia, Morocco, Spain, Israel, Greece, Italy, South Africa etc. have lower area and production. The global pomegranate scenario clearly indicates that India has the advantage to come up with promising pomegranate technologies for the benefit of Indian population. Today estimated more than 2.5 lakh

families are earning livelihood from this crop in arid and semi-arid regions of India.

Envisaging the economic importance of pomegranate and the significant role of this crop in shaping the economy of the farmers in arid and semi-arid regions, the ICAR-NRCP addressed these hurdles on priority and gave solutions to major challenges. Noteworthy technologies for promotion of pomegranate include:

- A well established, 'Field Gene bank' with 362 germplasm lines including indigenous and exotic lines established at ICAR-NRCP, Solapur which serves collection of genes for diverse characters.
- Promising, cost effective, eco-friendly integrated nutrient, disease & insect pest management schedule with the use of bio-formulations and preventive strategies, resulting in quality fruit production.
- Bio-hardened micro-propagation technology for propagation of disease free planting material.
- Novel bio-formulation for potassium fertilizer supplement, with *Penicillium pinophilum,* that reduces70% requirement of potassium to pomegranate, saves ~Rs.40,000/ha on fertilizers cost and increases yield by 25%.
- Processing technologies for total utilization of pomegranate for diversification of utilization pattern, and higher returns. These are pomegranate juice and ready to serve drink from low market value fruits; minimally processed pomegranate arils with shelf life of 14 days; high pharmaceutical value seed oil from dried seeds of cv. Bhagawa (28% w/w oil) and Ganesh (26.43 % w/w oil); hi-fibre cookies from de-oiled seed cake of pomegranate; sparkling pomegranate wine from pomegranate juice.
- Bio-fortified pomegranate variety, 'Solapur Lal' developed through breeding matures in 160-165 days, has 25-35% higher yield over cv. Bhagawa and is nutritionally rich with more iron, zinc, ascorbic acid and anthocyanin contents over the ruling cv. Bhagawa. This bio-fortified variety is a boon to combat nutritional deficiencies in human beings and with TSS above 17 is a boon for processing industries too.
- The Centre in collaboration with NBSS&LUP, Nagpur has accomplished mapping of pomegranate growing areas based on soil type and climatic conditions. This will help promote pomegranate cultivation in areas suitable for its cultivation but not yet growing pomegranate, for promoting crop diversification and improving economy of the farmer.

The NRCP has popularised its promising technologies through licencing, consultancy extension activities, distribution of NRCP publications, digital mobile app 'Solapur Anar', demonstrations on framers field, providing on campus and off campus trainings to framers and entrepreneurs and TV shows.

Further analysis of Benefit:Cost ratio of different field, vegetable and fruit crops in Maharashtra revealed, maximum benefit (C:B::1:2.5) with pomegranate cultivation. Hence, this ancient health fruit with available technologies can be considered an ideal crop for diversification under climate resilience and developing rural economy with the technologies available, cluster approach and government intervention. Government support for encouraging community farming and putting up processing units for value addition of unmarketable produce during natural calamities and poor market value will go a long way in improving economic status of farmers. Pomegranate cultivation in arid and semi-arid regions and tribal areas will not only be beneficial in monitory terms but its consumption will ensure nutritional security of the rural and tribal population, hence it should be promoted as an important crop for diversification in agriculture/horticulture in these areas.

ICAR-NRCP in a short span of 14 years has developed infrastructure with state-of-art facilities for conducting basic, strategic and applied research and take it to the beneficiaries through extension activities, publications in popular languages, digital apps in multi-languages to fulfil the vision of Honourable Primer Minister of India of Digital India, Doubling Farmer's Income and Aatma Nirbhar India.

* * * * * * * *

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.

कार्यकारी सारांश

पिछले दस वर्षों से भारत में अनार के क्षेत्रफल और उत्पादन में लगातार वृद्धि हुई है। 2018-19 के नवीनतम आकड़ों के अनुसार भारत में अनार 2.62 लाख हैक्टर क्षेत्रफल में उगाया जाता है तथा इसका उत्पादन 30.34 लाख टन रहा एवं 67.89 हज़ार टन निर्यात किया गया है। अनियमित वर्षा वाले शुष्क तथा अर्ध शुष्क में यह फल-फ़सल किसानों की आजीविका सुरक्षा के लिए एक महत्वपूर्ण फल है। भा.कृ.अनु.प. - राष्ट्रीय अनार अनुसंधान केंद्र अनार में किसान भाईयों के सामने आने वाली विभिन्न शोध संबन्धित समस्याएँ तथा चुनौतियों का हल निकालने में मुख्य भूमिका अदा करता रहा है। विगत वर्ष में इस केंद्र ने 12 संस्थागत परियोजनाओं, 8 बाह्य वित्त पोषित परियोजनाओं, 2 अंतसंस्थागत: सहयोगी परियोजनाओं, 1 अनुसूचित जाति उप योजना, 1 अनुसूचित जनजाति उप योजना का कार्यान्वयन किया तथा मेरा गाँव मेरा गौरव के तहत किसानों का मार्गदर्शन तथा सरकारी योजनाओं के बारे में उन्हे जानकारी प्रदान की। विगत वर्ष बारह संस्थागत परियोजनाओं में से एक परियोजना को सफलतापूर्वक पूर्ण किया गया है। मुख्य उपलब्धियों का सारांश नीचे दिया गया है।

जननद्रव्य संसाधन

- वर्ष 2019 में कुल्लू, हिमाचल प्रदेश से 4 जननद्रव्यों के कठोर काष्ठ एवं 8 वेरियन्ट्स के फल संग्रहीत किये गए हैं।
- भा.कृ.अनु.प.-राष्ट्रीय अनार अनुसंधान केंद्र के नए संकरों (एनआरसीपी H-4 एवं एनआरसीपी H-14) का प्रथम वर्ष
- के लिए ऑनसाइट डीयूएस परीक्षण तथा एनआरसीपी H-6 (सोलापुर लाल) एवं एनआरसीपी H-12 (सोलापुर अनारदाना) का दो वर्षों का संग्रहीत डीयूएस रिपोर्ट पौ. कि. कृ. अधि.सं.प्रा., नई दिल्ली को भेजी गई है।
- अनार के आठ क़िस्मों का आण्विक गुणचित्रण 84 एसएसआर आण्विक चिन्हकों के द्वारा किया गया। चौरासी में से पच्चीस एसएसआर आण्विक चिन्हक पालीमोर्फिक पाये गए। पीआईसी मूल्यांक तथा हेट्रोजायगोसिटी (%) के आधार पर आण्विक चिन्हक पीजीकेवीआर-24, 32, 121 और पीजीएसएसआर-1, 2, 44, 53, 56, 70, 81, 87 किस्म पहचान हेतु उपयोगी पाये गए थे।
- आण्विक असमानता गुणक मूल्यांक आधारित आनुवांशिक विविधता विश्लेषण, भगवा एवं सुपर भगवा (0.01) में सबसे कम आनुवांशिक विविधता उसके मृदुला और फूले अरक्ता (0.03) में तथा अधिकतम आनुवांशिक विविधता सोलापुर लाल एवं गणेश (0.19) में दर्शाया गया है।
- भा.कृ.अनु.प.-राष्ट्रीय अनार अनुसंधान केंद्र द्वारा विकसित दो नई संकर क़िस्मों का तुलनात्मक मूल्यांकन पांचवे वर्ष के लिए किया गया। भगवा कि तुलना में सोलापुर लाल में 18.5 दिन पहले फल

परिपक्वता तथा 32.0 % अधिक ऊपज के साथ-साथ उत्तम फल गुणवत्ता भी दर्ज़ की गई थी।

- भा.कृ.अनु.प.-राष्ट्रीय अनार अनुसंधान केंद्र द्वारा विकसित 12 संकरों में से गणेश x नयना के पौधों में चौथे वर्ष में सबसे अधिक फल आये (20.14 किलोग्राम/ पेड़) थे।

- भा.कृ.अनु.प.-राष्ट्रीय अनार अनुसंधान केंद्र द्वारा विकसित 14 चयनित जीनोटाइप्स का पांचवे वर्ष में ऊपज 18.20 से 24.35 किलोग्राम/ पेड़ तक पाया गया। सेलेक्सन 348 और 375 ने सबसे अधिक उत्पादन एवं कुल घुलनशील ठोस की मात्रा दर्ज़ की गई थी।

- भा.कृ.अनु.प.-राष्ट्रीय अनार अनुसंधान केंद्र, सोलापुर द्वारा अनार के सबसे प्रचलित किस्म भगवा का होल जीनोम सीक्वेन्स और एसम्ब्ली चार अत्याधुनिक नैक्सट जेनेरेशन सीक्वेन्सिंग के माध्यम से पूर्ण किया गया। कुल 352.54 एमबी (के=31) में से 346.08 एमबी (98.17 %) जीनोम जिसका एन50 16.12एमबी और जीसी कोंटेंट 41.01% पाया गया जो की पहले सीक्वेन्स की गई चाइनिज किस्में ताईशनहाँग तथा दाबेन्ज़ी से बहुत बेहतर है।

- औसतन 2,991 बेस पेयर्स वाले जींस के कुल 31,364 जीन मॉडल्स अनुमानित किये गए। कुल 14,902 जीन मॉडल्स चार डेटाबेसेस में अनोटेट हुये तथा 24.01 एमबी (लगभग 7%) एसएसआर आण्विक चिन्हकों के रूप में पहचाने गए हैं।

- भगवा जीनोम का तुलनात्मक अध्ययन पहले से प्रकाशित उकेल्प्टस, कोकोआ और अंगूर के जीनोम से किया गया। भगवा का प्लास्टोम 158641 बीपी का पाया गया तथा इसमे 36.9% जीसी कोंटेंट था।

किस्म सुधार

- पौधों में सर्वाधिक विपत्ररण एथेफोन 200 पीपीएम तथा एक सप्ताह बाद 400 पीपीएम के छिड़काव से दर्ज़ किया गया है (87.5 % छिड़काव के 9 दिनों के बाद एवं 92.5 % छिड़काव के 12 दिनों के बाद)। फल बढ़वार के समय जिब्रेलिक अम्ल के 50 पीपीएम छिड़काव से भगवा क़िस्म में मृग बहार के दौरान फल आकार, फल वजन (औसत वज़न 269.2 ग्राम) एवं ऊपज (25.44 किलोग्राम/ पेड़) में सार्थक वृद्धि दर्ज़ की गई है।

- इन सिलिको विश्लेषण के जरिये पूर्ण जीनोम में miRNA तथा उनके लाक्ष्य जींस आधारित एसएसआर आण्विक चिंह्कों की पहचान अनार में की गई ।पौध से लेकर फल बढ़वार तक 897 miRNA एसएसआर तथा 58 ईएसटी-एसएसआर चिंह्कों को दर्शाने वाले कुल 955 उपयोगी चीन्ह्कों का विकास एवं पीसीआर मान्यकरण किया गया है।

- बीजकठोरता गुणधर्म के लिए 132 miRNA एसएसआर आण्विक चिन्ह्कों का विकास एवं ए-पीसीआर द्वारा उनका मान्यकरण किया गया तथा इसमे से 123 आण्विक चिन्हक तूनीसिया जीनोम के 8 गुणसूत्र पर चिन्हित किये गए हैं।

पौध प्रवर्धन

- भगवा की विभिन्न जंगली मूलवृंत पर कलम बांधने की सफलता दर 66.88 % से 75.21% तक पायी गई है।

- संरक्षित संरचना के अंदर गूटी कलम की सफलता दर सुपर भगवा में सोलापुर लाल की तुलना में सार्थक रूप से अधिक पायी गई, प्रक्षेत्र परिस्थितियों में सुपर भगवा और भगवा में सोलापुर लाल की तुलना में कटिंग एवं गूटी कलम की सफलता दर अधिक पायी गई।

- सूक्ष्म प्रवर्धन में किये गए प्रयोगों में संशोधित एमएस मीडियम के साथ आईएए, एनएए, ऍडनिन सल्फेट, आर्जेनिन एवं कसिन हाइड्रोलाईसेट समायोजित करने से सबसे अधिक साइड प्ररोह (3.83) पाये गए। बीएपी, एनएए, नारियल पानी, ऍडनिन सल्फेट, आर्जेनिन, पेक्टिन एवं ग्लूटामिन समायोजित डबल्यूपीएम मीडियम में सबसे ज्यादा प्ररोह बढ़वार और साइड प्ररोह प्राप्त हुए थे।

- सूक्ष्म प्रवर्धित क्लोन्स की आनुवांशिक समानता सिद्ध करने हेतु एसएसआर, हाइपर वेरियबल एसएसआर, आईएसएसआर एवं आरएपीडी आण्विक चिंहकों का उपयोग किया गया।

- इन विट्रो पलाश और फास्फोरस घुलनशीलता हेतु 9 एंडोफाएट्स प्रभावशाली पाये गए तथा इनकी कार्यशीलता पेनीसिलियम पिनोफिलम के तुलनात्मक पायी गई है।

फसल उत्पादन

- पलाश और फास्फोरस के मिनरल स्रोतों का इस्तेमाल करके पेनीसिलियम पिनोफिलम युक्त पलाश एवं फास्फोरस खाद का विकास किया गया तथा कुछ एडीटिव्स के उपयोग से इस खाद को सामान्य तापमान पर लंबे समय तक भंडारित कर सकते हैं।
- अमीनो अम्ल आधारित सूक्ष्मपोषकतत्व योग 1 एवं 2 के छिड़काव से ऊपज, फल गुणवत्ता और निर्यात योग्य फलों के प्रतिशत में व्यावसायिक ईडीटीए चीलेटेड सूक्ष्मपोषकतत्व योगों की तुलना में अधिक दर्ज़ की गई है।
- 2019 में अड़सठ जननद्रव्यों के फल फटाव हेतु मूल्यांकन में आईसी-1201, 1198, 318718, 318743, 318766, 318712, 318716 और एसीसी नं. 5 में किसी भी फल में फटाव देखने को नहीं मिला।
- जननद्रव्यों में अरिल ब्राउनिंग का संक्रमण 0-16.69 % तक दर्ज़ हुई। भगवा में 2.58 % जबकि सबसे अधिक ब्राउनिंग विदेशी जननद्रव्य क्रीनेडो-डी-एल्च (16.69 %) में दर्ज़ की गई थी।
- सिंचाई हेतु पानी की आवश्यकता पौध लगाने के प्रथम वर्ष में छाया गृह तथा प्रक्षेत्र परिस्थितियों में पौधों की बढ़वार हेतु क्रमश: 650 लिटर और 6193 लिट / पेड़/ वर्ष पायी गई। भा.कृ.अनु.प.-राष्ट्रीय अनार अनुसंधान केंद्र द्वारा विकसित संकर किस्म सोलापुर लाल दूसरे किस्मों की तुलना में अधिक बढ़वार करने वाला पाया गया।
- सात वर्ष के अनार के बाग के लिए पीआरज़ेडडीआई पद्धति में सिंचाई हेतु गीली मिट्टी का 80%* ईटीसी तथा *एएसडबल्यूडी का 20% अनुकूल पाया गया है।

फसल सुरक्षा

- अनार में छेदक एवं चूषक कीटों के खिलाफ नये कीटनाशकों के मूल्यांकन में अफीडोपाएरोफेन 50 जी/एल डीसी फूल कीड़े को 87.72% कम करने में तथा थायमिथोक्साम 12.6% + लंबडा सायहॅलोथ्रिन 9.5% ज़ेडसी मीली बग को 68.37% कम करने मे कारगर पाया गया। स्पिनोट्रम 11.7% एससी 1 मिलीलीटर/ लीटर की दर से पुष्पन के समय फूल कीड़ों के प्रबंधन में प्रभावशाली पाया गया।
- जैवकीटनाशक- सरसों पाउडर 10 ग्राम + करंज तेल 3 मिलीलीटर/ लीटर के उपयोग से 24 और 72 घंटो बाद कृत्रिम परिवेशीय में क्रमश: 77.44 एवं 79.56% फूल कीड़े मृत पाये गए।
- सेक्स फेरोमोने एवं फल वाष्पशील योगिकों के विभिन्न मिश्रणों का उपयोग फल चूसी शलभ के लिए किया गया। सबसे अधिक बक्ट्रोसेरा डोरसालिस (342/ ट्रेप) मीथाईल ईयूज़ीनोल वाले मैकफैल में फंसे पाये गए थे।
- जैव-नियंत्रक एजेंट ब्रेचीमेरिया स्पी. को ड्यूडोरिक्स आइसोक्रेट्स का इल्ली-प्युपा परजीवी पाया गया।
- अनार के विभिन्न भागों पर नये कीट-पीडकों का विभिन्न स्तरों पर संक्रमण दर्ज़ किया गया, इनमे इन्वेसिव मीली बग निपाकोकस विरीडिस, हेलीकोवेर्पा आर्मिजेरा, नेज़रा विरिडुला, वायर वर्म (क्लिक बीटल), रेड स्टेम बोरर (ज्यूज़ेरा कोफ्फे) एवं दो माध्यमिक फल चूषी शलभ ओफुसिया तिरहाका एवं अचैया जनाटा सम्मलित हैं।
- इक्यावन जननद्रव्यों की स्क्रीनिंग फूल कीड़े एवं फल भेदक के संक्रमण के प्रति की गई और इनमें इनका संक्रमण क्रमश: 13.25- 75.5% एवं 8.5-12.75% पाया गया।
- भा.कृ.अनु.प.-राष्ट्रीय अनार अनुसंधान केंद्र के विल्ट सिक प्लॉट प्लॉट में हार्ड वूड कटिंग एवं बीज से तैयार देसी और विदेशी जननद्रव्यों, संकर एवं अन्य किस्मों की स्क्रीनिंग की गई। सर्वाधिक मुरझान (100%) आईसी-318733 के बीजू पौधों तथा अमलीदाना के हार्ड वूड कटिंग से तैयार पौधों में दर्ज़ की गई। एसीसी जनद्रव्य के सभी बीजू पौधों में, केवल एसीसी-5 को छोड़कर, मुरझान 5% से कम पाया गया था। केवल एक संकर (7/10) के बीजू पौध मुरझान विमुक्त पाये गए, 2 संकर पौधों भगवा X आईसी-318702/ एसीसी -13 तथा जंगली जननद्रव्य- दारू में एक वर्ष उपरांत भी मुरझान 15% से कम पाया गया था।

- भारतीय बागवानी अनुसंधान संस्थान, बेंगालुरु द्वारा रागी आधारित ट्राइकोडर्मा आइसोलेट टीएचजीजे6बी का रोपण के समय उपयोग सी. फिंब्रियाता मुरझान को नियंत्रित करने में प्रभावशाली पाया गया।

- कृत्रिम परिवेशीय में एक नये उत्पाद कसूगामायसिन 5% + कॉपर ऑक्सी क्लोराइड 45% डबल्यूपी का 0.2 एवं 0.3% इस्तेमाल फलों पर धब्बों एवं सड़न पैदा करने वाले कवक कोलेटोट्रायकम ग्लोएस्पोरायड्स, अलटेरनेरिया अलटेरनाटा, सेर्कोस्पोरा पुनिके का 100% तक दमन करता पाया गया है।

- गामा अमीनोब्यूट्रिक अम्ल पौधों में जीवणू झुलसा और अन्य संबन्धित रक्षा प्रतिक्रियाओं के खिलाफ प्रतिरोधक क्षमता को प्रेरित करता है। गामा अमीनोब्यूट्रिक अम्ल का 600 पीपीएम का प्रोफीलक्टिक छिड़काव से जीवणू झुलसा में 34.78% की कमी आयी तथा फल आकार और उत्पादन भी बढ़ा पाया गया।

- लौंग का तेल (0.2%) जीवणू झुलसा के खिलाफ एक प्रबल प्रतिरक्षा प्रेरक पाया गया। लौंग तेल के प्रोफीलक्टिक छिड़काव से पथोजेनेसिस रीलटेड प्रोटीन्स, फेनायल अमोनिया लायेस, चाइटीनेस, कल्लोस सींथेस 3, परऑक्सीडेस की अनार के पौधों में उच्च सापेक्षिक अभिव्यक्ति पायी गई। लौंग का तेल कॉपर ऑक्सी क्लोराइड के साथ कंट्रोल की तूलना में जीवणू झुलसा को 95.5% तक कम करने में तथा ऊपज 4.05 ट/है. से 14.04 ट/है. तक लाने में प्रभावकारी रहा।

- अनार में तेलिया प्रतिरोधी जननद्रव्य आईसी 318735 और संवेदनशील जननद्रव्य की मेटाबोलिक (फेनायल प्रोपेनायड) प्रोफायलिंग का अध्ययन किया गया। रोगजनक संशोधित तेलिया प्रतिरोधी जननद्रव्यों में सात मेटाबोलाईट (फेरुलिक अम्ल, काऊमेरिन, सिन्नेमिक अम्ल, यूजिनाल, क्यूनिक अम्ल, कैम्पफिराल, पी- काऊमेरिक अम्ल) संवेदनशील व्यवसायिक किस्म भगवा की तुलना में सार्थक रूप से प्रेरित पाया गया। सभी मेटाबोलाईट केवल क्यूनिक अम्ल, कैम्पफिराल, पी- काऊमेरिक अम्ल को छोड़कर तेलिया रोगजनक को अवरोधित करने मे सक्षम पाये गए जबकि यूजिनाल एवं सिन्नेमिक अम्ल में सर्वाधिक तेलिया अवरोधक क्षमता पायी गई है।

- एक्सएपी स्ट्रेन एलएमजी 859 के रिफ्रेन्स जीनोम का माइक्रोसेटेलीइट्स की पहचान के लिए पूर्ण जीनोम सर्वेक्षण किया गया। कुल 2746 स्पेसिफिक एसएसआर प्राइमर्स की संरचना एवं मान्यकरण एक्सएपी के 22 आइसोलट्स की आनुवांशिक विविभितता के लिए किया गया। ये सभी आण्विक चिन्हक इस रोगजनक के पॉप्पुलेशन डाइनेमिक्स, टैक्सोनामी, एपिडिमोलाजी एवं क्वेरेंटाइन अधय्यन की दृष्टि से महत्वपूर्ण हैं।

- पॉलीहाउस में 17 जीवणू एंडोफायट्स जिसमें 13 अनार के कृत्रिम परिवेशीय स्थापित एक्सप्लांट्स से (टीसी श्रंखला) तथा 4 सब्ज़ा (बीई श्रंखला) का मूल्यांकन किया गया। सभी एंडोफायट्स केवल टीसी-2 को छोड़कर, पौधों में तेलिया (0-38%) को कम करने में सफल रहे और टीसी-4 एवं टीसी-310 के 4 छिड़कावों तेलिया को पूर्ण रूप से नियंत्रित करने में सक्षम पाये गए हैं।

- तेलिया रोग के सस्ते, पर्यावरण संगत तथा प्रभावशाली प्रबंधन हेतु छः कदम वाला प्रोटोकॉल तेलिया को 4 बागों में 80-100% तक कम करने में कारगर पाया गया (इसको भा.कृ.अनु.प.-राष्ट्रीय अनार अनुसंधान केंद्र के 1 जैविक प्रक्षेत्र तथा 3 किसान भाइयों के बाग में प्रयोग किया गया) जिसमें पहले 50-100% तक तेलिया से नुकसान था।

फल प्रसंस्करण

- अनार के दानों का कम तापमान पर सक्रिय संशोधित वातावरण पैकेजिंग का सफलतापूर्वक मूल्यांकन किया गया । अनार दानों को 18 दिनों तक उच्च ऑक्सिजन कम तापमान पर सक्रिय संशोधित वातावरण पैकेजिंग में सफाई का ध्यान रखते हुए भंडारित किया जा सकता है।

- इमलशन एक्सट्रेक्सन तकनीक द्वारा अनार बीज़ तेल का माइक्रोइन्नकेप्सुलेसन किया गया तथा माइक्रोइन्नकेप्सुलेसन पद्धति का मानिकीकरण किया गया जिसमें 10% तेल, 350 µ नोज़ल व्यास एवं 3.23% सोडियम अल्जिनेट की सांद्रता उचित पायी गई।

- विभिन्न किस्मों तथा संकरों के मूल्यांकन में सोलापुर लाल में परिपक्क्वता के समय सर्वाधिक कुल घुलनशील ठोस (17.6° ब्रिक्स) पाया गया तथा सर्वाधिक दाना प्राप्ति सोलापुर अनारदाना में हुई (22.1%)।

अन्य गतिविधियां

- इस केंद्र ने अनुसूचित जाति उप योजना, अनुसूचित जनजाति उप योजना तथा मेरा गाँव मेरा गौरव के तहत महाराष्ट्र, राजस्थान, मध्य प्रदेश एवं छत्तीसगढ़ में अनार की खेती को प्रोत्साहन देने का कार्य किया है तथा इसके अंतर्गत प्रदर्शनी, खेती में लगने वाली सामग्री, मृदा स्वास्थ्य कार्ड, प्रशिक्षण एवं तकनीकी मार्गदर्शन का लाभ 662 किसानों को मिला है।

- भा.कृ.अनु.प.-राष्ट्रीय अनार अनुसंधान केंद्र की 2 तकनीकों का व्यवसायिकरण 2 उद्यमियों के साथ किया गया है तथा केंद्र ने 7 प्रदर्शनीयों अपनी तकनीकों का प्रदर्शन किया, इस केंद्र पर 900 से ज्यादा किसान भाई, विद्यार्थी एवं अन्य हितधारकों ने भ्रमण किया तथा अनार संबन्धित सूचना प्राप्त की, इनके अलावा मानव संसाधन विकास हेतु इस केंद्र के 12 कर्मचारियों ने विभिन्न प्रशिक्षण प्राप्त किये तथा 19 कॉन्फ्रेंस/ संगोष्ठी एवं 9 कार्यशालाओं में भाग लिया था।

- इस केंद्र ने अनार की खेती के ऊपर 3 कार्यशालाएं और 10 प्रशिक्षण कार्यक्रम किसान भाईयों एवं अन्य हितधारकों के लिए आयोजित किये, इसके अलावा विभिन्न बैठकों का आयोजन अन्य संगठनों के सामंजस्य से भा.कृ.अनु.प.-राष्ट्रीय अनार अनुसंधान केंद्र की तकनीकों का विस्तारण सभी हितधारकों तक पहुँचाने हेतु किया गया था।

- भा.कृ.अनु.प.-राष्ट्रीय अनार अनुसंधान केंद्र के सभी अधिकारियों एवं कर्मचारियों ने हिन्दी पखवाड़ा, स्वच्छ भारत अभियान, सतर्कता जागरूकता सप्ताह इत्यादि में भाग लिया था। इस केंद्र ने पीर रिव्यूड प्रकाशनों में 11 शोध पत्र प्रकाशित किया है, जिनमें से 3 शोध पत्र एनएएएस रेटिंग > 6, इसके अतिरिक्त 9 किताबें, 8 लोकप्रिय लेख एक 1 विस्तार बुलेटिन/ पुस्तिका प्रकाशित की है। इस केंद्र के वैज्ञानिकों को प्रॉफेश्नल सोसाइटी द्वारा कॉन्फ्रेंस/ संगोष्ठी में सर्वोत्तम मौखिक एवं पोस्टर व्याख्यान पुरस्कार मिला है।

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Executive Summary

The pomegranate cultivation in India has shown constant increase in acreage and production during last 10 years. As per the latest available figures India occupied an area of 2.62 lakh hectares with production of 30.34 lakh tonnes and export of 67.89 MT in 2018-19. The crop has shown its importance for improving the livelihood security of the farmers in arid and semi-arid regions of India with erratic rainfall. The ICAR-National Research Centre on Pomegranate, Solapur has been playing central role in solving various researchable issues faced by the pomegranate farmers and meeting the challenges of this popular crop. During the year under report, the Centre has handled twelve Institutional Projects, eight Externally Funded Projects, two Inter-Institutional Collaborative Projects, one Schedule Castes Sub Plan (SCSP) and one Tribal Sub-Plan (TSP) Scheme and also guided and adopted farmers under government scheme Mera Gaon Mera Gaurav (MGMG). Out of twelve Institutional Projects, one project has been completed successfully during the period under report. The major achievements are summarized below.

Genetic Resources

- During 2019, hard-wood cuttings of four genotypes and fruits of 8 variants were collected from Kullu, Himachal Pradesh.
- First year On-site DUS testing of ICAR-NRCP, Solapur new hybrid varieties (NRCP H-4 and NRCP H-14) was conducted. Two years consolidated on-site DUS report of NRCP H-6 (Solapur Lal) and NRCP H-12 (Solapur Anardana) varieties was submitted to PPV&FRA, New Delhi.
- Clonal fidelity of 12 *in vitro* raised plantlets of cv. Bhagawa was tested by using 55 SSR primers and has not shown any molecular variations.
- Molecular evaluation of eight pomegranate genotypes using 84 SSR primers was undertaken. Out of 84 primers, 25 SSRs were found polymorphic. Based on PIC and Heterozygosity % values PgKVR-24, 32, 121 and PgSSR-1, 2, 44, 53, 56, 70, 81, 87 markers were found useful for cultivar identification.
- The genetic diversity analysis based on molecular dissimilarity coefficient values indicated that Bhagawa and Super Bhagawa (0.01) having least genetic dissimilarity, followed by Mridula and Phule Arakta (0.03). Maximum genetic dissimilarity was observed between Solapur Lal and Ganesh with the coefficient value of 0.19.
- Comparative evaluation of 2 new varieties of pomegranate developed at NRCP was done during fifth year of planting. Variety Solapur Lal recorded 18.5 days early maturity and 32 % higher yield over ruling variety Bhagawa besides better fruit quality. The variety 'Solapur Anardana' recorded 4.8% titrable acidity and 462.5 mg/100g anthocyanin.

- Among 12 new hybrids developed at ICAR-NRCP evaluated during fourth year of planting, Hybrid Ganesh x Nayana recorded highest yield of 20.14 kg/tree.
- Evaluation of fourteen pomegranate selections during 5th year of planting revealed that yield ranged from 18.20 to 24.35 kg/tree. Selection 348 and 375 recorded highest yield and TSS.
- Genome assembly of most popular and commercial Indian pomegranate variety "Bhagawa" was completed by ICAR-NRCP, Solapur by adopting four advanced NGS technologies and assembled 346.08Mb (98.17%) of genome of estimated size 352.54Mb (k=31) by k-mer genome survey with N50 size of 16.12Mb and high GC content of 41.01%, which is much better than the previously assembled genome of Chinese Cultivars *i.e* Taishanhong and Dabenzi.
- A total, of 31,364 gene models were predicted with average gene size of 2,991 bp. A total of 14,902 (47.52 %) got annotated with four data bases and a total length of 24.01Mb (~7% genome) was identified to be SSRs.
- Gene family cluster analysis of the complete gene sets of finished genome of P. *granatum* cv. Bhagawa with previously reported genome of pomegranate *cv.* Bhagawa, Eucalyptus (*E. grandis*), Cocao (*T. cacao*) and Grape (*V. vinifera*) has been performed. The genome assembly of the chloroplast in "Bhagawa" cultivar found was158641 bp with GC content of 36.9%.

Crop Improvement

- Foliar spray of Ethephon@ 200 ppm followed by Ethephon @ 400 ppm at one week after first spray recorded highest defoliation (87.5% at 9 DAFS; 92.5% at 12 DAFS); Foliar spray of Gibberellic acid @ 50 ppm significantly improved the fruit size with average fruit weight (269.2 g/fruit) and yield (25.44 kg/tree) in Bhagawa during mrig bahar.
- Through *in silico* analysis we developed genome wide novel miRNA based and their target genes based SSR markers in pomegranate. A total of 955 functional markers representing 897 miRNA-SSRs and 58 EST-SSRs specific to seedling to fruit developmental stages were designed and validated through PCR.
- A total of 132 miRNA-SSR specific to seed hardness traits were also developed validated through e-PCR/mapping and finally 123 primers were successfully localized on the 8 chromosomes of Tunisia genome.

Plant Propagation

- The grafting success of 'Bhagawa' scion on wild rootstocks ranged from 55.00 % to 80.00%.
- The air layering success under protected structure was significantly higher in 'Super Bhagawa' as compared to 'Solapur Lal'. For mother plants maintained under filed conditions, 'Super Bhagwa' and 'Bhagawa' registered better cutting and layering success as compared to 'Solapur Lal'.
- The maximum number of side shoots per explant (3.83) was found when explants were inoculated on modified MS medium supplemented with IAA, NAA, adenine sulphate, argenine and casein hydrolysate. The explants on WPM medium supplemented with BAP, NAA, coconut water and adenine sulphate or argenine, pectin and glutamine recorded highest number of side shoots and shoot length.
- Clonal fidelity testing was performed using highly polymorphic SSRs, Hyper variable SSRs, ISSR and RAPD markers to confirm genetic similarity of *in vitro* propagated clones.
- Nine bacterial endophytes were found promising *in vitro,* for their ability to solubilize potash and phosphorous.

Crop Production

- Mineral sources of K and P have been used for developing K and P bio-mineral fertilizer having

Penicillium pinophilum with addition of some additives to improve the storage life of developed fertilizer at room temperature.

- Amino acid-based micronutrient formulations I & II significantly improved fruit yield, fruit quality and percent exportable grade fruits over the widely used micronutrient formulation (EDTA chelated micronutrients).
- Seventeen bacterial endophytes- 13 from pomegranate (TC series), 4 from *Ocimum spp.* (BE series) were evaluated in green house. All endophytes tested (except TC-2) recorded bacterial blight incidence (0-38%) significantly lower than untreated control (64.33%), however endophytes TC-4, TC-310 completely checked blight with 4 sprays.
- Sixty eight pomegranate germplasm accessions were evaluated for fruit cracking during 2019. No fruit cracking was recorded in eight wild genotypes (1201, 1198, IC-318718, IC-318743, IC-318766, IC-318712, IC-318716, Acc. No.-5).
- Aril browning incidence ranged from 0 to 16.69 %. In 'Bhagawa' 2.58 % aril browning incidence was observed and the maximum aril browning was observed in the exotic collection Crenedeo-de-elch (16.69 %).
- The irrigation water requirement for pomegranate under shade net house and open field conditions were estimated as 650 and 6193 L $tree^{-1}season^{-1}$ for the first year growth of pomegranate plants. The ICAR-NRCP hybrid 'Solapur Lal' was found vigorous under protected structure as compared to other commercial varieties.
- In PRZDI system, 80% *ET_c wetted soil volume with 20 % ***ASWD** was found to be optimum for 7 year old pomegranate orchards.

Crop Protection

- Among the different newer pesticides evaluated against the borer and sucking pests of pomegranate, promising pesticides were Afidopyrofen 50G/L DC for thrips with 87.72% reduction and formulation Thiamethoxam 12.6 % + Lambda cyhalothrin 9.5% ZC for mealybugs with 68.37% reduction. Spinetoram 11.7% SC @ 1ml/l water found best for the management of thrips during flowering 72.45% reduction of thrips.
- Biopesticide - mustard powder @ 10g + Pongamia oil 3ml/ l of water recorded highest percentage of dead thrips (77.44 and 79.56 %) after 24 and 48 hours respectively (in-vitro).
- Different blends (sex pheromone + fruit volatiles) were evaluated for fruit piercing moths. The highest trapping of *Bactrocera dorsalis* (342/trap) was recorded in McPhail trap lured with Methyl Eugenol.
- The biocontrol agent, *Brachymeria* sp. was reported as larva-pupal parasitoid of *Deudorix Isocrates.*
- New insect's pest were recorded on pomegranate with different level of infestation on different parts of the pomegranate. These were invasive mealybug *Nipaecoccus viridis*, *Helicoverpa armigera*, *Nezara viridula,* wire worm (click beetle), red stem borer (*Zuezera coffeae*) and two secondary fruit piercing moths viz., *Ophusia tirhaca* and *Achaea janata* .
- Among the 51 different pomegranate germplasm screened against thrips and fruit borer the infestation varied from 13.25-75.5 % and 8.5-12.75% by thrips and fruit borer respectively.
- Hardwood cuttings and seedlings of exotic and indigenous accessions, hybrids and varieties were screened for wilt caused by *Ceratocystis fimbriata* and root knot nematode *Meloidogyne incognita* in wilt sick plot developed at NRCP farm. The highest wilt incidence (100%) was observed in IC-318733 seedlings and cuttings of variety Amlidana. Seedlings of eight ACC accessions recorded less than 5% wilt except ACC-5. Seedlings of only one hybrid 7/10 remained free and 2 hybrids viz. BxIC-318702 and ACC-13, wild variety 'Daru' recorded below 15% wilt till 1 year of observation.

- The *ragi* based formulation containing *Trichoderma* isolate ThGJ16B of IIHR, Bengaluru was effective in controlling *C. fimbriata* wilt when applied at the time of plantation in wilt sick soil.
- A new product kasugamycin 5% + copper oxychloride 45% WP @ 0.2 and 0.3% tested *in vitro*, resulted in 100% inhibition of fruit rot and spot pathogens of pomegranate *viz. Colletotrichum gloeosporioides, Alternaria alternata*, *Cercospora punicae*.
- γ-aminobutyric acid (GABA) was found to induce resistance against bacterial blight and associated defense response. Prophylactic sprays with 600 ppm GABA resulted in blight reduction by 34.78% with significant improvement in fruit size and yield.
- Clove Oil (0.2%) was found to be a potent defense inducer for management of bacterial blight. Prophylactic application of clove oil recorded a high relative expression of pathogenesis-related (PR) proteins (PR1, PR4, and PR10), phenyl ammonia lyase, chitinase, callosesynthase 3 and peroxidase. Clove oil in combination with copper oxychloride reduced blight by 95.5% and recorded highest fruit yield of 14.04t/ha, whereas control recorded only 4.05t/ha.
- Metabolic (phenylpropanoids) profiling of pomegranate tolerant (IC318735) and susceptible genotypes to bacterial blight was studied. In pathogen treated tolerant genotypes, seven metabolites (Ferulic acid, coumarin, cinnamic acid, eugenol, kaempferol, quinic acid and p-coumaric acid) were significantly induced in comparison to susceptible commercial cultivar compared to Bhagawa. All metabolites except kaempferol and quinic acid were found inhibitory to blight pathogen and eugenol and cinnamic acid recorded highest inhibitory effect.
- Genome wide survey of microsatellites was performed in the reference genome of *Xap* strain LMG 859. A total of 2746 specific SSR primers were designed and validated to studying molecular diversity among 22 *Xap* isolates. These markers are important resources for future research on population dynamics, taxonomy, epidemiological and quarantine aspects of this pathogen.
- Six steps to manage bacterial blight was found to be the most economical, ecofriendly and promising strategy to check bacterial blight by 80-100% in 4 orchards (one organic block of ICAR-NRCP and 3 farmers field) facing above 50 to 100% losses in rainy season (Kharif) crop.

Post-Harvest Technology

- Active modified atmosphere packaging (MAP) combined with low temperature storage has been successfully evaluated for the storage of pomegranate arils. Pomegranate arils can be stored safely up to 18 days with active MAP with higher oxygen environment and low temperature storage by following hygiene during processing, packaging and storage.
- Microencapsulation of pomegranate seed oil (PSO) was carried out using emulsion extrusion technique. The optimized process conditions for the experiment were 10% oil loading, 350 μ nozzle diameter and 3.23% sodium alginate concentration.
- Among various cultivars and hybrids evaluated, fruits of pomegranate variety Solapur Lal had highest total soluble solids content (17.6°Brix) at the time of maturity and highest aril recovery was from variety Solapur Anardana (22.1%).

Other Activities

- The Centre has taken up pomegranate cultivation in the states of Maharashtra, Rajasthan, Chhattisgarh, Madhya Pradesh through SCSP, TSP and Mera Gaon Mera Gaurav through demonstration, supplying inputs, providing Soil Health Card, imparting trainings and technical guidance benefitting around 662 farmers.

- ICAR-NRCP technologies were commercialized to two entrepreneurs and displayed its activity in seven exhibitions and more than 900 visitors including farmers, students and other stakeholders visited the Centre for information. In addition to this, a total 12 staff underwent trainings under HRD and attended 19 conferences/seminars/ symposia and 9 workshops under the capacity building activities.
- The Centre also organized three workshops and 10 training programmes for farmers and various stakeholders involved in pomegranate cultivation. Apart from this, various interactive meetings were conducted in collaboration with different organizations to disseminate the ICAR-NRCP technologies to different stake holders.
- All the staff of ICAR-NRCP actively participated in activities under Hindi Pakhwada, Swachch Bharat Abhiyan, Vigilance Awareness Week etc.
- The Centre published 11 research papers in peer reviewed journals, out of which 3 were in NAAS rating > 6. In addition, 9 book chapters, 8 popular articles and 1 extension bulletins/folder were published. The scientists also got recognitions from professional Societies besides best oral presentation and best poster presentation awards.

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Research Programmes & Projects

Institute Research Projects

S. No.	Project title	PI	Co-PIs	Status
1	Flagship project on integrated approach to eradicate bacterial blight	Dr. Jyotsana Sharma	Dr. N.V. Singh Dr. Prakash G. Patil Dr. A. Kumar, ICAR-IARI, New Delhi Dr. Manjunath, UHS, Bagalkot	Ongoing
2	Crop regulation practices for improving productivity of pomegranate	Dr. K. Dhinesh Babu	Dr, N.V. Singh Dr A. Maity Dr J. Sharma	Ongoing
3	Development and refinement of integrated production technologies for improved productivity in Pomegranate (*Punica granatum* L.) intercropping	Dr. D.T. Meshram	Dr. K. D. Babu Dr. N.V. Singh Dr. A. Maity Dr. J. Sharma	Ongoing
4	Sensor based irrigation scheduling for water productivity of Pomegranate (*Punica granatum* L.)	Dr. D.T. Meshram	Dr. K. D. Babu Dr. N.V. Singh Dr. A. Maity Dr. J. Sharma	Ongoing
5	Propagation, bio-hardening and mass multiplication of elite planting material in pomegranate (*Punica granatum* L.)	Dr. N.V. Singh	Dr. K.D. Babu Dr. J. Sharma Dr. Shilpa P. Ms. Roopa Sowjanya P.	Ongoing
6	Draft genome sequencing of Pomegranate (*Punica granatum* L.) cv. Bhagwa	Dr. Roopa Sowjanya P.	Dr. Shilpa P. Dr. N.V. Singh Dr. P. Patil	Ongoing
7	Post-harvest management, value addition and improving knowledge of stakeholders for increasing production and marketing of pomegranate	Dr. Gaikwad N.N.	Dr. K. D. Babu,	Completed
8	Post-harvest management and valorization of pomegranate	Dr. Gaikwad N.N.	Dr. K. D. Babu, Dr. A. Maity	Ongoing
9	Development and refinement of integrated crop protection technologies for improved productivity of pomegranate	Dr. Mallikarjun	Dr. J. Sharma Dr. U.R. Sangle	Ongoing

10	Breeding for bacterial blight resistance in pomegranate	Dr. Shilpa P.	Dr. J. Sharma Dr. K. D. Babu Dr. P. G. Patil	Ongoing
11	Genetic Mapping of Bacterial Blight and Fruit Quality Traits in Pomegranate	Dr. P. G. Patil	Dr. J. Sharma Dr. Shilpa P. Dr. N. V. Singh Dr. K. D. Babu	Ongoing
12	Package of practices for organic cultivation of pomegranate	Dr. A. Maity	Dr. J. Sharma Dr. N.N. Gaikwad Dr. Mallikarjun, H.	Ongoing

Externally Funded Projects

S. No.	Funding agency	Project	PI	Co-PIs	Status
1	ICAR	ICAR-All India Coordinated Research Project on Arid Zone Fruits	Dr. K. Dhinesh Babu	Dr. N.V. Singh Dr. Mallikarjun	Ongoing
2	ICAR-Consortia Research Platform on water	Response of pomegranate to deficit Irrigation and partial root zone drying.	Dr. A.K. Nair ICAR-IIHR, Bangalore	Dr. D.T. Meshram	Ongoing
3	BVG Life Sciences	Effect of BVG Products on growth, pests & diseases incidence & yield of Pomegranate	Dr. N.V. Singh	Dr. J. Sharma Dr. Mallikarjun Mr. Mahadev Gogaon	Ongoing
4	NHB, Gurugram	Standardization and demonstration of production technologies for protected cultivation of pomegranate	Dr. N.V. Singh	Dr. Mallikarjun Dr. N.N. Gaikwad Dr. D.T. Meshram	Ongoing
5	NMPB, Ministry of AYUSH Government of INDIA	Utilization of pomegranate for development of functional medical ingredient	Dr. Gaikwad N.N.	Dr. Debi Sharma ICAR-IIHR, Bangalore (CPI) Dr. Krishna Das Saha CSIR-IICB, Kolkata, (CPI)	Ongoing
6	PPV&FRA, New Delhi	Establishment of DUS centre on pomegranate at ICAR-NRCP, Solapur	Dr. Shilpa P.	Ms. Roopa P. Sowjanya	Ongoing
7	Bayer Crop Science Limited	Study of residue and persistence of Fosetyl-Al and phosphonic acid in pomegranate fruit after application of Aliette and Profiler	Dr. A. Maity	Dr. (Mrs.) J. Sharma Shri Vijay Lokhande	Ongoing
8	InGene Organics	Effect of Cardle, Nanozim drip and Nanozim delite on Pomegranate yield and fruit quality.	Dr. A. Maity	Dr. (Mrs.) J. Sharma Shri Vijay Lokhande	Ongoing
9	Indofil Industries Limited	Evaluation of bio-efficacy and Phyto-toxicity of IFFC016, IFFC017 and IFFC018 against fungal leaf and fruit disease complex in pomegranate.	Dr. Jyotsana Sharma	Dr. K.D. Babu	Ongoing
10	RKVY, Department of Agriculture, Government of Maharashtra	Horticulture Crop Pest Surveillance and Advisory Project for Mango, Pomegranate & Banana	Dr. Jyotsana Sharma	Mr. Mallikarjun	ongoing

Tribal Sub-Plan

S. No.	Project title	PI	Co-PIs	Status
1	Introduction of pomegranate cultivation to tribal farmers of Gadchiroli dist. of Maharashtra, Bankura & Purulla dist. of West Bengal	Dr. D.T. Meshram	Dr. A. Maity	Ongoing
2	Promotion of pomegranate cultivation in tribal areas of M.P. and Chhattisgarh in collaboration with SRIJAN, India	Dr. N.V. Singh	-	Ongoing

Scheduled Castes Sub-Plan

S. No.	Project title	PI	Co-PI	Status
1	Promotion of Pomegranate Cultivation in Barmer and Alwar districts of Rajasthan	Dr. N.V. Singh	Dr. Shilpa P. Mr. Yuvraj Shinde Mr. Mahadev Gogaon	Ongoing
2	Promotion of Pomegranate Cultivation among SC farmers of Maharashtra	Dr. N.V. Singh	Dr. Shilpa P. Mr. Yuvraj Shinde Mr. Mahadev Gogaon	Ongoing

Inter-Institutional Collaborative Projects

S. No.	Project title	Collaborative Institute	PI	Co-PIs	Status
1	Delineation of potential areas for pomegranate cultivation in India using remote sensing and GIS techniques	ICAR-NBSS&LUP Nagpur	Dr. D.T. Meshram	Dr. J. Sharma Dr. A. Maity	Ongoing
2	Unraveling mechanism and developing mitigation strategies for aril browning and fruit cracking in pomegranate	ICAR-NIASM, Baramati	Dr. N.V. Singh	Dr. Shilpa P. Dr. K.D. Babu Dr. A. Maity Dr. D.T. Meshram	Ongoing

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Genetic Resources

1.1 Project: Breeding for Bacterial Blight Resistance in Pomegranate (*Punica Granatum* L.)

1.1.1 Development of New Seedling Population from Selected Hybrids/ Chemical Mutants/ Open Pollinated Seeds of Varieties

During *mrig* bahar (2019-20), the screening materials constituting 35 F_1 hybrids of cross Bhagawa x 1181; 67 hardwood cutting plants of 15 pomegranate germplasm lines; 105 seedlings of Mridula and 41 of IC-318762; 49 M_2 seedlings of gamma irradiated cv. Bhagawa and 20 M_2 seedlings of Ganesh were raised in the nursery. These all panting materials were subjected to screening against bacterial blight under controlled conditions. Apart from this, 523 seedlings obtained from 5-bromouracil (5-BU) and 89 seedling from Ethyl methanesulfonate (EMS) treated cv. Bhagawa with different doses of 5-BU: 0, 0.2, 0.4, 0.6, 0.8, 1% and EMS of 0, 0.1, 0.2, 0.3, 0.4, 0.5%, respectively, at varying timings 0, 30, 60, 90, 120, 150, 180 min. were generated. Finally, all these mutant seedling populations were screened against bacterial blight under challenged inoculation conditions to identify BLB resistant plants.

1.1.2 Evaluation of Varieties Released from ICAR-NRCP

1.1.2.1 Comparative Evaluation of Solapur Lal

Evaluation of pomegranate variety Solapur Lal in comparison to the ruling variety, Bhagawa during the fifth year of planting in mrig bahar recorded about 18.5 days early maturity, around 32% higher yield over Bhagawa besides better fruit quality traits.

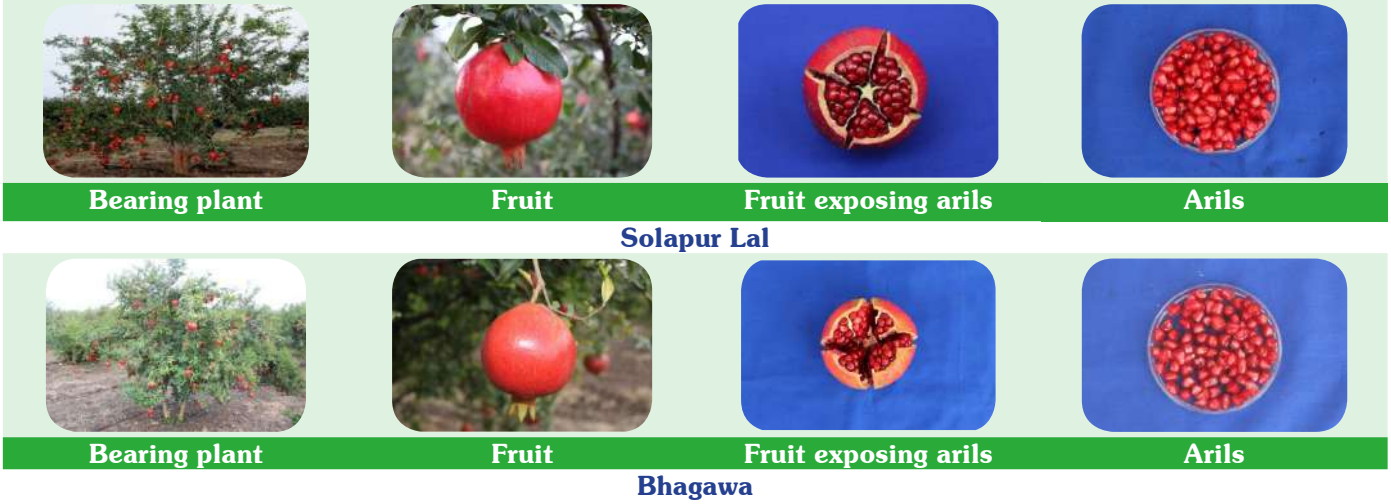


Fig. 1: Comparative evaluation of Solapur Lal vs Bhagawa during fifth year of planting

Table 1: Comparative evaluation of Solapur Lal and Bhagawa

Characters	Solapur Lal	Bhagawa
Plant height (m)	1.85	1.70
Fruit maturity (days)	161.5	180.0
Fruit weight (g)	255.2	264.0
No. of fruits /tree	120.0	88.0
Yield (kg/plant)	30.62	23.23
Yield (t/ha)	22.65	17.19
Aril colour	Deep red	Red
Fruit colour	Red	Red
Rind thickness (mm)	Medium	Medium
Juice (%)	43.0	44.0
TSS (°Brix)	17.5	15.8
Titrable acidity (%)	0.40	0.45
Ascorbic acid (mg/100g)	19.0	14.9
Anthocyanin (mg/100g)	398	356
Iron (mg/100g)	1.50	0.90
Zinc (mg/100g)	0.50	0.40

1.1.1.2 Comparative Evaluation of Solapur Anardana

Evaluation of pomegranate variety Solapur Anardana in comparison to Amlidana during the fifth year of planting in mrig bahar recorded 4.8% titrable acidity and 465.0 mg/100g anthocyanin.

Table 2: Comparative evaluation of Solapur Anardana and Amlidana

Characters	Solapur Anardana	Amlidana
Plant height (m)	1.90	1.50
Fruit maturity (days)	148.0	150.0
Fruit weight (g)	260.0	228.0
No. of fruits /tree	95.0	68.0
Yield (kg/plant)	24.70	15.50
Yield (t/ha)	18.27	11.47
Aril colour	Red	Light pink
Fruit colour	Red	Yellow
Seed texture	Medium	Medium
Juice (%)	42.5	41.0
TSS (°Brix)	16.6	15.6
Ascorbic acid (mg/100g)	18.0	14.2
Anthocyanin (mg/100g)	462.5	65.5
Titrable acidity (%)	4.80	4.20

Fig. 2: Comparative evaluation of Solapur Anardana with Amlidana during fifth year of planting

1.1.1.3 Evaluation of Hybrids Developed from ICAR-NRCP

Twelve hybrids developed at ICAR-NRCP, Solapur were evaluated for yield and quality during fourth year of planting. The yield ranged from 10.34-20.14 kg/ tree. The highest yield was recorded by Ganesh x Nayana (20.14kg/tree) which was followed by Bhagawa x Nayana (19.08 kg/ tree).

Table 3: Evaluation of pomegranate hybrids developed by ICAR-NRCP

Hybrid	Fruit weight(g)	No. of fruits/ tree	Yield (kg/ tree)	TSS (°B)	Titrable acidity (%)
Bhagawa	260.5	65.0	16.93	15.8	0.45
Bhagawa x Patna-5	295.0	60.0	17.70	16.5	0.35
Bhagawa x Nana	204.4	50.6	10.34	13.8	2.60
Bhagawa x Daru	240.6	60.3	14.51	17.0	2.80
Bhagawa x Kalpitiya	282.0	65.3	18.41	13.6	0.32
Bhagawa x Nayana	271.4	70.3	19.08	15.9	0.38
Bhagawa x IC-318712	225.4	65.0	14.62	14.4	2.81
Ganesh x Kalpitiya	218.4	48.0	10.48	15.6	0.50
Ganesh x Nayana	285.2	70.6	20.14	16.0	0.32
Bhagawa x [(Ganesh x Nana) x Daru]-HA	245.8	75.3	18.51	15.8	0.54
Kalpitiya x Ruby	288.0	65.0	18.72	15.6	0.40
Nayana x Ruby	270.0	70.0	18.90	15.4	0.40
Ruby x Nayana	210.6	74.3	15.65	15.3	0.35

Fig. 3: Evaluation of pomegranate hybrids developed by ICAR-NRCP

1.1.1.4 Evaluation of Pomegranate Selections

Evaluation of fourteen pomegranate selections during 5th year of planting was carried out for physico-chemical characters. The results revealed that yield ranged from 18.20 to 24.35 kg/tree. The yield was highest in Sln. 348 (24.35 kg/tree) closely followed by Sln. 375 (24.14 kg/tree). Total soluble solids content ranged from 15.8 to 16.6°Brix.

Table 4: Evaluation of pomegranate selections

Genotype	Fruit weight (g/fruit)	No. of fruits/ tree	Yield (kg/ tree)	TSS (°B)	Acidity (%)	Fruit Color	Aril Color
Bhagawa	264.2	80	21.14	15.8	0.45	Red	Red
IC-24686	268.5	74.3	19.95	15.9	0.44	Red	Red
934	267.4	81.3	21.74	15.8	0.37	Yellowish red	Light red
391	270	78.3	21.14	15.7	0.42	Yellowish red	Light red
528	275	85	23.38	15.9	0.42	Yellowish red	Red
375	275.2	87.7	24.14	16.6	0.4	Yellowish red	Light Red
348	270.5	90	24.35	15.9	0.37	Red	Red
388	265.5	82.3	21.85	16.4	0.41	Yellowish pink	Light red
317	264	79.3	20.94	16.5	0.39	Yellowish pink	Light red
216	272.5	72.7	19.81	16.2	0.39	Yellowish pink	Light red
311	282	82.3	23.21	16.0	0.37	Red	Red
1128	280.4	83.3	23.36	15.9	0.38	Yellowish red	Light red
1129	266.8	81.3	21.69	15.8	0.42	Yellowish red	Light red
1121	260	70	18.20	15.9	0.39	Yellowish red	Light red
1130	270.2	85	22.97	15.9	0.42	Yellowish red	Red

Bhagawa

IC24686

Sln. 934

Sln. 391

Sln. 528

Sln 375

Sln.348

Sln.388

Sln. 317

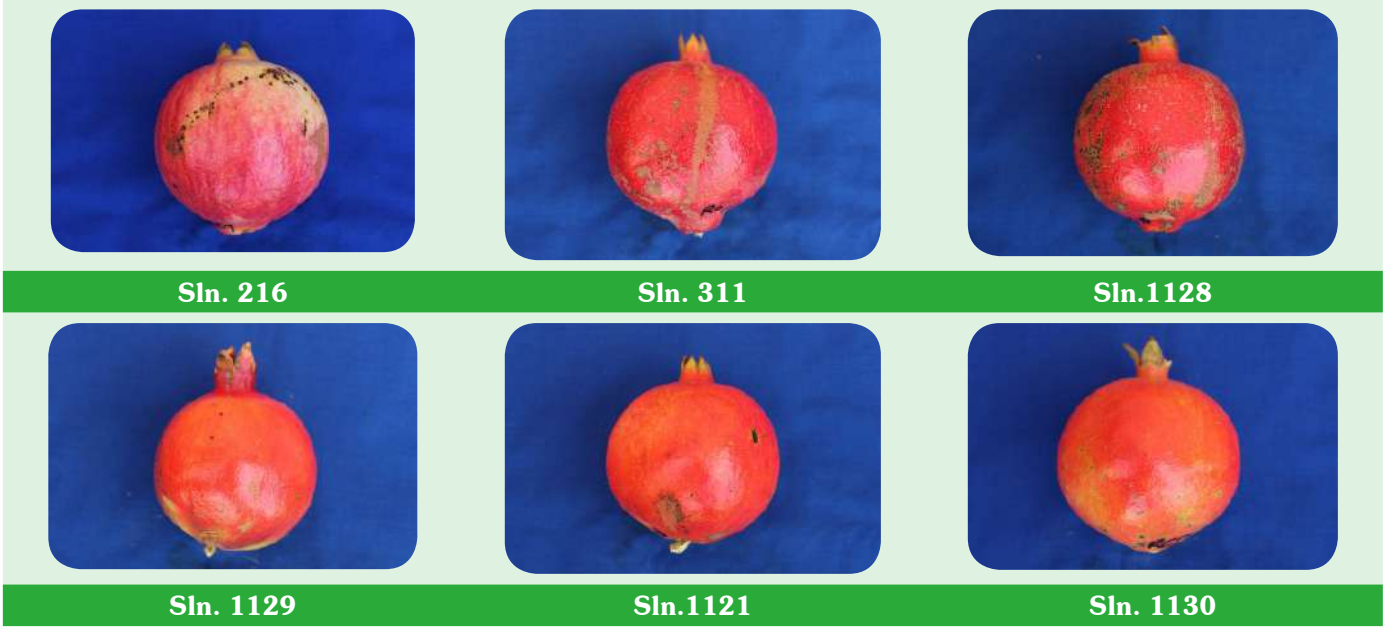


Fig. 4: Evaluation of pomegranate selections

1.1.3 Screening of Generated Experimental Materials Against Bacterial Blight

(a) Screening of Open Pollinated Seedlings of Selected Varieties Against BBD

Seven months old seedlings of 'Mridula' and IC-318762' genotypes were sprayed with *Xap* May 6, 2019 under challenge inoculation technique. Totally 9 observations were made to record the disease incidence (%) and severity grade. Maximum incidence in 'Mridula' seedlings ranged from 38-85% and severity grade 2 to 3, while in 'IC-318762' seedlings 48-98% (incidence) and 3 severity grade was recorded (Table 2).

Table 5: Selected varietal seedlings reaction to BBD under controlled condition

Sl. No.	Variety name	No. of seedlings	DAI First symptoms of BBD observed	DAI Max BBD observed	Max BBD range in different seedling treatment			
					Incidence (%)		Severity Grade	
					Min	Max	Min	Max
1	Mridula	105	17/32	90	38	85	2	3
2	IC-318762	41	17/32	90	48	98	3	3

* 1 seedling was free but had very poor growth, hence rejected

(b) Screening of Gamma Irradiated M2 Population of cv. Ganesh and Bhagawa

M_2 mutant seedlings developed from γ-irradiated M_1 plants of *cv.* Ganesh (14 nos.) and Bhagawa (28 nos.) were also evaluated for *bacterial blight resistance* under challenge inoculation technique. The blight incidence recorded was above 50% in all the seedling population. None of the seedling population was found promising for blight resistance in *cv.* Ganesh and Bhagawa.

(c) Screening of Bhagawa Variety Seedlings Treated with Chemical Mutagens (EMS &5-BU)

Seeds of variety Bhagawa were treated with 5-Bromocracil (0.0, 0.2, 0.4, 0.6, 0.8 and 1%) and EMS (0.00.1, 0.2, 0.3, 0.4, and 0.5%) concentration for 6

time durations (0, 30, 60, 90,120 and 180 minutes). 25 seeds per replication were treated and sown and one year old 523 5-BU and 89 EMS treated seedlings that survived were screened for BBD reaction. Plants raised from Bhagawa cuttings were used as control. The seedlings were challenge inoculated with bacterial blight pathogen Xap 99, on Sep 9, 2019 following standard procedure. Five observations were made at weekly interval.

In case of 5-BU treated plants, after one week of inoculation all recorded bacterial blight incidence of 5-55% with 35-55% in control Bhagawa. After 2 weeks most of the seedlings recorded above 40 to 100% blight incidence. After one month all have recorded above 75% blight incidence and severity grade of 4 on scale of 1-5.

While in EMS treated plants after one week of inoculation all have recorded bacterial blight incidence 25-55% with 35-45% in control Bhagawa. After 2 weeks all recorded above 60 to 100% blight incidence. After one month all have recorded above 75% blight incidence and severity grade of 4 on scale of 1-5.

(d) Screening of Hybrid Population for BBD Resistance

Thirty-five F1 hybrid seedlings of Bhagawa x 1181 cross were tested against BBD reaction using challenge inoculation technique. In total 9 observations were made to record BBD incidence (%) and severity grade (0-5). Evaluated population has shown 34-60% Incidence of bacterial blight with the disease severity scale between 2-4.

(e) Screening of Pomegranate Genotypes Selected Based on Evaluated Horticultural Traits

Fifteen selected pomegranate genotypes including 5 germplasm accessions and 10 selected genotypes from the existing breeding material were also evaluated for BBD reaction under controlled condition. BBD incidence and severity grade in the screened material ranged from 40-57.67 % and 2-4 in comparison to Bhagawa (79% and 3.33) (Fig. 5).

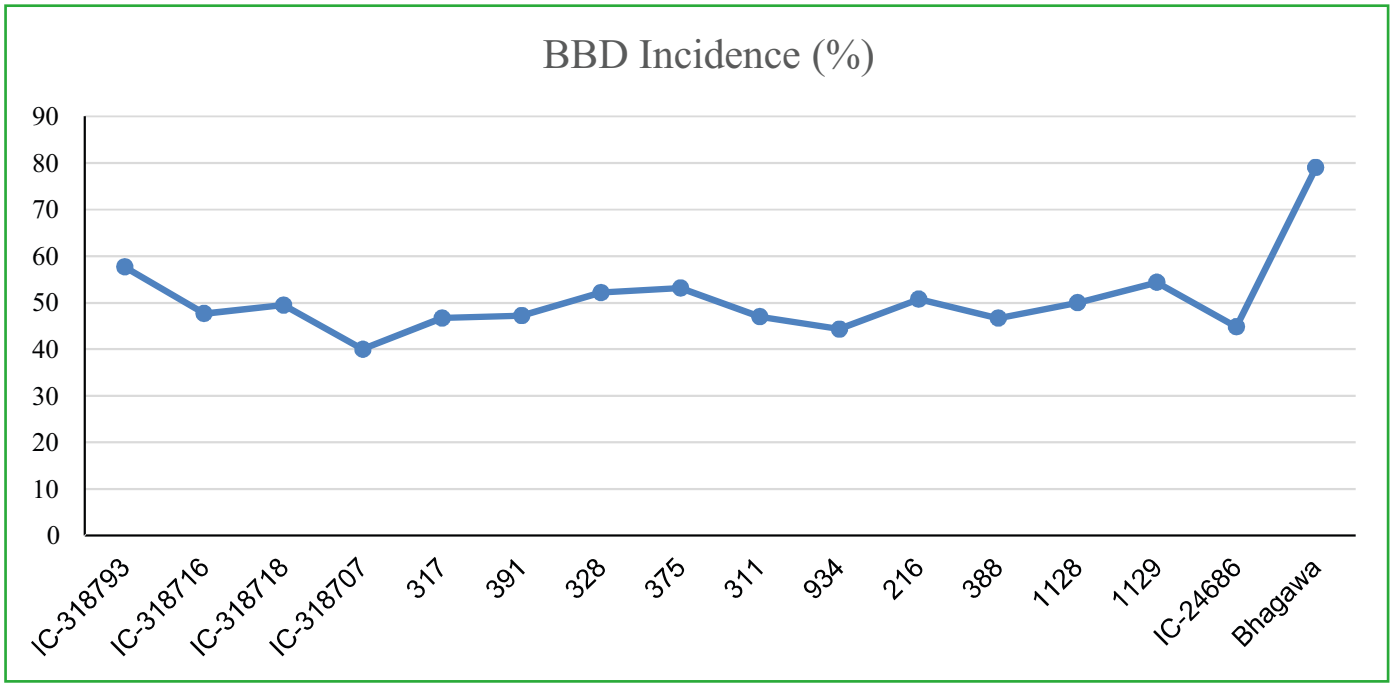


Fig. 5: BBD incidence recorded among selected genotypes of pomegranate

2.1 Project: Draft Genome Sequencing of Pomegranate (*Punica granatum* L.) cv. Bhagawa

2.1.1 Finished Genome Assembly of Pomegranate (*Punica granatum* L.) cv. "Bhagawa"

First finished genome assembly of most popular and commercial Indian pomegranate variety "Bhagawa" was completed by ICAR-NRCP, Solapur. Four advanced Next Generation Sequencing technologies

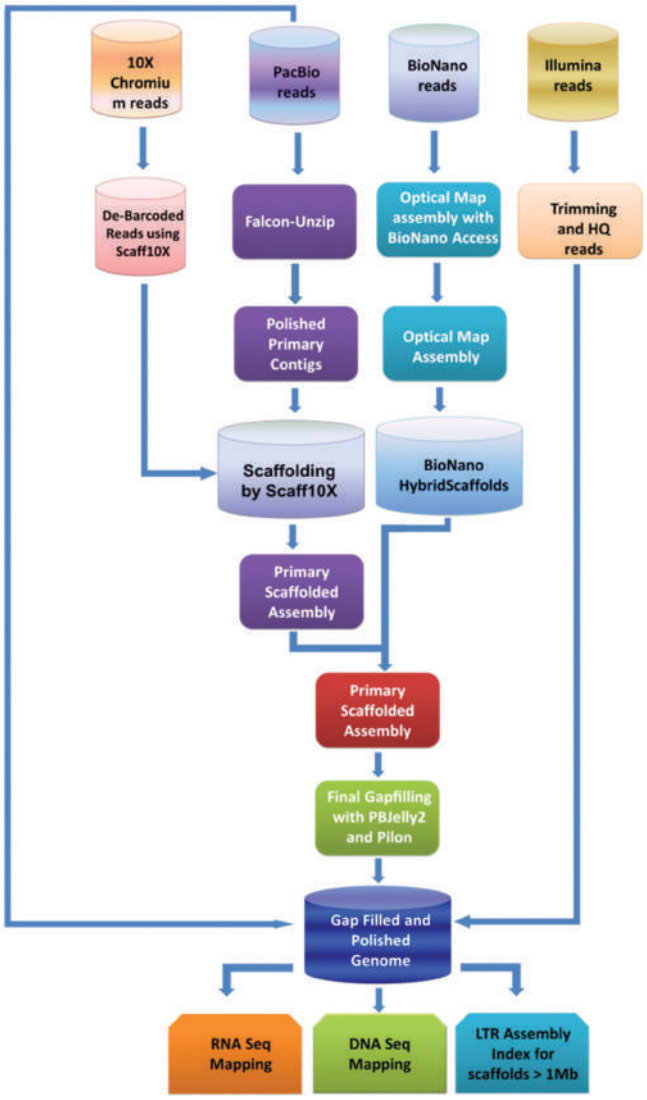


Fig. 6: Flow diagram of the strategy used for the assembling the finished genome of pomegranate *cv.* Bhagawa

(Illumina, 10X Chromium Genomics, PacBio Sequel, and BioNano Optical map) were used for the genome assembly. We have assembled 346.08Mb (98.17%) pomegranate genome of the estimated size 352.54Mb (k=31) based on k-mer genome survey analysis for cv. Bhagawa. This finished assembly consists of ever smallest number of scaffolds (342) with N50 size of 16.12Mb and high GC content of 41.01%, which is much better than the previously assembled genome of Chinese Cultivars i.e Taishanhong and Dabenzi which portrayed 274Mb and 296Mb, with an N50 of 2.3Mb and 1.7Mb, respectively using Illumina sequencing platform (Qin et al. 2017 and Yuan et al. 2018).

A total, of 31,364 gene models were predicted with average gene size of 2,991 bp having average exon and intron sizes 288 bp and 389 bp, respectively. All predicted genes were functionally annotated following a consensus approach of either known homologous or predictive sequence signatures using COGs, GO, InterProScan, KEGG, Uniport and EggNOG. Out of 31,361 predicted genes, maximum genes 14,902 (47.52 %) got annotated in all four protein databases namely, COGs, InterProScan, UniProt and eggNOG and rest of the genes got annotated in at least one of the six databases.

The finished genome also represented 93.68% of the 1440 ortholog genes, with 64 missing and 27 fragmented genes through step-wise BUSCO assessment on the Embryophyta lineage. The previously generated four transcriptome data samples (NCBI database, SRR5187757, SRR5187758, SRR5187763 and SRR5187764) of BLB challenged pomegranate tissues (unpublished data) were validated by mapping on to the reference genome. As a result, 85% - 95% reads showed significant matches on to the genome. The majority of genome is masked by LTR 91553321 bp (30.76%), of which Copia and Gypsy elements contributing about 5.03% and 12.77%, respectively. A total length of 24.01Mb (~7% genome) was identified to be SSRs. Penta-nucleotide SSRs are present in very high abundance. InDels/ SNPs discovery and Hi-C mapping of assembled genome is under progress.

Gene family cluster analysis of the complete gene sets of finished genome of P. *granatum* cv.

Table 6: Comparative assembly and annotation details of *Punica granatum* genomes*

Sr. No	Assembly parameters	Taishanhong	Dabenzi	Bhagwa
1	Estimated genome size (Mb)	336	328.13	352.53 (k=31)
2	Total size of assembled scaffolds (Mb)	274	296.38	346.08
3	Number of scaffolds (≥1 kb)	2117	2601	342
4	N50 scaffold length (Mb)	1.7	2.3	16.12
5	Longest scaffold (Mb)	7.6	9.97	22.45
6	Total size of assembled contigs (Mb)	269	N/A	337.7
7	Number of contigs (≥1 kb)	7088	N/A	446
8	N50 contig length (Kb)	97	82.31	6.8Mb
9	Largest contig (Kb)	528.6	N/A	18.89Mb
10	GC content (%)	39.2	39.64	41.01
11	Number of gene models**	30903	29226	31364
12	Mean transcript length (bp) **	2332.8	2543	2991
13	Mean coding sequence length (bp) **	1110.4	1077	1441
14	Mean number of exons per gene**	4.52	4	5
15	Mean exon length (bp) **	245.9	308	288
16	Mean intron length (bp) **	N/A	365	389

NOTE: *based on genomes submitted in NCBI. **based on annotation information either in NCBI or in the Manuscript

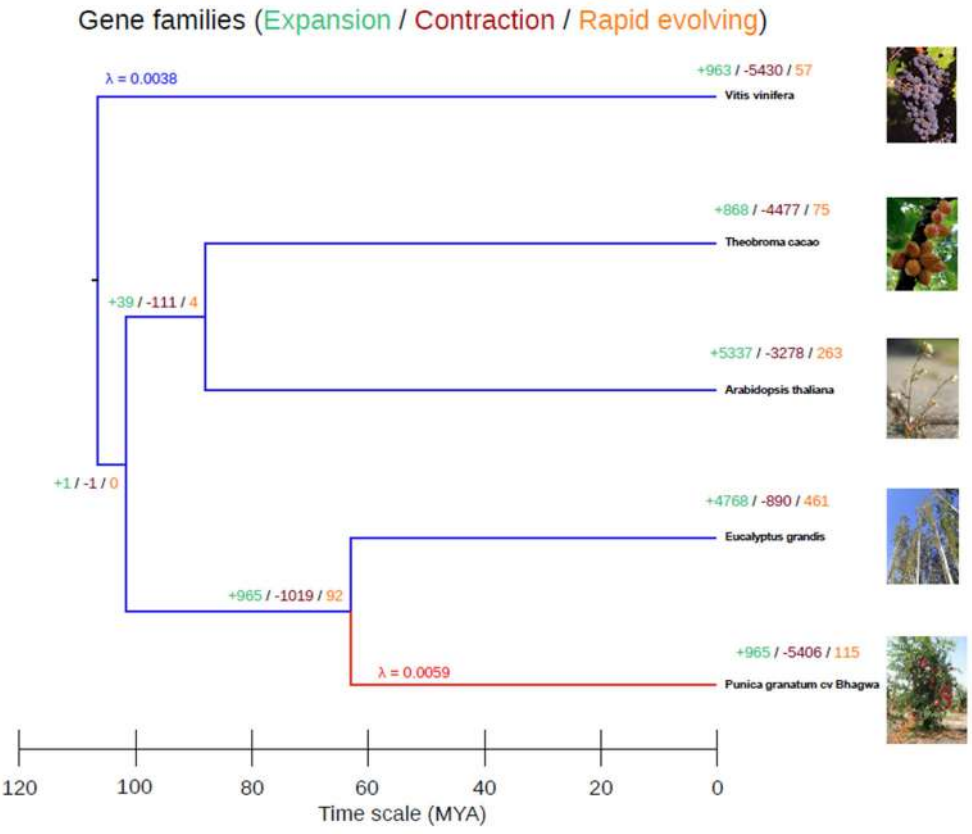


Fig. 7: Phylogenetic tree based on gene families using CAFE software

Bhagawa with previously reported genome of pomegranate cv. Dabenzi, Eucalyptus (*E. grandis*), Cocao (*T. cacao*) and Grape (*V. vinifera*) was also performed. A total of 31,364 genes in the pomegranate were grouped into 18,974 orthogene families, with 10,782 orthogene families shared by all the five species. Total 346 gene families were found to be species specific. Bhagawa genome is sharing 967 common gene families with Dabenzi, Eucalyptus, Cacoa and 9,815 families with inclusion of grape genome. However, Bhagawa genome is sharing maximum common gene families 2,935 with Dabenzi. It is interesting to note that Bhagwa and Dabenzi are sharing 63 and 64 gene families with the Eucalyptus genome, respectively. Whole genome phylogenetic analysis showed that pomegranate and *Eucalyptus grandis* got diverged after 64 (60-70) million years ago (MYA), after the paleotetrapoidy event (109 MYA) identified in the *E. grandis* genome (Myburg *et al.*, 2014). In total, 965 gene families had expanded, 5406 gene families had contracted and 115 gene families rapidly evolved in the pomegranate genome with λ 0.0059 value compared to its most recent common ancestor Eucalyptus.

Apart from this the LTR Assembly Index (LAI) index was calculated for all the three publicly available pomegranate genomes, Bhagawa (LAI=10), Taishanhong (LAI= 8) and Dabenzi (LAI= 2.5). These results also proved our genome is of reference quality with high standard compared to other draft genomes of pomegranate. Genome sequence data of cv. Bhagawa was submitted to NCBI data, obtained accession nos. SRR6917658, SRR6917659, SRR6917660.

2.1.2 Chloroplast Genome Assembly and Annotation of Indian Pomegranate cv. "Bhagawa"

The chloroplast genome of pomegranate was determined using the whole genome sequencing data. Sixteen diverse pomegranate genotypes including cv. "Bhagawa" were sequenced using Illumina HiSEq 2500 platform and subsequently GetOrganelle (v.1.5.1c) was used for *de novo* assembly of the chloroplast genome. The total organellar like reads are *de novo* assembled into a FASTA Graph ("fastg") file using SPAdes. The web-server CPGAVAS2 was used for annotating and visualizing the plastid genomes.

The chloroplastgenome structure and composition of *P. granatum* cv. Bhagawa, showed the archetypal circular double-stranded DNA and a quadripartite structure. The genome assembly of the cp genome in "Bhagawa" particular is 158641 bp with GC content of 36.9%, which is almost identical with the published *P. granatum* genome.

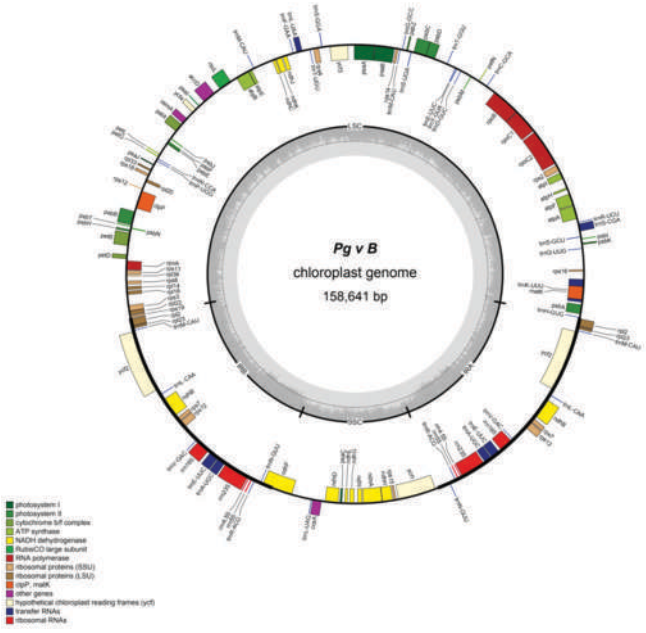


Fig. 8: Genome map of the Bhagawa cp genome: Thick line in the outer ring indicates the extend of IR regions (IRA and IRB). Genes drawn inside the circle are transcribed clockwise, and those outside are transcribed counter clockwise. Genes belonging to different functional groups are color-coded. The dark grey in the inner circle corresponds to the GC content and the light grey corresponds to the AT content.

A total of 127 genes were found, including 82 protein-coding, 8 rRNA, and 37 tRNA genes. Structurally, the cp genomes comprised of 2 inverted repeats (IRs; a and b), with a large single copy (LSC) and small single copy (SSC). The LSC, IRs and SSC size of all the assembled cp genomes were 89025, 25467 and 18682bp, respectively where as in the published *P. granatum* cp genome (NC035240.1) the size of LSC, IRs and SSC region is 89017, 25465 and 18687 bp.

* * * * * * * *

Crop Improvement

2.1 Project: Crop Regulation Practices for Improving Productivity of Pomegranate

2.1.1 Standardization Ethephon Concentration for Crop Regulation in Pomegranate

Pomegranate plants are basically deciduous in nature. Defoliation of plants through foliar spray of chemicals / growth regulators is useful for crop regulation through ethephon. The growth regulator ethephon was applied through foliar spray to pomegranate variety Bhagawa in mrig bahar. Ethephon was applied in single spray or double sprays at one week interval along with a control. The observations revealed that T3 (Ethephon @ 200ppm followed by ethephon @ 400 ppm at 1week after first spray) recorded the highest defoliation on 9 DAFS (87.5%) and 12 DAFS (92.5%). Beyond 12 days, there was no increase in the defoliation percentage.

Table 1: Defoliation percentage in pomegranate variety Bhagawa due to foliar spray of ethephon

Treatment	First Spray (07.06.19)	Second Spray (1 Week after First Spray)	Defoliation (%)				
			Days after First Spray (DAFS)				
			3 Days	6 Days	9 Days	12 Days	15 Days
T1	Ethephon @1000ppm	-	50.0	70.0	77.5	80.0	80.0
T2	Ethephon @200ppm	Ethephon @200ppm	30.0	45.0	55.0	60.0	60.0
T3	Ethephon @200ppm	Ethephon @400ppm	30.0	45.0	87.5	92.5	92.5
T4	Ethephon @200ppm	Ethephon @600ppm	30.0	45.0	87.5	90.0	90.0
T5	Ethephon @200ppm	Ethephon @800ppm	30.0	45.0	85.0	90.0	90.0
T6	Ethephon @200ppm	Thiourea@0.3%	30.0	45.0	67.5	72.5	72.5
T7	Thiourea @0.3%	-	35.0	50.0	60.0	65.0	65.0
T8	Control (water)	-	15.0	20.0	25.0	30.0	30.0

2.1.2 Effect of Growth Regulators on Enhancement of Fruit Size of Pomegranate

An experiment was conducted to enhance the fruit size of pomegranate cultivar Bhagawa during eleventh year of planting in mrig bahar. The growth regulator, Gibberellic acid was foliar sprayed at 7 different concentrations (10ppm, 20ppm, 30ppm, 40ppm, 50ppm, 60ppm, 70ppm) along with control (water spray). The highest mean fruit weight (269.2 g/fruit) was recorded by GA_3 @ 50ppm, followed by GA_3 @ 60ppm (264.8 g/fruit). The fruit weight was lowest in control (220.5 g/fruit). The highest yield was recorded from GA_3 @ 50ppm (25.44 kg/tree), closely followed by GA_3 @ 60ppm (24.36 kg/plant).

Table 2: Effect of Gibberellic Acid on Fruit Size Enhancement of Pomegranate

Treatment	Fruit weight (g/ fruit)	Fruit length (cm)	Fruit diameter (cm)	No. of fruits/tree	Yield (kg/tree)	Yield (t/ha)
GA3@ 10ppm	235.2	7.50	7.34	83.0	19.52	14.45
GA3 @ 20ppm	240.4	7.60	7.44	85.5	20.55	15.21
GA3 @ 30ppm	247.8	7.70	7.56	89.2	22.10	16.36
GA3 @ 40ppm	256.0	7.80	7.64	91.0	23.30	17.24
GA3 @ 50ppm	269.2	7.90	7.74	94.5	25.44	18.83
GA3 @ 60ppm	264.8	7.82	7.68	92.0	24.36	18.03
GA3 @ 70ppm	253.5	7.74	7.58	90.0	22.82	16.88
Control	220.5	6.98	6.84	78.5	17.30	12.80

Control GA_3@50ppm

Fig. 1: Effect of Gibberellic acid on Yield of Pomegranate cv. Bhagawa

Fig. 2: Effect of Gibberellic acid on fruit size enhancement of pomegranate cv. Bhagawa

2.1.3 Determination of Pruning Intensity for Pomegranate

To determine the pruning intensity for pomegranate, an experiment was conducted in mature plants of pomegranate variety Bhagawa. The treatments consisted of 3 levels of pruning (light pruning of 6'' shoots, medium pruning of 12" shoots and heavy pruning of 18' shoots) individually and combined with removal of tertiary branches which was compared with a control. The fruit weight was highest (266.5g/frit) in heavy pruning combined with removal of tertiary branches followed by heavy pruing (265.5g/fruit). Medium pruning combined with removal of tertiary branches recorded the highest yield (24.11kg/tree).

Table 3: Effect of pruning intensity on flowering and yield of pomegranate

Pruning Treatment	Time Taken for FBI	No. of Bisexual Flowers/ Tree	Fruit Set (%)	No. of Fruits/Tree	Fruit Weight (g/ Tree)	Yield (kg/ Tree)	TSS (Brix)	Acidity (%)
Light pruning	26.5	184.3	51.9	95.6	248.5	23.75	15.5	0.46
Light pruning & removal of tertiary branches	24.0	178.6	50.0	89.3	256.0	22.86	15.6	0.46
Medium pruning	28.0	183.0	50.6	92.6	260.4	24.11	15.7	0.44
Medium pruning & removal of tertiary branches	26.5	179.3	47.9	86.0	263.2	22.63	15.8	0.43
Heavy pruning	34.5	167.6	46.5	78.0	265.5	20.70	15.9	0.43
Heavy pruning & removal of tertiary branches	34.0	152.6	46.0	70.3	266.5	18.73	15.9	0.42
Control (without pruning)	26.5	186.3	53.5	99.6	178.7	17.80	15.2	0.48

Light pruning

Light pruning & tertiary removal

Medium pruning

Medium pruning & tertiary removal

Heavy pruning

Heavy pruning & tertiary removal

Control (Unpruned)

Fig. 3: Determination of pruning intensity for pomegranate

2.1.4 Standardization of Fertilizer Dose for Pomegranate cv. Solapur Lal

Solapur Lal is a high yielding variety of pomegranate developed through hybridization. To determine the nutritional requirement of Solapur Lal, an experiment was conducted in four year old Solapur Lal with different fertilizer doses viz., 100% RDF, 125% RDF and 150% RDF on adhoc basis. The manures and fertilizers were applied in split manner during rest period, flowering and fruit set period & fruit development period. Preliminary results revealed that highest no. of fruits (130.0), fruit weight (254.5g /fruit)

and yield (33.1 kg/tree) was obtained from 150% RDF. This was closely followed by 125% RDF. The yield was lowest in 100% RDF.

Table 4: Response of Pomegranate cv. Solapur Lal to fertilizer Doses

Tretment	No. of fruits/ tree	Fruit weight (g)	Yield (kg/tree)	Yield (ton/ha)	TSS (°Brix)	Acidity (%)	TSS/ Acid ratio
T1 -100% RDF	101.0	239.5	24.2	17.9	17.4	0.40	43.5
T2- 125% RDF	128.5	252.8	32.5	24.1	17.6	0.40	44.0
T3- 150% RDF	130.0	254.5	33.1	24.4	17.7	0.40	44.2

Fig. 4: Fruits of pomegranate variety Solapur Lal

(Left :100%RDF, Centre: 125%RDF, Right: 150% RDF)

2.2 Project: Genetic Mapping of Bacterial Blight and Fruit Quality Traits in Pomegranate

2.2.1 *In silico* Analysis and Development of Genome-Wide miRNA-SSR Markers

The availability of whole genome, coding and non-coding transcriptome sequences hasopened unprecedented opportunities for discovery of genome-wide novel functional markers for downstream genetic applications in pomegranate. Recently, non-coding RNA sequencing has resulted in the identification of huge number of putative miRNAs during seedling to fruit development stages in pomegranate (Saminathan *et al.* 2016). Since, various aspects of plant development and stress response are controlled by miRNA families. The DNA based markers from miRNA coding regions *i.e.* miRNA-SSRs and miRNA-SNPs have greater significance in development of a novel functional markers for trait mapping. For instance, SSRs in pre-miRNAs are known to be involved in alternative splicing events to produce mature RNA isoforms in response to stressed environments. Recently, the potential role for SSR and SNP markers located in miRNAs *vis-a-vis* expression of quantitative traits has been revealed in plants. Since, information on large scale development of miRNAs-SSRs markers in pomegranate is lacking. Therefore, through this experiment we report large scale development of genome-wide novel 897 miRNA-SSRs markers in pomegranate.

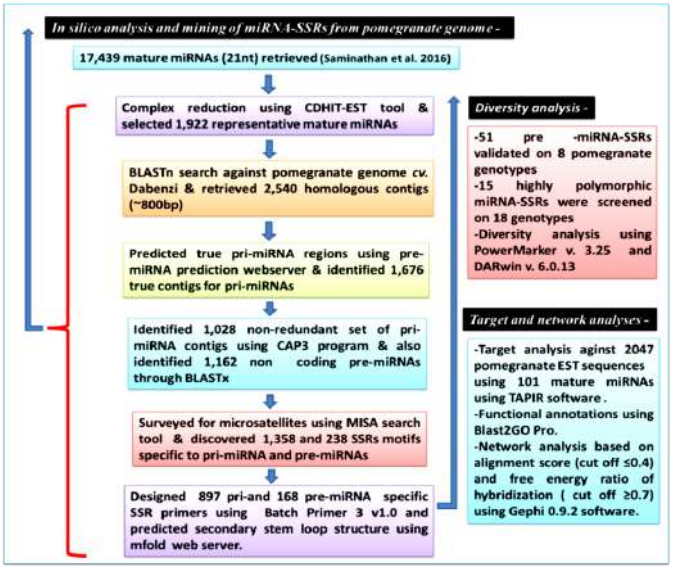


Fig. 5: The Flow Chart showing Steps of Development and Validation of miRNA-SSRs in Pomegranate

Apart from this, we also designed 58 EST-SSR markers from putative 128 target genes of 51 miRNAs for genetic mapping work. These 955 functional markers will serve as important genomic resources which could greatly strengthen our genetic mapping work against BLB resistance and fruit quality traits in pomegranate. The detailed methodology followed for development and validation of markers is shown in above Figure.

2.2.1 Characterization of miRNA-SSRs in the Pomegranate Genome cv. Dabenzi

Total 17,439 mature miRNA sequences were retrieved and CDHIT-EST search tool identified 1,922 non-redundant mature miRNAs. These sequences were then used as query sequences for homology BLASTn

search against pomegranate genome cv. Dabenzi at an e-value threshold ≤ 0.01. Total 2,540 contigs were selected to extract ~800bp flaking sequences around miRNA complementarity regions. Using miRNA prediction web server identified 1,676 contigs (~821) that code for true pri-miRNAs. These sequences were further analysed to identify 1,162 pre-miRNA sequences through BLASTX search against non-redundant protein database. Finally, 1,028 Pri-miRNAs sequences identified that are coding for 1,162

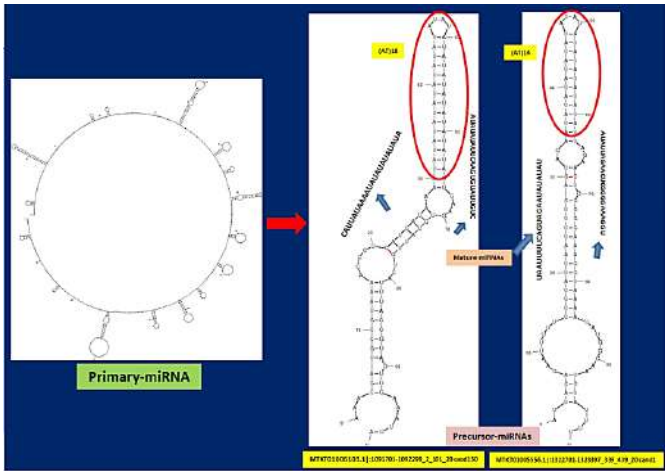


Fig. 6: Prediction of Secondary Stem Loop Structures in pri- and pre-miRNAs and Locating the SSR Motifs

Table 5: Chracterization of Microsatellites in Pri- and Pre-miRNAs Sequences of Pomegrante Genome cv. Dabenzi

Parameters	Pri-miRNA	Pre-miRNA
Number of sequences examined	1,028	1,162
Examined sequences size (bp)	701,888	119,835
Total number of identified SSRs	1,358	238
Number of sequences with SSRs	656	204
Number of sequences with more than 1 SSRs	385	31
Number of compound SSRs	366	34

pre-miRNAs and all these sequences were surveyed for SSRs motifs using MISA search tool. As a result, 1,358 SSR motifs from 656 (63.8%) pri- and 238 SSRs from 204 (17.55%) pre-miRNA sequences were identified. Out of 1,358 pri-miRNA-SSRs and 238 pre-miRNA-SSRs, 366 (26.95 %) and 34 (14.28%) were compound motifs, respectively. Through RNA fold software, we tried to predict stem loop structures in pri and pre-miRNA sequences and located the SSR motifs. As illustrated by overall frequency distribution graphs in pri-miRNAs and pre-miRNA sequences, hexa- repeats were found more dominant (44.18 %). Further, frequency distribution for SSR motif types suggested abundance of A/T (94.80%) in pri-miRNAs followed by AT/AT (51.95%) and AG/CT (36.80%). In pre-miRNA sequences, AT (.....) and AT/AT (.....) motifs were found dominant.

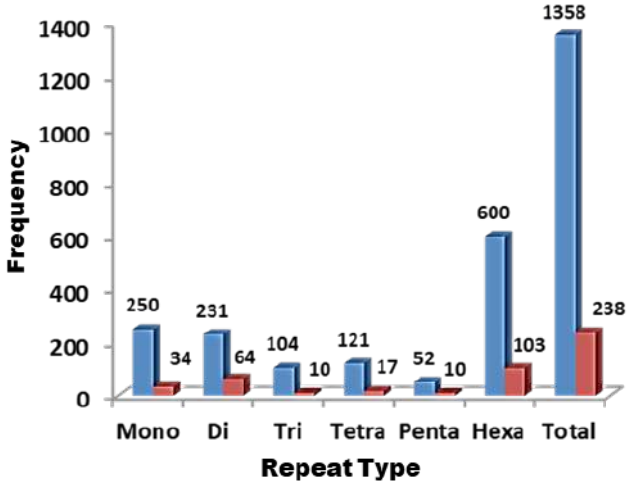


Fig. 7: Frequency Distribution of Different SSR Repeats in pri-and pre-miRNA Sequences of Pomegranate

2.2.3 Designing, Validationand Diversity Analysis using miRNA-SSR Markers

Using web based high throughput primer designing Batch Primer 3 tool, we designed 897 primer pairs from 1,028 pri-miRNA sequences. Out of 897 pri-miRNA-SSRs, 168 primers were exclusively specific to pre-miRNA sequences. Further, we synthesized a set of 51 SSRs for experimental validation. Initially, the primers were assayed on eight pomegranate genotypes *viz.*, Ganesh, Kalpitiya, Co-White, Dholka, Yercaud, P-23, Daru 17 and Nana on 3% metaphor agarose gels. As a result, 47 (92.15 %) primers showed scorable amplicons with significant level of DNA polymorphism. Further,15 SSR primers were selected and genotyped on a panel of 18 pomegranate genotypes for genetic diversity estimation using fragment analyser. These markers revealed, 3 to 9 number of allele/locus with an average of 5.8. The frequency of major alleles (MAF)

per locus ranged from 0.22 to 0.67, with average of 0.37. Similarly, PIC values varied from 0.48 to 0.81, with an average of 0.68. The heterozygosity values ranged from 0.0 to 1.00 with average of 0.57. Average gene diversity for these makers was 0.72 among 18 pomegranate genotypes.

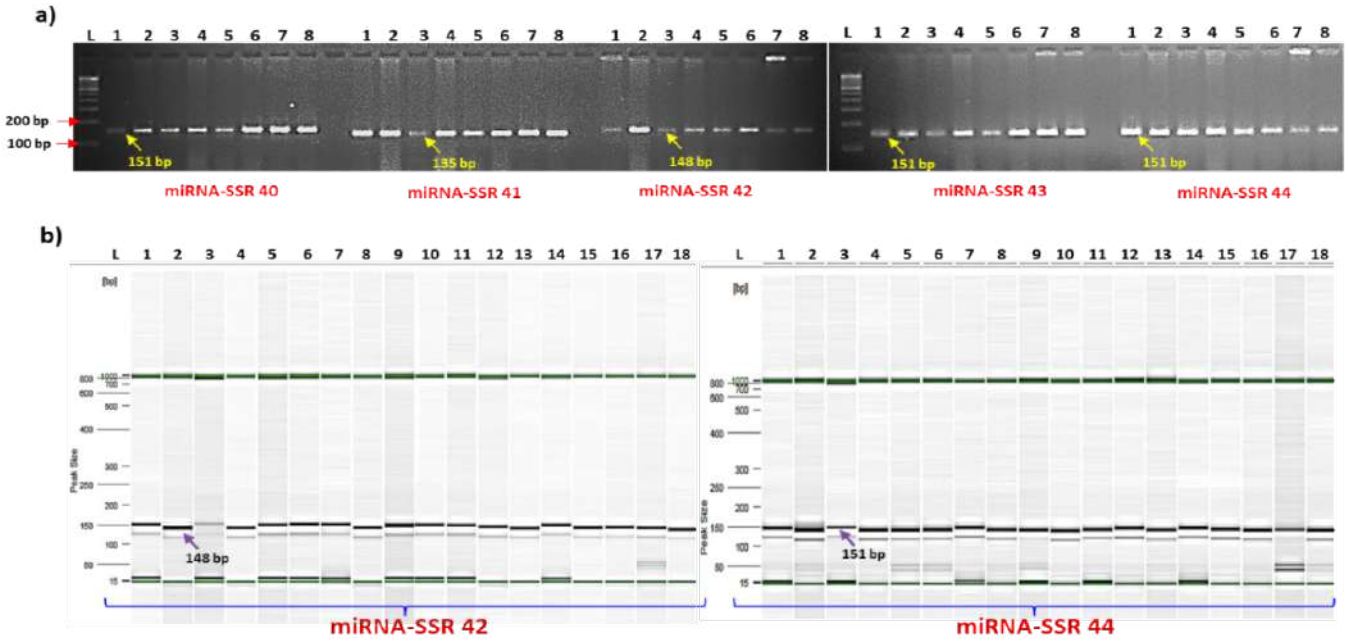


Fig. 8: Gel images showing allelic variations as revealed by novel mi-RNA-SSR markers a) Assaying eight pomegranate genotypes with the markers miRNA-SSR 40, 41,42,43 & 44 on 3% metaphor gel b) Assaying miRNA-SSRs 42 and 44 on 18 pomegranate genotypes using fragment analyzer

Table 6: Diversity analysis of 18 pomegranate genotypes using 15 pre-miRNA-SSR markers

Sl. No	Marker	Family	MAF	NA	PIC	Heterozygosity	GD
1	Pre miR_SSR32	ath-MIR5664	0.50	4	0.58	0.00	0.64
2	Pre miR_SSR33	ath-MIR169c	0.67	5	0.48	0.06	0.52
3	Pre miR_SSR2	ath-MIR157c	0.25	9	0.81	0.89	0.83
4	Pre miR_SSR3	ath-MIR156b	0.42	6	0.58	0.78	0.65
5	Pre miR_SSR8	crm-mir-244	0.44	3	0.57	0.00	0.64
6	Pre miR_SSR9	ath-MIR156b	0.28	9	0.81	0.94	0.83
7	Pre miR_SSR13	ath-MIR156b	0.47	5	0.61	0.94	0.67
8	Pre miR_SSR17	ath-MIR5651	0.28	9	0.80	0.94	0.82
9	Pre miR_SSR16	ath-MIR156b	0.28	5	0.75	0.72	0.78
10	Pre miR_SSR30	gga-mir-7439	0.39	4	0.67	0.00	0.72
11	Pre miR_SSR45	ath-MIR167d	0.22	7	0.80	0.89	0.82
12	Pre miR_SSR41	ath-MIR157c	0.44	4	0.62	0.61	0.68
13	Pre miR_SSR42	ath-MIR156b	0.22	7	0.81	0.83	0.83
14	Pre miR_SSR44	ath-MIR5645d	0.31	6	0.74	1.00	0.78
15	Pre miR_SSR26	sly-MIR172c	0.44	4	0.61	0.00	0.67
	Mean		0.37	5.8	0.68	0.57	0.72

Note: * MAF- Major allele frequency, NA- No. of obtained alleles, PIC polymorphic information content, GD- Gene diversity, miR-miRNA

The pooled marker data as obtained for 18 genotypes were used to construct UPGMA-NJ tree and factorial analysis. These suggested existence of three major clusters and NJ tree cluster 1 comprised of six genotypes, whereas clusters 2 and 3 had eight and four genotypes, respectively. As evident in both NJ tree and factorial plots, higher diversity was observed for genotypes belonging to CL-II, followed by CL-I and CL-III.

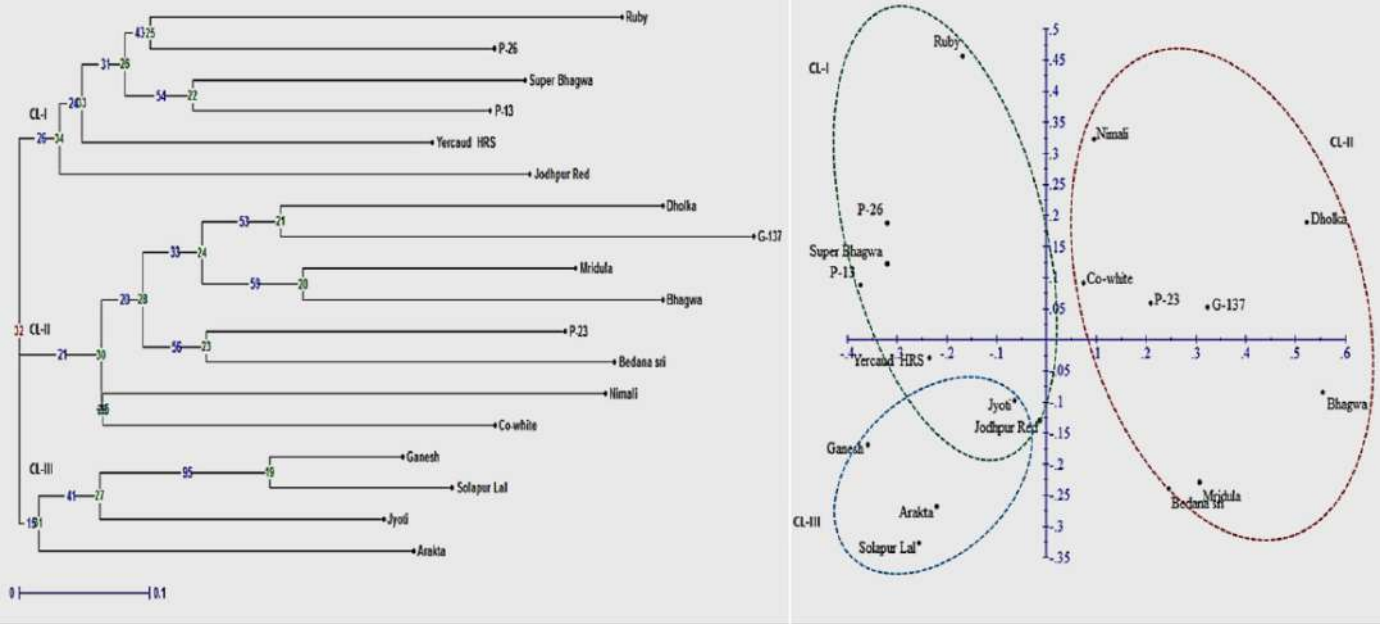
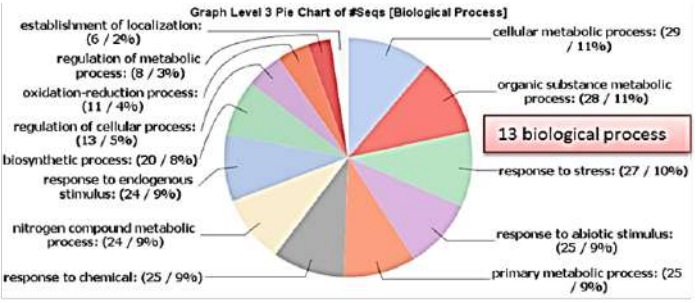


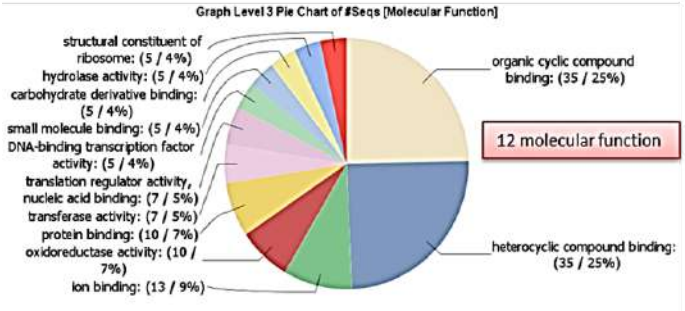
Fig. 9: Neighbor joining tree and factorial analysis depicting genetic relationships among 18 pomegranate genotypes based on 15 miRNA-SSR marker data

2.2.4 Functional Annotation and Pathway Enrichment for miRNA Target Genes

To demonstrate the functional utility of miRNA-SSR markers for genetic analysis, mature RNAs of 51 miRNA-SSRs used for diversity analysis were deployed for target analysis using TAPIR program against 2,417 pomegranate EST sequences as the reference transcript library. As a result, a total of 128 putative gene targets were identified. Further, the GO annotations of all the predicted targets were analyzed by identifying most significant BLAST hits across different species based on BLASTx search. GO terms were classified for the target genes, with 13, 12 and 7 involved in biological process, molecular function, and cellular component, respectively. In the biological process category, the majority of the targets were potentially involved in cellular and organic substance metabolic processes. With respect to molecular function category, predicated targets showed participation in organic and hetero cyclic compound binding, followed by ion binding, protein binding and oxidoreductase activity. In the cellular component category, 44 target genes were assigned to intrinsic component of membrane, followed by intracellular and intracellular part, and membrane bounded organelle.

KEGG enrichment pathwayanalysis revealed, out of 128 target genes, 18 genes coding for 14 enzymes that are part of 11 important pathways *viz.*, purine metabolism, thiamine metabolism, phenylpropanoid biosynthesis, amino sugar and nucleotide sugar metabolism, mTOR signaling pathway, glutathione metabolism, drug metabolism-other enzymes, ascorbate and aldarate metabolism, phosphonate and phosphinate metabolism, glycerol phospholipid metabolism and pyrimidine metabolism.





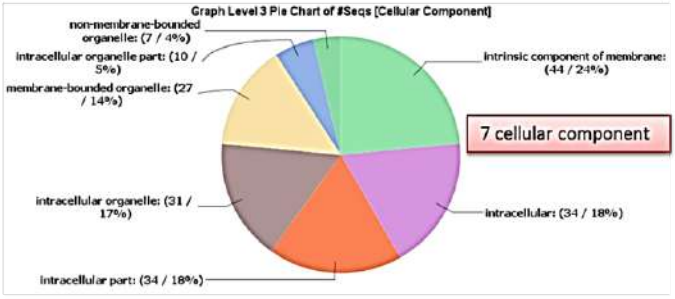


Fig. 10: Distribution of GO terms in the Biological, Molecular function and Cellular component category

2.2.5 miRNA-mediated Regulatory Networks

To further explore the relationship among the miRNAs and their targets, miRNA-mediated regulatory networks were constructed. Thirteen independent networks were developedfor miRNA families. Exploring these results ath-miR157c has revealed maximum targets (79 genes), followed by ath-MIR394a (26 genes), ath-MIR841b (25 genes), ath-MIR2111b (23 genes), ath-MIR5651 (20 genes), ath-MIR167d (19) and ath-MIR156b (12). However, the lowest targets were observed for ath-MIR161 (1), sly-MIR172c (1), gga-mir-12253 (1), ath-MIR8183 (1), mtr-MIR156e (2) and ath-MIR396a (3). The ath-miR157c was the largest regulatory network and shared maximum genes with MIR2111b (18 genes) and ath-MIR156b (6) for tropinonereductase, Zf-FLZ domain protein, homeodomain-like protein, mitogen-activated protein kinase 3, NADH dehydrogenase (ubiquinone) 1 beta sub-complex, ubiquitin-40S ribosomal protein S27, RPM1-interacting protein 4, thioredoxin H-type, Calcium-binding EF-hand family protein and proteinChromatin Remodeling 8. Similarly, ath-MIR394a regulatory network shared many common targets with ath-MIR5651 and ath-MIR167d. Further, network analysis for the individual miRNAs families based on alignment score and minimum free energy ratio of hybridization, ath-MIRNA 157c revealed strongest interaction with stress associated protein 8, ath-MIR394a with unknown gene (JG771766.1),

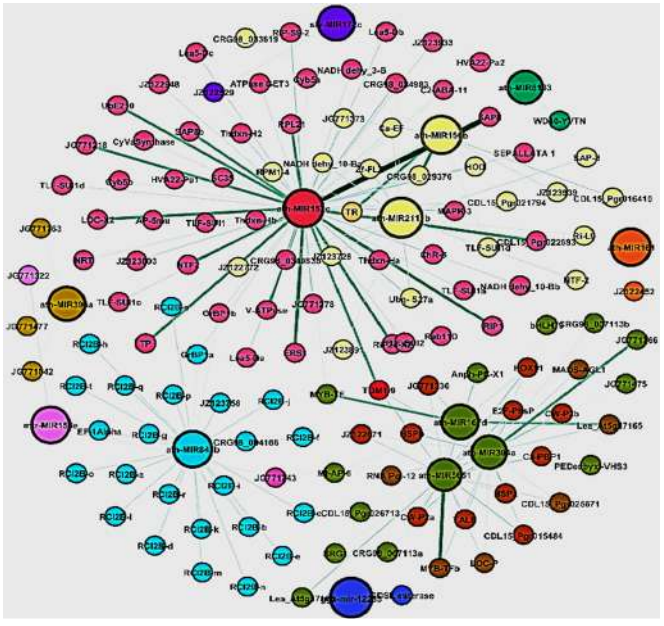


Fig. 11: A Comprehensive miRNA-target genes regulatory network identified in pomegranate for 13 miRNA families (darker green lines for each family indicates stronger interactions for miRNAs with their target genes based on minimum free energy of hybridization

ath-MIR2111b (Zf-FLZ, UBq-S27a and NADH dehy_10Ba), ath-MIR5651 (MYB-TF), ath-MIR167d

(MYB-TF and Lea_At5g17165), ath-156b (TR and CRG98_029376) and for ath-MIR841b many genes.

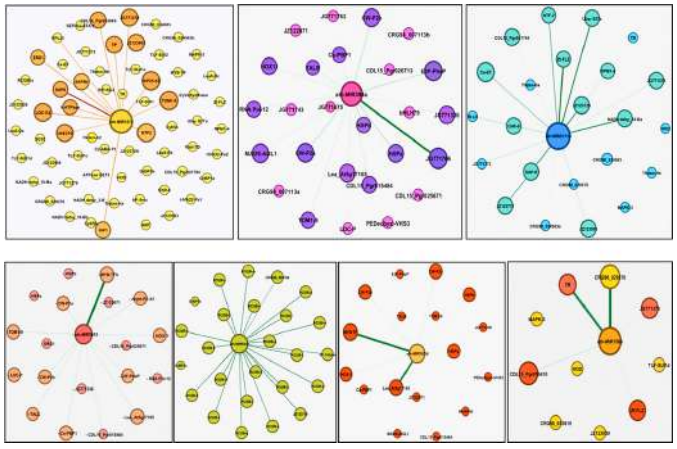


Fig. 12: Regulatory network for individual miRNA families with their targets genes

(Darker green lines for each family indicates stronger interactions for miRNAs with their target genes based on minimum free energy of hybridization)

2.2.6 Designing of EST-SSR Markers

SSR mining in the 128 target genes of miRNAs, revealed 143 SSR motifs with maximum frequency of mononucleotide repeats (65), and followed by dinucleotides (63) and trinucleotides (15). We observed 53 of target gene sequences have more than one SSR motifs and 29 have compound SSR motifs. Finally, 58 functional EST-SSR markers were designed that can be deployed for mapping genes/QTLs for quality traits in pomegranate.

Through this experiment, we successfully demonstrated development of novel miRNA-SSRs in pomegranate through *in silico* analysis. Also shown, if we associate these markers through association mapping or linkage mapping, then through target analysis using mature miRNA of that linked marker with the transcriptome data for BLB or fruit development,we can identify trait specific candidate gene or master miRNAs for genome editing applications in pomegranate.

2.2.7 Development of miRNA-SSRs in relation to seed hardness trait in pomegranate

For this experiment 761 potential novel miRNA candidate-precursors RNA sequences reported for seed harness trait in pomegranate (Luo et al., 2018), were deployed for *in silico* analysis. After performing various preliminary analyses like SSR motif search and BLASTx in these sequences, a total of 69 non-coding pre-miRNA sequences were selected as query sequences for BLASTn homology search against pomegranate genome to retrieve 69 homologous contigs with fianking regions (~800). Through pre-miRNA prediction web server, 63 true pri-miRNAs contigs encoding 213 pre-miRNAs were identified. Based on SSR search, a total of 227 SSRs specific to pri-miRNAs and 79 to pre-miRNA sequences were identified (Table 3). The frequency distribution graphs for SSRs revealed, hexa nucleotides repeats were more dominant (47.58 %) followed by mono (19.82%) and di nucleotide (16.74%) in pri-miRNAs sequences, which is also evident in pre-miRNAs (Fig. 9). Total 132 miRNA-SSR primers were designed for seed hardness traits using 63 true pri-miRNAs, of which 46 primers are specific to pre-miRNAs. Out of 132 primers, 123 primers were successfully validated and localized on 8 chromosomes of Tunisia genomes through e-mapping (Fig. 14). Further, 80 SSRs producing specific amplicons were validated across multiple genomes i.e. Dabenzi, Taishanhong and AG2017 including Tunisia, resulting in identification of 63 polymorphic SSR markers (PIC>0.5). Further, the potential application of miRNA-SSRs in discovering the seed hardness specific candidate genes was showed by validating 44 mature miRNA against publically available 2047 EST sequences of pomegranate using target, network analysis and designed 272 EST-SSR markers. This study offered a set of novel markers to map seed hardness trait in pomegranate.

Table 7: Characterization of microsatellites for seed hardness in pri-and pre-miRNAs sequences in pomegranate genome

Parameters	Pre-miRNA	Pri-miRNA	Pre-miRNA
Number of sequences examined:	761	63	213
Examined sequences size (bp):	148,791	81788	22214
Total number of identified SSRs:	199	227	79
Number of sequences with SSRs:	144	60	65
Number of sequences with more than 1 SSRs:	42	55	12
Number of compound SSRs:	44	67	14

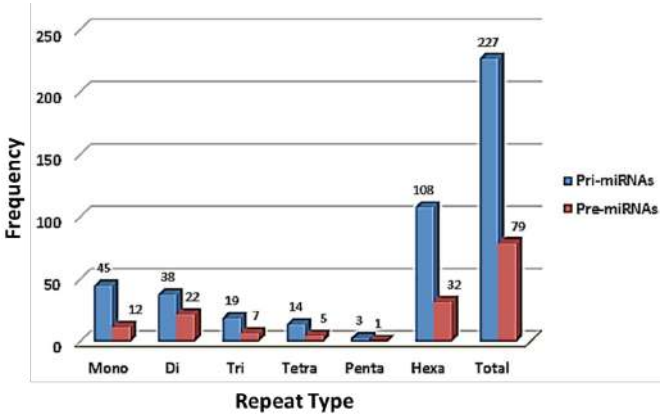


Fig. 13: Frequency distribution for SSR repeats in pri-and pre-miRNA sequences of pomegranate genome cv. Daenzi

Fig. 14: Chromosome specific localisation of miRNA-SSRs markers on Tunisia genome

2.2.8 miRNA-mediated Regulatory Networks

The miRNA-mediated regulatory networks were constructed to explore the relationship among the miRNAs and their target genes. Total five independent networks were obtained for miRNA families, three of them had multiplicity behavior i.e., one miRNA can target more than one genes (Fig. 15). The ath-miR5021 has revealed maximum targets (84 genes), followed by ath-miR156b (41 genes) and ath-miR5651 (18 genes). Whereas, lowest targets were noticed for ath-miR406 (1) and ath-miR157c (1). Among the regulatory network, ath-miR5021 was found largest network that is targeting unique genes. However, ath-miR156 was found second largest network that has shared few common genes with ath-miR5021 (4) for Zf-FLZ domain containing protein, protein MARD1-like, hypothetical protein CRG98_029376 and unknown gene JZ123933.1. Whereas, all other three families i.e. ath-MIR5651, ath-MIR406 and ath-MIR157c targeted unique genes.

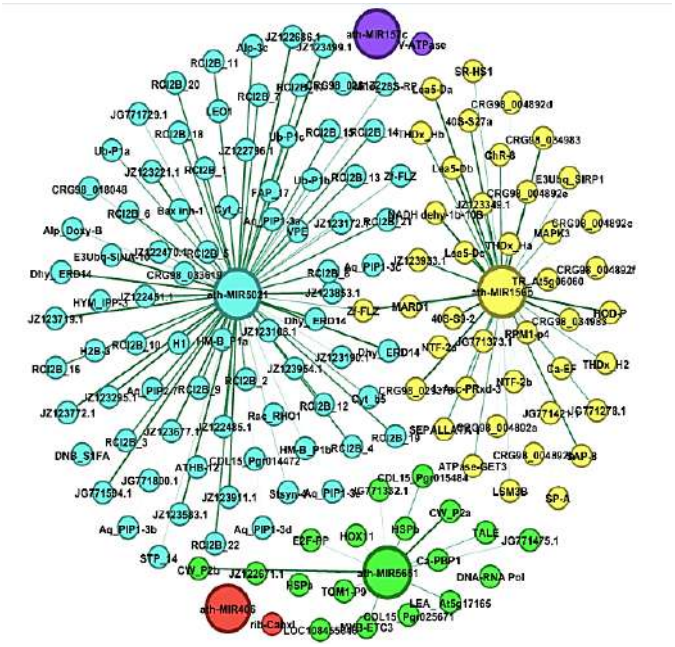


Fig. 15: A comprehensive miRNA-target genes regulatory network identified in pomegranate for five miRNA families (darker green lines for each family indicates stronger interactions for miRNAs with their target genes based on minimum free energy of hybridization)

2.2.9 Screening for Bacterial Blight Resistance

During this year (2019-2020), a total of 148 breeding materials representing commercial varieties, cultivars, germplasm lines and F_1 segregating lines derived from different parental crosses were screening against BLB resistance through challenge inoculation technique under polyhouse conditions. All the tested lines showed highly susceptible reaction with more than 50% blight incidence. The blight incidence ranged between 8.33 to 53.33% at 7 days of inoculation (DAI) and 15 to 97.67% at 14 DAI. At 26 DAI all the breeding material under test were recorded above 50-95% blight incidence, except one genotype *i.e.* Drau 2, with blight incidence ranged from 8.33-50% till 45 DAI. The minimum disease severity grade of 1.67 was recorded in Daru-2 in comparison to highly susceptible breeding material with disease severity grade of 2.63 to 5 on scale of 1-5. Hence Daru-2 was found most promising genotype with lowest bacterial blight severity. The details of pomegranate genotypes used for screening are given in the table below.

Table 8: Breeding material tested for reaction to bacterial blight through challenge inoculation

Germplasm	No. Tested	Germplasm	No. Tested	Germplasm	No. Tested
Nayana	11	1194	1	Bhagawa x Nana	1
Jodhpur Seedless	1	Kalpitiya x Ruby	16	Bhagawa x Kalpitiya	1
Amlidana	1	Nayana X Ruby	10	Bhagawa x 3/5 (Bx (GxnxD)	1
Kasuri	1	Moderately Resistant BBD:Bx [(Gxn)xD]	10	Wonderful	1
Karnataka Region Selection	1	[(Ganesh X Nana) x (Ganesh x Daru)] x Ruby	10	Rosette	1
Muskat	1	[(Ganesh x Daru)x Ganesh)]x Ruby	5	6/7	5
Double Flower	1	Hybrid-B	2	7/10	3
Damini	1	Hybrid-A	1	6/5	5
Bedana Sedana	1	1/2GxG	1	6/4	3
Gulesha Red	1	Bhagawa x Nayana	1	Daru	7
Dholka	1	Acc-15	1	G-137	1
Jodhpur Collection	1	Acc-50	1	Ganesh	1
Kalpitiya	1	Acc-51	1	Ruby	1
Kerala Local	1	Farmers variety Sln.	1	Bhagawa	1

* * * * * * * *

Plant Propagation

3.1 Project: Propagation, Bio-hardening and Mass Multiplication of Elite Planting Material in Pomegranate (*Punica granatum* L.)

3.1.1 Comparative Evaluation of Pomegranate Saplings Raised Through Different Propagation Methods

An experiment was initiated in August, 2018 to evaluate the effect of rootstocks and compare the performance of saplings raised through different propagation methods in pomegranate. The vegetative growth among plants raised through different propagation methods didn't show any significant variations and registered at par with plant height and canopy spread. The grafting success of 'Bhagawa' scion on wild rootstocks ranged from 66.88% to 75.21%.

Table 1: Comparative evaluation of pomegranate saplings raised through different propagation methods

Treatments	Plant height (cm)	Canopy spread E-W (cm)	Canopy spread N-S (cm)
Micropropagated plants	119.583	136.250	140.000
Air layered plant	130.833	137.499	141.250
Hard wood cutting raised plant	132.917	151.250	140.833
Grafted plant (Bhagawa on IC 318706 rootstock)	112.917	124.166	130.833
Grafted plant (Bhagawa on IC 318707 rootstock)	120.833	132.083	142.083
Grafted plant (Bhagawa on IC 1181 rootstock)	125.417	117.083	133.333
Grafted plant (Bhagawa on IC 318712 rootstock)	131.667	147.500	134.583
CV	10.495	13.606	12.501
CD (p=0.05)	NS	NS	NS

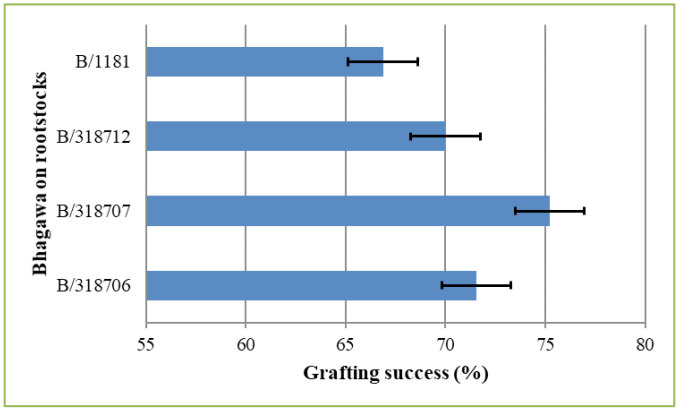


Fig. 1: Grafting success of Bhagawa on different rootstocks

3.1.2 Evaluation of Growth and Propagability of 'Solapur Lal', 'Bhagawa' and 'Super Bhagawa'

Morphological growth of 'Solapur Lal', 'Bhagwa' and 'Super Bhagawa' varied significantly under 35% shade net house conditions. Among these three varieties 'Solapur Lal' was found to be significantly vigorous than 'Bhagawa'. However, 'Bhagawa' and 'Super Bhagawa' registered at par with plant height and canopy spread. The air layering success was significantly higher in 'Super Bhagawa' as compared to 'Solapur Lal'. 'Super Bhagwa' and 'Bhagawa' registered better cutting and layering success as compared to 'Solapur Lal'.

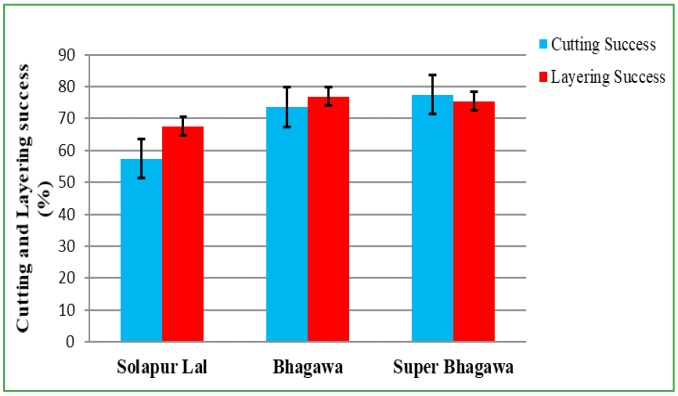


Fig. 2: Cutting success of 'Solapur Lal', 'Bhagawa' and 'Super Bhagawa

Table 2: Growth and Propagability of Solapur Lal, Bhagawa and Super Bhagawa under Shade Net House

Variety	Plant height (cm)	Canopy spread E-W (cm)	Canopy spread N-S (cm)	Layering success (%)
Super Bhagawa	156.990	151.009	157.546	77.200
Bhagawa	126.074	119.009	129.528	71.000
Solapur Lal	186.388	157.759	178.416	63.000
CD (p=0.05)	36.775	27.480	34.249	9.024

3.1.3 *In vitro* Propagation and Genetic Fidelity Testing

In toto 144 media, media additives, growth regulator and their supplement combinations were tried to improve the *in vitro* multiplication efficiency of pomegranate explants. Maximum average shoot growth (5.33 cm) was recorded with Modified MS medium + IAA (1 mg/l) + Sodium Phosphate Monobasic (221.71 mg/l) + Casein Hydrolysate (10 mg/l). However, maximum number of side shoots per explant (3.83) was found when explants inoculated on modified MS medium supplemented with IAA (1 mg/l) + NAA (0.1 mg/l) + Adenine Sulphate (80 mg/l) + Argenine (80 mg/l) + Casein Hydrolysate. The shoot tip explants on WPM medium supplemented with 1 mg/l BAP + 0.1 mg/l NAA + 100 ml/l Coconut water + 50 mg/l Adenine Sulphate and Argenine + Pectin and Glutamine 250 mg/l also produced 3.42 number of side shoots and 3.53 cm average shoot growth with good Greenness Index of leaves (4.00).

The genetic fidelity testing was performed using SSR, Hypervariable SSR, ISSR and RAPD markers with high PIC values. Representative samples of 20 *in vitro* raised saplings were taken from different lots of 400 plants for DNA isolation. All the markers produced monomorphic banding patterns upon PCR amplification and separation on agarose gels, which confirmed the genetic similarity of *in vitro* raised clones.

Fig. 3: Gel photograph of amplicons of pomegranate clones using PG SSR56 primer (L-100bp ladder and lane 1-20: 20 clones of pomegranate, 21-24: 4 mother pomegranate plant samples)

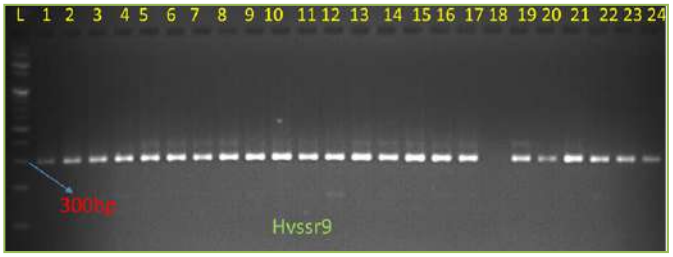


Fig. 4: Gel photograph of amplicons of pomegranate clones using HvSSR9 Primer (L-100bp ladder and lane 1-20: 20 clones of pomegranate, 21-24: 4 mother pomegranate plant samples)

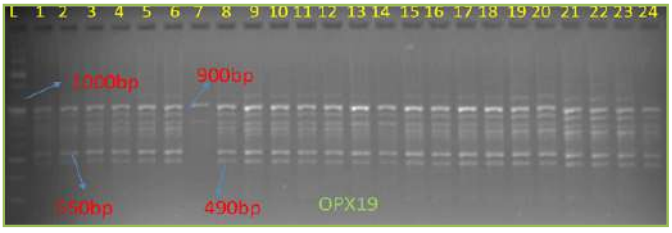


Fig. 5: Gel photograph of amplicons of pomegranate clones using OPX19 Primer (L-100bp ladder and lane 1-20: 20 clones of pomegranate, 21-24: 4 mother pomegranate plant samples)

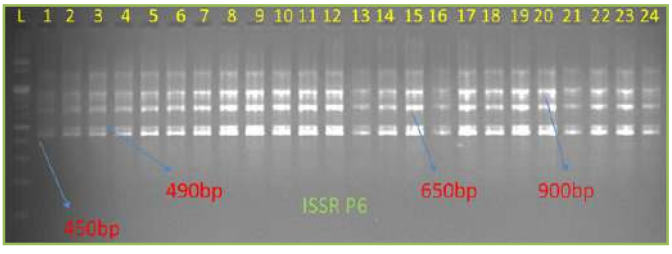


Fig. 6: Gel photograph of amplicons of pomegranate clones using ISSR6 primer (L-100bp ladder and lane 1-20: 20 clones of pomegranate, 21-24: 4 mother pomegranate plant samples)

EST-SSRs and variety specific unique SNPs for ultimate utilization in genetic fidelity testing and variety identification.

3.1.4 EST-SSRs Predicted from Pomegranate Transcriptome

We used Microsatellite identification tool (MISA) for the prediction of di, tri, tetra and penta nucleotide repeats in the transcriptome data generated from *denovo* assembly of RNAseq data from different tissues of pomegranate. A total of 1,88,337 transcripts were given as input to MISA for the prediction of SSR markers.

Table 3: Statistics of predicted SSRs

Description	Number
Total number of sequences examined	188337
Total size of examined sequences (bp)	222923628
Total number of identified SSRs	55144
Number of SSR containing sequences	40192
Number of sequences containing more than 1 SSR	10907
Number of SSRs present in compound formation	3703

In depth analysis of the predicted SSRs show that the frequency of SSRs which have about six types of repeats (Complex SSRs) are about 69 which constitutes about 0.12% of the total predicted SSRs. The SSR locus numbers of the mono, di, tri, tetra, penta and hexa nucleotide SSRs are as 25520, 18574, 9931, 927, 123, and 69, respectively.

Table 4: Frequency of repeats and their distribution in the predicted SSRs

Frequency of types of repeats	Number of SSRs
1	25520
2	18574
3	9931
4	927
5	123
6	69

3.1.5 Variety Specific Unique SNPs

For Variant Calling, we mapped back all the clean reads from the multiple libraries to the reference Bhagawa genome. Using the Reference genome we created an Index using BWA on the genome to create a Bower-Wheeler Transform based FM-Index. The alignments are reported in a bam (binary alignment and mapping) format using BWA at default parameters. All the libraries were passed into BWA for the alignment. The alignments were processed using Samblaster to exclude duplicates. A non-overlap of 20 bases between the two reads was taken for split alignment. InDels were marked, if they were <=50 bases in size. An alignment was considered Discordant, if the paired-reads were not mapped within the expected insert-size. Joint-genotyping was performed in order to get better support and confidence by Freebayes. These variants are emitted in a cumulative form in a VCF file (Variant Calling Format) which were then strictly filtered using Bcftools-v1.7. Bedtools was used in order to calculate the genome coverage profiles from the mapping of the two genomes. Subsequent to filtering, both Freebayes and GATK output using recommended parameters, we have obtained the concordant SNPs between the two databases using bcftools isec module.

Table 5: Variety specific unique SNPs

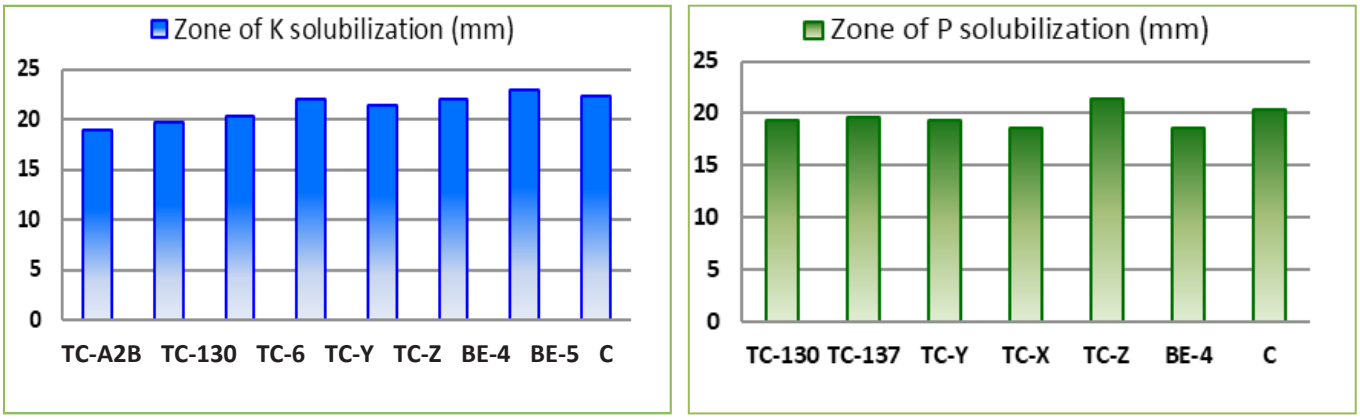
Name of the variety	Unique SNPs
Bhagawa	25
Super Bhagwa	14
Mridula	17
Arakta	11
Wonderful	11
Solapur Lal	7

3.1.6 Potential Endophyte Isolation and Their Evaluation

3.1.1.1 Potash and Phosphate Solubilizing Ability of Promising Endophytes

Pomegranate endophytes having potential to control bacterial blight under green-house conditions

were evaluated for their ability to solubilize potash and phosphorous in comparison to ICAR-NRCP identified and commercialized native rhizospheric fungus *Penicillium pinophilum*-exploited as K and P solubilizing microbe- used as control. All endophytes performed at par with control which confirms their utility as potential K and P solubilizers. Quantitative estimation and further investigations at field level are required for their potential utility in pomegranate cultivation.



(a) **(b)**

Fig. 7: Potash (K) and phosphorous (P) solubilizing ability of promising endophytes nine days after inoculation in comparison to *P. pinophilum* used as control (C)

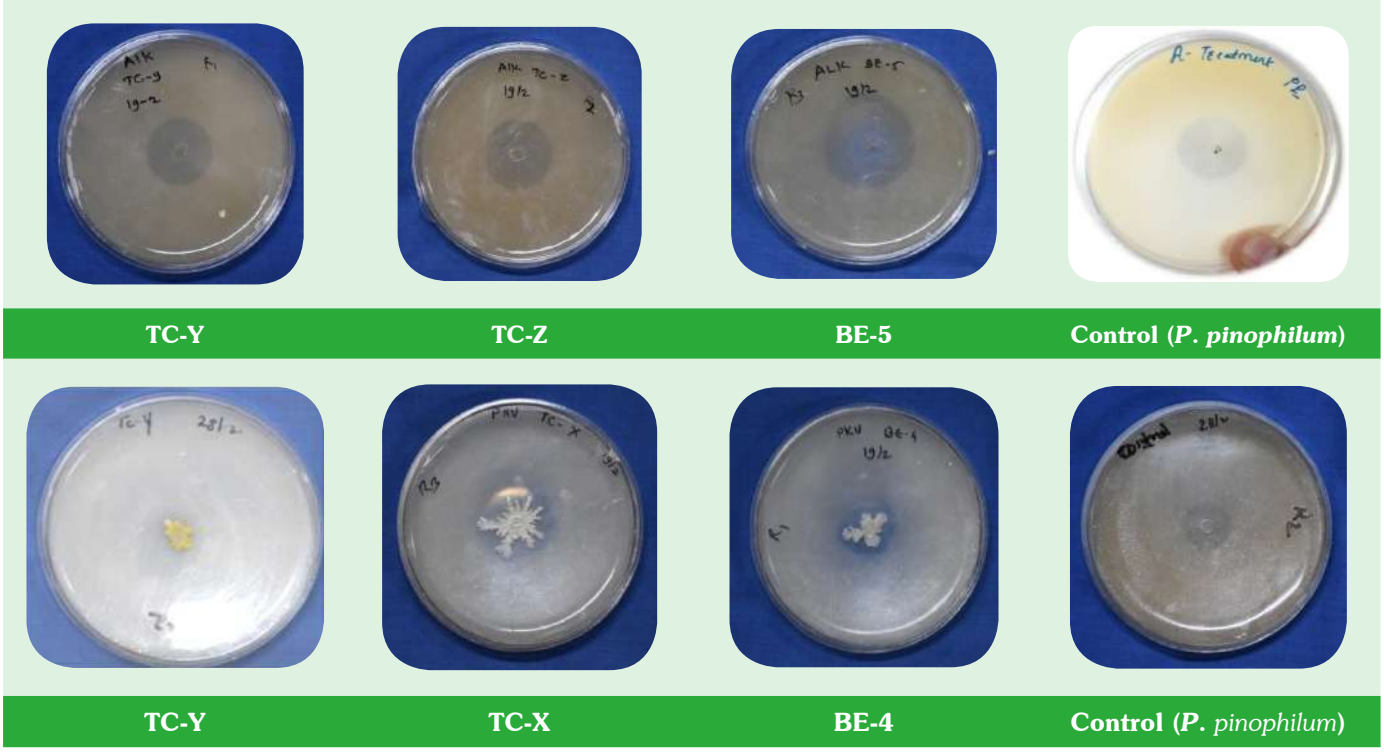


Fig. 8: Potash (K) and phosphorous (P) solubilizing ability (seen as clear zones) of promising endophytes

* * * * * * * *

Crop Production

4.1 Project: Package of Practices for Organic Cultivation of Pomegranate

4.1.1 Developing Bio-mineral Fertilizer for Supplementing K and P to Pomegranate Tree

From our previous study, it was observed that conjunctive use of *Penicillium pinophilum* based potassium solubilizing bio-formulation with insoluble K containing mineral powder (potassium feldspar) resulted greater yield improvement compared to use of potassium solubilizing bio-formulation alone. Hence, the effect of mixing insoluble K containing mineral powder with the bio-formulation on the shelf life of *Penicillium pinophilum* spores was studied. It was observed that inoculation of fungal spores with talc powder in 1:10 ratio followed by mixing with potassium feldspar in 1:5 ratio (Protocol II) maintained higher viable spore count after 8 months of storage at ambient temperature compared to protocol I wherein fungal spores were inoculated with talc in 1:20 proportion followed by mixing with potassium feldspar powder in 1:2.5 ratio.

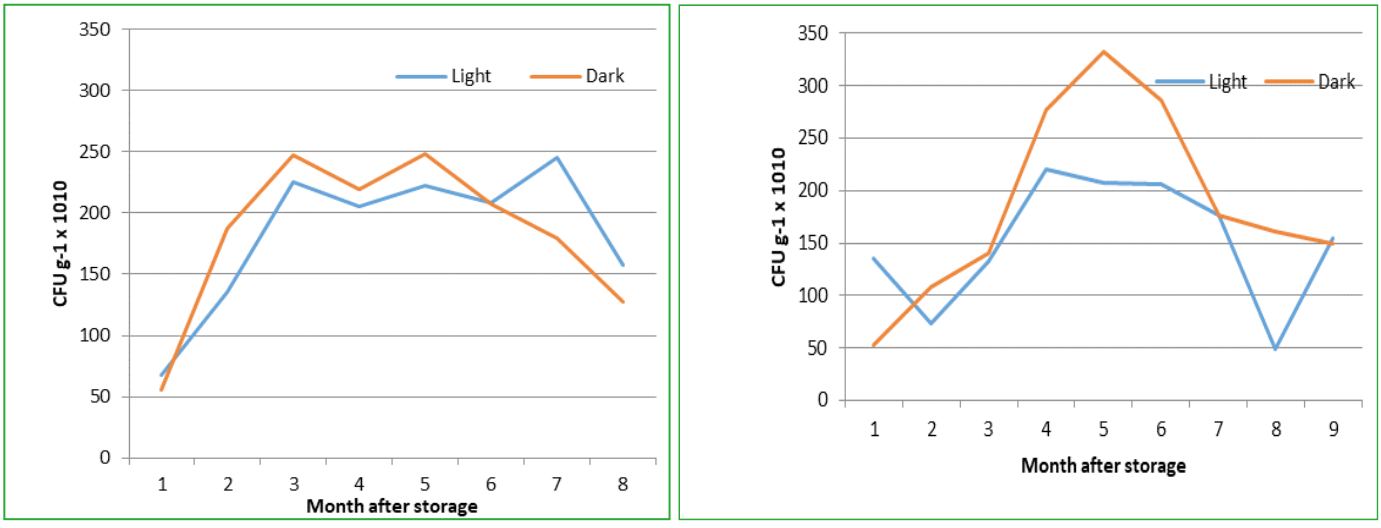
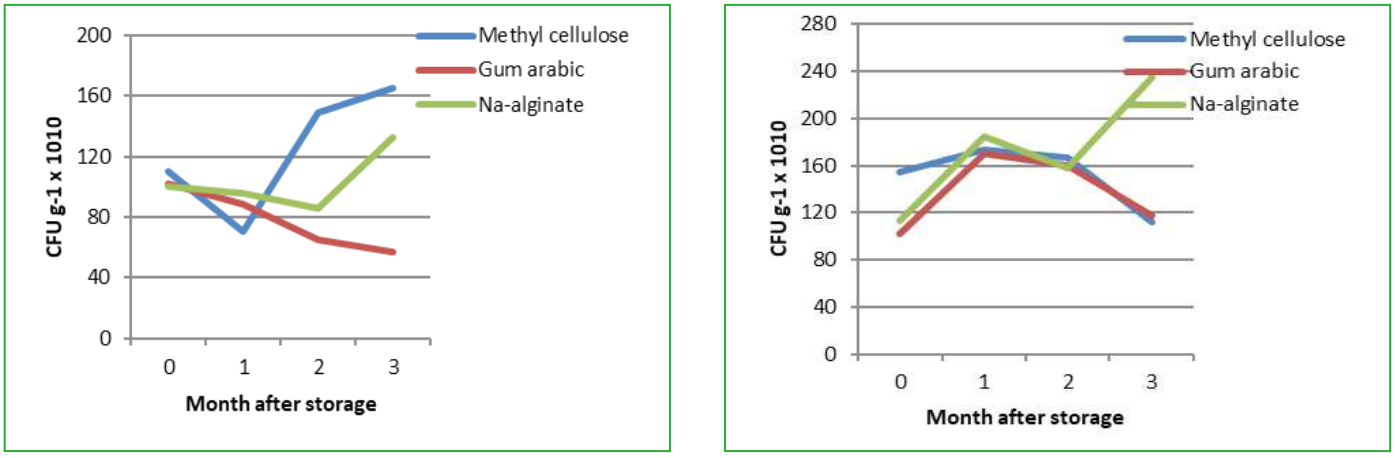


Fig. 1: Effect of mineral blending on the shelf life of fungi *Penicillium pinophilum* in (a) Protocol I and (b) Protocol II in the formulation at ambient room temperature

In the former case, higher amount of product was produced with higher viable fungal spore count. The data showed that storing bio-formulation mixed with mineral powder in darkness under ambient temperature condition maintained higher viable spores count than in the presence of light.

Further, the effect of different additives on the shelf life of fungal spores in the bio-mineral fertilizer was studied. Two processes were followed, viz. protocol-I, wherein fungal spores were suspended in different additive solution (1%) and sprayed on to the mineral mixture consisting of potassium feldspar and rock-phosphate in 2:1 ratio; protocol-II, wherein spores were inoculated with talc powder followed by mixing with mineral mixture fortified with different additives viz. methyl cellulose, gum Arabic and sodium alginate. Protocol-II was found to be superior than protocol-I as it led to higher production of bio-mineral fertilizer with higher viable spores count. Among the additives, sodium alginate maintained higher viable spore count during storage in darkness at ambient temperature.



(a) **(b)**

Fig. 2: Effect of additives on the shelf life of fungi *Penicillium pinophilum* in (a) Protocol I and (b) Protocol II in the formulation at ambient room temperature

4.1.2 Impact of Amino Acid Based Customized Micronutrient Formulations on nutritional Status, Fruit Yield and Quality of Pomegranate

Higher dose of amino acid-based micronutrient formulations did not make any clear-cut effect in our previous study. Realizing the smaller requirement of micronutrient by pomegranate tree, evaluation of amino acid-based micronutrient formulations was carried out at lower dose and in different combinations under field condition. The results of second season trial showed significant improvement in foliar micronutrient (except copper) status upon use of amino acid-based micronutrient formulations thrice in a crop season. The foliage of trees sprayed with Formulation- I followed by two sprays of Formulation-II at the rate of 2.5 ml/l recorded the highest concentration of Fe and Zn, while those with lower dose i.e. 1.0 ml/l recorded the highest concentration of Mn at flowering. Even those trees recorded significantly higher concentration of Fe, Mn, Zn and B than with EDTA chelated micronutrient formulation application @ 0.1%.

Foliar application of these formulations significantly increased total number of flowers, hermaphrodite flowers, fruit set and ultimately the fruit yield. The highest fruit yield was recorded with the foliar application of Formulation-I followed by Formulation-II @ 2.5 ml/l which was 64.72% and 28.58% higher over the control and EDTA chelated micronutrient formulation sprayed trees respectively. Further, there was 88.34 % increase in above 250 g sized fruits (exportable grade fruits) over the control tree.

Table 1: Effect of Amino Acid-based Micronutrient Formulations on Nutritional Status of Trees at Flowering

Treatment	Micronutrient Concentration in Leaves (mg kg^{-1})				
	Fe	Mn	Zn	Cu	B
T1: Control	167.95^{e}	58.07^{cd}	16.87^{e}	172.45^{b}	17.54^{e}
T2: EDTA chelated micronutrient formulation @ 0.1% (3 sprays)	153.27^{f}	55.67^{de}	27.40^{bc}	192.67^{a}	17.89^{e}
T3:Formulation I followed by 2 sprays of Formulation II @ 2.5 ml/l	241.60^{ab}	62.33b^{cd}	32.87^{a}	118.15^{f}	19.89^{cd}
T4:Formulation I followed by 2 sprays of Formulation II @ 1.0 ml/l	232.67^{b}	74.73^{a}	31.13^{ab}	162.63^{c}	21.77^{b}
T5:Formulation I followed by 2 sprays of Formulation III @ 2.5 ml/l	215.60^{c}	67.20^{ab}	31.47^{ab}	158.55^{cd}	18.73^{de}
T6:Formulation I followed by 2 sprays of Formulation III @ 1.0 ml/l	249.27^{a}	54.67^{de}	22.67^{d}	155.63^{d}	21.37^{bc}
T7:Formulation I followed by Formulation II and III@ 2.5 ml/l	146.53^{f}	49.40^{e}	24.13^{cd}	170.60^{b}	17.41^{e}
T8:Formulation I followed by Formulation II and III@ 2.5 ml/l	18.00^{d}	64.47^{bc}	23.60^{cd}	136.50^{e}	28.22^{a}
LSD $\alpha_{0.05}$	13.71	8.41	4.16	5.28	1.70

Table 2: Effect of amino acid-based micronutrient formulations on flowering and fruit yield

Treatment	No. of total flowers	No. of herma-phrodite flowers	No. of fruit set	Fruit yield (kg/ tree)	Per cent fruits ≥ 250 g	Per cent fruits ≤ 250 g
T1: Control	322^{f}	127^{d}	60^{c}	9.75^{f}	22.64^{f}	77.36^{a}
T2: EDTA chelated micronutrient formulation @ 0.1% (3 sprays)	375^{c}	131^{d}	65^{bc}	12.49^{d}	32.03^{cd}	67.97^{cd}
T3: Formulation I followed by 2 sprays of Formulation II @ 2.5 ml/l	523^{a}	193^{a}	79^{a}	16.06^{a}	42.64^{a}	57.36^{f}
T4: Formulation I followed by 2 sprays of Formulation II @ 1.0 ml/l	358^{d}	157^{b}	80^{a}	14.38^{b}	33.06^{c}	66.94^{d}
T5: Formulation I followed by 2 sprays of Formulation III @ 2.5 ml/l	278^{g}	126^{d}	65^{bc}	14.04^{bc}	38.27^{b}	61.73^{e}
T6: Formulation I followed by 2 sprays of Formulation III @ 1.0 ml/l	403^{b}	147^{bc}	70^{b}	12.92^{cd}	28.83^{de}	71.17^{bc}
T7: Formulation I followed by Formulation II and III@ 2.5 ml/l	337^{e}	145^{c}	65^{bc}	10.91^{ef}	25.88^{ef}	74.12^{ab}
T8: Formulation I followed by Formulation II and III@ 2.5 ml/l	405^{b}	154^{bc}	64^{c}	11.88^{de}	27.34^{e}	72.66^{b}
LSD $\alpha_{0.05}$	14.08	10.43	5.71	1.22	4.10	3.70

T1: Control

T3: Formulation I followed by 2 sprays of Formulation II @ 2.5 ml/l

T2: EDTA chelated micronutrient formulation @ 0.1% (3 sprays)

Fig. 3: Effect of amino acid-based micronutrient formulations on bearing of pomegranate fruit on trees

These amino acid-based micronutrient formulations significantly improved average fruit weight, aril and juice per cent in fruit and TSS. Fruits also recorded significantly higher concentration of phenol and anthocyanin. However, the juice acidity got decreased.

Fruits produced with amino acid-based micronutrient formulations @ 2.5 ml/l had significantly higher concentration of Fe, Zn and B, while lower dose i.e. 1.0 ml/l of same formulations improved Cu concentration in fruit in addition. These formulations also improved macronutrients viz., N, P & K & Secondary elements particularly Ca and Mg in fruits. Apart from this, foliar application of these formulations significantly increased micronutrient particularly Fe, Zn, Cu and B concentration in the edible part of the fruits i.e. arils. Besides, they also increased macronutrient & secondary nutrient (P, K, Ca, Mg, S) content in the edible part of the fruit.

Table 3: Effect of amino acid-based micronutrient formulations on fruit quality

Treatment	Avg. fruit weight (g)	Aril per cent in fruit	Acidity (%)	Phenol (mg GAE/100 ml)	Anthocyanin (mg l^{-1})
T1: Control	166.94^{f}	51.80^{d}	0.35^{ab}	147.57^{de}	21.61^{bcd}
T2: EDTA chelated micronutrient formulation @ 0.1% (3 sprays)	195.07^{c}	52.75^{cd}	0.35^{ab}	149.37^{cde}	23.78^{ab}
T3:Formulation I followed by 2 sprays of Formulation II @ 2.5 ml/l	207.14^{b}	57.84^{b}	0.28^{c}	155.43b^{cd}	24.50^{a}
T4:Formulation I followed by 2 sprays of Formulation II @ 1.0 ml/l	182.10^{de}	56.00^{bc}	0.31^{bc}	163.77^{a}	23.18^{abc}
T5:Formulation I followed by 2 sprays of Formulation III @ 2.5 ml/l	230.72^{a}	64.80^{a}	0.36^{a}	163.47^{ab}	21.17^{cd}
T6:Formulation I followed by 2 sprays of Formulation III @ 1.0 ml/l	196.25^{c}	52.42^{cd}	0.35^{ab}	156.40^{abc}	24.86^{a}
T7:Formulation I followed by Formulation II and III@ 2.5 ml/l	174.73^{ef}	55.96^{bcd}	0.31^{bc}	152.77^{cde}	19.55^{d}
T8:Formulation I followed by Formulation II and III@ 2.5 ml/l	189.13^{cd}	54.86^{bcd}	0.32^{abc}	146.10^{e}	24.69^{a}
LSD $\alpha_{0.05}$	8.17	4.17	0.04	8.04	2.56

Table 4: Effect of amino acid-based micronutrient formulations on macronutrient content in edible part of fruits

Treatment	Macronutrient Content in Arils (mg/100 arils)					
	N	P	K	Ca	Mg	S
T1: Control	73.16^{b}	23.53^{bc}	77.20^{c}	17.85^{d}	6.43^{e}	9.49^{bc}
T2: EDTA chelated micronutrient formulation @ 0.1% (3 sprays)	77.35^{a}	21.04^{d}	85.42^{bc}	19.28^{cd}	6.31^{e}	10.42^{bc}
T3:Formulation I followed by 2 sprays of Formulation II @ 2.5 ml/l	59.26^{c}	26.17^{a}	89.85^{ab}	29.42^{a}	7.45^{c}	12.79^{a}
T4:Formulation I followed by 2 sprays of Formulation II @ 1.0 ml/l	58.35^{cd}	26.26^{a}	98.12^{a}	25.21^{ab}	7.29^{d}	10.97^{ab}
T5:Formulation I followed by 2 sprays of Formulation III @ 2.5 ml/l	51.91^{e}	21.86^{cd}	83.70^{bc}	22.43^{bcd}	5.77^{f}	9.99^{bc}
T6:Formulation I followed by 2 sprays of Formulation III @ 1.0 ml/l	55.19^{cde}	24.69^{ab}	90.44^{ab}	26.73^{ab}	7.73^{b}	12.62^{a}
T7:Formulation I followed by Formulation II and III@ 2.5 ml/l	54.81^{de}	24.52^{ab}	86.78^{bc}	25.92^{ab}	5.55^{g}	8.95^{c}
T8:Formulation I followed by Formulation II and III@ 2.5 ml/l	53.85^{e}	25.14^{ab}	83.00^{bc}	24.59^{abc}	7.90^{a}	10.33^{bc}
LSD $\alpha_{0.05}$	4.19	2.44	9.86	5.76	0.14	1.99

Table 5: Effect of amino acid-based micronutrient formulations on micronutrient content in edible part of fruit

Treatment	Micronutrient content in arils (mg/1000 arils)				
	Fe	Mn	Zn	Cu	B
T1: Control	7.51^{c}	0.44^{abc}	1.41^{d}	1.18^{de}	6.25^{b}
T2: EDTA chelated micronutrient formulation @ 0.1% (3 sprays)	7.32^{d}	0.54^{a}	1.57^{bc}	1.23^{cd}	4.05^{d}
T3: Formulation I followed by 2 sprays of Formulation II @ 2.5 ml/l	7.97^{a}	0.49^{ab}	1.63^{b}	1.36^{b}	7.26^{a}
T4: Formulation I followed by 2 sprays of Formulation II @ 1.0 ml/l	7.91^{ab}	0.50^{ab}	1.58^{bc}	1.45^{a}	5.04^{c}
T5: Formulation I followed by 2 sprays of Formulation III @ 2.5 ml/l	6.84^{e}	0.37^{c}	1.44^{d}	1.06^{f}	5.46^{c}
T6: Formulation I followed by 2 sprays of Formulation III @ 1.0 ml/l	8.06^{a}	0.43^{bc}	1.87^{a}	1.26^{c}	6.49^{b}
T7: Formulation I followed by Formulation II and III@ 2.5 ml/l	7.96^{a}	0.34^{c}	1.81^{a}	1.12^{ef}	5.34^{c}
T8: Formulation I followed by Formulation II and III@ 2.5 ml/l	7.79^{b}	0.34^{c}	1.49^{cd}	1.11^{ef}	5.04^{c}
LSD $\alpha_{0.05}$	0.16	0.10	0.11	0.08	0.54

4.1.3 Evaluation of Micoorganisms for Bacterial Blight Management

4.1.3.1 *In vitro* Screening of Endophytes against Bacterial Blight

In order to develop ecofrienly management of bacterial blight of pomegranate, promising endophytes were isolated and evaluated *in vitro* and *in planta at* ICAR-NRC on pomegranate, Solapur. Total 17 bacterial endophytic isolates were tested; 13(TC series) from nodal segent used for developing tissue culture plants, 1 (BE 10) from stem *Ocimum tenuiflorum* (holy basil), and 3(BE-2, BE-4, BE-5) from leaves and stems of *Ocimum basilicum* (sweet basil). *In vitro* screening of endophytes was done using dual culture technique on nutrient glucose agar (NGA), endophytes were inoculated 8 days prior to inoculation of *Xap culture.* Data was recorded 8 days after Xap inoculation.

All the bacterial endophytes were significantly effective against *Xap* with respect to control. Endophyte BE-10, isolated from holy basil registered significantly highest *Xap* inhibition (90.00 %) *in vitro* followed by endophytes from established *in vitro* cultures of pomegranate namely, TC-A2(B), TC-4, TC-310, TC-B and from sweet basil BE-4 and BE-5 which significantly reduced in *vitro Xap* growth (72.3 to 76.6%) when compared to control where no endophyte was co-inoculated (Fig. 4). The inhibitory effect of endophytes on *in vitro* growth of *Xap* might be due to secretion of certain compounds and secondary metabolites that are inhibitory to the pathogen.

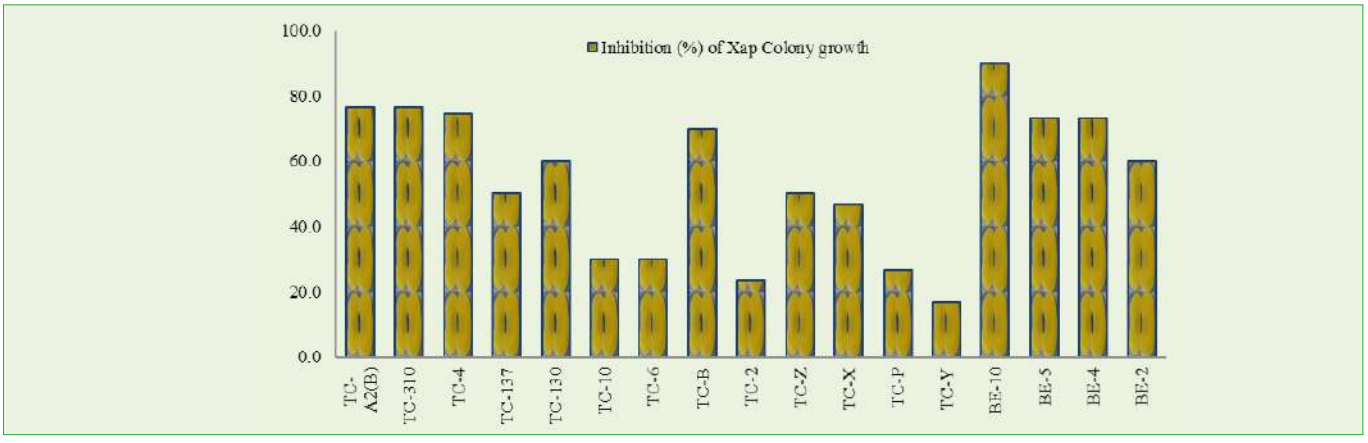


Fig. 4: Percent inhibition of *Xap* growth with promising endophytes from pomegranate and basil

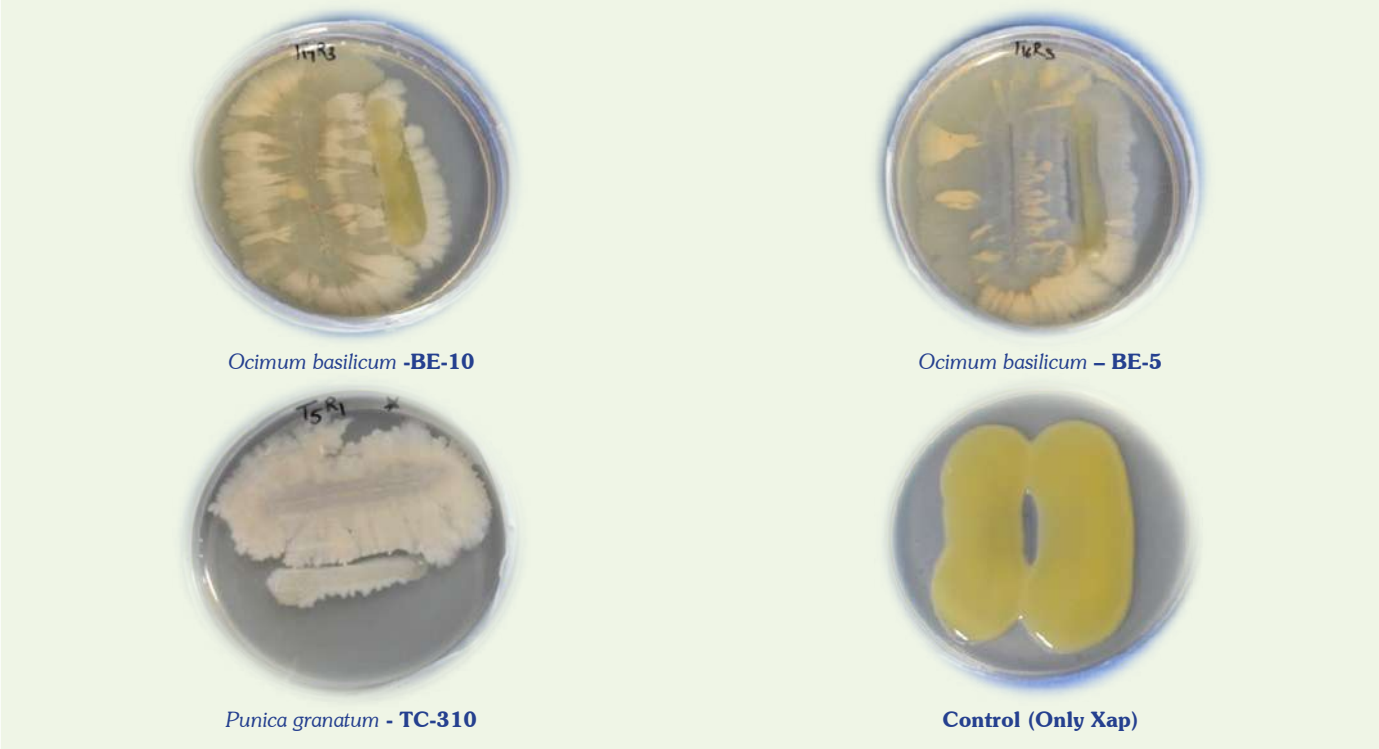


Fig. 5: Inhibition of *Xap* growth with promising endophytes from different hosts in dual culture

4.1.3.2 *In Planta* Evaluation of Endophytes for Managing Bacterial Blight

To evaluate the performance of endophytes against *Xap* in pot culture experiments, two prophylactic sprays of endophytes were given, followed by pathogen-Xap spray 1 week after second spray of endophyte. Xap was sprayed repeatedly 4 times (total) at 7 days interval. This strategy with prophylactic use of endophytes was found to be the highly effective in reducing blight incidence and severity. All endophytes tested (except TC-2) recorded bacterial blight incidence (0-38%) significantly lower than control (64.33%) with no endophyte sprayed. Third and 4th spray of endophytes TC-4, TC-310 completely checked blight (I=0.00%) which initially was having 13.7% and 21.0% blight incidence respectively. Endophytes TC-A2(B), TC-130, TC-137 and TC-X recorded blight incidence below 10.0 %. In all 4 endophytes from basil plant bacterial blight incidence remained below 20%. The study indicated prophylactic sprays of endophytes can be highly effective in managing bacterial blight disease in pomegranate as compared to curative sprays. The plants treated with endophytes also recorded good foliar growth in comparison to control with only Xap treatment. Further, nine endophytes (TC-A2(B), TC-130, TC-137, TC-6, TC-X, TC-Y,TC-Z, BE-4, BE-5) were found promising potash and phosphate solubilizer with 19-23 mm zone of solubilization on selective media.

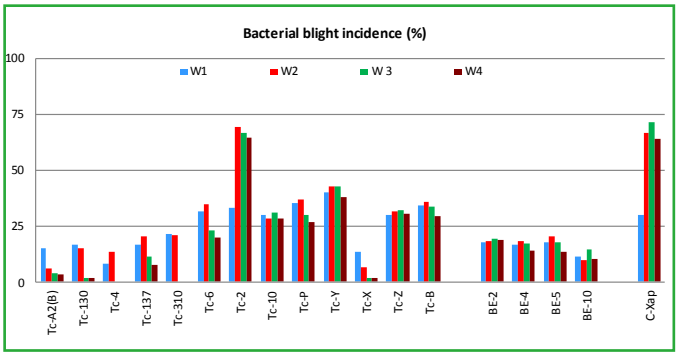


Fig. 6: Percent incidence of bacterial blight on pomegranate with weekly (W1 to W4) sprays of endophytes from *Punica granatum* (TC series) and *Ocimum spp* (BE series) in comparison to control (C-xap).

4.1.3.3 Phenotypic Characterization of Antagonistic Strain, *Brevundimonas*

Phenotypic fingerprinting of one of the phyllosphere associated bacterial isolate *Brevundimonas* tested

antibacterial against *X. axonopodis* pv. *punicae* and other plant pathogens, was performed at IARI, New Delhi. The strain suppressed bacterial blight incidence in orchard upon foliar spray application. The leaf associated bacterial isolate, *Brevundimonas* utilized or displayed growth in 15 different nutrient sources and was able to tolerate several spray chemicals in the field is suggestive of its ecological adaptation.

The leaf associated bacterial isolate, *Brevundimonas* utilized sources like Dextrin, Maltose, N-Acetyl-D-Galactosamine, α-D-Glucose, L-Rhamnose, L-Malic acid, Glucuronamide as growth factor, and showed tolerance to Lincomycin, Glucuronamide, Tetrazolium violet, and Tetrazolium blue. The isolate could not show any growth at 1% NaCl, 4% NaCl, or 8% NaCl indicating its sensitivity to sodium chloride. However, the bacterium was unable to grow in the presence of Stachyose, N-Acetyl Neuramic acid, Fusidic acid, D-Aspartic acid, 4-Hydroxyphenyl Acetic acid, D-Lactic-Acid Methyl Ester, α-Hydroxybutyric acid, Sodium Butyrate. *Brevundimonas* displayed growth in 15 different nutrient sources and was able to tolerate several spray chemicals in the field is suggestive of its ecological adaptation. The microbial phenomics data would assist in understanding their ecological fitness as well to exploit them as a biological control agent for bacterial blight.

4.1.4 Invitro Bioefficacy Evaluation of Brown Mustard Powder alone and in Combination with Neem and Pongamia Oil

The brown and yellow mustard seeds were procured from the market and ground to a fine powder. The powder is mixed with water @ 5, 10 and 15 g/litre of water + 0.25 ml of spreader sticker alone and in combination with the Neem and Pongamia oil @ 3ml/l water with 0.25ml of spreader sticker. The treatment T8 recorded the highest percentage of dead thrips (77.44 and 79.56 %) followed by treatment T6 (76.87 and 78.36%) and least was recorded in T1 (54.28 and 56.91) and control T10 (16.67 and 19.05) after 24 and 48 hours respectively. Further, it needs to be evaluated in the field for confirmatory results.

Table 6: Details of the bio-pesticides used for bio-efficacy evaluation

Treatment details		Dosage (ml or g/l water)	24 HAS	48 HAS
T1	MP	5	54.28	56.91
T2	MP	10	59.24	60.24
T3	MP	15	64.71	66.47
T4	MP+ NO	5+3	67.92	69.38
T5	MP+ NO	10+3	74.24	77.46
T6	MP+ NO	15+3	76.87	78.36
T7	MP+ PO	5+3	66.57	68.90
T8	MP+ PO	10+3	77.44	79.45
T9	MP+ PO	15+3	73.44	76.56
T10	Control		16.67	19.05

MP= Mustard powder, NO= Neem oil, PO=Pongamia oil, HAS: Hours after spray

4.2. Project: Development and Refinement of Integrated Production Technologies for Improved Productivity in Pomegranate (*Punica granatum* L.) Intercropping

The field experiment was initiated on comparative performance evaluation of various crops namely, Marigold (Pusa Narangi Genda); Summer Mung (Western Proto); Sunflower (VSH-405) and Drumstick (PKM-1) to find out the effect of intercrops on the performance of pomegranate cv. 'Super Bhagawa'.

(a) (b) (c)

Fig. 7: Plots showing intercropping of pomegranate with (a) summer mung (b) marigold (c) sunflower

4.2.1 Estimation of Pomegranate and Intercrops Evapotranspiration (ETp, Litres/ Week/ Tree)

The alternate day irrigation water was applied through drip irrigation system at 90 % efficiency from Nov to Dec, 2019 and it ranged from 26.0 to 32.0 liters/week/ tree for two months old pomegranate trees at 100 % *ETc and at 15 days interval water delivered through flood irrigation to intercrops and its evapotranspiration ranged from 270 to 540 m3.

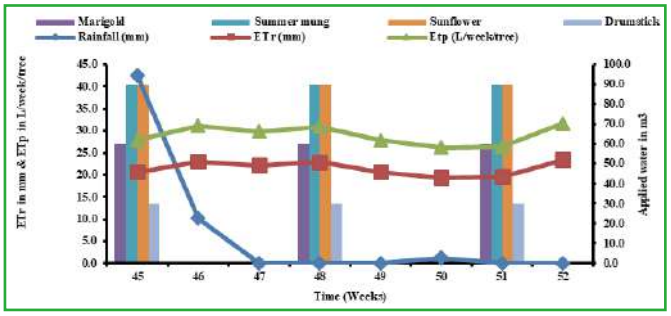


Fig. 8: Water applied in intercrops (m^3) and Pomegranate evapotranspiration (Liters/week/tree)

4.2.2 Growth Parameters

Pomegranate cv. Super Bhagava was evaluated for their growth parameters in intercropping. Plant height, plant spread (EW & NS), stem diameter, stem girth and thorn length ranged from 73.8 to 89.5 cm, 55.8 to 82.3 cm, 63.4 to 85.6 cm, 1.1 to 2.2 cm, 1.1 to 1.5 cm and 0.5 to 0.8 cm.

Table 7: Cumulative growth performance and irrigation water used in intercropping

Treatments	Water use (Litrs/m^3)	Plant Height (cm)	Plant Spread (cm)		Stem dia. (cm)	Stem Girth (cm)
			EW	SE		
T_1	1856 .00	89.5	82.3	85.6	2.2	1.5
T_2	0540.00	73.8	55.8	63.4	1.1	1.2
T_3	0810 .00	74.0	74.4	74.6	1.6	1.1
T_4	0810 .00	75.0	68.0	76.0	1.9	1.3
T_5	0270.00	85.0	79.0	80.6	2.1	1.4

Note: T_1-Pomegranate with no intercrop; T_2-Marigold as intercrop; T_3–Summer Mung as intercrop; T_4-Sunflower

4.3 Project: Sensor based Irrigation Scheduling for Water Productivity of Pomegranate (*Punica granatum* L.)

An experiment was planned and initiated in pomegranate orchard planted on light textured soil at a planting density of 4.5 x 3 m at ICAR-NRCP, Solapur (latitude 17° 10', longitude 74°42' and 483.5 m above msl) to assess the impact of sensor based irrigation system in pomegranate cv. Bhagawa.

4.3.1 Estimation of Reference Crop Evapotranspiration (ET_r, mm)

Reference crop evapotranspiration (ET_r, mm) is the major component of pomegranate irrigation

water requirement. It is used to describe the atmospheric "demand" for water. Reference crop evapotranspiration expresses the evaporative power of the atmosphere at a specific location and time of the year and does not consider the crop characteristics and soil factors. Hence, the daily climatic data for the period of Jan, 2019 to Dec, 2019 were used to determine daily, weekly and monthly reference crop evapotranspiration (ET_r) by using Penman-Monteith Method. The monthly ET_r values are presented in below mentioned figure Figure shows that the trend of variation of average ET_r values over the year. The yearly reference crop evapotranspiration (ET_r) obtained was 1720.36 mm. The ET_r was maximum in May (19-21 SMW) and minimum in Nov-Dec (45-52 SMW). The monthly minimum and maximum ET_r ranged from 83.16 to 230.03 mm.

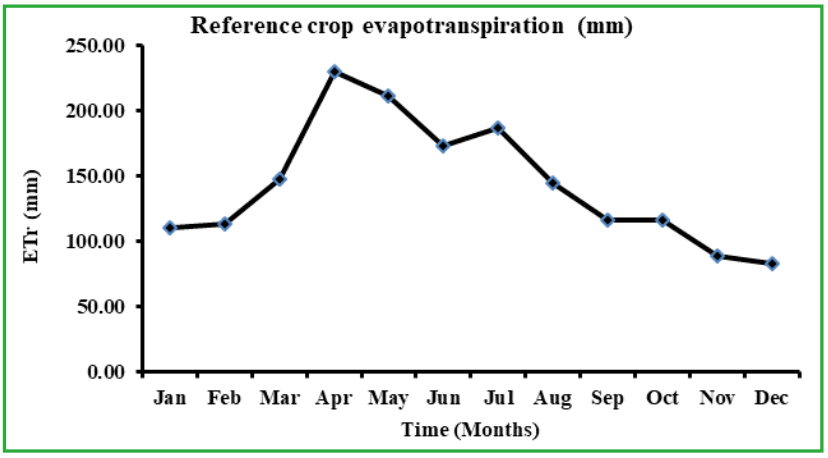


Fig. 9: Monthly ET_r (mm) values from Jan, to Dec, 2019 at experimental site

4.3.2 Estimation of Pomegranate Evapotranspiration (ET_p, Litres/ Day/ Tree)

The alternate day water to be applied through drip irrigation system at 90 % efficiency from Nov to Dec, 2019 ranged from 4-10 liters/day/tree for pomegranate tree in first year of growth at 100 % *ET_c, growers practice, tensiometer and solenoid valve. It gradually increases or decreases during development of pomegranate tree due to the variation of reference crop evapotranspiration, pan coefficient, wetted area and crop coefficient values. Lower K_c values represent slower plant growth and lower plant canopy cover, indicating lower ET_p. The two months average pomegranate evapotranspiration was 3118 Litres/tree and water to be applied to pomegranate trees under various treatments ranged from 1856.00 to 4356.00 Liters/tree.

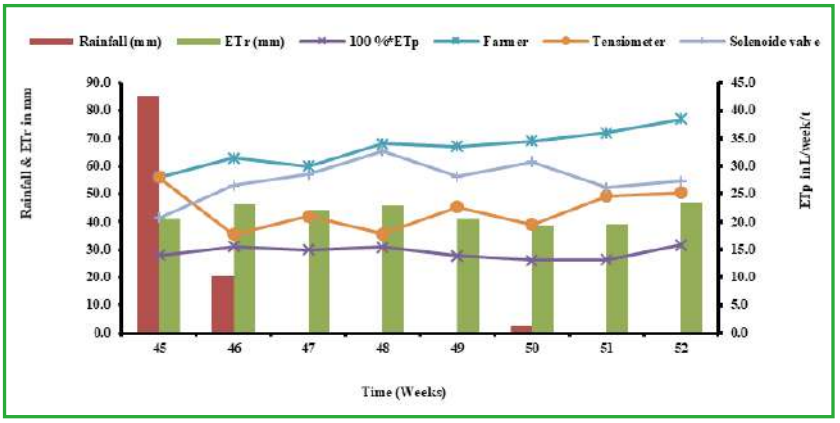


Fig. 10: Weekly pomegranate evapotranspiration (Liters/week/tree) of 1st year orchard

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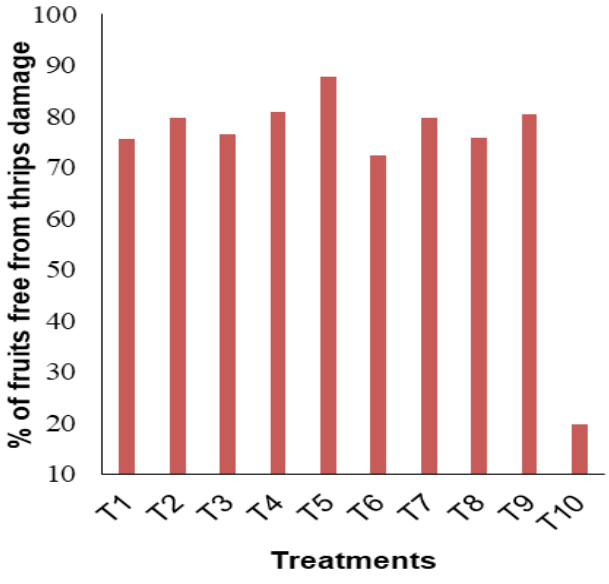
Crop Protection

5.1 Project: Development and Refinement of Integrated Crop Protection Technologies for Improved Productivity of Pomegranate

5.1.1 Bio-efficacy Evaluation of Newer Insecticides and Combi Formulations Against Thrips and Fruit Borer Pests of Pomegranate

An experiment was conducted to evaluate the bio-efficacy of the six newer insecticides and three combi insecticide formulations at different doses with 0.25ml spreader sticker per litre of water for the first seasons against the borer and sucking pests of pomegranate. The treatment T5 (Afidopyrofen 50G/L DC) recorded the highest percentage (87.72%) of fruits free from thrips damage followed T4 (80.95%) and T9 (80.51%) and least was observed in T8 (75.78%) wherein control it was 19.78%. The incidence of the fruit borer was very low during the experimental period in both control and treatments.



Treat.	Name of the insecticide	Dose (ml or g /l water)
T1	Thiamethoxam 12.6 % +Lambda cyhalothrin 9.5% ZC	0.75
T2	Cyantraniliprole 10.26 % OD	0.3
T3	Spinosad 45 % SC	0.5
T4	Tolfenpyrad 15 % EC	0.75
T5	Afidopyrofen 50G/L DC	0.75
T6	Flonicamid 50% W/W	0.75
T7	Emamectin benzoate 3%+ Thiamethoxam 12% WG	0.75
T8	Difenthiuron 40.1% + Acetamiprid 3.9% WP	0.75
T9	Spinetoram 11.7% SC	0.75
T10	Control	Water

Fig. 1: Effect of newer insecticides formulations on the incidence of thrips (*S. dorsalis*)

5.1.2 Report of *Brachymeria sp.* as Pomegranate Fruit Borer Larval-Pupal Parasitoid

The pomegranate fruit borer (*Deudorix isocrates*) pupae infested by parasitoids was observed in the field. The infested pupae were collected from the field to acquire the adults. After collection, isolated the pupae were kept individually in polystyrene, Petri dishes (100mm × 20mm) and tops were covered with lids and they were incubated at the temperature of 28 ± 1°C, relative humidity (RH) of 70 ± 5% and a photoperiod of 12 L:12 D and observed the eclosion. The freshly emerged adult females parasitoids were subjected for the reinfestation/ parasitization on fresh uninfected laboratory-reared larvae and pupae. The adults parasitised both on larvae and pupae (Fig. 2 B&C) but a higher preference for the pupae was observed. The 3-4% pupal parasitization was recorded under field condition and no infested larvae were observed. The parasitoids have been identified as *Brachymeria sp*. This may serve as a good bio-control agent for the management of pomegranate fruit borer. Hence further studies need to be conducted for further detailed.

Fig. 2: A. Healthy Pupae B. Parasitization on Pupae C. Parasitization on larva D. Pupae with parasitoid emergence hole

5.1.3 First Record of Invasive Mealybug *Nipaecoccus viridis* (Newstead) on Pomegranate

After noticing heavy infestation of white wax on branches and pomegranate fruits (Fig. 3) in net house and field. Samples were sent for species-level identification to NBAIR Bengaluru. The Mealybugs has been identified as *N. viridis* (Newstead) (Coccoidea: Pseudococcidae) through slide mounting techniques (Fig. 5). This mealybug measures approximately 4 mm long by 3 mm wide with body-colour black, purple to blue-green with thick white or pale-yellow wax. Females produce an ovisac (Fig. 3B) with sticky wax. In high densities (Fig. 3-B), waxy secretions may appear as a continuous layer of wax which will obscure individual mealybugs. Wax may turn yellow in older infestations. Specimens do turn black in 70% alcohol. This mealybug infests on different parts of the plant *viz*., shoots, flower bud, flower and all stages of the fruits. The per cent infestation varies from 30-50% if timely proper management practices were not taken. The plants infested by mealybugs exhibit the stunted growth, yellowing of leaves with no or poor flower induction and dropping of flower and young fruits. Symptoms recorded on the maturing, developing and ripening fruits indicates the eruptions, reddening of the rind deformation in shape and browning of arils (Fig. 4B).

Fig. 3: A. Infestation of *N. viridis* on shoots B. Infestation on developing fruits

Fig. 4: A. Infestation on ripening fruits B. Symptoms of water washed fruits

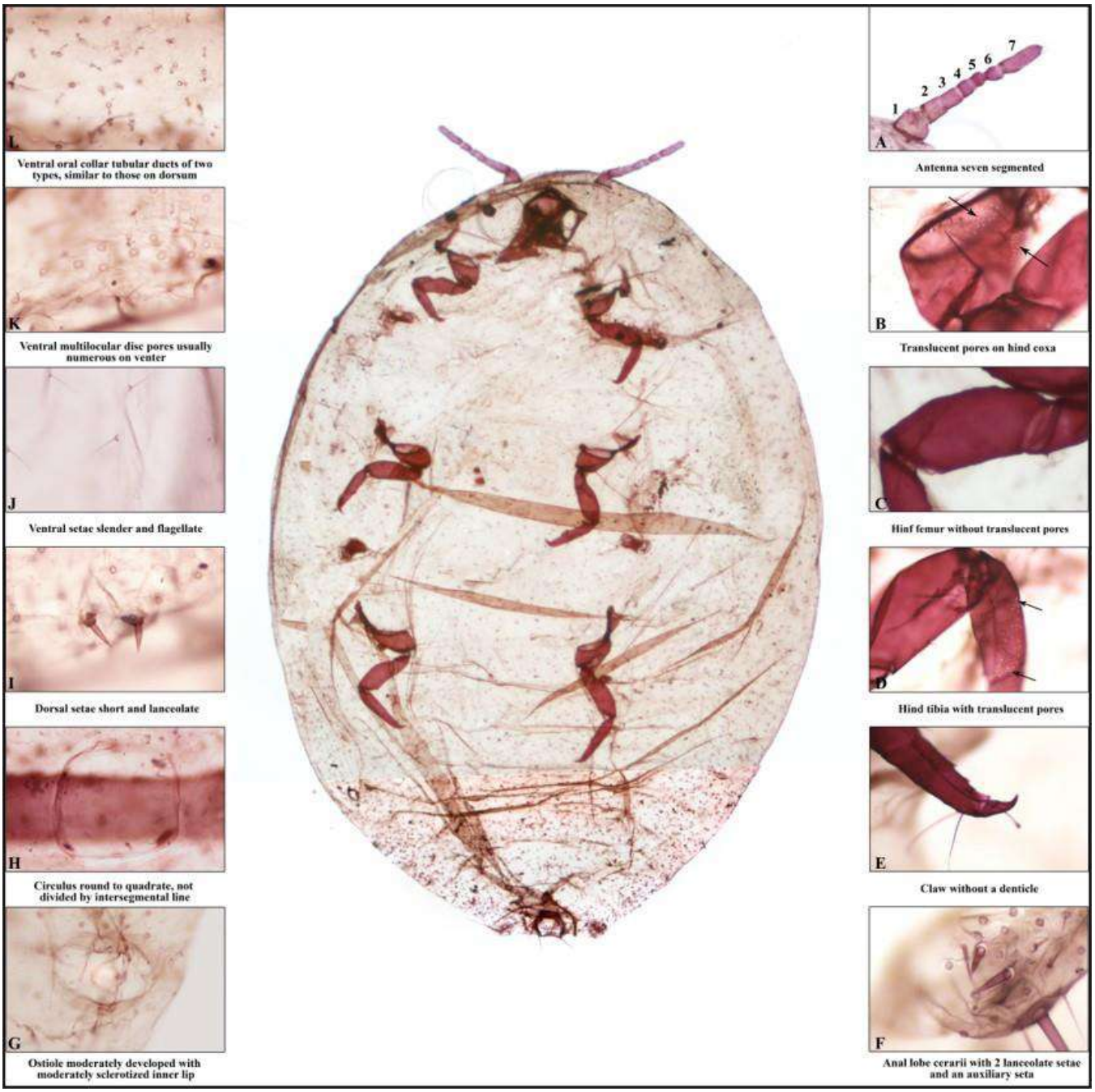


Fig. 5: Mounted female characters of *N. viridis*

5.1.4 Bio-efficacy Evaluation of Newer Insecticides and Combi Formulations Against Mealybugs

The bio-efficacy of six newer insecticides and three combi insecticide formulations at a different dose with 0.25ml of spreader sticker per litre of water was evaluated against pomegranate mealybugs for the Season-I. The highest per cent reduction of mealybugs over the control was recorded in treatment T1 (68.37%) followed by T7 (66.26), T8 (64.32) and least reduction was observed in T5 (34.25%). Further studies need to be conducted for conclusive results.

Table 1: Details of the insecticides used for bio-efficacy evaluation against mealybugs

Trt.	Insecticides	Dose (ml or g/l water)	% Reduction over control
T1	Thiamethoxam 12.6 % +Lambda cyhalothrin 9.5% ZC	0.75	68.37
T2	Cyantraniliprole 10.26 % OD	0.3	53.71
T3	Spinosad 45 % SC	0.5	44.21
T4	Tolfenpyrad 15 % EC	0.75	56.25
T5	Afidopyrofen 50G/L DC	0.75	34.25
T6	Flonicamid 50% W/W	0.75	57.12
T7	Emamectin benzoate 3%+ Thiamethoxam 12% WG	0.75	66.26
T8	Difenthiuron 40.1% + Acetamiprid 3.9% WP	0.75	64.32
T9	Spinetoram 11.7% SC	0.75	59.89
T10	Control	Water + Sticker	

5.1.5 First Report of Fruit Fly *Bactrocera dorsalis* Infestation on Pomegranate

The infested pomegranate fruits collected from the field and received from the farmers were diagnosed with the presence of the maggots and pupae inside (Fig. 6B). The infested fruits were kept on fine sand in plastic bucket lid in wooden case (60 × 45 cm) at room temperature for pupation. The pupae from infested fruits and fine sand were collected and kept individually in polystyrene, Petri dishes (100 mm× 20 mm) and tops were covered with lids and they were incubated at the temperature of 28 ± 1°C, relative humidity (RH) of 70 ± 5% and a photoperiod of 12L:12D and observed the eclosion. The emerged adults after 7-8 days after incubation were taxonomically get identified as *B. dorsalis* from NBAIR, Bengaluru and this confirms fruit fly damage on pomegranate fruits. The infestation varies from 3-5% under field condition. Further Choice (with Banana) and non-choice tests with a different stage of pomegranate were conducted for ovipositional preference under in-vitro condition. The observation indicates that in choice test banana is preferred over pomegranate and in non-choice test preference was a low on a different ripening stage of pomegranate fruits. Damage symptoms on ripening fruits were oviposition puncture, breakdown of tissues and internal rotting associated with maggot and water-soaked appearance. The regular monitoring and survey were also conducted for further details.

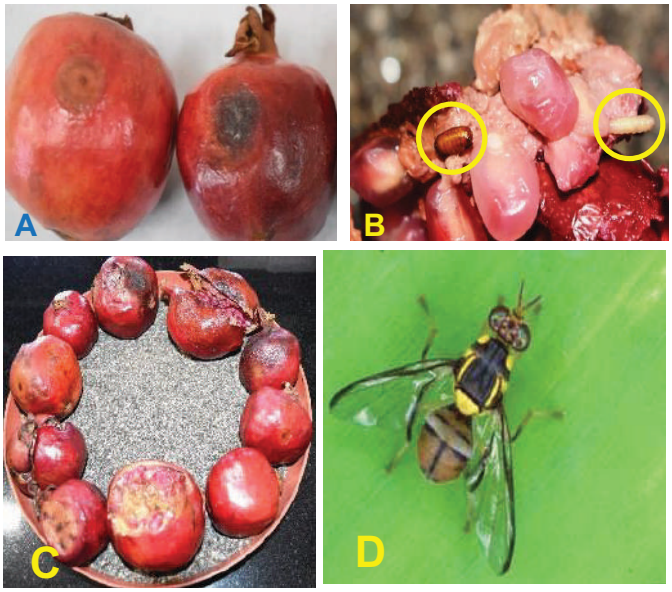


Fig. 6 A. The oviposition punctures on fruits B. Pupa and Maggot C. fruits kept for Pupation D. Emerged adult

5.1.6 Monitoring and Mass Trapping of Fruit Flies in Pomegranate

Four trapping systems were tested: One food attractant (Torula yeast) and three sex attractants (Methyl Eugenol, Trimedlure and Cue-lure) in McPhail trap and Bucket trap. Five traps per treatment with three replications per site were set up. Three species of flies have been identified: *Bactrocera dorsalis,* Gastrozonini, *B. cucurbitae*. The incidence of *Ceratitis capitata* was not found. Among these species, *B. dorsalis* was dominant. The average number of individuals

Table 2: Monitoring and mass trapping of fruit flies in pomegranate

Lure	McPhail Trap				Bucket Trap			
	B. cucurbitae	*B. dorsalis*	*C. capitata*	*Gastro-zonini*	*B. cucurbitae*	*B. dorsalis*	*C. capitata*	*Gastro-zonini*
Cuelure	300	20	0	0	331	12	0	0
Trimedlure	15	0	0	7	22	0	0	6
Methyl Eugenol	11	342	0	0	11	341	0	0
Torula yeast	31	0	0	0	21	0	0	0

captured varied from one species to another, depending on the attractants. The average number of fruit flies captured were, 300, 15,11 and 31 for *B. cucurbitae* and 20, 0, 342, and 0 for *B. dorsalis* respectively for attractants Cue-lure, Trimedlure, Methyl Eugenol and Torula yeast in McPhail trap. Similarly, the average number of fruit flies captured were 331, 22, 11 and 21 for *B. cucurbitae* and 12, 0, 341and 0 for *B. dorsalis* respectively for attractants Cuelure, Trimedlure, Methyl Eugenol and Torula yeast in Bucket trap. The highest average no. of *B. dorsalis* catch was observed in Methyl Eugenol and highest average no. of *B. cucurbitae* was in Cue-lure.

5.1.7 Report of *Helicoverpa armigera* Damage on Pomegranate

The infestation of the *H. armigera* was recorded for the first time on pomegranate during September-October

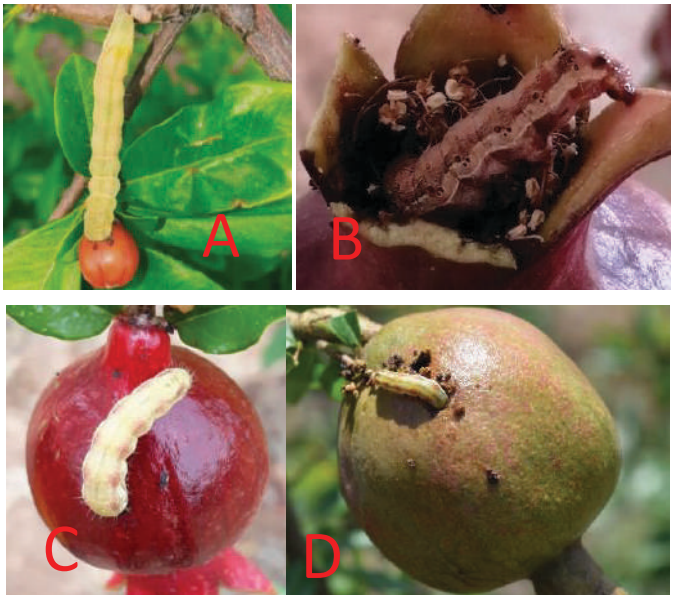


Fig. 7: *H. armigera* infesting on A. Flowerbud B. Fruit calyx, C. Young fruits D. Maturing Fruits

months. The larvae feed on different reproductive parts of the pomegranate *viz*., flower buds, flowers, young and maturing fruits. The infestation of 2-3 fruits on 6-8 plants was recorded. The *H. armigera* damage queries were also received from different pomegranate growing parts of India. Hence, this pest in future may become the major concern for pomegranate farming. The regular monitoring and survey will be conducted for further details.

5.1.8 Report *Nezara virdula* Damage on Pomegranate

The nymphs and adults of southern green stink bug, *Nezara viridula* (Linnaeus) sucks the sap from all plant

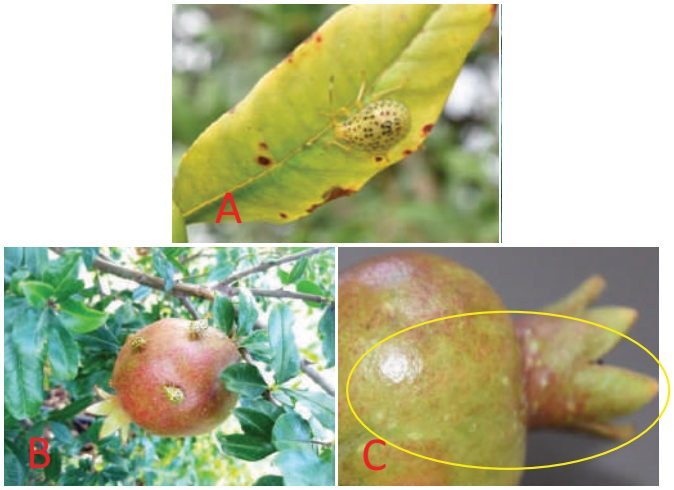


Fig. 8: A. Nymphs feeding on Leaf B. Maturing fruit C. Feeding punctures on the fruits

parts, but growing shoots and developing fruit are preferred. Attacked shoots usually wither, in extreme cases, may die. The damage on fruit from the punctures is hard and later turns to brownish or black spots. These punctures affect the fruit's edible qualities and

decidedly lower its market value. Young fruit growth is retarded and the fruit often withers and drops from the plant. The infestation of the fruits varied from 5-8%. The regular monitoring and survey will be conducted for further details.

5.1.9 Report of Wireworm Damage in Young Pomegranate Plants

The young pomegranate plants of 5-6 months old grown under protected cultivation were showing wilting symptoms. The root zone of the affected plants was got examined and it was found with the beetle larvae with fibrous and taproots system of the affected plant get damaged. The grubs reared for adult emergence and it has been identified as Wireworm. Wireworms are the larval stage of click beetles (Coleoptera: Elateridae). Wireworm larvae are slender, yellowish to brown-orange (Fig. 9D) with short legs.

Fig. 9: A. Yellowing of leaves B. withered plant C. Damaged roots D. Grubs

The tip of the abdomen is flattened and has a pair of short hooks. Mature larvae range from 12 to 25 mm in length, depending on species. The larvae damage on fibrous and taproots system of the plants, as a result, the plants shows the symptoms of, yellowing, stunted growth and wilting of young plants with terminal leaves wilt first. This pest problem was is mainly due to the application of the un-decomposed/ partially decomposed sugarcane waste and constant availability of the moisture at the affected site. This is the first report of Wireworm (click beetle) grubs damage on pomegranate.

5.1.10 Population Dynamics of Fruit Sucking Moths of Pomegranate

The population of fruit sucking moth was monitored from August-October, 2019. Three different species of primary fruit piercing moths (*Eudocima sp.*) and two species of secondary piercers (*Ophusia tirhaca* and *Achaea janata)* were also recorded with the dominance of *E. materna.* The higher number of male moths was recorded in primary piercers. The peak activity of the moth was from 7.30 pm to till 11.30 pm and from the first week of August to September, though reduced activity was observed up to 2.00 am and until October.

Sex ratio: The sex ration of the field-collected population (Agust-October) was recorded in which males are dominant, with male to the female sex ratio of 1.69 from total moths of 492; males: 315 and female 177) and similar observations were also recorded from the laboratory-reared population from August-February) a total of 765 moths were recorded with sex ration of 1.78 (males=481; females=284) were recorded.

5.1.1.1 Field Trial for Lure Optimization for Fruit Piercing Moths

Three superior blends B, Q, and N were tested against fruit piercing moths of pomegranate in funnel trap. Five traps per treatment with three repetitions were set up. The incidence of fruit piercing moths was low compared to last season. The blend "B" tested at 20μl and 40 μl whereas the blends "Q" and "N"

were tested at 20μ. Among these three blends, B had the better catches at 20μl and 40μl compared to Q and N at 20μl. The average number of male moths trapped was 4.5 and 3.25 respectively for blend B at 20 and 40μl and 2.75 and 2.25 for the blends Q and N @ 20μl. The number of females caught was very low and varied from 1.5-1.0 moths/trap in all the blends and dosages. No catches were observed in control. The reasons for the low number of moth catches per trap may be attributed to prolonged and continuous rainfall during the experimental period and low/ reduced stability of the blends as they are not stable under field conditions due to absence of antioxidant. The occurrence of a low number of moths in traps was quite intriguing. However, further investigations are required for conclusive results.

Table 3: Monitoring and mass trapping of fruit piercing moths

Blend and dose	Avg. no. of male moths caught	Avg. no. of female moths caught
B-20μl	4.5	1.5
B-40 μl	3.25	1.25
Q-20 μl	2.75	1.25
N- 20μl	2.25	1.0
Control	0.0	0.0

5.1.1.2 Screening of Pomegranate Germplasms Against Borer and Sucking Pests

Total 51 different pomegranate germplasm has been screened against thrips and fruit borer and it was found that none of the germplasm found resistant or tolerant against thrips and fruit borer. Infestation varied between 13.25-75.5 % and 8.5-12.75% by thrips and fruit borer respectively.

5.1.1.3 Fungal Diseases and Disorders

5.1.1.3.1 Screening of Germplasm and Seedling Population for Wilt Resistance

Cuttings of exotic accessions (16 nos. in set-I and 33 nos. in set –II) from ICAR-NRCP farm, Hiraj block H1 and 14 nos. of IC-accessions and 4 varieties from ICAR-NRCP farm Kegaon block B6 & C1 were planted in wilt sick (*Ceratocystis fimbriata* and root knot nematode (RKN) *Meloidogyne incognita*) plot of ICAR-NRCP, Solapur on November 11, 2017 (Set-I) and second lot on August 17, 2018 (Set –II). Two plants of cv. Bhagawa were planted randomly in each accession row as control. All plants were healthy till Dec 11, 2018, therefore fresh *Ceratocystis fimbriata* (Cf) culture was added to the root zones on January 24, 2019 and observations recorded periodically till January 6, 2020. Wilted plants were observed for Cf and RKN infestation. Results of both EC (2 Sets) and IC accessions and varieties evaluated are given below.

(i) Screening of EC accessions

Set–I: Wilt initiated 70-301 days after fresh Cf inoculation in different accessions. In control wilt started 70 DAI and all 100 percent plants wilted in 303 days. All wilted plants were found infected with Cf and RKN. Among different EC accessions, the lowest wilt was recorded in accessions EC-676923 (20%) and EC-676922 (20%); while EC-676960 (37.5%) and EC-676930 (40%) recorded less than 50% wilt. Wilt initiation also got delayed (initiated 303 DAI) in EC-676960 with 25% partial wilt and 12.5% complete wilt in 330 days. All other accessions recorded 50% or higher wilt incidence with 5 accessions recording 100% wilt. The results are presented in table below.

Set–II: Wilt initiated 162-348 days after fresh Cf inoculation in different accessions. In control wilt started 208 DAI and only 56.52 percent plants wilted in 348 days. All wilted plants were found infected with Cf and RKN. EC-accessions at S. No. 1-17 showed less than 50% plants wilted whereas EC-accessions at S. No. 18-33 exhibited above 50-100% wilt. Among different EC accessions, the lowest (10%) wilt was recorded in EC-798767 and EC-798814 and the highest (100%) wilt in EC-676964 and EC-81839. The results are presented in table below.

(ii) Screening of IC accessions and Indian varieties

All the 14 nos. of IC accessions and 4 Indian varieties evaluated were found highly susceptible. Wilt initiated at 70-102 DAI. More than 50 to 100% wilt was recorded within 179-201 DAI. Results are shown below.

Table 4: Screening of EC Accessions from ICAR-NRCP farm, Hiraj block H1 (Planted on Nov. 30, 2017)

S. No	Exotic Collection Number	Number of plants	DAI Wilt initiated	Max Wilt (%) till date of observation Jan 6, 2020	DAI Max wilt observed	Major Organisms Associated
C	Bhagawa	32*	70	100	303	CF+RKN
1	EC-676923	11	102	20 (ALL PW)	330	CF+ RKN
2	EC-676922	13	70	20 (ALL PW)	201	CF+RKN
3	EC-676960	8	303	37.5 (25%PW+12.5%W)	330	CF+RKN
4	EC-676930	16	102	40 (30%PW+10%W0	330	CF+RKN
5	EC-676947	14	102	50	201	CF+RKN
6	EC-676958	20	146	60	330	CF+RKN
7	EC-676938	5	303	60 (ALL PW)	330	CF+RKN
11	EC-676927	10	201	80 (50%PW+ 30%W)	330	CF+RKN
12	EC-676961	22	146	100	201	CF+RKN
13	EC-676955	23	102	100	201	CF+RKN
14	EC-676959	26	102	100	146	CF+RKN
15	EC-676931	13	70	100	201	CF+RKN
16	EC-676954	8	102	100	201	CF+RKN

*2-3 plants of Bhagawa were planted randomly in each accession row as Control
Cf fresh Inoculum added on Jan 24, 2019
DAI=Days after Inoculation (24.01.2019) of fresh Cf in wilt sick plot; **PW:** Partial wilt; **W:** Complete wilt; **CF:** *Ceratocystis fimbriata*; **RKN:** Root Knot Nematode

Table 5: Screening of EC Accessions from ICAR-NRCP farm, Hiraj block H1 (Planted on Aug 17, 2018)

S. No.	Hybrid	No. of plants	DAI Wilt initiated	DAI Max wilt observed	Max Wilt (%)
C	Bhagawa	23*	208	348	56.52
1	EC-798767	10	348	348	10
2	EC-798814	10	307	348	10*
3	EC-798806	9	307	308	11.1
4	EC-798731	8	348	348	12.5*
5	EC-798749	10	307	348	20*
6	EC-798724	10	307	348	20
7	EC-798797	10	307	348	20
8	EC-798838	10	307	307	20
9	EC-798818	9	308	348	22.22*
10	EC-798847	11	307	348	27.27
11	EC-798768	10	162	307	30
12	EC-798729	10	307	348	30
13	IC-318735	14	307	348	37.5
14	IC-318712	18	307	348	38.9
15	EC-798751	5	162	348	40
16	EC-798807	7	307	348	42.9
17	EC-798780	9	162	348	44.4

S. No.	Hybrid	No. of plants	DAI Wilt initiated	DAI Max wilt observed	Max Wilt (%)
18	EC-798763	9	307	348	55.55
19	EC-798753	9	307	348	55.6
20	EC-676991	7	162	307	57.1
21	EC-676930	12	307	348	58.3
22	EC-798740	10	307	348	60
23	EC-676960	8	307	348	62.5
24	EC-676981	18	162	348	66.7
25	EC-676923	12	307	348	75
26	EC-676939	8	307	348	75
27	EC-676927	10	307	348	80
28	EC-676958	10	307	348	80
29	EC-676922	10	307	348	80
30	EC-798810	5	162	248	80
31	EC-676938	7	307	348	85.7
32	EC-676964	9	162	307	100
33	EC-81839	1	307	307	100

Cf fresh Inoculum added on Jan 24, 2019
DAI: Days after inoculation
* Partial wilt till last observation

Table 6: Screening of indigenous accessions and germplasm from ICAR-NRCP farm Kegaon Blocks B6 and C1

Screening of indigenous accessions and germplasm from NRCP farm Kegaon Blocks B6 and C1						
S. No	**Indigenous Collection Number**	**Number of cuttings**	**DAI Wilt initiated**	**Max Wilt (%)**	**DAI Max wilt observed**	**Major Organisms Associated**
C	**Bhagawa**	**40***	70	100	179	CF+RKN
1	IC-318720	16	102	50	201	CF+RKN
2	IC-318728	10	102	60	179	CF+RKN
3	Co-white	14	**102**	**70**	**201**	CF+RKN
4	Gul-e-shah Red	21	102	70	201	CF+RKN
5	G-137	13	102	70	201	CF+RKN
6	IC-318703	16	102	70	201	CF+RKN
7	IC-318723	12	102	75	146	CF+RKN
8	IC-318790	13	102	80	146	CF+RKN
9	IC-318724	17	102	80	201	CF+RKN
10	Nimali	13	70	90	102	CF+RKN
11	IC-318779	13	70	100	179	CF+RKN
12	IC-318753	10	70	100	179	CF+RKN
13	IC-318705	15	70	100	179	CF+RKN
14	IC-318762	10	102	100	179	CF+RKN

* 2-3 plants of Bhagawa were planted randomly in each accession row as Control
DAI=Days after Inoculation (24.01.2019) of fresh Cf in wilt sick plot; **PW:** Partial wilt; **W:** Complete wilt; **CF:** Ceratocystis fimbriata; **RKN:** Root Knot Nematode

(iii) Screening of seedling population of different germplasm

Seeds of 52 accessions as given in the table below, hybrids and varieties were sown in the wilt sick plot on Jan 16, 2018. Fresh Cf inoculum was added to the 1 year old seedlings on Jan 24, 2019 and data recorded periodically till January 6, 2020. Wilt ranged from 0.66% in ACC-11 to 95.83% in hybrid Bhagawa X Double Flower X Nana. Seedlings of all eight ACC accessions recorded less than 5% wilt except ACC-5 which recorded 9.86% wilt. Hybrid seedlings of Bhagawa X Double Flower X Nana, Bhagawa X Daru X Nana recorded 95.83% and 53.57% wilt respectively. The highest wilt incidence (100%) was observed in IC-318733 seedlings. Among the commercial cultivars, seedlings of Bhagawa and Super Bhagawa recorded 3.47% and 15.41% wilt respectively. The detailed results are presented in table below.

Table 7: Screening of seedling population of different germplasm for wilt resistance

S. No.	Accession / Variety	Total Seedlings (No.)	Seedlings Wilted (No)	Wilt (%)	S. No.	Accession / Variety	Total Seedlings (No.)	Seedlings Wilted (No)	Wilt (%)
1	1182	16	6	37.50	**27**	IC-318703	593	21	3.54
2	1184	246	7	2.85	**28**	IC-318705	140	125	89.29
3	1195	290	17	5.86	**29**	IC-318706	95	31	32.63
4	1196	295	12	4.07	**30**	IC-318707	416	35	8.41
5	1197	125	8	6.40	**31**	IC-318712	69	15	21.74
6	1198	310	26	8.39	**32**	IC-318716	75	12	16.00
7	1201	75	13	17.33	**33**	IC-318718	74	27	36.49
8	1203	39	5	12.82	**34**	IC-318720	587	15	2.56
9	1205	110	11	10.00	**35**	IC-318723	273	33	12.09
10	1262	151	11	7.28	**36**	IC-318724	0	0	-
11	ACC-1	297	5	1.68	**37**	IC-318728	407	18	4.42
12	ACC-2	600	7	1.17	**40**	IC-318733	22	22	100.00
13	ACC-4	109	3	2.75	**41**	IC-318734	399	17	4.26
14	ACC-5	142	14	9.86	**42**	IC-318735	596	22	3.69
15	ACC-6	1220	20	1.64	**43**	IC-318739	2	1	50.00
16	ACC-9	247	12	4.86	**44**	IC-318740	164	41	25.00
17	ACC-11	305	2	0.66	**38**	IC-318743	514	23	4.47
18	ACC-12	460	15	3.26	**39**	IC-318744	323	20	6.19
19	BxDFxN	48	46	95.83	**45**	IC-318749	192	126	65.63
20	BxDxN	28	15	53.57	**46**	IC-318753	257	12	4.67
21	Bhagawa	1267	44	3.47	**47**	IC-318754	327	20	6.12
22	GxNxD	67	21	31.34	**48**	IC-318762	624	33	5.29
23	Nana	83	9	10.84	**49**	IC-318764	210	26	12.38
24	Root sock	0	0	-	**50**	IC-318766	268	50	18.66
25	Super Bhagawa	1025	158	15.41	**51**	IC-318779	151	76	50.33
26	IC-318702	290	48	16.55	**52**	IC-318790	583	37	6.35

BxDFxN: **Bhagawa X Double Flower X Nana;** BxDxN: **BhagawaX DaruX Nana;** GxNxD: **Ganesh x Nana x Daru**

Fig. 10: Screening of different pomegranate germplasm in wilt sick plot at ICAR-NRCP, Solapur

(iv) Screening of Hybrids for Wilt Resistance

Seedlings in Set-I (29 nos. of hybrids) and cuttings in Set-II (11 nos. of hybrids and 1 wild variety) of different hybrids of ICAR-NRCP hybrid block were planted in the wilt sick plot on August 17, 2018, fresh inoculum of Cf was added on Jan 24, 2019 and data recorded till Jan 2020 on monthly interval.

Seedlings of only one hybrid 7/10 remained free and 2 hybrids viz. BxIC-318702 and ACC-13 recorded the lowest wilt below 15% till 1 year of observation. In general wilt initiation was delayed till 307 days in seedling population as shown in table below.

Cuttings of wild variety 'Daru' recorded 10% wilt till last observation at 348 days after inoculation although wilt in this variety started 307 days after Cf inoculation and cv. 'Amlidana recorded 100 % wilt at 348 days after inoculation. In all other indigenous hybrids wilt ranged from 45-80%.

Table 8: Set-I, Screening of Seedlings of different hybrids at NRCP, Solapur

S. No.	Hybrid Name	No. of Plants	DAI Wilt Initiated	DAI Max wilt Observed	Max wilt (%)
1	7/10	3	-	348	0
2	B x IC-318702	14	348	348	7.1 (PW)
3	ACC-13	8	307	307	12.5
4	B x 318712	10	162	307	20
5	B x IC-318749	4	348	348	25
6	ACC-51	12	307	348	25
7	H-12	19	307	348	26
8	KRS x B	10	307	348	30
9	Jallore seedling	5	307	348	40
10	H-14	10	307	348	40
11	B x IC-1253	9	307	307	44.4
12	B x Mukteshwar	6	307	348	50
13	(N x R) x B	10	307	348	50
14	1194 x G	4	307	307	50
15	ACC-15	2	307	348	50
16	K x R	6	307	348	50
17	B x KRS	18	162	348	55.6
18	G x HA	10	162	348	60
19	K x R x B	12	307	348	66.7
20	R x KRS	6	162	307	66.7
21	B x IC-318740	11	307	348	72.7
22	ACC-50	4	307	348	75
23	B x P5	27	162	348	77.8
24	H-4	12	307	348	78.6
25	B x IC-318712	5	307	348	80
26	Arakta	5	307	307	80
27	B x Nana	10	162	348	80
28	B x H-28	5	208	307	80
29	B x IC-318733	8	307	348	87.5

DAI: Days after inoculation

Table 9: Set-II: Screening of plants raised from cuttings of different hybrid material for wilt resistance at NRCP, Solapur

S. No.	Hybrid	No. of Plants	DAI Wilt Initiated	DAI Max wilt Observed	Max Wilt (%)
1	H-24	15	162	307	46.7
2	NY-3	5	162	348	60
3	HA-1	5	307	348	60
4	H-4	21	94	307	66.67
5	NY-1	5	94	162	80
6	H-14	20	94	348	80
7	N x R	10	94	307	80
8	HA	5	94	307	80
9	K x R	10	307	348	90
10	Bhagawa	23	208	348	56.52
11	Amlidana	5	94	348	100
12	Daru	10	307	348	10

DAI: Days after inoculation
* Partial wilt till last observation

5.1.11 Seedlings Raised from Different Seed Treatments

(i) Hot water and Sulphuric acid: Hot water treatment of Seeds of Mridula and IC-318762 was done at three temperatures 25°,50° and 75°C for 10, 20 and 30 minutes respectively and IC-318762 were also treated with Sulphuric acid 98% lab grade, for 15, 45 and 60 minutes. Each treatment was replicated thrice. Total 75 seeds/treatment (25/replication) were germinated in polyhouse and seedlings of 7 months old were transplanted in wilt sick plot.

(a) Mridula: In Mridula though no wilt was recorded in seedling raised from seed treatment with hot water at 25°C and 50°C for 30 minutes and 75°C for 10-20 minutes but seed germination was very poor. Low germination (1.33 -30.67%) was recorded in different treatments.

Table 10: Screening of seedlings (cv. Mridula) raised after different hot water treatments for wilt resistance

Hot water treatment		No. of seedlings	% seed germintaion	DAI Wilt initiated	DAI Max wilt observed	Seedlings Wilted (No)	Wilt (%)
T1	Control	20	26.67	307	348	9	45.0
T31A	25 °C for 10 min.	12	16.00	307	348	7	58.3
T31B	25 °C for 20 min.	4	5.33	348	348	1	25.0
T31C	25 °C for 30 min.	8	10.67	-	348	0	0.0
T32A	50 °C for 10 min.	23	30.67	307	348	7	30.4
T32B	50 °C for 20 min.	20	26.67	307	348	5	25.0
T32C	50 °C for 30 min.	2	2.67	-	348	0	0.0
T33A	75 °C for 10 min.	2	2.67	-	348	0	0.0
T33B	75 °C for 20 min.	1	1.33	-	348	0	0.0
T33C	75 °C for 30 min.	13	17.33	307	348	3	23.1

(b) IC-318762 : In **IC-318762** no wilt was recorded in seedling raised from seed treated with Sulphuric acid (H_2SO_4) for 15 min and hot water treatments at 75°C for 20 minutes but seedling germination was extremely poor (1.33-9.33%). In rest of the treatments 14-100% mortality of seedlings was recorded.

(ii) Seedlings from Gamma (γ) irradiated plants: Seedlings developed from promising γ-irradiated trees of cv. Ganesh and cv. Bhagawa in H-1 and H-2 blocks at Hiraj farm were also evaluated for response against *Ceratocystis* wilt. In all 1-6 seedlings available from different plants were evaluated. Wilt was recorded only in seedlings from plant number 364 and 371 of cv. Ganesh and plant number 94, 72, 60 and 43 of cv. Bhagawa at 348 days after planation of seedlings in wilt sick plot and rest were free from wilt.

Table 11: Screening of seedlings (IC-318762) raised after different hot water treatments for wilt resistance

Treatment		No. of seedlings	% seed germintaion	DAI Wilt initiated	DAI Max wilt observed	Seedlings Wilted (No)	Wilt +Partial wilt (%)
T1	Control	5	6.67	-	348	0	0
T21	H_2SO_4 15 min	1	1.33	-	348	0	0
T23	H_2SO_4 45 min	3	4.00	307	348	1+1*	66.67
T24	H_2SO_4 60 min	1	1.33	348	348	1*	100
Hot water treatment							
T31A	25°C for 10 min	2	2.67	307	348	1*	50
T31B	25°C for 20 min.	7	9.33	348	348	1*	14.29
T31C	25°C for 30 min.	6	8.00	348	348	1+1*	33.33
T32A	50°C for 10 min.	6	8.00	348	348	2+1*	50.00
T32B	50°C for 20 min.	4	5.33	307	348	2+2*	100
T32C	50°C for 30 min.	1	1.33	307	307	1	100
T33A	75°C for 10 min.	2	2.67	307	348	2	100
T33B	75°C for 20 min.	2	2.67	-	348	0	0.00
T33C	75°C for 30 min.	1	1.33	307	307	1	100
* Partial Wilt							

Table 12: Reaction of seedlings raised from different γ irradiated plants to *Ceratocystis* wilt

Cultivar	Gamma (γ) irradiated plant number	
	Wilt	Wilt free
Ganesh	364, 371.	157, 171, 175, 234, 264, 265, 270, 370, 307, 376, 384, 391
Bhagawa	43, 60, 72, 94, 98, 109, 180, 227, 405.	71, 75, 82, 85, 86, 88, 101, 106, 107, 108, 129, 132, 179, 210, 215, 220, 221, 365.
Data recorded at 348 days after planting in wilt sick plot		

5.1.12 Evaluation of *Trichoderma* Formulation for Wilt Management

The *ragi* based formulation containing *Trichoderma* isolate ThGJ16B received in September 2019, from Department of Plant Pathology, IIHR, Bengaluru was evaluated for control of wilt pathogen *Ceratocystis fimbriata* (Cf) under pot culture trials. The pots had wilt sick soil. The formulation was applied after incubation with farmyard manures (Formulation: FYM:: 1:100 ratio for 20 days following recommended procedure). The multiplied formulation with 50% moisture was applied at the rate of 500 g/pot. Planting was done on Sept. 11, 2019. The treatments are detailed in the table. Wilt data was recorded till Jan. 20, 2020

(130 days after planation and treatment) when all plants in control with only Cf wilted. The results showed that *Trichoderma* formulation was effective in controlling *C. fimbriata* wilt when applied at the time of plantation with or without fungicide propiconazole, however wilt was not controlled when it was applied 1 month after plantation where in all plants wilted in 130 days.

Table 13: Evaluation of *Trichoderma* formulation for the control of wilt pathogen *Ceratocystis fimbriata*

Treatment	Days after plantation/ treatment when wilt		Percent plants wilted	Plant growth*
	Initiated	Reached Maximum		
T1: *Trichoderma formulation* (IIHR) applied at the time of pomegranate plantation in *Ceratocystis fimbriata* sick soil	-	-	0.00	Better than negative control 1- without pathogen or formulation
T2: *Trichoderma formulation* (IIHR) +Propiconazole applied at the time of pomegranate plantation in *Ceratocystis fimbriata* sick soil	-	-	0.00	Normal growth similar to negative control 1- without pathogen or formulation
T3: *Trichoderma formulation* (IIHR) applied after one month of pomegranate plantation in *Ceratocystis fimbriata* sick soil	98	130	100	All wilted
T4: Positive Control- Pomegranate plantation in *Ceratocystis fimbriata* sick soil without any treatment	66	130	100	All wilted
T5: Negative Control 1-Pomegranate plantation in sterile healthy soil-No pathogen & No formulation	-	-	0.00	Normal growth
T6: Negative control 2- Pomegranate plantation in sterile healthy soil with only *Trichoderma formulation* (IIHR).	-	-	0.00	Better than negative control 1- without pathogen or formulation

Fig. 11: Evaluation of Trichoderma formulation for control of wilt pathogen *Ceratocystis fimbriata*. For treatment details please see above table

5.1.13 Evaluation of New formulation Kasugamycin 5% + Copper oxychloride 45% WP for pomegranate diseases

5.1.13.1 Effect of New Formulation Kasugamycin 5% + Copper Oxychloride 45% WP on Fungal Rot and Spot Pathogens of Pomegranate

A new product kasugamycin 5% + copper oxychloride 45% WP was tested for efficacy in checking various pathogens of pomegranate. The pathogens tested were- *Colletotrichum gloeosporioides, Alternaria alternata*, *Cercospora punicae* and *Sphaceloma punicae*, the leaf and fruit spot/rot pathogens of pomegranate. Observations were recorded on 9th day of inoculation.

In *in vitro* poisoned food technique, kasugamycin 5% + copper oxychloride 45% WP @ 2 and 3g/l resulted 100% inhibition of *Colletotrichum gloeosporioides, Alternaria alternata* and *Cercospora punicae*, whereas in COC alone inhibition in different treatments ranged from 12.59 to 51.86% and in kasugamycin from 11.67% to 53.38%.

Table 14: Effect of kasugamycin 5% + copper oxychloride 45% WP in inhibiting fungal rot and spot pathogens of pomegranate (Poisoned food technique)

Treatment		Average Colony Diameter (mm)		
		Colletotrichum	*Alternaria*	*Cercospora*
T1	Kasugamycin 3% SL @ 2ml/lit	45.00	72.17	6.67
T2	Kasugamycin 3% SL @ 3ml/lit	39.33	55.33	9.67
T3	Copper oxychloride 50% WP @ 2g/lit	57.00	44.67	11.83
T4	Copper oxychloride 50% WP @ 3g/lit	66.67	39.33	12.50
T5	Kasugamycin 5% + copper oxychloride 45% WP @ 2gm/lit	0.00	0.00	0.00
T6	Kasugamycin 5% + copper oxychloride 45% WP @ 3gm/lit	0.00	0.00	0.00
C	Control (Water)	78.50	81.67	14.33

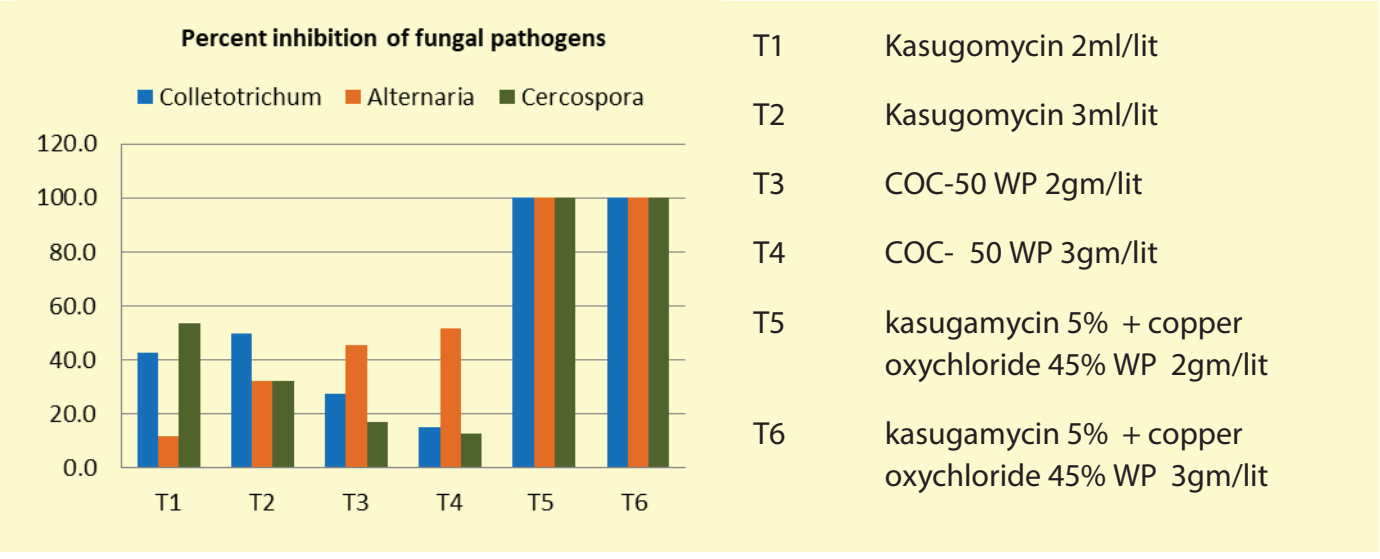
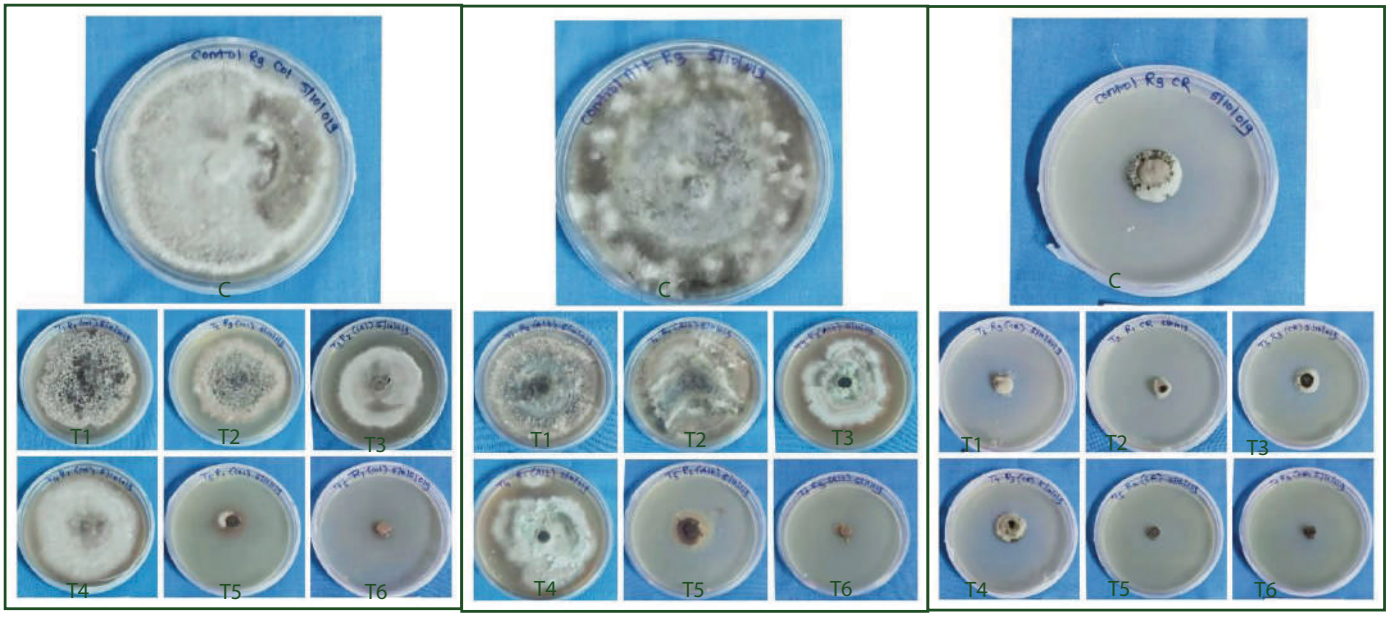


Fig. 12: Percent inhibition of fungal rot and spot pathogens of pomegranate with kasugamycin 5% + copper oxychloride 45% WP (Poisoned food technique)



Colletorichum gloeosporioides ***Alternaria alternata*** ***Cercospora punicae***

Fig. 13: Effect of formulation kasugamycin 5 %+ copper oxy-chloride 45 % in inhibiting different fungal spot and rot pathogens: C: Water Control; T1: Kasugomycin 2ml/lit; T2: Kasugomycin 3ml/lit; T3: COC-50 WP 2gm/lit; T4: COC- 50 WP 3gm/lit; T5: kasugamycin 5% + copper oxychloride 45% WP 2gm/lit; T6: kasugamycin 5% + copper oxychloride 45% WP 3gm/lit.

Sphaceloma punicae being slow growing was not evaluated *in vitro*. However, kasugamycin 5% + copper oxychloride 45% WP is expected to give good control of scab pathogen (*Sphaceloma punicae)* based on field evaluation of copper baesd products on scab incidence in the year 2017-18. All copper based products including, COC (0.2%), copper hydroxide (0.2%) and Bordeaux mixture (0.5%) resulted more than 90% control (incidence 0.47-1.04%) of scab over control with 14.5% disease incidence. Hence, combi product kasugamycin 5% + copper oxychloride 45% WP may be promising for scab also.

5.2 Project: Flagship Project on Integrated Approach to Eradicate Bacterial Blight

5.2.1 Effect of γ-aminobutyric Acid (GABA) in Inducing Resistance Against Bacterial Blight of Pomegranate and Associated Defense Response

Studies were conducted at UHS, Bagalkot to investigate the elicitation effect of γ-aminobutyric acid (GABA) treatment in inducing resistance against bacterial blight and study phenylpropanoid pathway. At the outset GABA was evaluated *in vitro* at all tested concentrations for bactericidal effects if any; no inhibition of bacterial blight pathogen *Xap* was recorded even after 72 hours of incubation. Further greenhouse results indicated that prophylactic treatment with GABA, at 600 ppm, induced strong resistance against bacterial blight by recording lowest bacterial blight with severity of 3.76% when compared to control with 14.22% blight severity thus reducing blight by 73.58% (Fig. 14A). Similar trend was also recorded under field conditions. GABA recorded 42.37% reduction in bacterial blight incidence on leaves and 34.78% reduction of blight on fruits (Fig. 14B). It also significantly improved fruit yield and fruit size (Fig. 15).

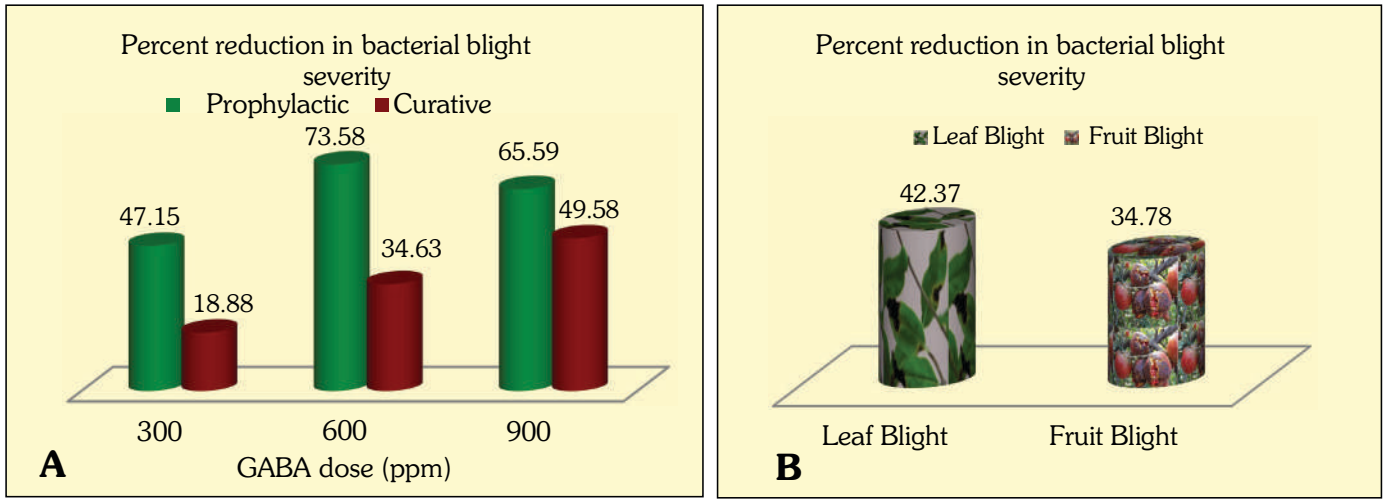


Fig. 14: Effect of γ-aminobutyric acid (GABA) in reducing bacterial blight (A) greenhouse conditions (B) field conditions

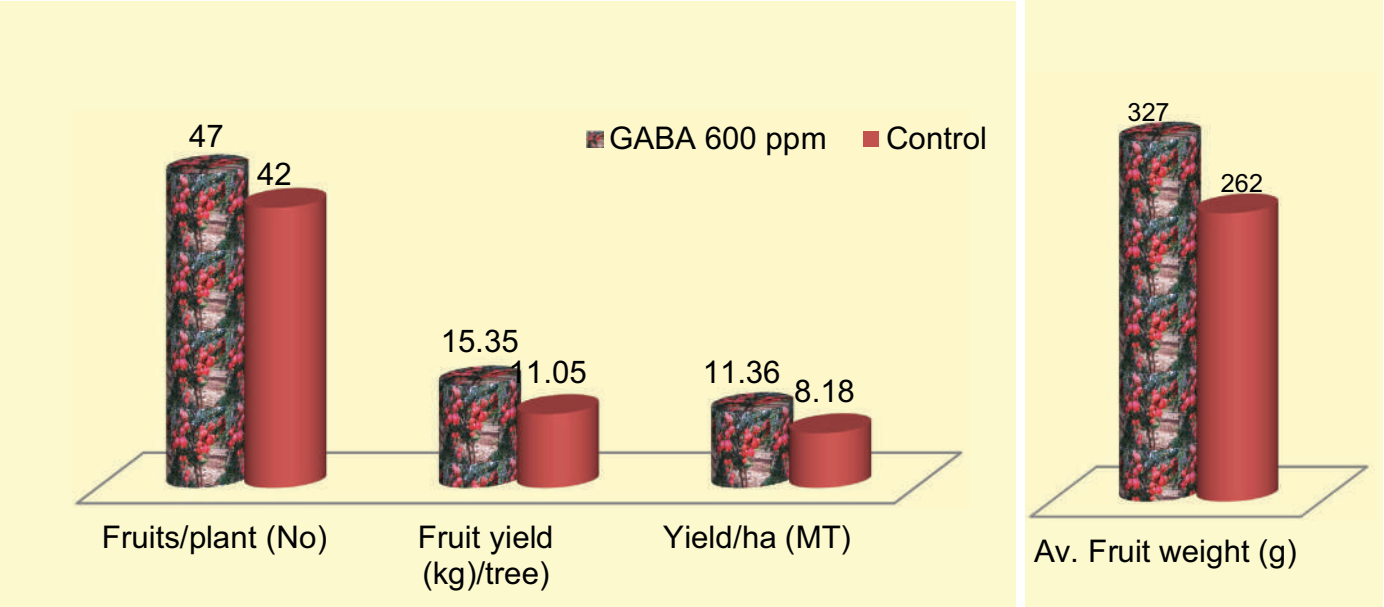


Fig. 15: Effect of GABA on fruit yield of pomegranate

Expression analysis of the phenylpropanoid pathway genes (PAL, C4H, 4CL, COMT and CAD) was done by real-time PCR, using the SYBER green method on a Step One Plus Real-Time PCR system (Applied Biosystems). It was found that the activities of these genes (PAL, C4H, 4CL, COMT and CAD) were enhanced in the treatment where both GABA was sprayed and *Xap* was inoculatd compared to check with pathogen alone. Further the temporal time gap studies revealed that GABA recorded maximum resistance when Xap was inoculated 5 days after GABA application showing least bacterial blight severity of 1.42% in comparison to control with severity of 8.34 % after 2 weeks of inoculation (Fig. 16). Thus indicating preventive sprays of GABA will be useful in inducing resistance to bacterial blight under field conditions.

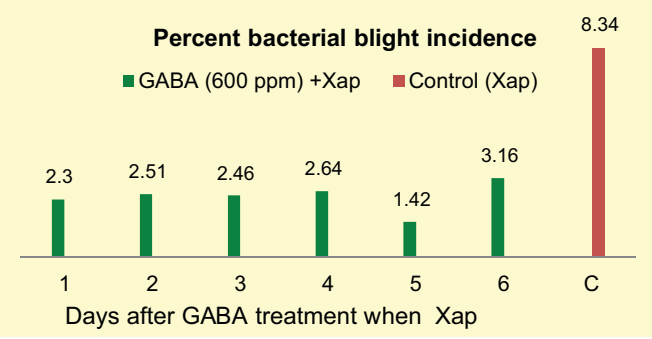


Fig. 16: Incidence of bacterial blight when Xap inoculated at different time points after GABA application

5.2.3 Clove Oil- a Potent Defense Inducer for Management of Bacterial Blight Disease in Pomegranate

Investigations conducted at UHS Bagalkot revealed clove oil as a potential defense inducer against bacterial blight of pomegranate. Studies were conducted with clove oil individually and in combination with copper oxy chloride (COC) for the management of bacterial blight.

In vitro Evaluation of Clove Oil

Different concentrations of clove oil were evaluated *in vitro* using diffusion disc method. Clove oil at 0.2-1.0% concentration inhibited *Xap* under *in vitro* condition (Table 15; Fig. 16). In polyhouse trials for phytotoxicity of clove oil if any, dose up to 0.2% was found safe (Table 1) and hence used for further field evaluation.

Table 15: *In vitro* inhibition of *Xap* with different concentration of clove oil by disc diffusion method and phytotoxicity on plants

Clove oil (%)	0.0	0.1	0.2	0.3	0.5
Inhibition zone (mm)	0.00	21.33	25.33	35.53	39.06
Phytotoxicity on plants	-	-	-	+	+

efficacy of clove oil in reducing bacterial blight: Clove oil efficacy for checking bacterial blight was evaluated under polyhouse and field conditions. Clove oil at 0.2% concentration recorded 7.34% disease severity and combination of clove oil (0.2%) and copper oxy chloride (0.3%) recorded least disease severity of 2.38% and 3.25% respectively, under polyhouse conditions (Fig. 18). Streptomycin sulphate90%+ tetracycline hydrochloride 10% (0.05%) recorded severity of 3.64% under greenhouse conditions and 7.09% under field condition. All the treatments resulted in significant control of bacterial blight with 82.56 to 95.16% reduction under polyhouse trials. In field blight reduction was 78.54-94.69% on leaves and 87.91-96.95% on fruits (Fig. 19). The reduction of disease severity by different treatments reflected on total yield, recording lowest fruit yield in untreated control 4.05t/ha and maximum (14.04t/ha) in clove oil + COC treatment followed by streptomycin sulphate 90%+ oxytetracycline10% with 11.12 t/acre (Fig. 20).

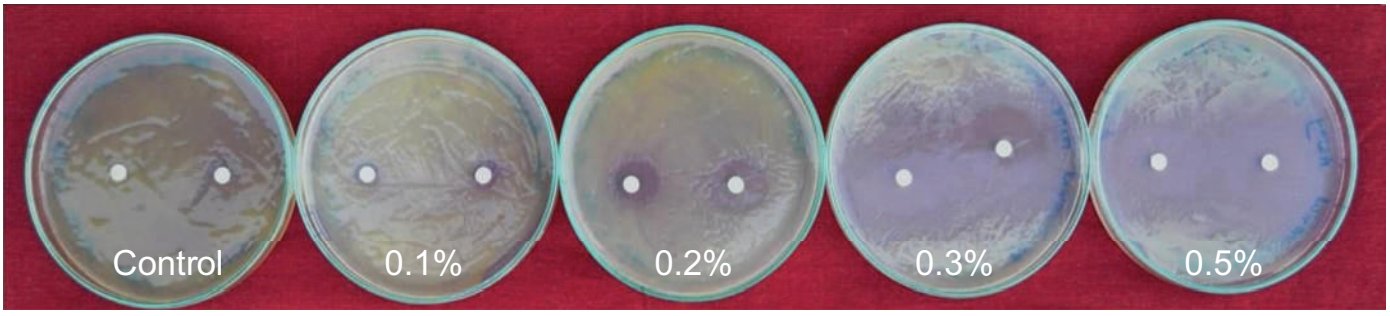
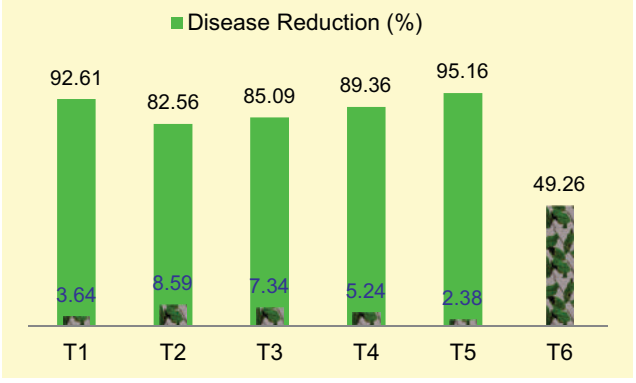
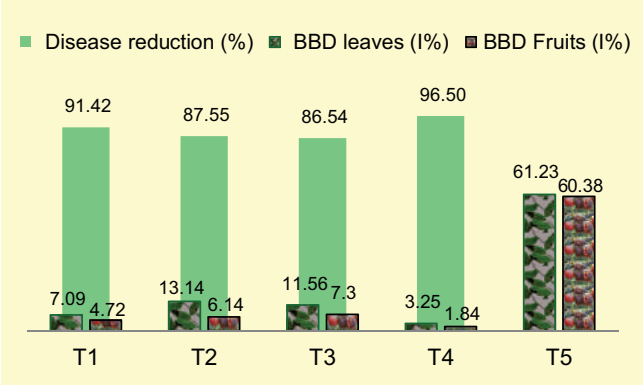


Fig. 17: I*n vitro* inhibition of *Xap* with different concentration of clove oil by disc diffusion method and phytotoxicity on plants



T1- Streptocycline 0.5 g/l^{-1}
T2- Clove oil 1 ml/l^{-1}
T3- Clove oil 2 ml/l^{-1}
T4- COC 2.5g/l^{-1}
T5- Clove oil 2 ml/l^{-1} + COC 2.5 g/l^{-1}
T6- water control

Fig. 18: Efficacy of clove oil in checking bacterial blight under polyhouse conditions



T1	Streptomycin 90%+oxytetracycline10% @ 0.5 g//l
T2	Clove oil @2 ml /l
T3	COC@ 2.5g/l
T4	Clove oil @ 2 ml + COC @ 2.5 g/l
T5	Water control

Fig. 19: Effect of clove oil on bacterial blight under field conditions

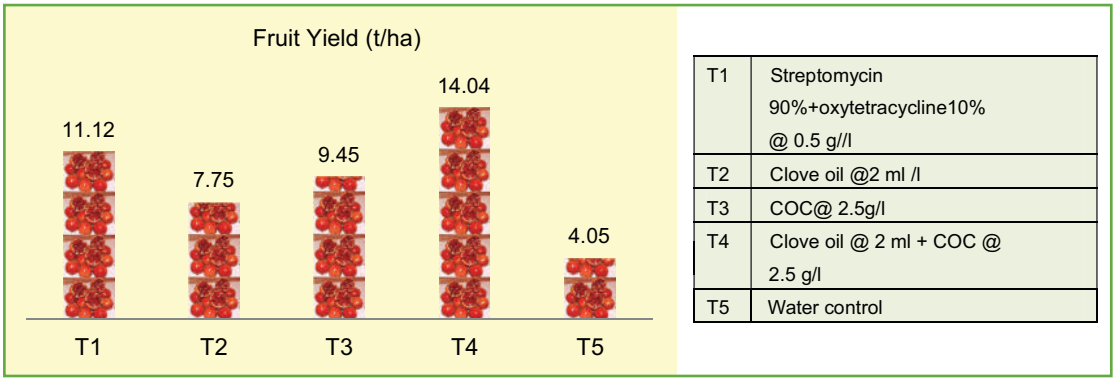


Fig. 20: Effect of clove oil treatment on fruit yield

Defense Responses Associated with Clove Oil Treatment

The potential of clove oil in triggering systemic acquired resistance was also investigated. Prophylactic application of clove oil recorded a high relative expression of pathogenesis-related (PR) proteins (PR1, PR4, and PR10), phenyl ammonia lyase, chitinase, callosynthase 3 and peroxidase. The present study reflects that clove oil can be effectively used as a bio-control agent for the successful management of bacterial blight in pomegranate and also as an alternative to antibiotics.

In vivo Pathogen Quantification in Response to Treatments

Pathogen quantification was carried out using qPCR method using *XopQ* primerby measuring the DNA concentration of the pathogen in leaves after 15 days post inoculation (dpi) with Xap. The relative abundance of the pathogen DNA was found highest in pathogen treated control plants with 214.22 folds DNA. Clove oil +COC treated plants recorded lowest pathogen DNA abundance of 9.85 folds. Standard control Streptomycin 90%+oxytetracycline10% and COC recorded 23.20 and 24.03 folds DNA respectively.

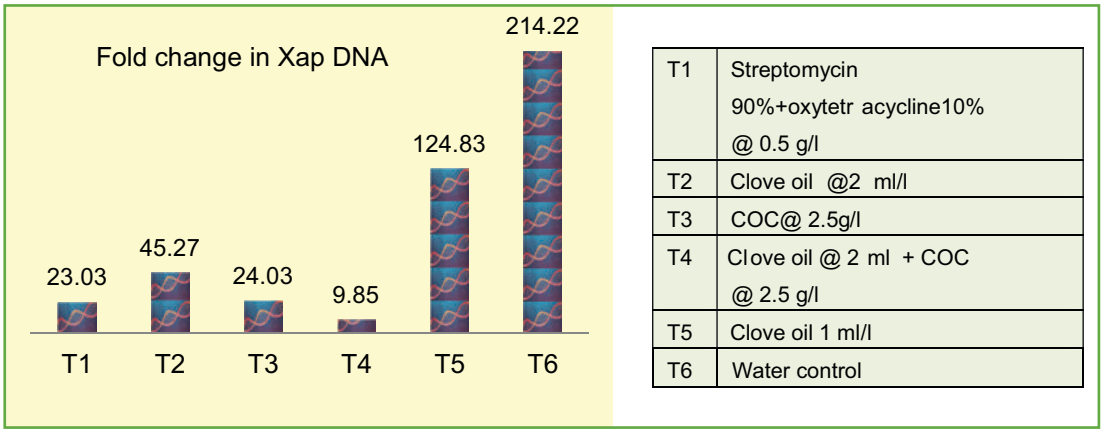


Fig. 21: Relative quantification of *Xap* DNA in pomegranate leaves with different treatments

These results were found correlating with the visual scoring of the disease, thereby, indicating efficiency and accuracy in quantifying pathogen using qPCR method (Fig. 21).

Expression Analysis of Defense Gene in Response to Clove Oil Treatment

The effect of clove oil in inducing systemic resistance against pathogen was determined through qPCR

analysis. A total of seven 7 different defense genes (Table 16) belonging to different pathways were tested for their expression upon clove oil treatment from 6 to 168 hours post inoculation (hpi). Among various defense response genes, Pathogenesis-related (PR) protein gene families have been frequently used as marker genes for studying systemic acquired resistance in many plant species.

The **PR1** gene upregulation recorded from 12 hpi (15.5 folds) and continued till 168 hpi, with significant upregulation observed at 120 and 168 hpi with 77 and 82 folds respectively. The expression level of **PR4** was found upregulated from at 6 hpi (11 folds) and found maximum at 120 hpi (27 folds)over control. Similarly, **PR10** was also found to be upregulated from 6 hpi with 1.85 folds and higher fold change was observed at 24, 72 and 120 hpi with 12.2, 12 and 15.46 folds respectively. **Phenyalalanine ammonia-lyase (PAL)** is a gateway enzyme in the phenylpropanoid pathway and was found increased upon treatment with clove oil. Regulation of PAL gene was found significant in all the time points. Gradual increase of PAL was observed from the initial 6 (2.95 folds) to 168 hpi (61.7 folds) with slight decreases at 72 hpi with 14 folds (Fig. 22). It is very interesting to note that all pathogenesis related (PR) proteins expressed maximum at 120 hpi of the pathogen, which is the key time for pathogen expression phenotypically. Defense enzymes such as PAL, peroxidase, chitinase and callose synthase (CS) were also studied for understanding the systemic nature of clove oil in protecting against *Xap*.

Table 16: Oligonucleotide primers used for qPCR analysis of different defense gene induced after clove oil treatment

Target Gene	Primers (5'-3')	Accession No.	Amplicon size (bp)
Pathogenesis-related protein 1 (*PR-1*)	F-ACTACGCCAACAAGCACATTG R-GTCCACCCACATTTTCACTG	KU977458	122
Pathogenesis-related protein 3 (*PR-10*)	F-GCCAGTACAAATCAGTGAAG R-TACTTGCTCGTGTTCTTGC	KY635883.1	175
Pathogenesis-related protein 4 (*PR-4*)	F-GCACAACTGGGACCTGAATG R-TGTCACCCTGAGGCATCTTC	KU977460	154
Phenyalalanine ammonia-lyase (*PAL*)	F-TCGGGAAGCTGATGTTTGC R-CCCCTTGAAGCCATAGTCC	KX450397	116
Chitinase	F-AAGGGACGAGAGGAAGACTG R-CTGAGCGCCGAAATAAGGAG	KU977459.1	164
Callose synthase 3 (*CS-3*)	F-AGCCTATGGAGGTGAAGAC R-CTGGGAATGCTTTGACTTTC	KU977465	112
Peroxidase (POD)	F-CTTCCGACTCTTCTTTCACG R-GGGCACACCTTCTCAACAG	KY635883.1	168

Callose synthase greatly contributes to the plant's constitutive resistance and clove oil treatment was consistently found increasing **Callose synthase 3 (CS3)** expression from 6 to 168 hpi over control and maximum upregulation was found at 120 hpi with 14.12 fold change. **Chitinase,** an important cell-wall-degrading enzyme is actively involved in plant protection during pathogen attack and its expression was high with clove oil. Upregulation of chitinase gene was observed from 6 hpi (2.6 folds) and consistent transcript abundance was observed in 48, 72, and 120 hpi with 2.1, 1.5 and 2.2 folds respectively. Similarly, the expression of antioxidant **peroxidase** (POD) gene also increased with clove oil. The gene expression increased gradually from 24 h (5.72 folds) and continued till 120 hpi, and maximum upregulation was found at 120 hpi with 9.85 folds and subsequently, the activity was truncated (Fig. 23).

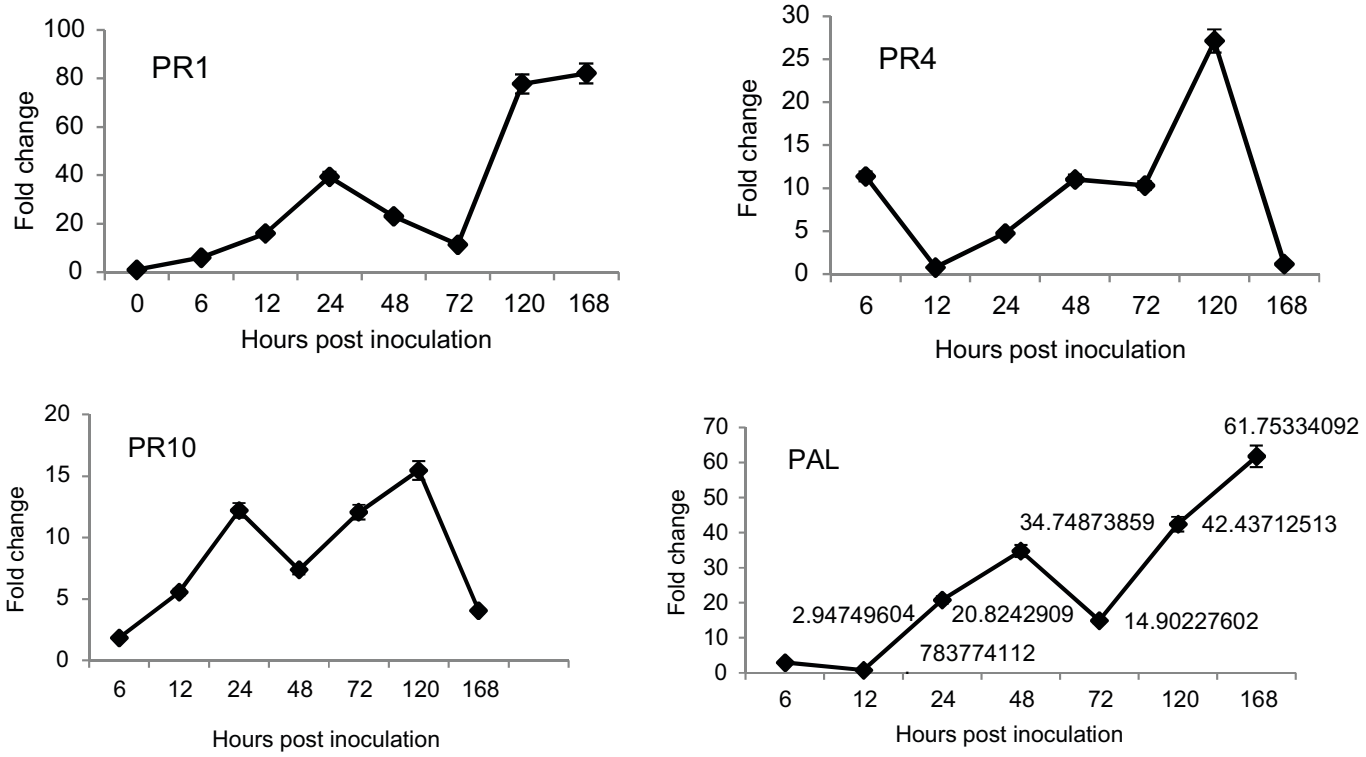


Fig. 22: Relative expression of pathogenesis related genes (PR-1, PR-10, PR-4) and PAL gene and its amplification plot as determined by qRT-PCR in Clove oil treated plants

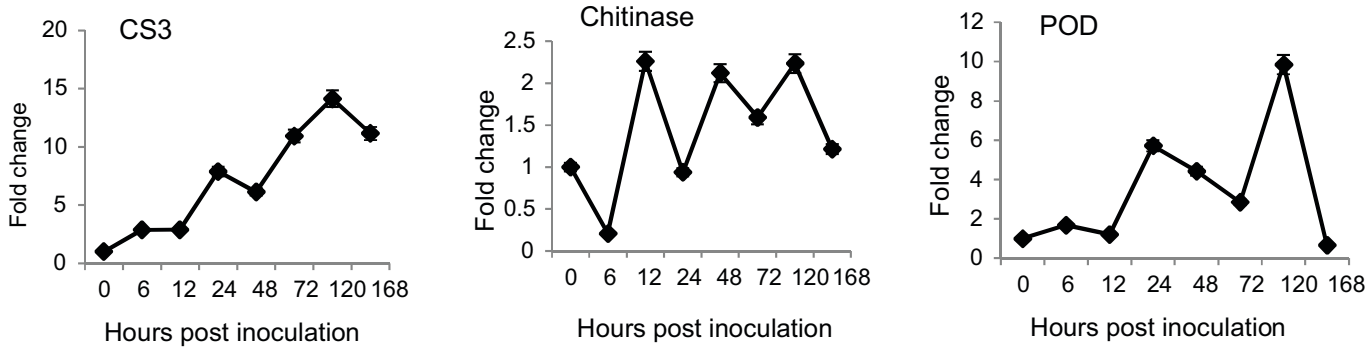


Fig. 23: Relative expression of defense related genes-CS3, Chitinase and POD its amplification plot as determined by qRT-PCR in Clove oil treated plants on one year plants

5.2.4 Metabolic (phenyl propanoids) profiling of pomegranate genotypes tolerant and susceptible to bacterial blight

Investigations were conducted at UHS, Bagalkot to identify metabolites accumulated in response to bacterial blight pathogen in blight tolerant wild genotype 'IC318735' and susceptible cultivar 'Bhagawa' of pomegranate. Accumulation of phenylpropanoid metabolites in pomegranate genotypes infected with Xap were expressed in metabolic profiling using LC/MS (Fig. 24). The PC1 vector explained 27.6, 41.1 and 35.2 % of the variance, discriminating the resistant from the susceptible genotype. Whereas the PC2 vector explained 16.4% and 13.7% of the variance, discriminating the untreated control and Xap treated plants. Resistant related induced (RRI) metabolites in tolerant compared with susceptible genotype were

further studied in detail. In tolerant genotypes, seven metabolites were significantly ($P<0.05$) induced under pathogen treated compared to Bhagawa. These RRI metabolites were mainly phenylpropanoids, confirmed by matching their respective MS/MS spectra with those of in-house spiked standards and available database compounds, and MS/MS spectral tags.

The elevated metabolites accumulated were isolated and tested for their efficacy *in vitro* against blight pathogen (Fig. 25). Relative antibacterial activity of RRI metabolites mainly Ferulic acid, coumarin, cinnamic acid, eugenol, kaempferol, quinic acid and p-coumaric acid were tested *in vitro* using inhibition zone technique. Streptomycin sulphate (90%) + tetracycline hydrochloride (10%), a synthetic antibiotic, widely recommended for Xap control, was used at 200 ppm as a positive check and dimethyl sulfoxide (DMSO) used for dissolution of metabolites as negative check. Metabolite concentrations used were 0.1, 0.2, 0.3 and 0.5 %, 1 disc of each concentration on each plate. Except for kaempferol and quinic acid all other compounds reduced bacterial growth at all or higher concentrations. Among these metabolites eugenol exhibited high inhibitory zone of 9.5 to19.5 mm and and cinnamic acid 1.0-5.5 mm zone, whereas positive control Streptomycin sulphate (90%) + Tetracycline hydrochloride (10%) at 200 ppm recorded average inhibition zone of 9.75 mm.

The active metabolites may be synthesized chemically and evaluated for their efficacy under field conditions to have the alternative for antibiotics which are currently recommended for the management of bacterial blight.

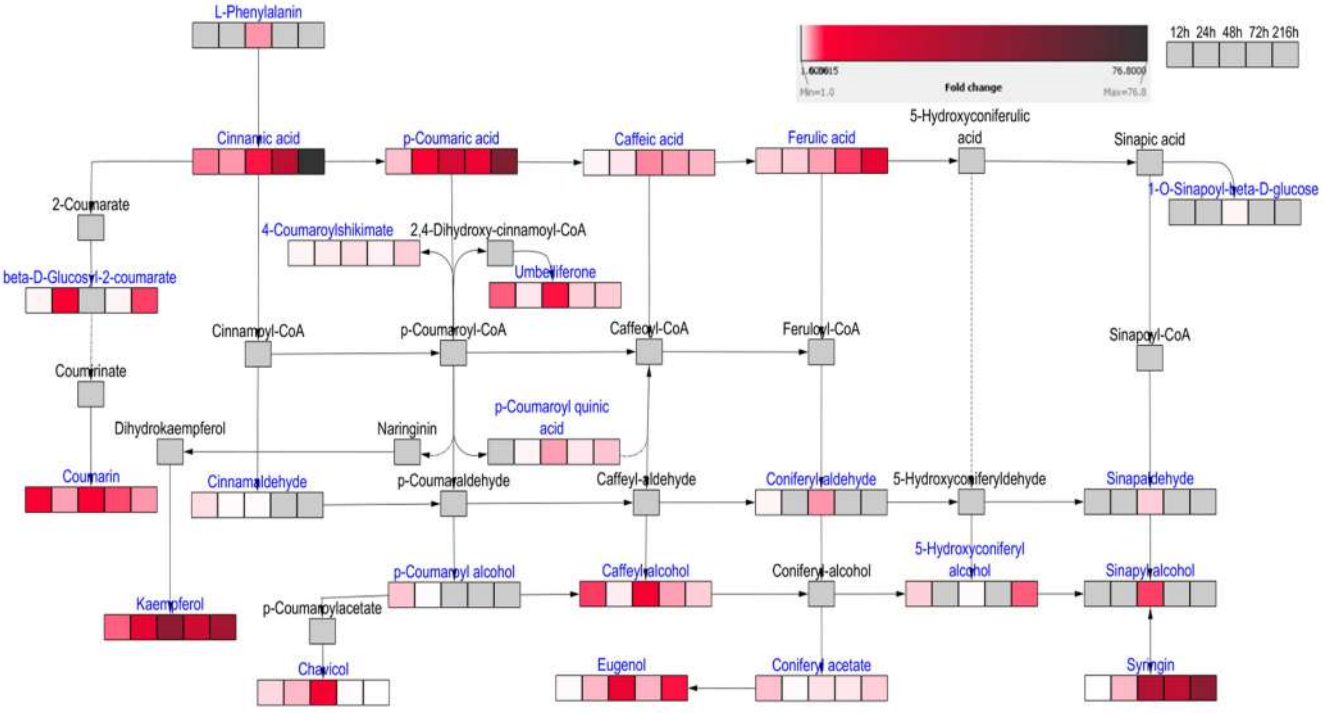


Fig. 24: Phenyl propanoids induced upon *Xap* infection in pomegranate

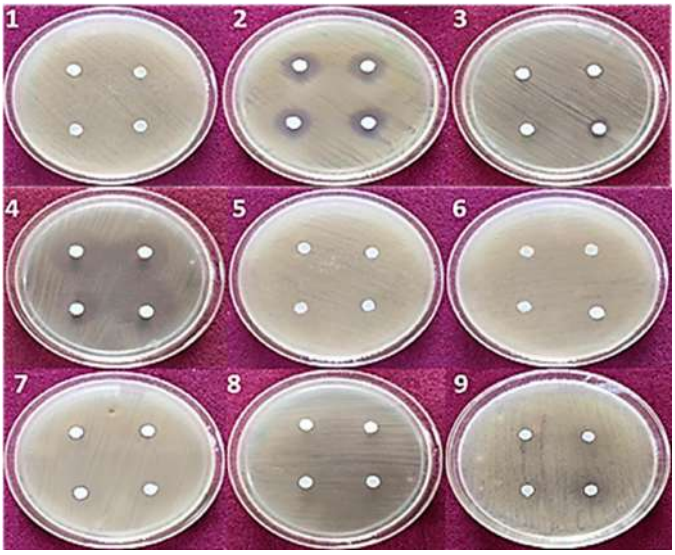


Fig. 25: Antibacterial (inhibition zone at 0.1 -0.5% concentrations) assay of pomegranate resistance related metabolites. 1. Control –DMSO (0.0 mm), 2. Streptocycline200 ppm (Av.9.75 mm), 3. Tras Cinnamic acid (1.0-5.5 mm) 4. Eugenol (9.5-19.5 mm) 5. Ferulic acid (0.0 mm) 6. Kampferol (0.0 -0.0 mm) 7. p-coumaric acid (1.0-3.0mm) 8. Quinic acid (0.0mm) 9. Coumarin (0-0.5mm).

5.2.5 Genome-wide Characterization and Molecular Diversity Analysis among Xap Isolates using Microsatellite Markers

Genome sequence of strain LMG 859 (4.94 Mb) *X. axonopodis*pv. *punicae* (Sharma et al., 2012) has opened the unprecedented opportunity for genome wide discovery of SSRs. Earlier many researchers deployed various marker techniques such as ERIC-PCR, RAPD, ISSR, BOX- PCR and MLST to understand genetic diversity among different isolates of *Xap*, however all these techniques are inadequate in terms of genome coverage and hence remain inconclusive regarding the information they generated. Since, SSRs are highly polymorphic, evenly distributed throughout genome and can effectively differentiate bacterial strains. We tried to perform genome wide characterization and development of SSRs in *Xap*. In the previous year we reported the preliminary results on the genome wide survey of SSRs in *Xap* genome. This year we report detailed results including experiment validation and molecular diversity analysis among 22 *Xap* isolates using *Xap*-SSRs.

In silico mining of SSRs in *Xap* genome

Total 217 contigs representing 4.94 Mb of *Xap* genome (LMG 859) were retrieved from EMBL database. SSR survey using web based MISA search tool resulted in identification of 4,341 SSRs motifs with an average marker density of 1142.15/Mb **(Table 17).**

Table 17: Characterization of microsatellites in the *Xap* genome

SSR mining	Total
Total number of sequences examined: Total size of examined sequences (bp):	217 4946642
Total number of identified SSRs:	4341
Number of SSR containing sequences:	186
Number of sequences containing more than 1 SSR:	166
Relative abundance of SSRs (per Mb)	1142.15/Mb
Number of SSRs present in compound formation:	410

Total 186 contigs with SSRs were identified, of which 166 contigs showed more than one SSRs and having 410 compound SSR types. A total 3,931 perfect SSRs were identified in which the frequency of hexa nucleotide (91.8%) dominated, followed by tri (4.6 %), tetra (2.00%), di (1.13%) and penta (0.48%) nucleotides (Fig. 26A).With respect to number of repeat units hexa nucleotides occupied all the repeating classes except 8, 10 and 12. Similarly, tri nucleotides represented only in repeating unit class (4, 5 and 6), di nucleotides represented in (6, 7, 8 and 10), tetra nucleotides (3), penta (3 and 4), and mono in unit class 12 (Fig. 26B).

Further with respect to motif types, CCG/CGG (43.94%) represented maximum, followed by ACC/GGT (28.79%), AGC/CTG (16.67%) and ACG/CGT (7.57%) among tri nucleotides, CCGG/CCGG (6.9% followed by AAGC/CTTG (2.3%) in tetra nucleotides and CG/CG (97.9%) in di nucleotides (Fig. 27).

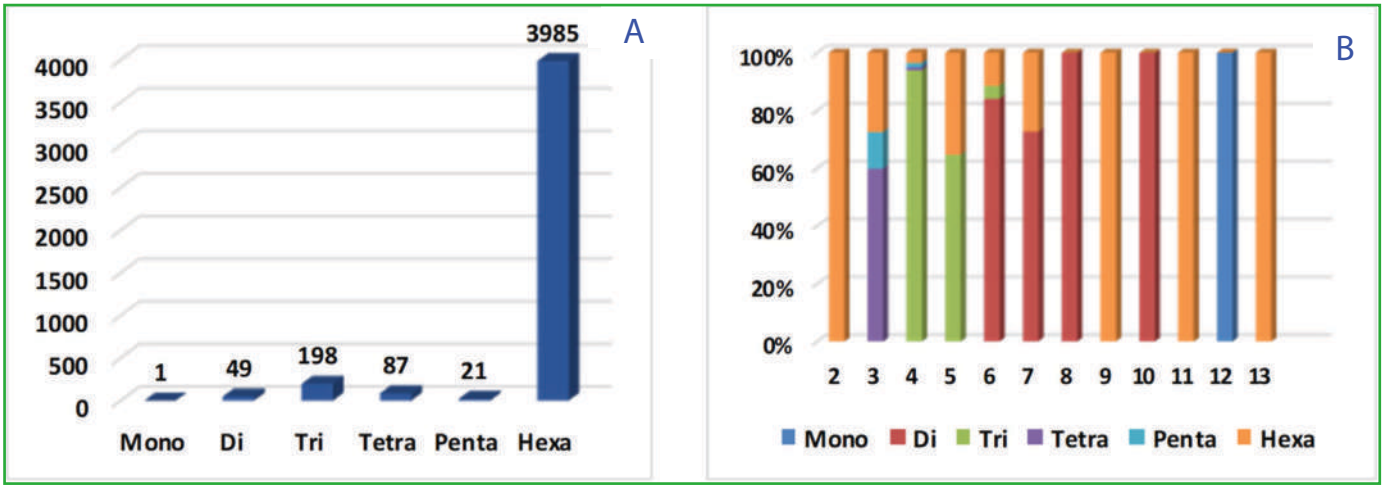


Fig. 26: (A). Contigs with SSR identified (B) Overall distribution frequency of different SSR repeat types in *Xap* genome

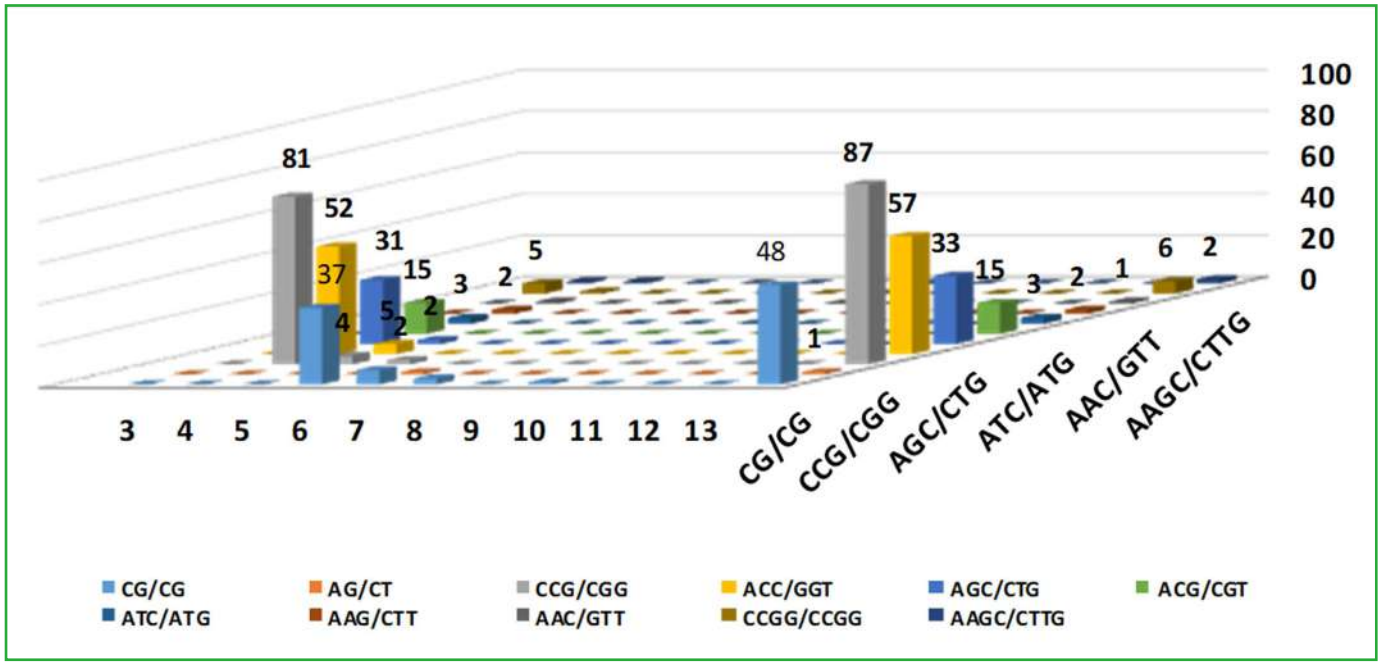


Fig. 27: Frequency distribution of different SSR repeats types and numbers in *Xap* genome

Designing, Validation and Diversity Analysis using Xap_SSR Markers

Using Batch Primer 3 and Krait software, we designed a total of 2746 SSR primers specific to *Xap* genome. The majority of these primers were specific to hexanucleotide motifs (2446, 89.07%), followed by tri- (primers 191, 6.95 %), di and tetra- (47, 1.71%) and penta- (15, 0.55%) repeats, respectively. We randomly selected a sub set of 70 *Xap*_SSRprimers for experimental validation on eight selected isolates. As a result, 60 primers (85.71%) showed clear amplifications and ten primers did not show amplification (Fig. 28a). Further, 20 primers were selected for assaying on 22 *Xap* isolates for molecular diversity analysis (Fig. 28b).

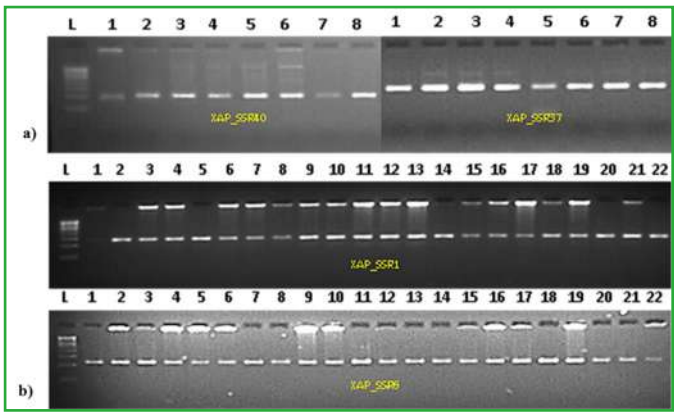


Fig. 28: Gel images showing allelic variations as revealed by XAP_SSR markers a) Assaying primers XAP_SSRs 40 & 37 on 8 *Xap* isolates; b) Assaying XAP_SSR 1 & XAP_SSR63 on 22 Xap isolates

These SSR markers revealed, a total of 40 alleles across 22 isolates with number of effective alleles ranged from 1.11 (XAP_SSR61) to 1.77 (XAP_SSR3) with an average of 1.43 alleles per locus. Shannon's information index (I) ranged from 0.21 (XAP_SSR61) to 0.63 (XAP_SSR3) with mean of 0.46. Based on the PIC values, 12 SSRs (XAP_SSRs 1, 3, 8, 9, 10, 22, 25, 32, 34, 40, 54 and 63) exhibited moderate level of polymorphism(0.5 < PIC >0.25) as depicted in Table 18.

The pooled marker data as obtained for 22 *Xap* isolates were used to construct UPGMA-NJ tree and factorial analysis (Fig. 29 a & b). The NJ tree classified entire isolates into two major clusters, Cluster I comprised 11 *Xap* isolates represented from five different states i.e. Maharashtra (XAP-93, XAP-99, XAP-100, XAP-104 and XAP-106), Karnataka (XAP-112 & XAP-118), Telangana (XAP-94), Himachal Pradesh (XAP-92), Uttar Pradesh (XAP-115) and Rajasthan (XAP-116). Cluster II also comprised 11 isolates mainly from Solapur, Jalna, Ahmednagar and Nashik districts (XAP-105, XAP-103, XAP-125, XAP-120, XAP-107, XAP-114, XAP-102, XAP-101, XAP-96, XAP-98 and XAP-124) of Maharashtra state. Genetic distances based on Jaccards dissimilarity values ranged from 0.14 (between XAP-125 and XAP-103) to 0.75 (XAP-107 and XAP-96) suggested a wide range of diversity (14 to 75 %) among the isolates studied. Further, based on Jaccards dissimilarity values, the 11 *Xap* isolates belonging to CL-I revealed 26-66% genetic diversity, whereas those belonged to CL-II revealed 14-75% diversity. PCoA results corroboted the patterns inferred from the phylogenetic analysis and the first two axes accounted for 33.64 % of the total variability. Our study reconfirmed the earlier findings that wider spread of ST3 sequence type for *Xap* isolates exists across the different states of India i.e. Himachal Pradesh, Rajasthan, Karnataka, Telangana and Maharashtra as reported by using MLST (Aundy Kumar et al., 2019).

Table 18: Marker statistics for twenty XAP_SSRs loci screened on 22 *Xap* isolates

Sl. No	Marker	Na	Ne	MAF	I	PIC
1	XAP_SSR1	2	1.42	0.82	0.47	0.25
2	XAP_SSR3	2	1.77	0.68	0.63	0.34
3	XAP_SSR8	2	1.45	0.81	0.49	0.26
4	XAP_SSR9	2	1.42	0.82	0.47	0.25
5	XAP_SSR10	2	1.66	0.73	0.59	0.32
6	XAP_SSR13	2	1.25	0.89	0.35	0.18
7	XAP_SSR18	2	1.20	0.91	0.31	0.15
8	XAP_SSR22	2	1.54	0.77	0.54	0.29
9	XAP_SSR25	2	1.57	0.76	0.55	0.30
10	XAP_SSR26	2	1.32	0.86	0.41	0.21
11	XAP_SSR32	2	1.66	0.73	0.59	0.32
12	XAP_SSR34	2	1.71	0.71	0.61	0.33
13	XAP_SSR37	2	1.36	0.84	0.44	0.23
14	XAP_SSR40	2	1.42	0.82	0.47	0.25
15	XAP_SSR50	2	1.32	0.86	0.41	0.21
16	XAP_SSR54	2	1.54	0.77	0.54	0.29
17	XAP_SSR57	2	1.20	0.91	0.31	0.15
18	XAP_SSR61	2	1.11	0.95	0.21	0.09
19	XAP_SSR63	2	1.54	0.77	0.54	0.29
20	XAP_SSR70	2	1.20	0.91	0.31	0.15
	Mean	2	1.43	0.82	0.46	0.24

Note * Na-No of alleles, Ne- No of Effective alleles, MAF-Major allele frequency, I- Shannon's information index, PIC-Polymorphism information content

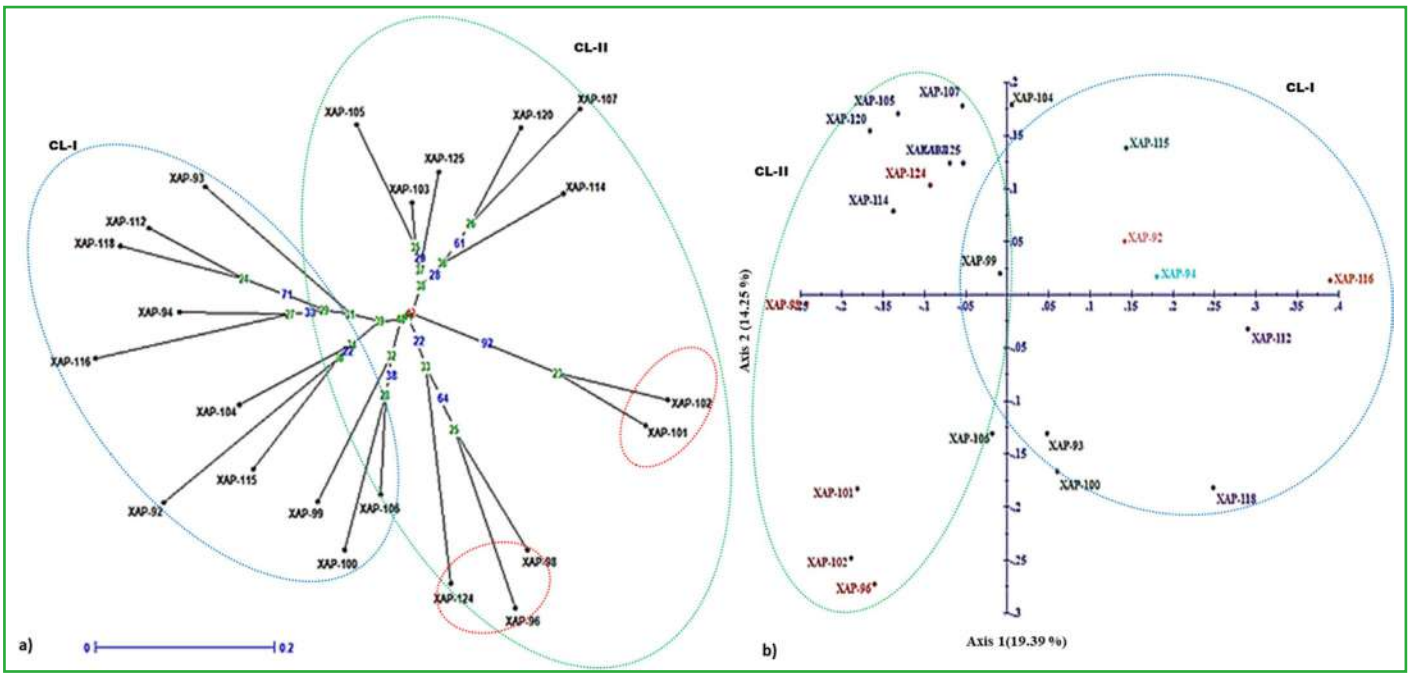


Fig. 29: a) Neighbor joining tree b) PCoA plot of for 22 *Xap* isolates based on SSR data

5.2.6 Demonstration of Modified IDIPM Schedule

Six steps to manage bacterial blight was found to be a most economical, ecofriendly and promising strategy to check bacterial blight up to 80-100% in orchards facing above 50 to 100% losses in rainy season (Kharif) crop. At ICAR-NRCP one organic block of pomegranate cv. Bhagawa near the campus boundary and pomegranate germplasm was severely affected with bacterial blight in the previous (2018) year with 85% blight incidence as being organic block recommended chemical sprays could not be taken and had to be discontinued. In the year 2019 the below mentioned 6 step strategy was followed and got 100% blight free produce. The strategy involved (i) pruning and application of recommended organics, bio-formulations and fertilizers soon after harvest in December 2018 last week (ii) irrigating the crop for 3 months till March 2019 and taking sprays of 1% Bordeaux mixture every 10-12 days (iii) stopping irrigation for 2 months (April-May 2019) and putting the crop on stress for complete defoliation (iv) allowing exposure of the defoliated naked stems to sun radiation for 20 days till June 20, 2019 (v) light pruning of upper 10-15 cm stems (vi) applied recommended manures, bio-formulations and fertilizer and applied first irrigation on June 22, 2019 for taking rainy season crop. Hundred percent blight free crop with good fruit quality was harvested on Jan 02, 2020.

The schedule was also recommended to 3 farmers (2 at taluka Akalkot, district Solapur and 1 at taluka Man, district Satara, Maharashtra) each having 4-5 acres area under pomegranate and facing more than 70% losses due to bacterial blight, all reported complete check of bacterial blight. One farmer Mr. Shashidhair Gadeppa Hatture, PO Nagansur, tal. Akkalkot, Dist. Solapur (MH) having 5 acre of pomegranate plantation faced severe losses due to blight in previous year. He lost 75% fruit yield due to bacterial blight and got 21t yield in 5 acre at input cost of 2,40,000/-. NRCP staff visited his orchard and advised the 6 steps for blight management. After following the 6 steps, he got 100% blight free produce of 85 t in 5 acre, at input cost of only Rs.1,80,000/-. Thus he increased yield by 305 % and saved Rs 60,000/- (25%) on cost.

Bacterial blight affected orchard in previous year

Fig. 30: Produce of organic block at Kegaon, Solapur after following modified IDIPM

Another field demonstration for bacterial blight management was conducted in the farmers field of Mr. Srennivas, Gonur, talkua Devanahally, Bengaluru. Having 6 acres (1800 plants) area under pomegranate and affected with bacterial blight. In addition to the IDIPM schedule, biological consortia developed by UHS Bagalkot and NRCP were also used. These were consortia of *Trichoderma harzianum* + *Pseudomonas putida* + *Paecilomyces lilacinus* + N-fixing bacteria + chitosan 0.2% developed by UHS Bagalkot and *Penicilium pinophilum formulation developed by ICAR-NRCP*, Solapur applied in soil with FYM and prophylactic sprays of Darakshaka (bio-formulaiton developed using *Pseudomonas putida* + *chitosan*+ *pongamia oil)* recorded the additional yield of 18% compared to untreated plants and 75.8% reduction in bacterial blight infection and total yield of 13.5MT/ acre was recorded. The adjacent plot farmer following his own practices completely lost crop due to bacterial blight.

* * * * * * * *

Post-harvest Management and Value Addition

6.1 Project: Post-harvest Management and Value Addition in Pomegranate for Entrepreneurship Development

6.1.1 Active Modified Atmospheric Packaging (MAP) of Pomegranate Arils

The minimally processed or "ready-to-eat" pomegranate arils are more popular due to their convenience, high value, unique sensory characteristics and health benefits. However, low shelf life of pomegranate arils due to susceptibility to deterioration becomes biggest impediment in popularization of fresh aril consumption. Therefore, MAP combined with low temperature storage has been successfully used to prolong the shelf life in many fruits and vegetables. MAP of fresh produce is done in the suitable packaging materials usually in punnets and is mainly depending on respiration rate (RR) of the produce. Active MAP involves flushing of appropriate quantity of oxygen, carbon dioxide and nitrogen gas mixtures into the package before sealing. The suitable equilibrium atmospheres are achieved by proper matching of fresh produce RR and film permeability characteristics. The objective of this study was to ascertain the effect of different gaseous mixtures (O_2, CO_2 and N_2) on quality of pomegranate arils during storage.

Determination of Respiration Rate of Arils

The rate of oxygen consumption (RO_2) and carbon dioxide production (RCO_2) of fresh arils were measured using the closed system method. Air-tight glass jars with a lid containing a rubber septum in the middle were used to store the samples. The pomegranate peel was separated manually and carefully to avoid physical damage to the arils. Total 150 g of fresh aril samples were placed inside the glass jars (842 mL) and were equilibrated at 5°C for at least 1 hour prior to the experiments. To ensure hermetic sealing of jars, the petroleum jelly was applied in between lid and glass jar followed by parafilm coating was done. The gas composition within the glass jars was monitored over time with an O_2/CO_2 gas analyzer. Gas samples were taken at an hourly time intervals from the jar head space through the rubber septum. Then glass jars were slightly opened overnight to minimize rapid moisture loss and also to avoid built-up of sub-atmospheric gases. After overnight storage, the jars were once again closed hermetically, and gas samples were taken. This cycle was repeated for 5 day storage period and no microbial infection or decay was observed over this period. Finally, RO_2 and RCO_2 were determined from experimentally obtained data on yO_2 and yCO_2 and putting that in Eqn. 1 and 2, respectively.

$yO_2 = y'O_2 - RO_2W/Vf. (t-ti) \times 100$ (1)

$yCO_2 = y'CO_2 + RCO_2W/Vf. (t-ti) \times 100$ (2)

Where,

$y'O_2$= O_2 concentration (%) at the initial time ti (hours, h)

yO_2= O_2 concentration (%) at time t (h)

$y'CO_2$= CO_2 concentration (%) at the initial time ti (hours, h)

yCO_2= CO_2 concentration (%) at time t (h)

W = total weight of the product (kg)

Vf = free volume inside the glass jar (mL)

RO_2 and RCO_2 are respiration rate in (ml kg^{-1} h^{-1}).

Table 1: O_2, CO_2 content and respiration rate of pomegranate arils

Days	Time (h)	0	1	2	3	4	5
Ist	O_2	20.3	20.2	20.1	20.0	19.5	19.9
	CO_2	0.80	0.90	1.00	1.10	1.25	1.40
	RO_2	0.00	4.69	4.69	4.69	9.37	3.75
	RCO_2	0.00	4.69	4.69	4.69	5.27	5.62
IInd	O_2	20.8	20.7	20.6	20.6	20.5	20.4
	CO_2	0.20	0.30	0.30	0.40	0.50	0.50
	RO_2	0.00	4.69	4.69	3.12	3.52	3.75
	RCO_2	0.00	4.69	2.34	3.12	3.52	3.75
IIIrd	O_2	20.9	20.7	20.6	20.6	20.5	20.6
	CO_2	0.20	0.30	0.30	0.40	0.50	0.50
	RO_2	0.00	9.37	7.03	4.69	4.69	2.81
	RCO_2	0.00	4.69	2.34	3.12	3.52	2.81
IVth	O_2	20.9	20.7	20.7	20.6	20.5	20.5
	CO_2	0.20	0.30	0.30	0.40	0.40	0.50
	RO_2	0.00	9.37	4.69	4.69	4.69	3.75
	RCO_2	0.00	4.69	4.69	3.12	3.52	2.81
Vth	O_2	20.9	20.8	20.7	20.6	20.4	20.2
	CO_2	0.20	0.30	0.40	0.40	0.50	0.50
	RO_2	0.00	4.69	4.69	4.69	5.86	6.56
	RCO_2	0.00	4.69	4.69	4.69	3.52	3.75

Table 2: Average values of RO_2 and RCO_2 for arils

Days	1	2	3	4	5
RO_2	5.436	3.952	5.717	5.436	5.295
RCO_2	4.991	3.296	3.296	3.764	4.264

The average O_2 consumption (RO_2) and CO_2 production (RCO_2) of pomegranate fresh arils was shown in Table 1 & 2. The RO_2 and RCO_2 varied in the range of 3.95 to 5.43 and 3.29 to 4.99, respectively.

6.1.2 Minimal Processing and Packaging of Arils

The pomegranate fruits, which are harvested and stored at 5°C in the cold storage were removed, washed and mopped for surface moisture removal. Then, fresh arils were extracted manually at low temperature, weighed and packed in punnets by sealing its top with peelable polylaminate film. An experiment was conducted with five different treatment combinations i.e. T1-Air, T2-

100% N_2, T3-20% O_2 + 10% CO_2 + 70% N_2, T4-30% O_2 + 10% CO_2 + 60% N_2, T5-40% O_2 + 10% CO_2 + 50% N_2. After imposing these treatments all the punnets were sealed with composite film and stored at 5°C. The physicochemical, microbial, and sensory parameters were evaluated at 0, 5, 10, 15, and 18th days after storage for understanding the best packaging atmosphere for arils.

O_2 Content in Different Treatments During Storage

The oxygen content in the punnets as measured during storage duration is depicted in Fig. 1. Results indicated that in all the treatments O_2 content of punnets tries to be in equilibrium with the atmospheric O_2. In case of treatment T4, the equilibrium was reached on the second day followed by T5, T3, T1 and T2. However, the results of O_2 content were not noted for T1 and T2 as the samples were got rejected on 10th day.

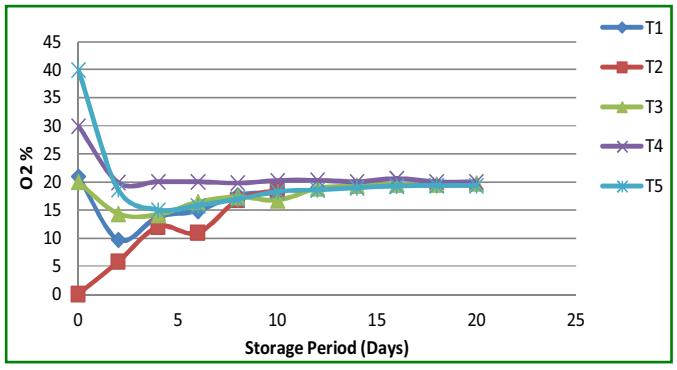


Fig. 1: O_2 content (% O_2) of pomegranate arils at 5°C

CO_2 Content in Different Treatments During Storage

The carbon dioxide content in the punnets as measured during storage duration is depicted in Fig. 2. Results depicted that in all the treatments CO_2 content of punnets tries to be in equilibrium with the atmospheric CO_2. In case of treatment T4, the equilibrium was reached on the 12th day followed by T5, T3, T1 and T2. However, the results of CO_2 content were not noted for T1 and T2 as the samples were got rejected on 10th day.

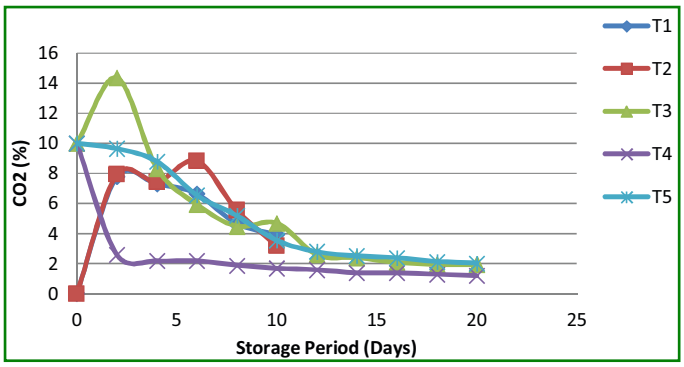


Fig. 2: CO_2 content (% CO_2) of pomegranate arils at 5°C

Total Soluble Solids (TSS)

It is an important parameter in the storage of minimally processed and packaged arils. General trend suggests decrease in TSS for all the treatment combinations (Fig. 3). Further, it was interesting to note that the TSS has decreased gradually from 17.06 to 13.8, 15.96 and 15.66 degree Brix for the T3, T4 and T5, respectively on 18th day of storage. It was also evident that the decline in TSS was restricted to 15.96 in case of T4 followed by T5 and T3.

Acidity

The decrease in acidity percentage was observed in all the treatment combinations from 0th day to18th day of storage (Fig. 4). Acidity has been declined from initial 0.23 to 0.08, 0.13 and 0.11 percentages, respectively for the T3, T4 and T5. Aril taste is mainly the combination of sugars and acids. It has been suggested that, decrease in arils titrable acidity is the result of breakdown of acids to sugars during respiration.

pH

The pH of the arils during storage for different treatment combinations showed increasing trend (Fig.5). It was observed, pH increased from 3.11 to up to 5.03, 4.23 and 4.33 for the T3, T4 and T5, respectively on 18th day of storage.

Texture

The texture of an aril is known to be affected by the gas composition. Texture is nothing but force required to rupture the aril. We noticed decreasing trend for

aril texture during the storage from 13.33 N on 0th day of storage (Fig. 6). The highest arils firmness was maintained in T4 (11N) and T5 (10.5N). Whereas, T3, T4 and T5 had significant difference for arils texture on 15th and 18th day of storage. The maintenance of highest arils firmness in T4 and T5 treatments suggested perceived crunchiness of these arils during eating. This might be correlated to quicker attainment of equilibrium conditions in T4 and T5 as compared to other treatments

Total Phenols

Total phenols showed decreasing trend in all the treatment combinations over the period of storage (Fig.7). The gaseous combination in T4 (1710 mg/100g of GAE) has shown maximum retention of phenolic content followed by T5 (1674 mg/100g of GAE) and T3 (1321 mg/100g of GAE) from initial value of 2789 mg/100g of GAE. We observed significant difference in total phenols in all the treatment combinations during the storage period.

Total Anthocyanin

Total anthocyanin content has been reduced in all the treatment combinations from 29.01 mg/100g of cynidine during storage period (Fig. 8). The differences

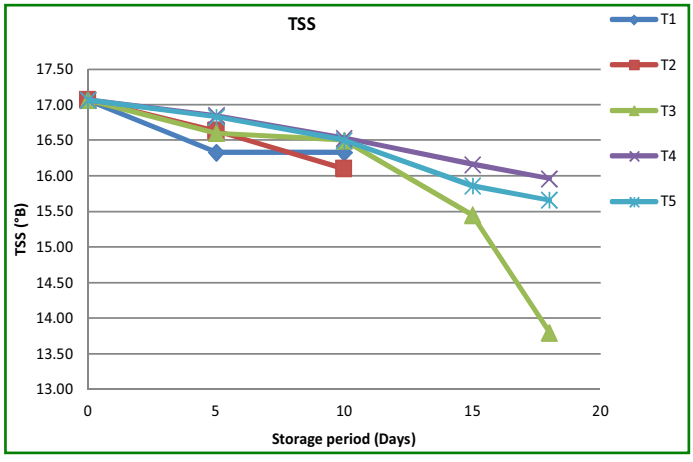


Fig. 3: Effect of MAP on TSS of pomegranate arils during storage

in total anthocyanin for different treatments were non-significant up to 5th day and were found significant thereafter. The highest retention of total anthocyanin was observed in T4 (16.99 mg/100g of cynidine), followed by T5 (13.43 mg/100g of cynidine) and T3 (11.90 mg/100g of cynidine).

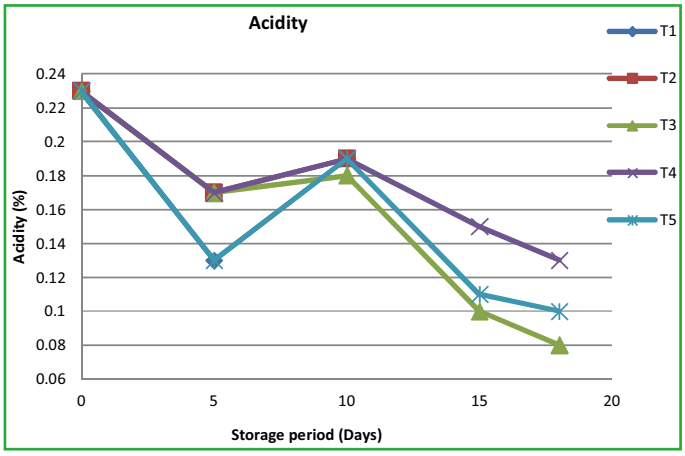


Fig. 4: Effect of MAP on acidity of pomegranate arils during storage

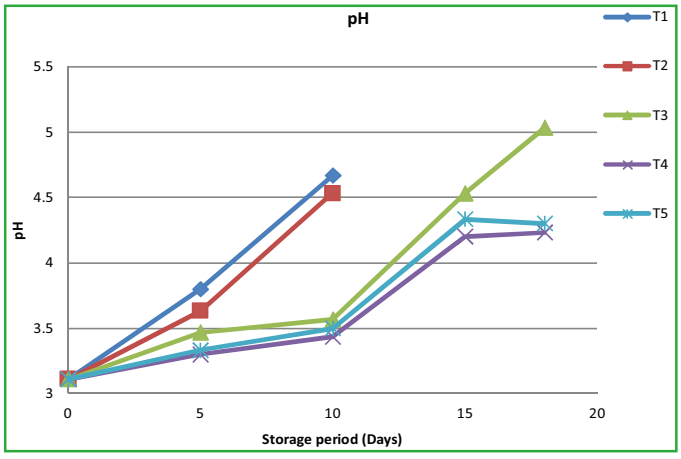


Fig. 5: Effect of MAP on pH of pomegranate arils during storage

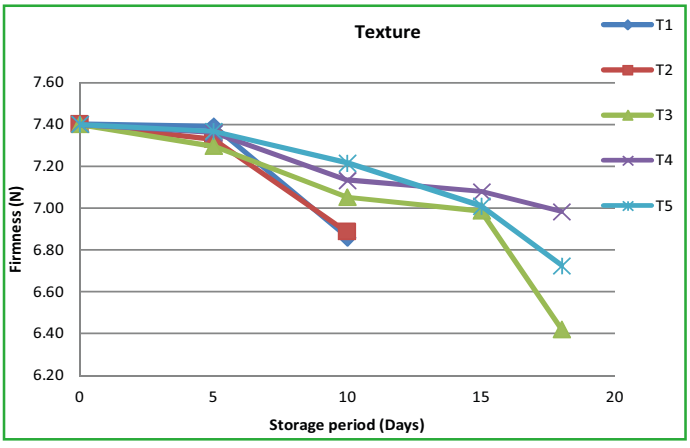


Fig. 6: Effect of MAP on texture of pomegranate arils during storage

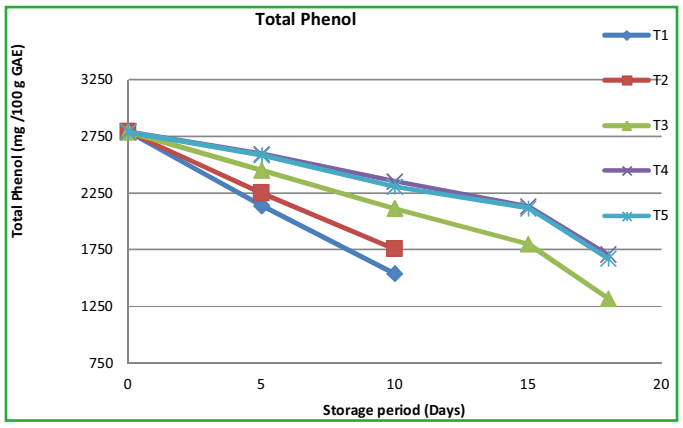


Fig. 7: Effect of MAP on total phenols of pomegranate arils during storage

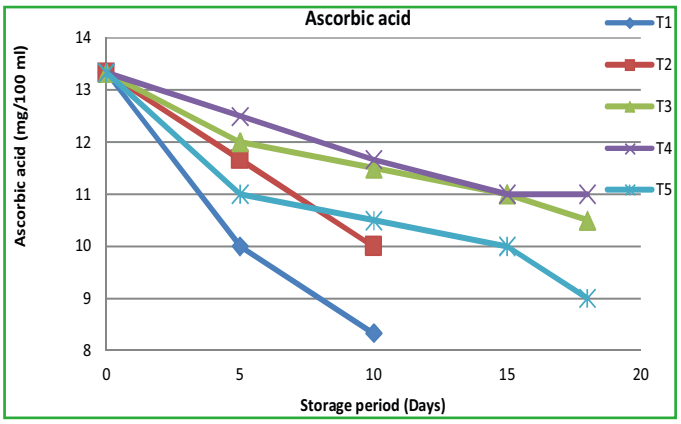


Fig. 10: Effect of MAP on ascorbic acid of pomegranate arils during storage

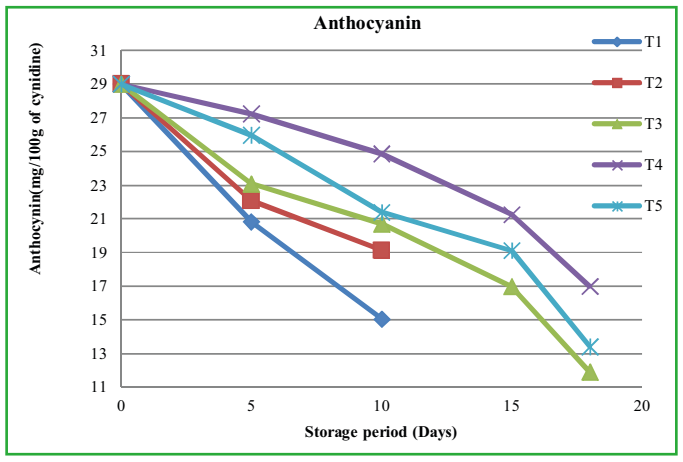


Fig. 8: Effect of MAP on total anthocyanin of pomegranate arils during storage

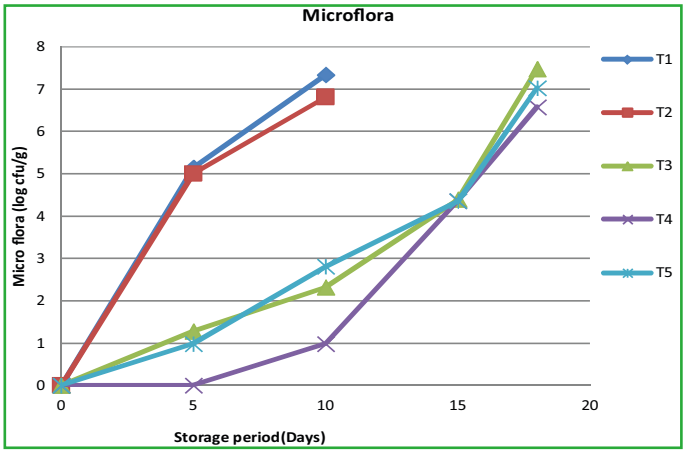


Fig. 11: Effect of MAP on Microflora of pomegranate arils during storage

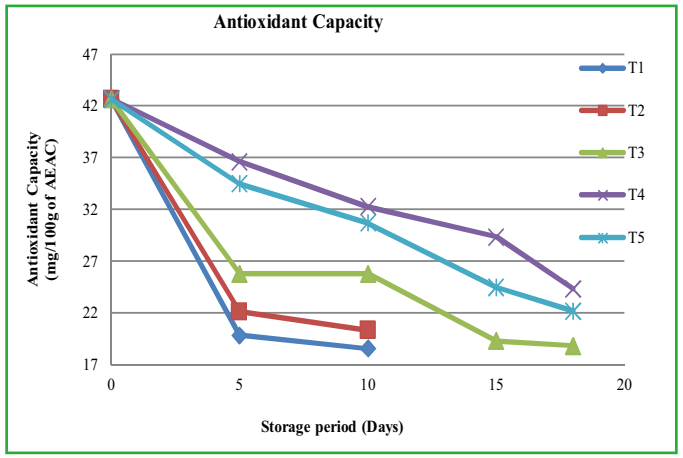


Fig. 9: Effect of MAP on antioxidant capacity of pomegranate arils during storage

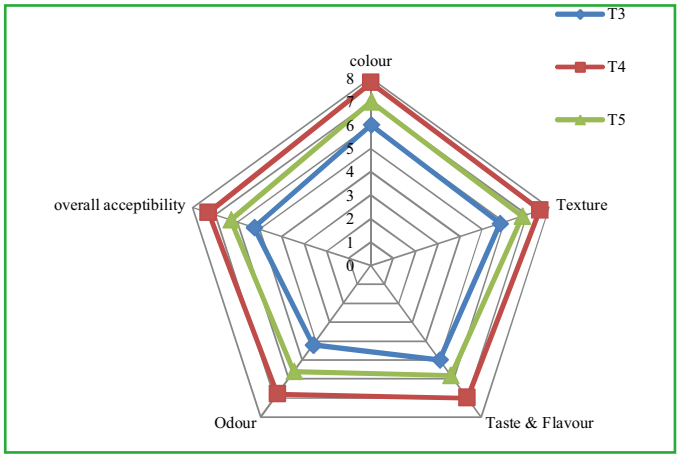


Fig. 12: Radar plot for sensory score of arils with different treatments on 18th day of storage

Antioxidant Capacity

The antioxidant capacity of pomegranate arils is due to presence of phenols, anthocyanin and ascorbic acid. During storage we found decrease in antioxidant capacity for all the treatments from initial 42.67 mg/100g of AEAC (Fig.9). The maximum retention was observed in T4, followed by T5 and T3. However, the significant difference in antioxidant capacity for different treatment combinations was observed from 5th day onwards during storage.

Ascorbic Acid

The steady decrease in ascorbic acid content has been witnessed in all the treatment combinations during storage from initial value of 13.33 mg/100 ml (Fig.10). All the treatment combinations were found non-significant up to 10th day of storage. However, significant treatment differences were observed on 15th and 18th day of storage. The highest retention of ascorbic acid content was found in T4, followed by T3 and T5.

Microflora

It is the total microbial count that includes aerobic count, yeast and mold count. When maximum total plate count of 7 log CFU/g (Spanish legislation) was reached the experiments was stopped considering this count as a best shelf life indicator. We observed increasing trends for total microbial count per gram of arils during storage in all the treatments (Fig. 11). The treatments T1 and T2 showed higher total microbial count on the 10th day of storage resulting in ceasing of experiment for those samples. However, the acceptable total microbial counts limit was not surpassed even up to 18 days in T4, and up to 15 days in T5 and T3. Suggesting, higher oxygen conditions were found to be better suited for pomegranate arils packaging during storage.

Sensory Evaluation

The sensory acceptability of food product is the ultimate test that brings acceptability and success to the product. Sensory evaluation by the trained panelist on nine points hedonic scale has shown sensory score for arils was highest on 18th day of storage in T4 and T5 (Fig. 12).

It has been concluded from these experiments that the pomegranate arils can be stored safely up to 18 days in higher oxygen environment if all these important hygienic practices are followed during processing, packaging and storage of pomegranate arils.

6.1.3 Determination of Maturity Indices for Pomegranate Variety Solapur Lal

To determine the maturity indices for harvesting of pomegranate var. Solapur Lal, the flowers were tagged on the day of anthesis. The fruit samples were collected after fruitset an an interval of 15 days. Once maturity is approached, the samples were collected at 5 days interval to fix up the appropriate maturity indices for harvesting. Solapur Lal attained maturity at 160 days after anthesis with highest total soluble solids content (17.6°Brix).

Table 3: Maturity indices for pomegranate variety Solapur Lal

Stage of fruit development (Days after anthesis)	Fruit weight (g)	TSS (°B)	Titrable acidity (%)	TSS/Acid ratio
90 days	170.4	13.1	0.58	22.6
105 days	197.6	14.3	0.51	28.0
120 days	221.4	15.2	0.48	31.7
135 days	243.2	16.1	0.45	35.8
150 days	262.6	16.9	0.42	40.2
160 days	271.0	17.6	0.40	44.0
165 days	271.6	17.6	0.40	44.0

6.1.4 Determination of Anardana Recovery

Anardana is the dried form of arils (the edible parts of pomegranate). It is obtained by drying the arils of pomegranate in the hot air oven with air circulation facility. It is useful as souring agent. Assessment of anardana recovery from ten sour type pomegranate hybrids was undertaken. The results revealed that anardana recovery ranged from17.5 – 22.1%. Anardana recovery was highest in Solapur Anardana (22.1%) closely followed by NRCP H-4 (21.0%). The recovery was lowest in Amlidana (17.5%).

Table 4: Anardana recovery from pomegranate hybrids

S.No.	Variety/ Hybrid	Anardana Recovery from airls (%)
1	NRCP H-1	19.4
3	NRCP H-3	19.2
4	NRCP H-4	21.0
5	NRCP H-11	20.4
6	NRCP H-12 (Solapur Anardana)	22.1
7	NRCP H-15	20.8
8	6/4	19.8
9	6/5	18.6
10	Hybrid A	20.6
11	Amlidana	17.5

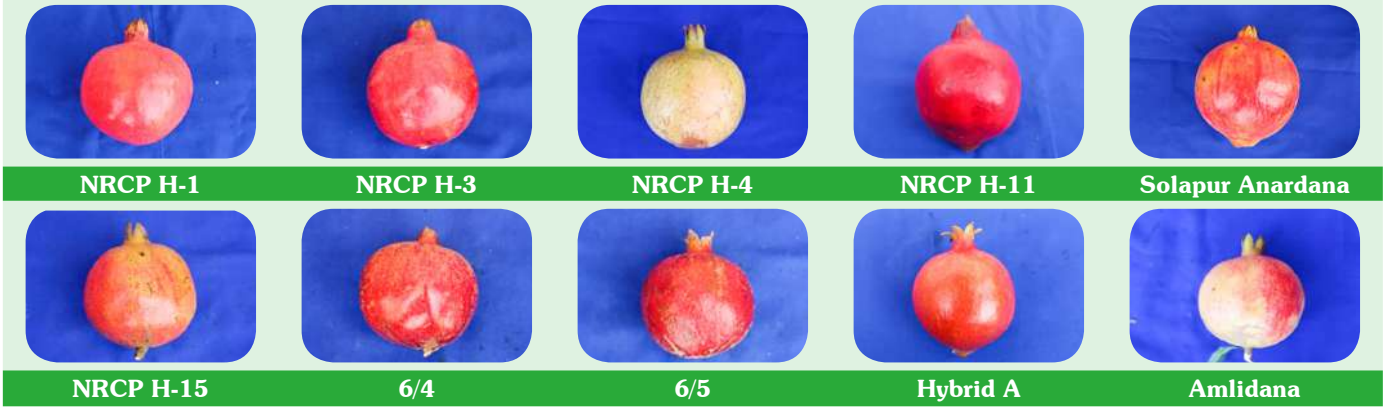


Fig. 13: Fruits from sour type pomegranate hybrids

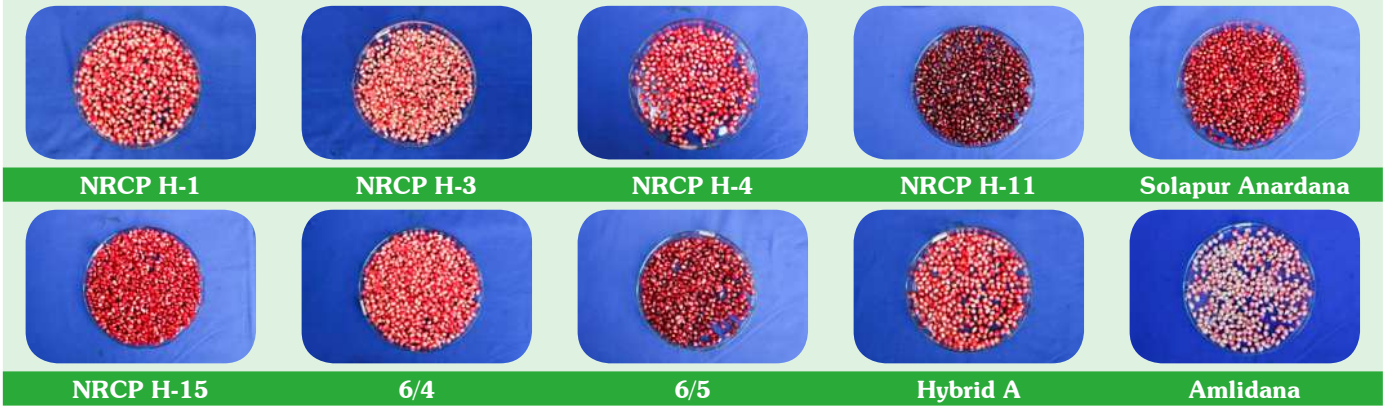


Fig. 14: Arils from sour type pomegranate hybrids

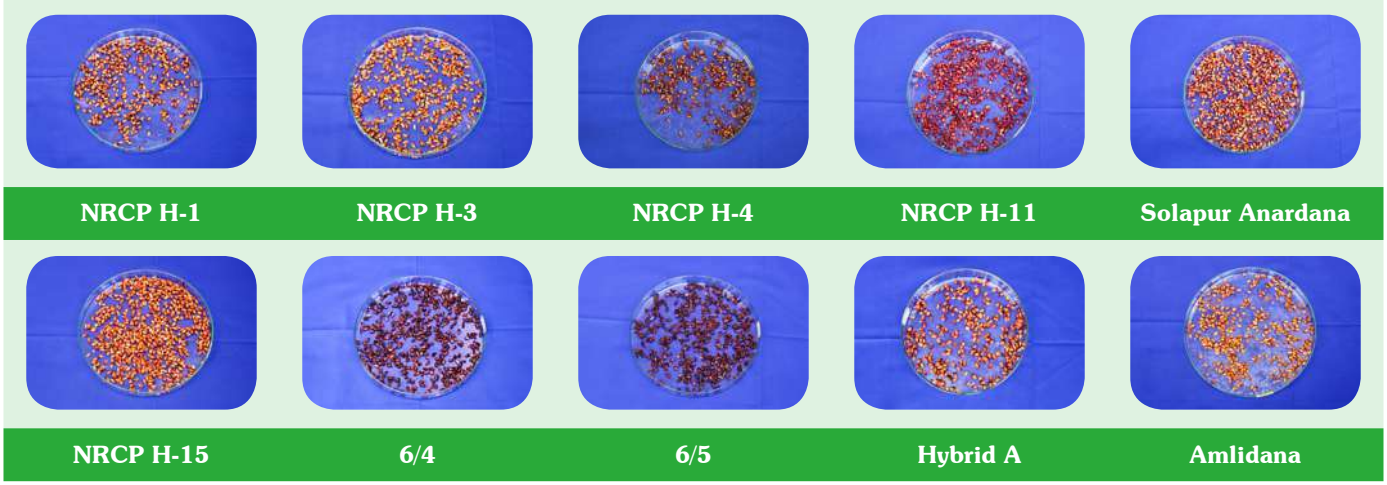


Fig. 15: Anardana obtained from sour type pomegranate hybrids

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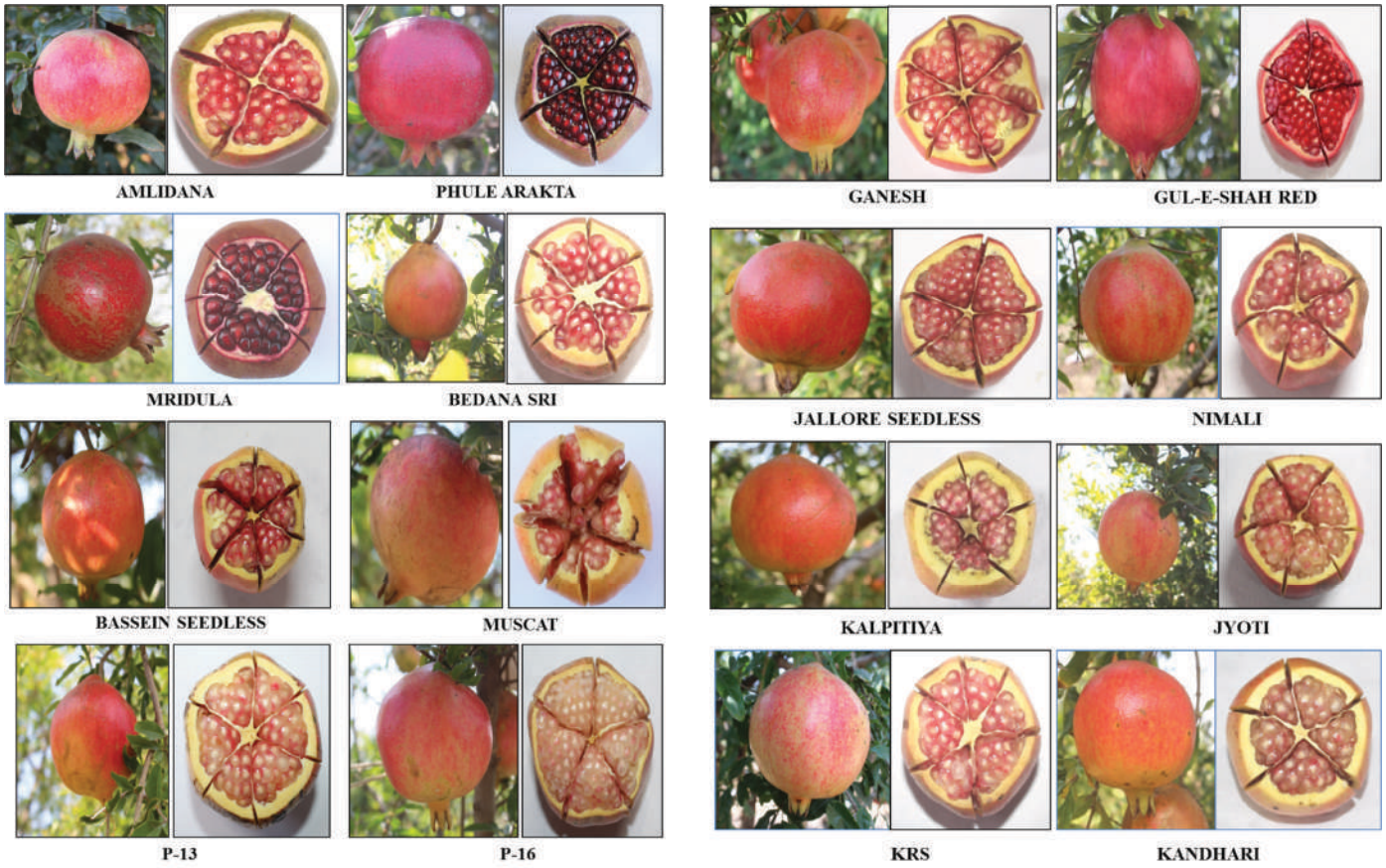
Externally Funded/ Collaborative Projects

7.1 Project: Establishment of Dus Centre on Pomegranate at ICAR- NRCP, Solapur

During first year on-site DUS testing of two new NRCP hybrid varieties i.e. NRCPH-4 and NRCPH-14 was carried out on 11th February, 2020 at ICAR-NRCP, Solapur **(Fig. 1).** Apart from this, 25 pomegranate reference varieties were also characterized for 35 DUS characters as per the PPV&FRA guidelines **(Fig. 2).** Among the varieties, 'Bhagawa' was found late maturing and 'Kabul yellow' as early maturing variety. For DUS testing, the varieties like Bassein seedless, Kabul Yellow and Yercaud-1 have showed tall with spreading growth habit; while Gul-e-Shah red variety showed upright growth habit. The longer leaf blade was recorded for the most of varieties (23), while medium length was observed in Ruby and Amlidana. With respect to leaf blade and leaf apex shapes, most of the varieties showed lanceolate and obtuse type, while 'Ruby' showed broad elliptic leaf with obtuse apex. Further, the high anthocyanin coloration in petiole was noted in Gul-e-Shah red variety. The medium calyx width was recorded in all the genotypes and 'Dholka' variety showed longer calyx. Further with respect to flower colour, red coloured calyx and corolla was observed in Bhagawa, Ruby, Gul-e-Shah red varieties; while Phule Arakta and Mridula varieties showed dark red coloured calyx with red corolla. Whereas, Kabul yellow variety showed unique flower colour having yellow calyx with white corolla. For corolla type, all the varieties showed single type of corolla. With respect to fruit traits, Ganesh, Bassein seedless, P-13, Kandhari, Jyoti, G-137, KRS, Bedana Sri, Muscat, Jallore Seedless, P-16, P-26, P-23, Dholka and Nimali varieties showed longer fruit length. For fruit diameter all the varieties showed larger dimeter except Amlidana and Gul-e-Shah red. The varieties like Bedana Sri, P-16, P-26 and Dholka showed oval shaped fruits, while in other accessions revealed ovate shape. The red coloured fruits with red arils were noticed in Bhagawa, Ruby and Gul-e-Shah red varieties; while deep red fruits with dark red arils were observed in Phule Arakta and Mridula varieties. Whereas, 'Kabul yellow' variety reflected yellow fruits with light yellow arils. With respect to rind thickness, Phule Arakta, Mridula, Ruby, Amlidana, Co-white, P-16, P-26 and Yercaud-1 showed thin rind. The prominent crown necks were observed in all the accessions. The 'Amlidana' showed shortest aril length and P-13 and G-137 showed broad aril size. With respect to seed hardness, Bhagawa, Ganesh, Phule Arakta, Mridula, Bassein seedless, P-13, Ruby, Kandhari, Jyoti, G-137, KRS, Muscat, Jallore Seedless, P-16, P-26, P-23, Dholka and Nimali showed soft seeds. Medium seed length was observed in all the varieties analyzed. However, narrow seed

width was noted in Ganesh, Phule Arakta, Mridula, Ruby, Kandhari, Jyoti, Jallore Seedless and P-26. The highest TSS (^{0}Brix) was recorded in Ganesh, Bassein seedless, P-13, Kandhari, Jyoti, G-137, KRS, Bedana Sri, Co-white, Muscat, Jallore Seedless, P-16, Dholka and Yercaud-1. The lower juice acidity percentage was found in all the accessions except Amlidana and Gul-e-Shah red showing higher acidity (%). However, the fruit juiciness percentage was medium in all the accessions evaluated.

Fig. 1: On-site DUS testing of new pomegranate hybrid varieties (NRCP H-4 and NRCP H-14) at ICAR-NRCP, Solapur



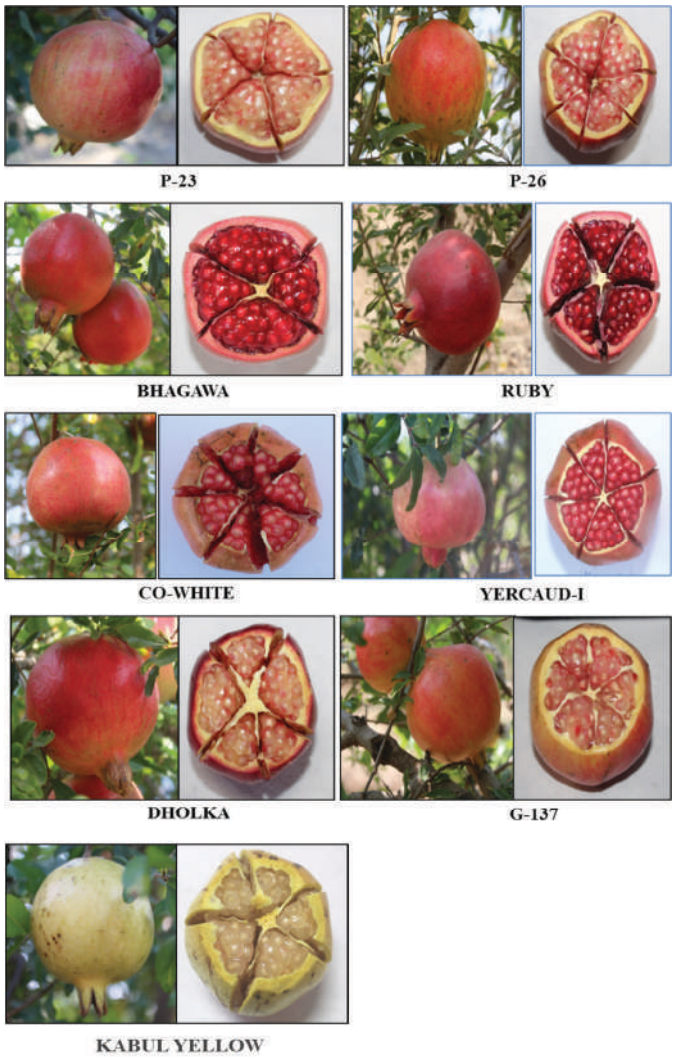


Fig. 2: DUS Characterization of 25 Pomegranate Reference Varieties Maintained at ICAR-NRCP, Solapur

7.2. Project: Standardization and Demonstration of Production Technology for Protected Cultivation of Pomegranate (*Punica Granatum* L.)

Field experiment was conducted during Jan, 2019 - Dec, 2019 on light texture soil at ICAR-NRCP, Solapur in the Western Part of Maharashtra to assess the growth performance under 35 %, 50 % shade net house and open field conditions. The areas under each shade net house and open field are 40 m x 20 m, 50 m x 100 m, respectively. The plant to plant and row to row spacing of 2.0 x 2.0 m for plants under shade net house and 4.5 x 3.0 m for open field conditions was maintained. Fertigation and crop protection measures were adopted as per the package of cultivation practices. The varieties of pomegranate *i.e.* 'Ganesh', 'Arakta', 'Mridula' under 50 % shadenet house and Super 'Bhagawa', 'Bhagawa', 'Solapur Lal' under 35 % shadenet house were planted in 2018.

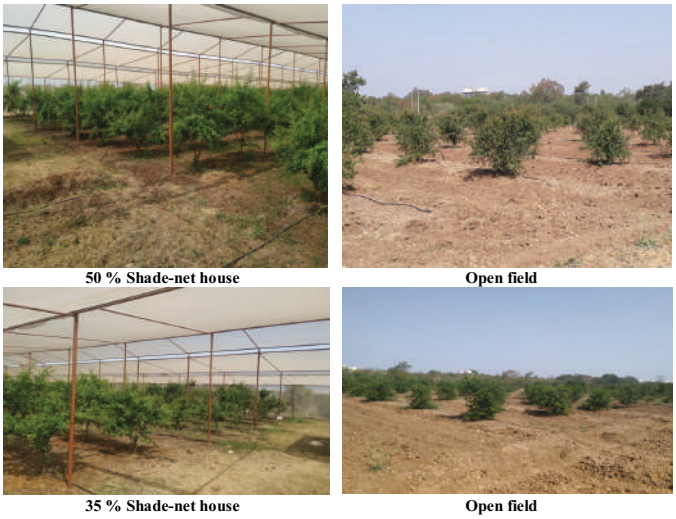


Fig. 3: Plant growing under shade-net house and open conditions

Water Requirement of Plants Grown under Shade-Net House Conditions

The daily water to be applied through drip irrigation system from Jan, 2019 to Dec, 2019 ranged from 1.5–30.4 $Ld^{-1}tree^{-1}$ for two years old pomegranate trees at 0.40*ET_r. It gradually increases or decreases during different periods of the years and different developmental stages of the pomegranate trees due to variations in the reference crop evapotranspiration, pan coefficient, wetted area and crop coefficient values. Lower Kc values represent slower plant growth and lower plant canopy cover, indicating lower ET_p. The irrigation water to be applied to pomegranate under shade net house and open field conditions were estimated as 650 and 6193 L $tree^{-1}season^{-1}$.

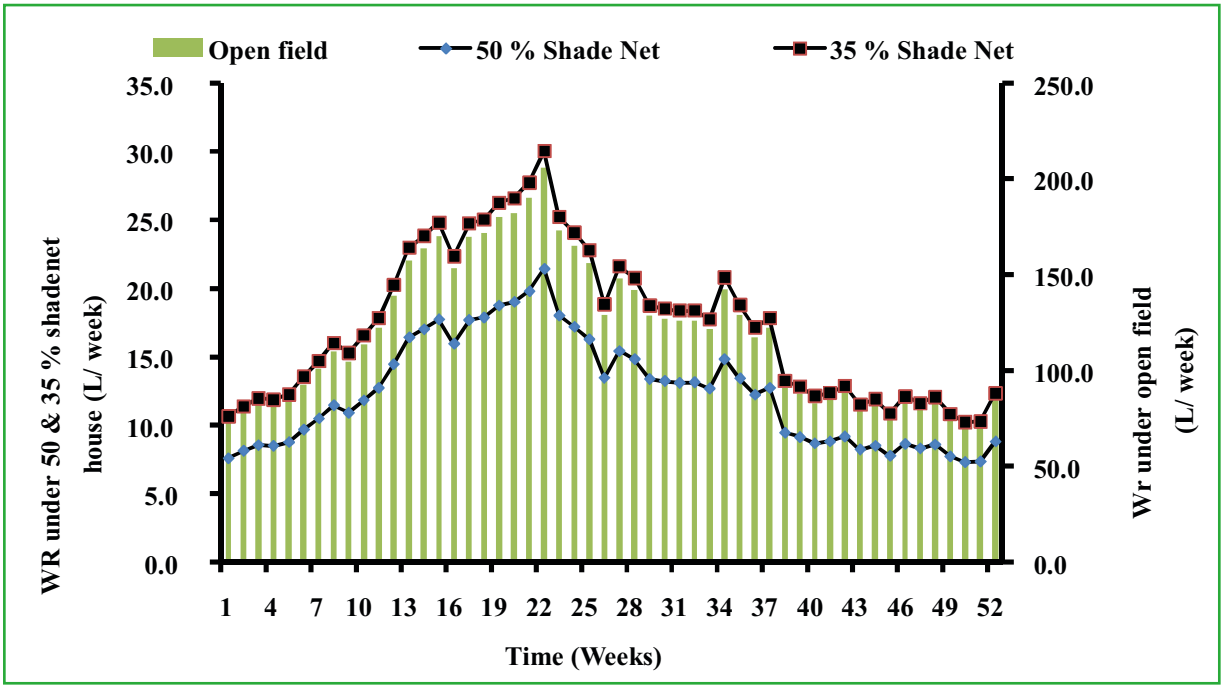


Fig. 4: Water requirement of plant under open field and shade net house (*i.e.* 35 % & 50 %)

Table 1: Vegetative growth of pomegranate varieties under shade net house condition

Varieties	50 % shade-net house condition		
	Plant height (cm)	Canopy spread E-W (cm)	Canopy spread N-S (cm)
Ganesh	136.166	161.666	169.250
Mridula	152.166	171.416	187.166
Arakta	103.833	109.166	117.250
	35 % shade-net house condition		
Super Bhagawa	185.536	169.524	179.139
Bhagawa	143.968	136.349	153.254
Solapur Lal	204.921	157.413	177.937

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

A field experiment was conducted during Jan, 2019 - Dec, 2019 in pomegranate orchard planted on light textured soil at National Research Center on Pomegranate, Solapur (latitude 17° 10', longitude 74°42'and 483.5 m above msl) in the Western Part of Maharashtra to assess the effect of deficit and partial root zone drying irrigation system on growth and yield at different phenological stages (*i.e.* new leaf initiation, development, maturity and harvesting period) of pomegranate cv. Bhagawa. Plants were planted at spacing of 4.5 X 2.0 m, 4.5 X 3.0 m and 4.5 X 4.0 m.

(a) (b) (c)

Fig. 5: Planting of pomegranate at different spacing (a) 4.5 m x 2.0 m (b) 4.5 m x 3.0 m (c) 4.5 m x 4.0 m

7.3.1 Effect of DI on Vegetative Growth Performance

The result showed that, the performance evaluation of DI systems at 70 % irrigation level is the best for 7th year's old age pomegranate orchards. DI reduced moisture content and maximum plant height, LAI and plant spread is recorded in having wetted soil volume (WSV) at 80 %.

Table 2: Effect of deficit irrigation on growths characteristics of seven years old pomegranate trees

Treatments	Plant height (cm)	LAI (m^2/ m^2)	Plant spread(cm)	
			E-W	N-S
Irrigation Level				
I1*60%	164.20	1.94	1.36	1.35
I2*70%	166.00	2.15	1.39	1.38
I3*80%	168.00	2.57	1.41	1.42
I4*90%	170.00	2.51	1.40	1.38
I5*100%	177.30	2.18	1.39	1.40

7.3.2 Effect of DI on Soil Moisture and Relative Leaf Water Content

The performance evaluation of **DI** systems reduced soil moisture content and relative leaf water content (%). The moisture content and relative leaf water content in % age at various phenological stages varies between 20.15 to 45.25 and 65.40 to 83.55 %, respectively.

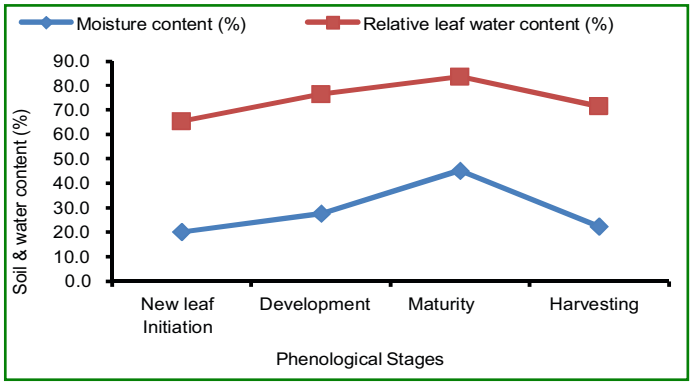


Fig. 6: Soil moisture and relative leaf water content

7.3.3 Effect of DI on Yield and Water Use Efficiency

The results revealed that pomegranate plants responded differently to different quantities of water applied through drip irrigation w.r.t yield**.** The best irrigation level recorded the mean yield of 18.95 kg $tree^{-1}$ at 80 per cent irrigation level for seven years old pomegranate trees. Irrigation level at 80 per cent recorded better number of fruits, weight of fruits and yield because of optimum and consistent moisture regime. As regard to best deficit irrigation level, maximum water use efficiency was 3.74 kg m^{-3} at 80 per cent.

Table 3: Effect of deficit irrigation on yield and water use efficiency of seven years old pomegranate tree

Treatments	No. of Fruits	Fruit weight (g)	Yield (kg)	WU (m^3)	WUE (Kg m^{-3})
I_1*60%	32.20	265.50	8.65	3.38	2.60
I_2*70%	38.30	271.70	10.40	4.22	2.46
I_3*80%	60.50	313.30	18.95	5.07	3.74
I_4*90%	52.20	301.50	15.73	5.91	2.66
I_5*100%	50.80	298.25	15.15	6.75	2.44

(*Note*: I_1-60, I_2-70, I_3-80, I_4-90 and I_5-100%*(ET_r) for 7thyear)

7.3.4 Effect of PRZDI on Vegetative Growth Characteristics

The performance evaluation of **PRZDI** systems at 80 %*ET_c having 20 % ASWD at drying side showed that less water produce good performance of vegetative growth, no water shoot and luxury. **PRZDI** reduced moisture content and maximum plant height, LAI and plant spread is recorded in having WSV at 80 % * ET_c with 20% ASWD.

Table 4: Effect of partial root zone drying on growths characteristics for 6th year pomegranate tree

Treatments	Plant Height (cm)	LAI	Plant spread(cm)	
			E-W	N-S
Irrigation Level				
I_1*40%	165.50	2.78	1.85	1.65
I_2*60%	166.25	2.65	1.78	1.85
I_3*80%	178.85	2.88	2.28	1.88
I_4*100%	180.80	2.98	1.95	1.67
Shifting of irrigation at drying side				
T_1- 20% ASWD	175.25	2.98	1.80	1.96
T_2-40% ASWD	165.45	2.72	1.85	1.78
T_3-60% ASWD	163.25	2.80	1.78	1.82

Fig. 7: Layout of partial root zone drying irrigation system

7.3.5 Effect of PRZDI on Soil Moisture and Relative Leaf Water Content as Influence by Different Moisture Regime

The performance evaluation of **PRZDI** systems reduced soil moisture content and relative leaf water content **(%)**. The moisture content and relative leaf water content at various phenological stages varied between 21.3 to 42.2 and 68.6 to 85.4%, respectively.

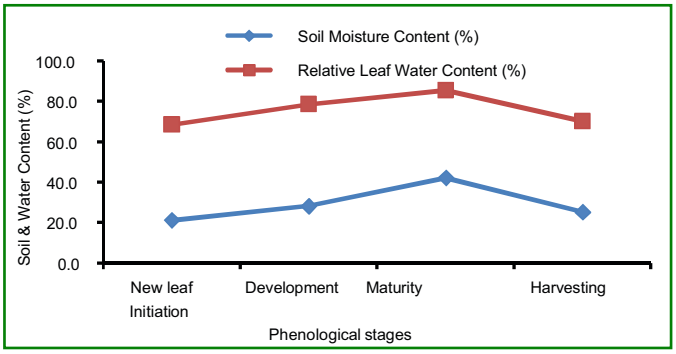


Fig. 8: Soil moisture content and relative leaf water content under variable moisture regime

7.3.6 Effect of PRZDI on Yield and Water Use Efficiency

The results revealed that pomegranate yield responded differently to different quantities of irrigation water and alternate drying and wetting of both sides of the plant. The best irrigation level recorded the mean yield of 25.01 kg $tree^{-1}$ at 80 per cent irrigation level with shifting at 20 % ASWD. Irrigation level at 80 per cent and 20 % shifting of ASWD has recorded better number of fruits, weight of fruits and yield because of optimum moisture regime required for seven years old pomegranate trees. As regards best deficit irrigation level, maximum water use efficiency was 2.51 kg m^{-3}.

Table 5: Effect of PRZDI on yield and water use efficiency of seven years old pomegranate tree

Treatments	No. of Fruits	Fruit weight (g)	Yield (kg)	WU (m^3)	WUE (Kg m^{-3})
I_1*40%	35.25	323.44	11.30	4.90	2.30
I_2*60%	60.33	305.14	16.78	7.48	2.24
I_3*80%	80.48	310.78	25.01	9.95	2.51
I_4*100%	62.55	315.62	19.74	12.44	1.58

7.4 Project: Utilization of Pomegranate for Development of Functional Medicinal Ingredients

7.4.1 Microencapsulation of Pomegranate Seed Oil

Pomegranate seed oil is a unique natural product as that of six plant sources that are known to contain conjugated fatty acids. These conjugated fatty acids have significant natural anti-inflammatory property. Apart from this, pomegranate seed oil is also richest source of a plant derived steroidal estrogen and estrone. The other important compounds that are found in pomegranate seed oil were gamma-tocopherol, a rare and potent form of Vitamin E and the phytosterols: beta-sitosterol, stigmasterol and campesterol. Therefore, pomegranate seed oil has been linked to improve the heart health and also imparts protection against cancer.

Microencapsulation is a technique by which solid, liquid or gaseous active ingredients are packaged within a second material for the purpose of shielding the active ingredient from surrounding environment. It provides protection (stabilization) from interactions with heat, moisture, and oxygen by avoiding the release of core material into the external environment. Therefore, the present study has been undertaken to standardize the process of encapsulation of pomegranate seed oil using calcium alginate as a wall material.

Microencapsulation is carried out by internal gelation using microencapssulator with vibrating-jet technique or prilling for the production of microspheres. The whole experiment was designed with response surface methodology and by using design expert software. Optimization of all the parameters was done by using RSM and box behnken design. For this experiment sodium alginate concentration (1.5, 2.5 and 3.5% w/v), nozzle size (200, 350 and 500 μm), and oil loading (10, 20, 30% v/v) were considered as independent variables. The encapsulation efficiency (%), encapsulation yield (%), loading capacity (%), rupture force (N), equivalent diameter (μm), and sphericity factor were considered as a response variables in this experiment.

Microencapsulation of seed oil was carried out using emulsion extrusion technique. Wherein, the emulsion of sodium alginate, pomegranate seed oil and Tween 80 (3% v/v) was prepared at desired concentration using magnetic stirrer at 500 rpm for 1hr. The emulsion is sprayed in calcium chloride solution (500 mM) using encapsulator (Nisco encapsulating systems Co., Zurich, Switzerland) with different nozzles diameters. This encapsulation process was standardized by varying air pressure and vibration frequency (1.50 to 3.00 kHz). The beads formation is done when distinguished beads of uniform size were observed against stroboscopic lamp. The resulting microcapsules were allowed to harden in 500 mM $CaCl_2$ solution for 1 hr. Then, oil-loaded alginate beads were collected from the cross-linking solution using a sieve. Finally, the microspheres were rinsed twice with distilled water followed by absorbing the surface excessive water using tissue paper. Further, these microspheres were stored in distilled water for analysis.

The response variables determined were as follows.

The encapsulation efficiency-It is the ratio of weight of pomegranate seed oil (PSO) loaded in microcapsules to initial weight of PSO.

Encapsulation Efficiency (%) $= W_O / W_I \times 100$

Where,

Wo = Weight of PSO loaded in microspheres

W_I = Initial weight of PSO

Loading capacity - It is the ratio of weight of loaded PSO to the weight of microspheres.

Loading Capacity (%) $= W_O / W_{MS} \times 100$

Where,

Wo = Weight of loaded PSO in microspheres

W_{MS} = Weight of microspheres

Quantification of PSO loaded within alginate microspheres - It was determined by extracting the loaded oil from 5.0 g of beads by their dissolution in 50 mL of sodium citrate (0.055 M) and 50 mL *n*-hexane. The absorbance was then measured at

wavelength of 360 nm, which is maximum for PSO by using spectrophotometer model UV-1700 (Shimadzu Corporation, Kyoto, Japan). The amounts of PSO was determined from the standard curves plotted for PSO of different concentration and by taking unloaded alginate microspheres as a control.

Encapsulation yield - It is the ratio of weight of microspheres obtained to the weight of emulsion used in encapsulation process. The microencapsulation process yield was calculated by using the following expression:

Encapsulation Yield (%) = W_{MS}/ W_{EM} × 100

Where,

W_{MS} =Weight of microspheres obtained

W_{EM} =Weight of emulsion used

The characterization of beads was done by using Nikon (Eclipse 90 i, Kawasaki, Japan) light microscope equipped with a Nikon photographic camera (DS- Ri 1 model, Kawasaki, Japan) to view, record and data acquisition of images. All the images as obtained were analyzed using NIS Elements BR version 3.22.00 software. Each microsphere was observed under microscope and five points were selected around the periphery of microsphere to determine its equivalent diameter. Further, the maximum diameter (D_{max}) and perpendicular diameter (D_{per}) of each microsphere was also measured to determine sphericity. The sphericity entails the roundness of microspheres.

Sphericity Factor (SF) = (D_{max}-D_{per}) / (D_{max} +D_{per})

Rupture force - It is measured by uniaxial compression of single wet alginate bead by using texture analyzer (TA-XT Plus, Stable Micro Systems, UK) attached with a 50 kg force transducer. In this experiment, only spherical beads with sphericity factor <0.05 were used for compression. A cylindrical probe with a diameter of 10 mm and having flat end was used to compress the bead. Compression was performed up to 60% deformation at a test speed of 0.5 mm/s. Probe was set to return to its original position immediately after compression. The peak force at which microsphere gets ruptured is the rupture force.

7.4.2 Encapsulation Efficiency (EE)

It is an important parameter, which refers to amount of oil encapsulated within the microsphere to the total oil used. Results revealed that the encapsulation efficiency varied from 11.96 to 76.92 % for different treatment combinations. The increase in oil loading from 10% onwards has shown corresponding gradual decrease in encapsulation efficiency up to 20% (Fig. 9a). There is no significant change observed beyond 20% oil loading, irrespective of nozzle size and 2.5% alginate concentration used. This could be due to capsule's limited capacity to contain oil. The lower oil content and corresponding higher proportion of wall material leads to better cross linking on the bead surface with stronger capsule matrix. Thus, these could avoid oil leakage and have higher encapsulation efficiency. Apart from this, the increase in alginate concentration resulted in gradual increase in EE up to 3% of alginate concentration (Fig. 9b). This might be due to formation of dense (thicker) network structures with cohesive pores (vacancy), which entrap the oil droplets to their maximum extent and ensuring homogeneous distribution. In general, the highest EE has been observed at alginate concentration of 3% and oil loading of around 10-12% (Fig. 9c).

ANOVA of quadratic model for EE showed significant model with R2= 0.94 (P<0.05). This model showed non-significant lack of fit. The results of regression analysis can be expressed in the form of second order polynomial equation as follows.

Encapsulation Efficiency = +7.02-0.4705*A-0.4384*B +0.4167*C -1.72*A*C +0.0107*B*C -0.082*A^2 -0.7230*B^2 -2.04*C^2.

7.4.3 Loading Capacity (LC)

It refers to quantity of PSO encapsulated to the total weight of microspheres. The LC has increased with increase in alginate concentration from 1.5% to 3 % (Fig. 10a). This could be attributed to formation of dense crosslinking network structures with cohesive vacancies at higher alginate concentration, which could trap more PSO. Further, the increase in alginate concentration from 3% to 3.5% has shown decrease

in LC. This might be due to higher alginate in polymer matrix leading to lower free volume and subsequently low oil loading into the microspheres. The percent PSO loading does not have significant effect on the LC of microspheres, however the inverse relationship was observed between them (Fig. 10b). Further, the smaller nozzle size at alginate concentration between 2.5 to 3%, and at lower oil loading up to 15 % had higher LC (Fig. 2a & b). This might be due to formation of smaller size microspheres by the smaller nozzle sizes, which could lead to higher loading of PSO.

ANOVA of quadratic model for LC showed significant model with R^2= 0.90 ($P<0.05$). This model also showed non-significant lack of fit. The results of regression analysis can be expressed in the form of second order polynomial equation as follows.

Loading Capacity = +35.12 -21.68*A -2.5*B +5.56*C -13.92*A*C +0.0534*B*C +10.43*A^2 -2.05*B^2 -11.75*C^2.

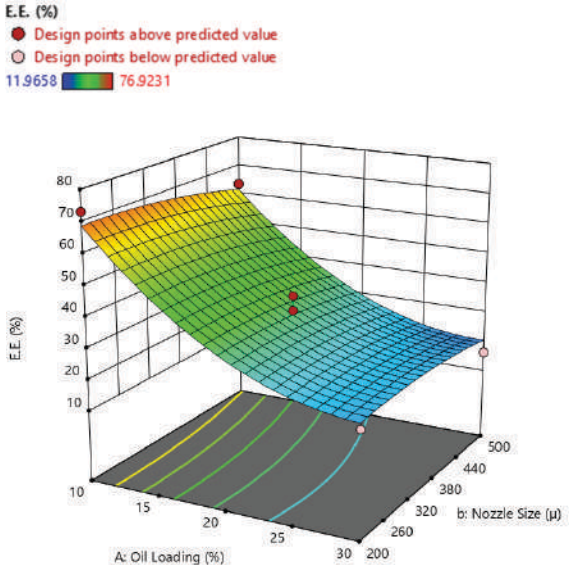


Fig. 9a: Effect of oil loading and nozzle size on EE at 2.5 % sodium alginate concentration

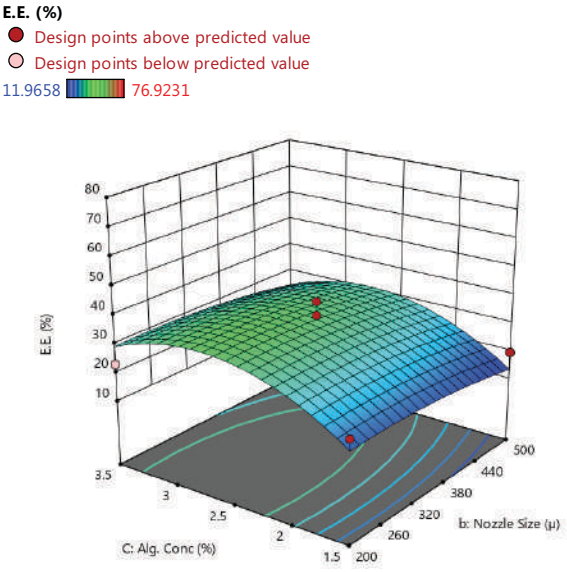


Fig. 9b: Effect of alginate concentration and Nozzle size on EE at 20% oil loading

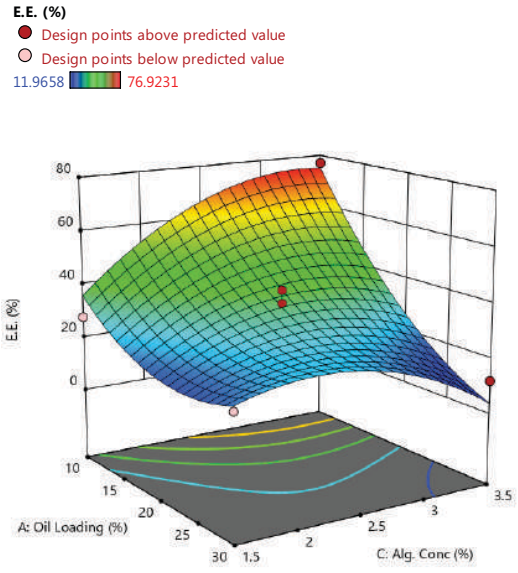


Fig. 9c: Effect of alginate concentration and oil loading on EE at 350μ nozzle size

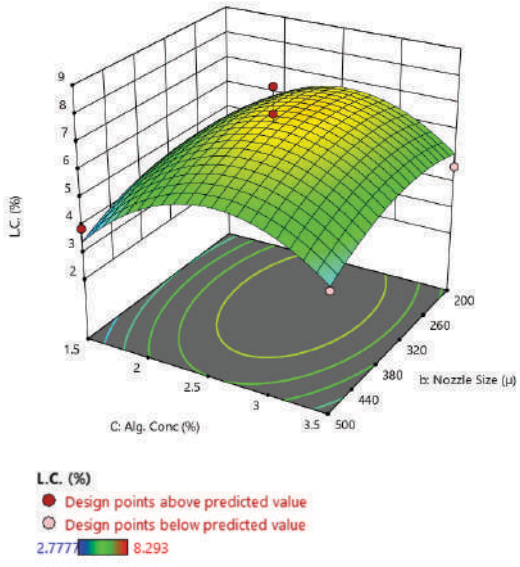


Fig. 10a: Effect of alginate concentration and nozzle size on LC at 20% oil Loading

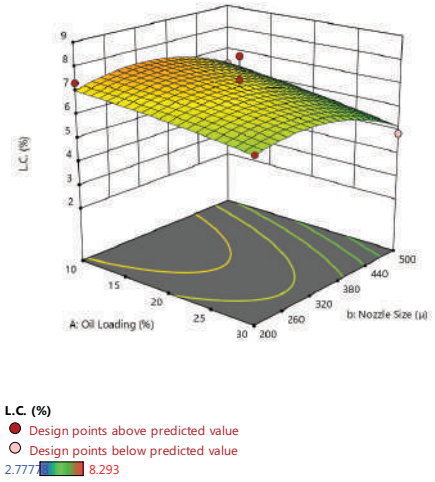


Fig. 10b: Effect of oil loading and nozzle size on LC on loading capacity at 2.5% alginate concentration

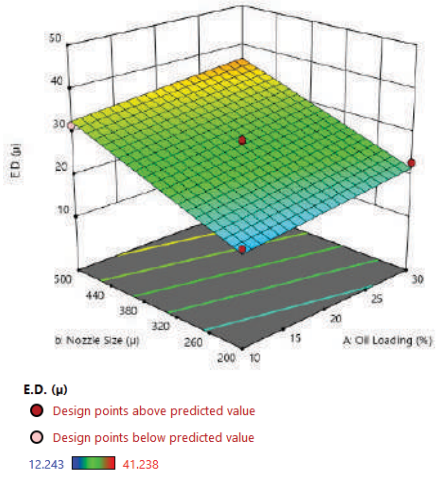


Fig. 11a: Effect of oil loading on the size of microspheres at 2.5% alginate concentration

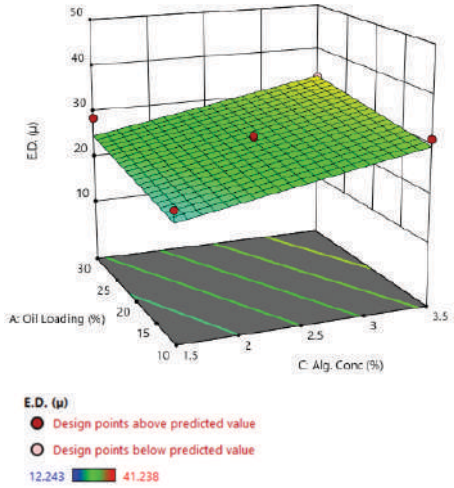


Fig. 11b: Effect of alginate concentration on the size of microspheres at 350μ nozzle size.

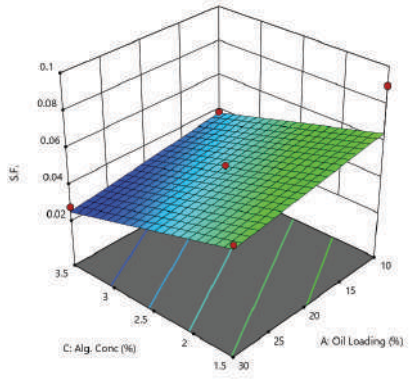


Fig. 11c: Effect of alginate concentration and oil loading at 350μ nozzle size.

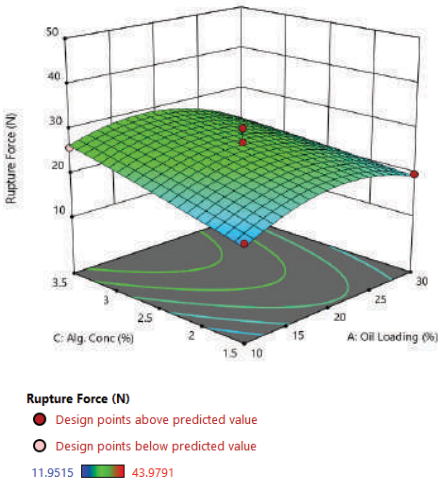


Fig. 12a: Effect of alginate concentration and oil loading on rupture force of microspheres at 350μ nozzle size.

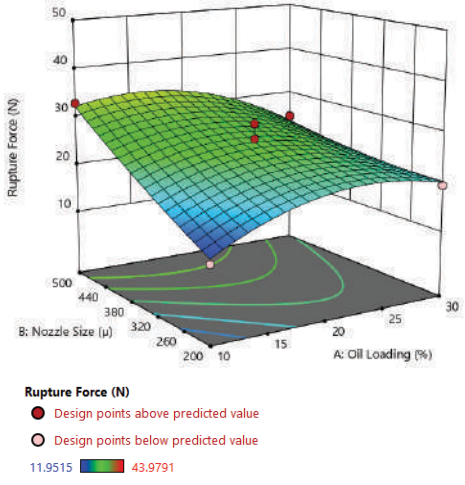


Fig. 12b: Effect of oil loading and nozzle size on rupture force of microspheres at 2.5% alginate.

7.4.4 Encapsulation Yield (EY)

It is an important performance parameter, which refers to efficient performance of encapsulator in producing the microspheres. The results revealed EY varied from 72 to 75 %. However, EY revealed non-significant trend with respect to all the experimental variables. This low EY could be due to loss of emulsion in the emulsion bottle, transfer tubes and syringe.

7.4.5 Size and Shape of Microspheres

These are depicted by the equivalent diameter (ED) and sphericity factor (SF) of microspheres. The ED of microsphere was gradually increased with the increase in oil loading from 10 % to 30% (Fig. 11a). This could be due to change in density of microspheres brought about by increasing the ED and oil loading. We noticed, addition of PSO has reduced the density of microsphere formed. Separation of microsphere drop from the nozzle requires minimum mass capable of breaking its surface tension. The reduction in the density of drop due to increased oil loading requires drop to be of proportionate higher volume for breaking its surface tension. Positive correlation was observed between nozzle size (inner diameter of nozzle) and ED of microsphere, which confirmed the earlier reports (Fig. 11a). The size of microsphere has gradually increased with the alginate concentration ($p<0.0001$) from 1.5% to 3.5%. This could be due to increase in crosslinking brought about by higher concentration of sodium alginate that readily binds to calcium chloride. The higher polymer (sodium alginate) concentration forms the viscous emulsion and consequent larger microspheres.

ANOVA of linear model for ED showed significant model with $R^2= 0.89$ ($P<0.05$). This model was found non-significant lack of fit. The results of regression analysis can be expressed in the form of linear equation as follows.

Equivalent Diameter = +27.15+2.04*A -7.54*B +54.59*C.

The SF is the good indicator for measuring shape of microspheres. Owing to low surface/volume ratio of spheres, the spherical beads are more stable than irregular shaped non spherical microspheres. The increase in alginate concentration has shown decrease in SF, thus has increased the sphericity of microspheres (Fig. 11b). In addition to this, increase in oil loading from 10 to 30% has decreased SF and consequently improved the sphericity of microspheres (Fig. 3c). Further, the increase in nozzle size has improved the sphericity (data not shown).

ANOVA of linear model for SF has showed significant model with $R^2= 0.56$ ($P<0.05$). The model was found non-significant lack of fit. The results of regression analysis can be expressed in the form of linear equation as follows.

Sphericity Factor = +0.045-0.0065*A -0.0046*B -0.00134*C.

7.4.6 Rupture Force

The maximum force (N) needed for compression represents the maximum resistance of the bead to compression by the probe, which indirectly gives an indication of hardness of the samples. The rupture force of microspheres has increased with increase in alginate concentration (Fig. 12a). Since, higher alginate concentration can lead to formation of larger size of microspheres with dense network structures with better strength. Further, the increase in size of nozzle has shown increased size of beads that consequently increased the rupture force required to break the microspheres (Fig. 12b). In addition to this, with increase in oil loading from 10 to 20% has increased the rupture force needed for microsphere. However, increasing oil loading from 20 to 30% has decreased the rupture force required for microsphere. Since, beads formed from emulsion with lower oil loading has higher EE, and thus oil content is higher and wall material is lower per unit weight of microsphere with lower rupture strength required. However, further increase in oil loading from 20-30% in emulsion shown no significant change in the EE, consequently no change in wall material per unit weight of microspheres and thus flat curve of rupture force required for breaking the microsphere.

ANOVA of quadratic model for rupture force has showed significant model with $R^2 = 0.92$ ($p<0.05$). The model was found non-significant lack of fit. The results of regression analysis can be expressed in the form of second order polynomial equation as follows.

Rupture Force = +26.39 -0.3625*A +5.74*B +3.24*C -3.87 A*B-1.58*A*C +8.34*B*C -4.90*A^2 -0.7368*B^2 -0.3352*C^2.

7.4.7 Optimization of the Parameters

Myers and Montgomery's desirability function were employed for the optimization process. The factors i.e. oil loading (10, 20 and 30%), nozzle diameter (200, 350 and 500μ) and alginate concentration (1.5, 2.5 and 3.5%) were set within range. The response variables such as encapsulation efficiency, loading capacity, and rupture force were set for maximization. Whereas, equivalent diameter and sphericity factors were set for minimization.

The final predicted and optimized process conditions were 10 % oil loading, 350 μ nozzle diameter and 3.23% alginate concentration with desirability of 0.72. Similarly, the optimized and predicted conditions for encapsulation efficiency, loading capacity, equivalent diameter, sphericity factor and rupture force were 74.18 %, 7.77 %, 30.30 μm, 0.040 and 29.06 N, respectively. The observed responses of encapsulation efficiency, loading capacity, equivalent diameter, sphericity factor and rupture force were 78.03 %, 7.83 %, 30.05 μm, 0.039 and 30.20 N, respectively. Models were validated by comparing the predicted and observed responses of confirmation experiments.

7.5 Project: Delineation of Potential Areas for Pomegranate Cultivation in India using Remote Sensing and GIS Techniques

The potential areas for pomegranate cultivation have been identified with respect to different categories under highly suitable, moderately suitable, marginally suitable, not suitable, built-up, forest and water bodies for Maharashtra state, based on temperature and humidity pattern.

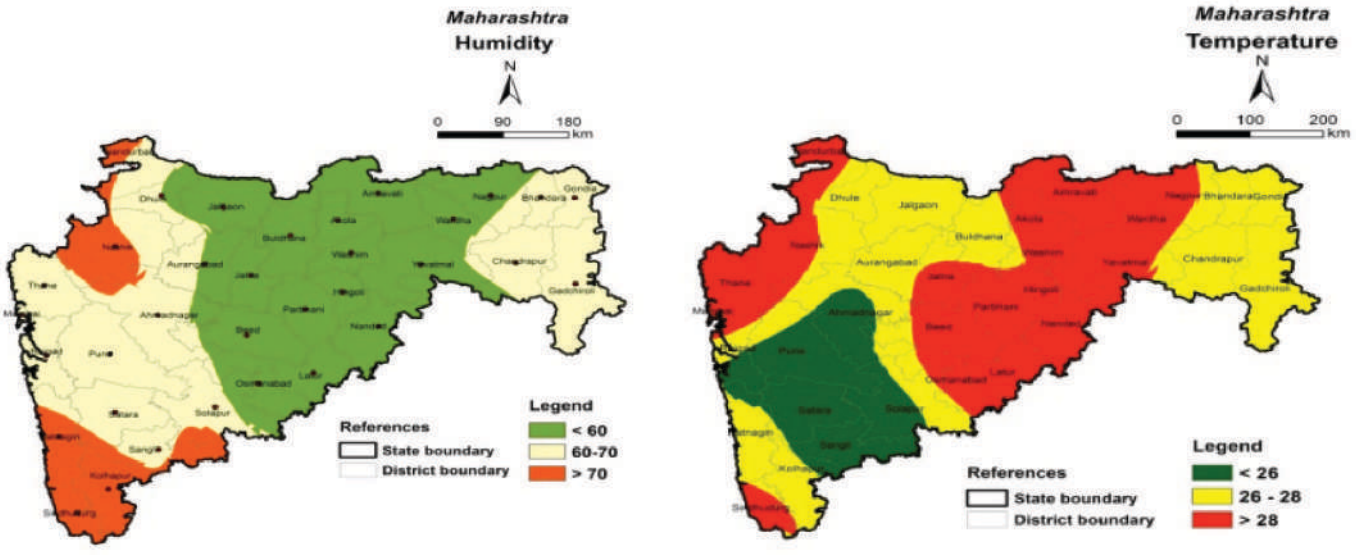


Fig. 13: Humidity and temperature maps for potential areas of pomegranate cultivation in Maharashtra, India

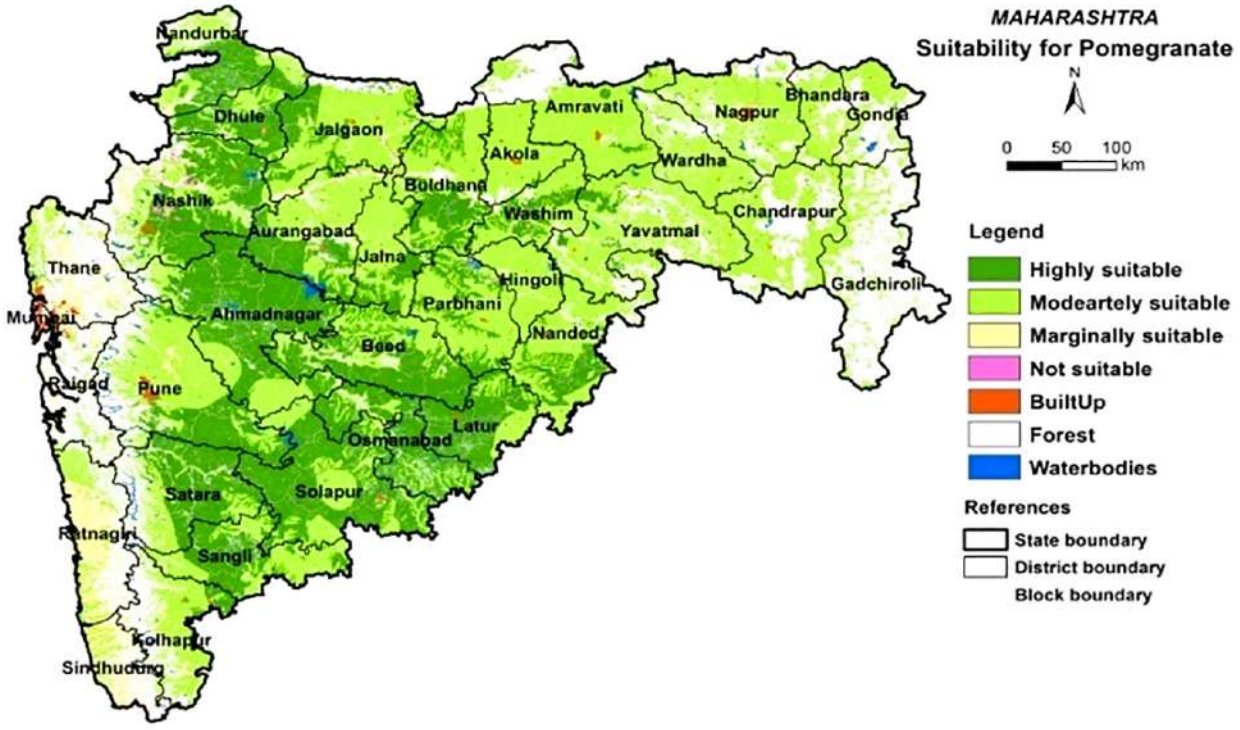


Fig. 14: Potential regions for pomegranate cultivation in Maharashtra, India

7.6 Project: Unraveling Mechanism and Developing Mitigation Strategies for Aril Browning and Fruit Cracking in Pomegranate

7.6.1 Germplasm Screening for Fruit Cracking and Aril Browning

Sixty eight pomegranate germplasm accessions were evaluated for fruit cracking (%) during 2019. ANOVA showed significant differences between the genotypes both at 1% and 5% level of significance (F@0.05-1.40*; F@0.05-1.61**). Fruit cracking (%) among the genotypes ranged from 0-53.90 %. Eight wild genotypes showed no fruit cracking (1201, 1198, IC-318718, IC-318743, IC-318766, IC-318712, IC-318716, Acc. No.-5). Aril browning incidence ranged from 0 to 16.69 %, in 'Bhagawa' 2.58 % aril browning incidence was observed and the maximum aril browning was observed in the exotic collection that is Crenedeo-de-elch (16.69 %).

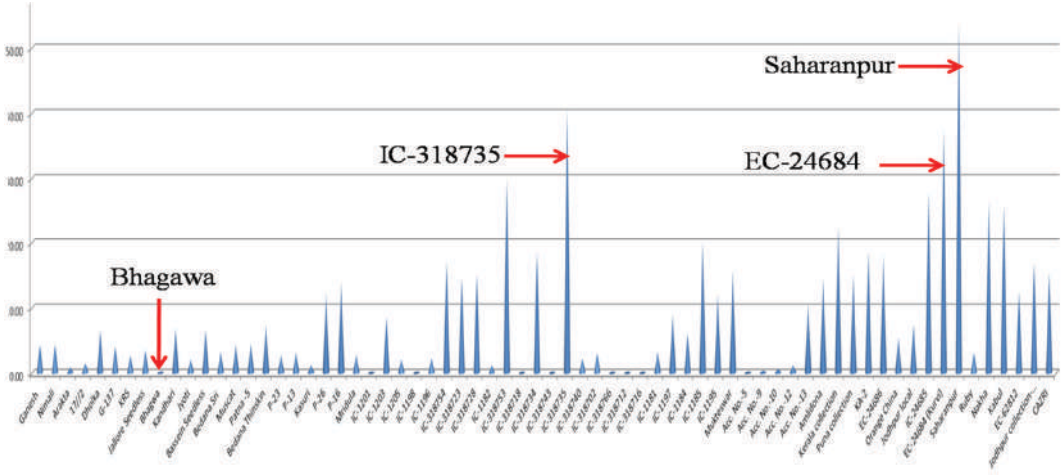


Fig. 15: Variation in fruit cracking (%) among 68 pomegranate genotypes

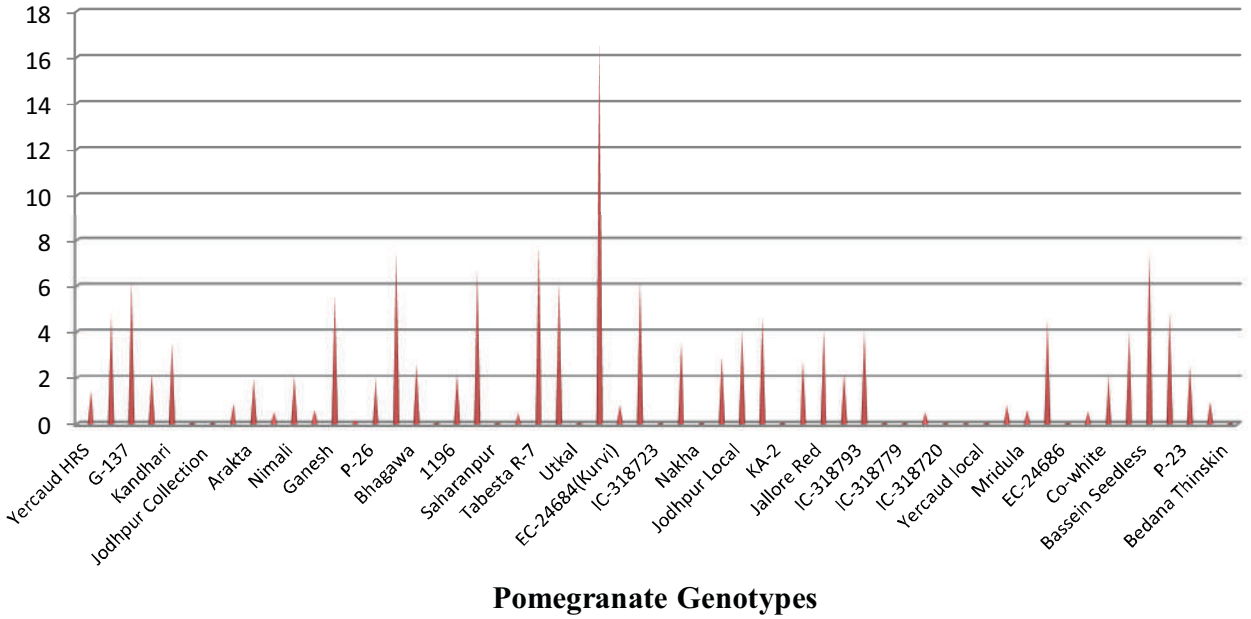


Fig. 16: Aril browning (%) incidence among pomegranate genotypes in the Mrig bahar harvest

7.6.2 Hyperspectral Imaging of Plant Canopy and Fruits of Pomegranate Genotypes

Hyperspectral signatures of plant canopy of 72 pomegranate genotypes along with cracked and healthy fruits of 67 genotypes were recorded using Spectroradiometer. Pomegranate varieties i.e. Ruby, Alandi, Nakha and Arakta showed higher NDVI, thus indicated higher greeniness. However, IC-318712 showed higher chlorophyll content of canopy (high NPCI). While, the other genotypes i.e. Alandi, Ruby, Nakha, IC-318716 and Arakta registered higher chlorophyll content of the leaves by virtue of higher GCI. The water index of all the genotypes were almost same indicating no water stress.

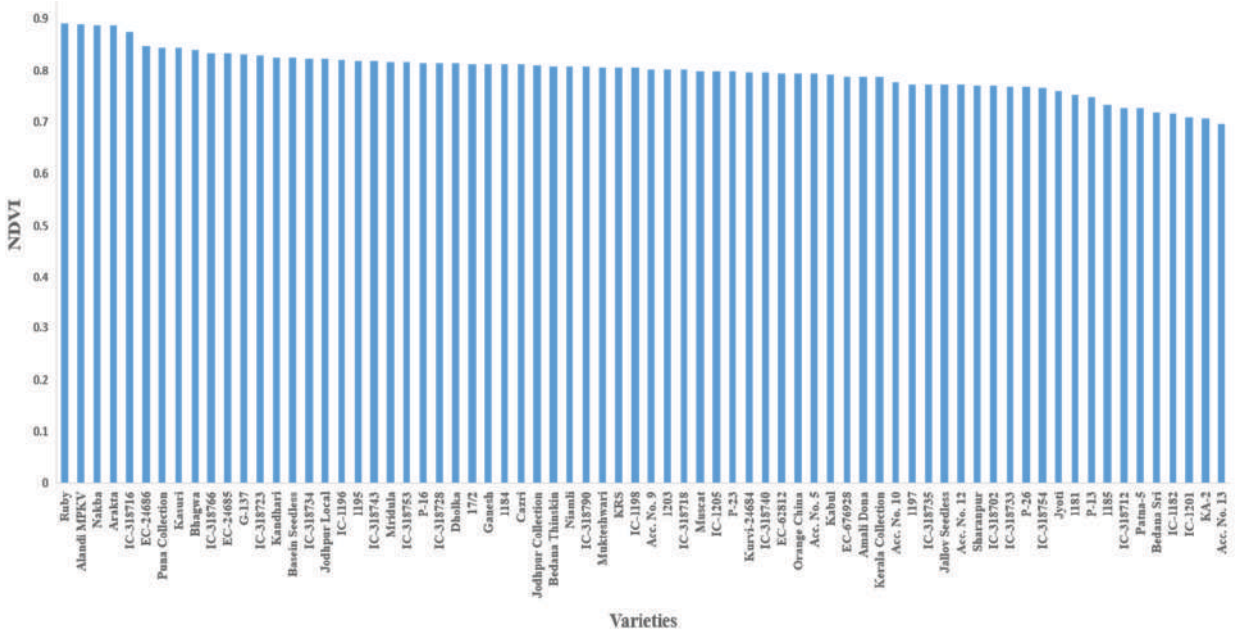


Fig. 17: Normalized Difference Vegetation Index (NDVI) of 72 pomegranate genotypes

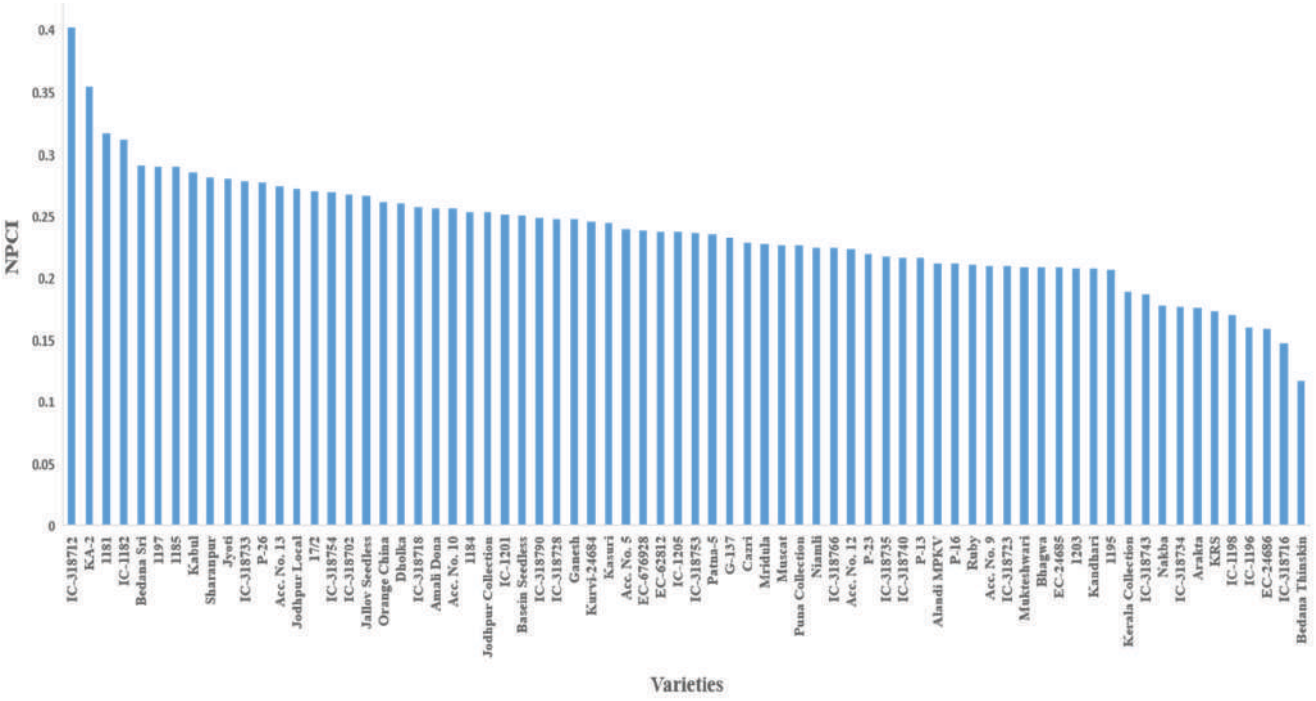


Fig. 18: Normalized Pigment Chlorophyll Index (NPCI) of 72 pomegranate genotypes

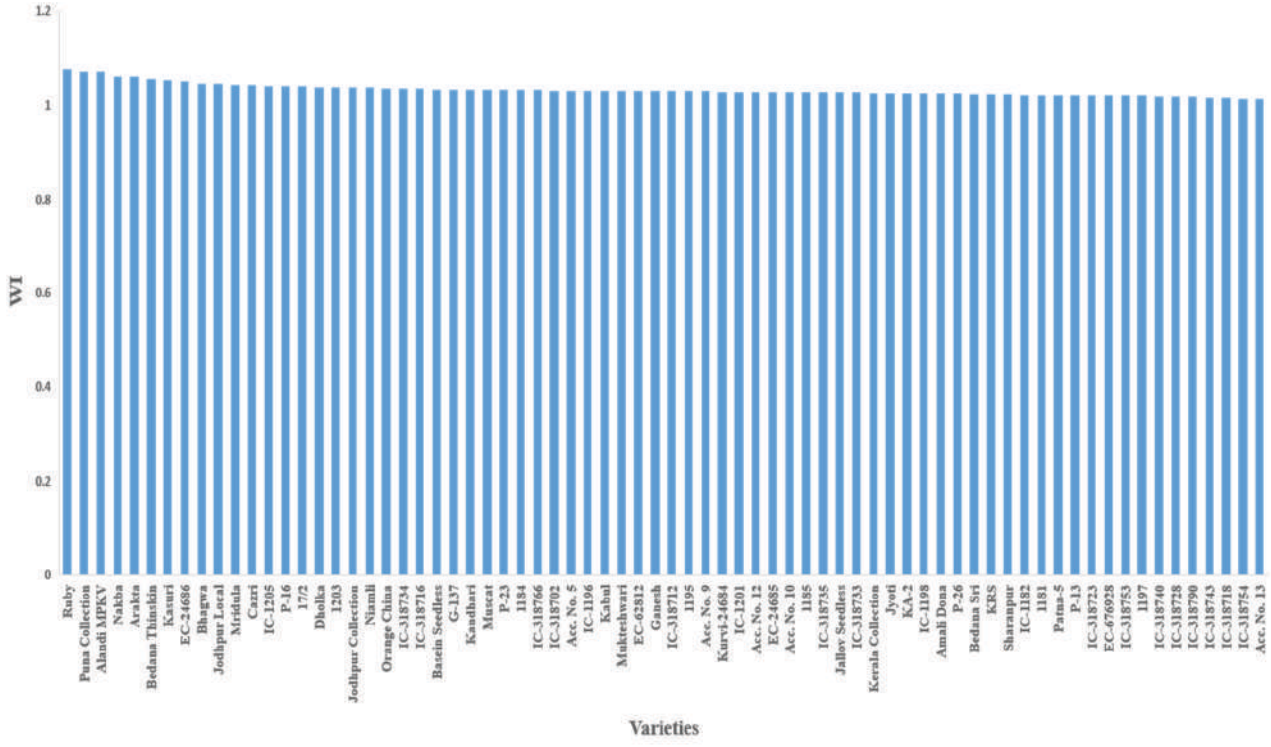


Fig. 19: Water Index (WI) of 72 pomegranate genotypes

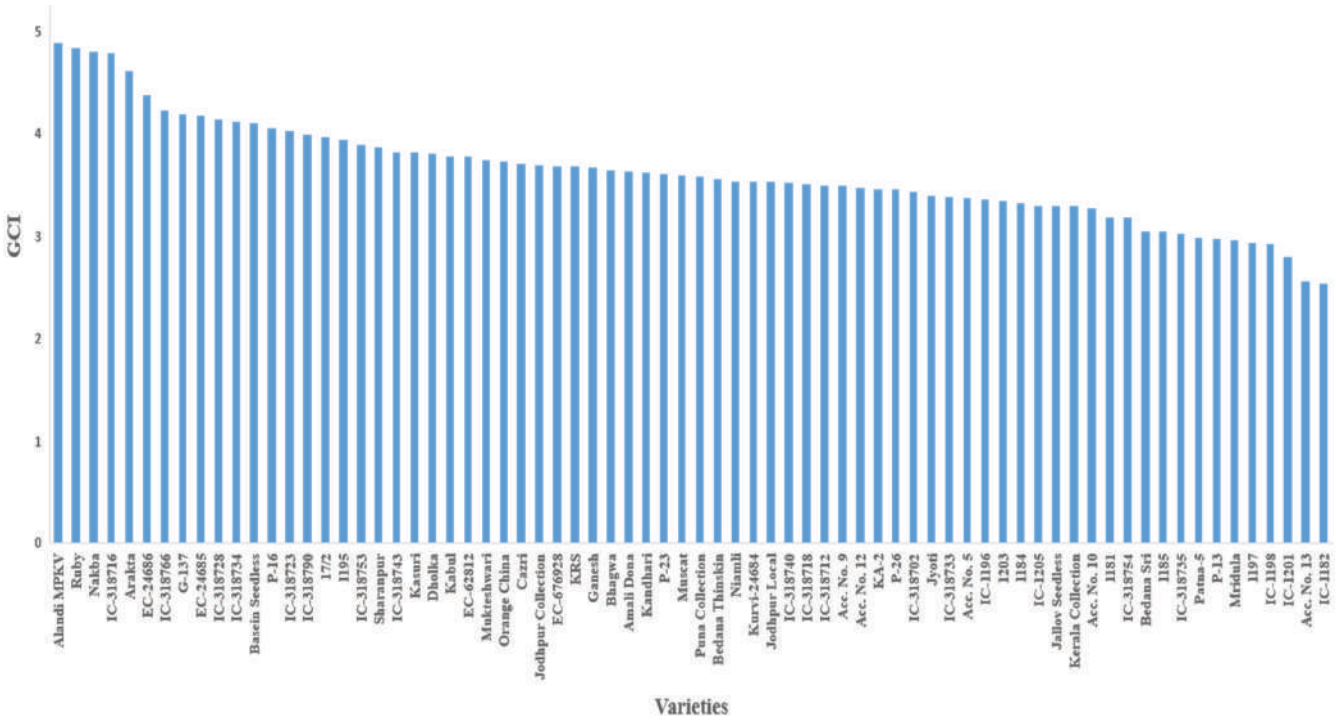


Fig. 20: Green Chlorophyll Index (GCI) of 72 pomegranate genotypes

Two clusters/groups were formed through both PCA and k-means classification techniques using hyperspectral signatures of cracked and healthy pomegranate fruits of different genotypes. Blue dots indicate cracked pomegranate fruits, while red dots indicate healthy fruits. Merging of blue and red dots probably represents for those fruits which are about to crack. However, the parameters like biochemical and nutritional compositional analysis needs to be included and correlated for better validation.

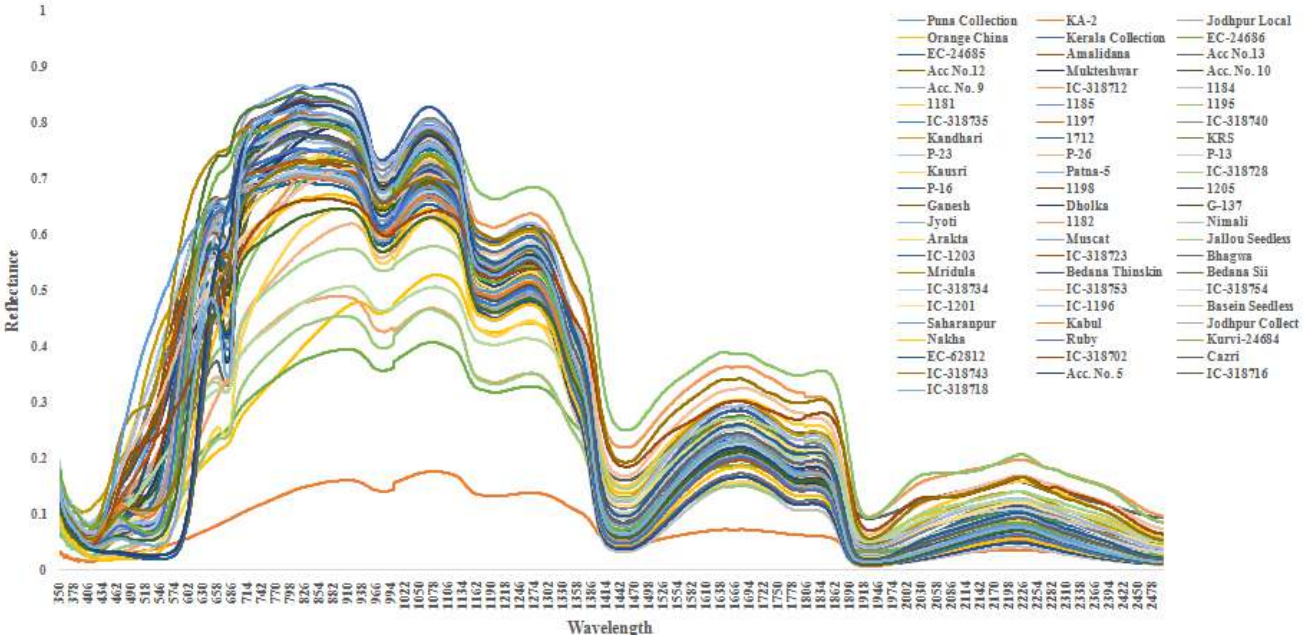


Fig. 21: Probe spectral signatures of pomegranate fruits

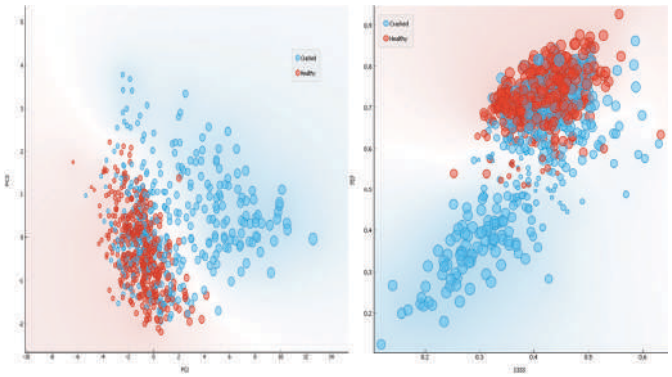


Fig. 22: Principal Component and K means analysis of cracked and healthy fruits

Meteorological Data

Various weather parameters viz., air temperature, soil temperature, relative humidity, wind speed, evaporation, rainfall, bright sunshine hrs. *etc*. were recorded daily at 7.30 and 14.30 hrs from **January-December-2019** and the details are given below.

Air and Soil Temperature

The mean monthly maximum temperature varied from 31.60 to 44.60 ˚C. May was the hottest month and temperature remain in between recorded for a single day was highest (44.60 ˚C) on 29th May and lowest (11.0˚C) on 08th January. The temperature gradually increased from April to May and then started declining till Jan then again it increased. Mean monthly minimum temperature varied from 11.00 ˚C in Jan. to 31.60 ˚C in December. The average monthly air and soil temperature at morning and evening time were ranged from 21.3-33.4˚C, 27.9-34.8˚C and 30.9-39.2˚C.

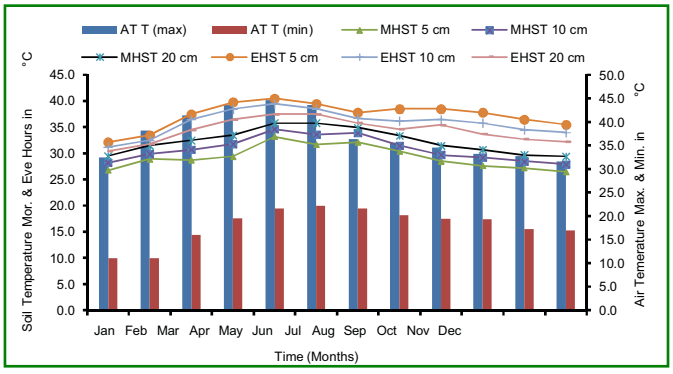


Fig. 23: Mean monthly variation of air and soil tempearture (˚C)

Relative Humidity, Wind Speed, Sunshine Hours, Evaporation, Rainfall and Rainy days

The relative humidity, wind speed, sunshine hours and evaporation were ranged from 65.8-76.0%, 8.7-17.3 kmhr^{-1}, 5.6-10.7 hrs and 4.5-11.7 mm. The total rainfall and rainy days was 677.80 mm and 60 days, respectively.

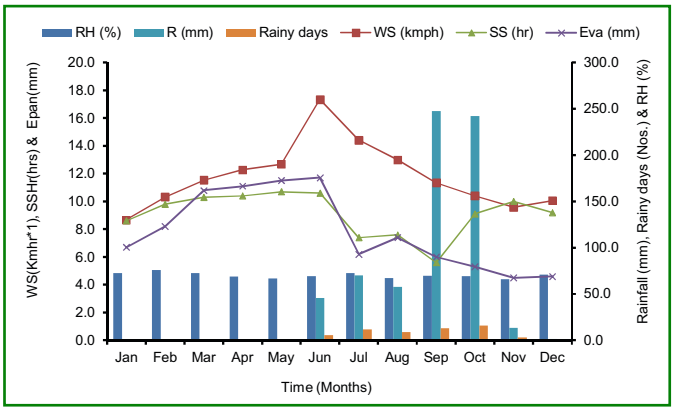


Fig. 24: Mean monthly variation of wind speed, sunshine hours, evaporation, rainfall, rainy days and relative humidity

7.7 Project: Aicrp on Arid Zone Fruit ICAR-CIAH, Bikaner

7.7.1 Bio-efficacy Evaluation of Spinetoram 12% SC w/v (11.7% w/w) SC against *Scirtothrips dorsalis*

The result of 4 consecutive sprays at five concentrations of Spinetoram 12% SC and standard evaluated against the borer and sucking pests of pomegranate at 10-12 days interval. The treatment T3 recorded the highest per cent reduction over the control in all the fours sprays (72.45, 74.23, 75.87 and 71.25) and followed by dose treatment T2 (70.43, 73.05, 73.45 and 70.35) and least was recorded in T1 and T4. The incidence of other sucking pest of pomegranate observed was low during the experimental period for satisfactory evaluation. The least effect on the non-targeted insects in both control and treatments was recorded.

Table 6: Bio-efficacy Evaluation of Spinetoram 12% SC w/v (11.7% w/w) SC Against Thrips (*S. dorsalis*)

Treatments	Dosage (ml or g/l Water)	% Reduction over control on the mean basis after each spray			
		1st Spray	2nd Spray	3rd Spray	4th Spray
T1: Spinetoram 12% SC w/v	0.50	65.05	67.25	62.18	64.43
T2: Spinetoram 12% SC w/v	0.75	70.43	73.05	73.45	70.35
T3: Spinetoram 12% SC w/v	1.00	72.45	74.23	75.87	71.25
T4: Cyantraniliprole 10.26%OD	0.75	64.60	66.98	61.43	63.95
T5: Control	--	0.00	0.00	0.00	0.00

7.8 Project: Horticulture Crop Pest and Disease Monitoring Project (Hortsap)

7.8.1 Report of Red Stem Borer (*Zuezera coffeae*) Damage on Pomegranate

During the survey, it was observed that 30-40 pomegranate plants shoots were showing the symptoms of yellowing and drying. When it was examined, the larvae were found inside. The infested shoots were collected from the field were kept in wooden cages (60 × 45 cm) for pupation. The collected pupae were isolated individually in polystyrene, Petri dishes (100 mm × 20 mm) and tops were covered with lids and they were incubated at the temperature of 28 ± 1°C, relative humidity (RH) of 70 ± 5% and a photoperiod of 12L:12D and observed the eclosion. The emerged adults were taxonomically identified as coffee red stem borer (*Z. Coffeae*). The larvae emerged from the eggs oviposited by an adult on branches and young shoots they enter through the junction of leaf stalk and twig, constructs a tunnel that extends even up to the roots. The early symptoms of damage were yellowing and partial drying of the branches and shoot with one or two holes through which, pellet-like excrement of the larva hangs out and accumulate at the base of the plant. In advanced cases, branches, shoots, and whole plants may dry up. Regular monitoring is essential to keep the pest under watch for effective management

Fig. 25: A. Dried shoot and larvae B. Fresh damaged branches

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Activities under Tribal Sub-plan

Table 1: Tribal farmers adopted by ICAR-NRCP, Solapur

Location details	Village/s adopted	ST population benefited (Nos.)	Year of adoption	Status as on 31.03.2020
Sub-district : Sironcha District: Gadchiroli State: Maharashtra	Bamani, Ranggapalli, Gumalkonda, Pochanpalli, Mukalliguta Venkatpura	12	2015-2016	Orchards established, fertilizers, chemicals, small equipments provided and training imparted.
Sub-district: Manendragarh District: Koriya State: Chhatisgarh	Kerabehara, Dorki	12	2018-19	Orchards planted in 2018 and are well established.
Sub-district: Kotma, Anuppur and Burhar District: Anuppur and Shahdol State: Madhya Pradesh	Baskhala Jamuniya Chaka Thoudha Dhurvasin Baskhali Chhauhari Pathrodi Chapani Reula Kadmaha Behratola	120	2017-18 & 2018-19	Three orchards planted in 2018, remaining 17 orchards are at bearing stage.

Inputs required for Pomegranate cultivation supplied for TSP Farmers at Sironcha , Dist. Gadchiroli

सकाळ

डाळिंब शेतीसोबत कोंबडीच्या व्यवसायातून भरारी

नवी संकल्पना : मुक्कीडगुट्टा येथील युवा शेतकरी जलमय्या कुरसम यांच्या अभिनव प्रयोगाची चर्चा

Publication in news-paper 'SAKAL' on Pomegranate cultivation with poultry farming

Pomegranate with intercropping (Beans)

Pomegranate cultivation with poultry farming at Mukalliguta, Gadchiroli district

Table 2: Training programmes/ workshop organized for tribal farmers

S. No.	Name of the training programme	Venue	Date	No. of ST farmers benefitted
1	Model propagation and pomegranate production technologies for farmers and coordinating agencies under SCSP	ICAR-NRCP, Solapur	Aug. 1-3, 2019	2
2	Skill Development on Water and Nutrient Management in Pomegranate" for pomegranate tribal farmers of Gadchiroli district (Maharashtra)	Vill-Bamani, Ta-Sironcha, Dist-Gadchiroli	Jan. 4, 2019	200
3	Training of pomegranate farmers and SRIJAN staff at Tikamgarh	Jatara, Tikamgarh	Feb., 19-20, 2019	100 participants (Pomegranate Farmers and Staff of SRIJAN)
4	Training of pomegranate farmers and SRIJAN staff at Anuppur and Koriya	Kotma Anuppur Manendragarh, Koriya	Feb., 22-23, 2019	60 participants (Pomegranate Farmers and Staff of SRIJAN)

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Activities under SCSP

Table 1: Farmers adopted by ICAR-NRCP, Solapur under SCSP scheme

Details of beneficiaries	SC population benefitted (Nos.)	Year of adoption	Status as on 31.12.2019
Village: Nimgaon Sub-district: Tembhurni District: Solapur State: Maharashtra	5	2019	One pomegranate orchards planted and established under ICAR-NRCP supervision, training organized and relevant information disseminated to farmer and coordinating agencies.
Village: Solankarwadi Sub-district: Madha District: Solapur State: Maharashtra	10	2019	Two orchards planted and established under ICAR-NRCP supervision, training organized and relevant information disseminated to farmer and coordinating agencies.
Village: Mundhewadi Sub-district: Akkalkot District: Solapur State: Maharashtra	6	2019	One pomegranate orchards planted and established, training organized and relevant information disseminated to farmer and coordinating agencies.
Village: Waghdari Sub-district: Akkalkot District: Solapur State: Maharashtra	15	2019	Two pomegranate orchards planted and established, another farmer has given agri-inputs and orchard plantation is under progress, training organized and relevant information disseminated to farmer and coordinating agencies.
District: Barmer State: Rajasthan	10	2019	Orchard planted and established, training organized and relevant information disseminated to farmers.
Village: Sherpur District: Alwar State: Rajasthan	10	2019	Orchard planted and established, training organized and relevant information disseminated to farmers and coordinating agencies.

Distribution of Agri-inputs to SC beneficiaries of Farmer for promotion of pomegranate cultivation

Adopted Orchard at Solankarwadi under SCSP scheme of ICAR-NRCP

Training-cum-distribution of Agri-inputs to beneficiaries under SCSP scheme of ICAR-NRCP

Material handover to selected SCSP Farmer at Malumbra, Dist-Osmanabad

Pomegranate cultivated with Rabi Mug intercropping at Malumbra, Dist-Osmanabad

Table 2: Training programmes/ workshop organized for SCSP farmers

Sl. No.	Name of the training programme	Place	Date	SC Farmers benefited (Nos.)
1.	Model Propagation and Pomegranate Production Technologies for Farmers and Coordinating Agencies under SCSP'	ICAR-NRCP	01st - 03rd August, 2019	35 (Including beneficiaries of TSP and MGMG)

Model Propagation and Pomegranate Production Technologies for Farmers and Coordinating Agencies under SCSP from Aug. 01 - 03, 2019

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Outreach Activities

Trainings/ Workshops/ Farmers Fair/ Field Day

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

Table 1: Trainings/ Workshops/ Farmers' Fair/ Field Day

S. No.	Title of Trainings/ Workshops/ Farmers Fair/ Field Day/ FLD	Venue	Date	No. of participants
1	Training Program on 'Management of bacterial blight and other economically important diseases in pomegranate' and file visit	College of Horticulture, UHS Campus, GKVK, Bangalore	Jan 7-8, 2019	175 farmers and extension officers
2	Workshop on Contemporary Research in Life Sciences and Cancer Biology	Department of Biotechnology, V.G.Shivdare College of Arts, Commerce and Science, Solapur	Jan 19, 2019	150 Students and Scientists
3	Organized field day to show the effect of fertigation with Zetol select water soluble fertilizers grades and ProRise package of NFCL on pomegranate fruit yield and quality	Hiraj Research farm, ICAR-NRCP, Solapur	Jan 24, 2019	50 farmers
4	Inaugural Ceremony and Farmers Melava	"Agriculture Technology Week - 2019" organised by KVK, Solapur	Jan 29, 2019	200 farmers
5	Workshop to transform the life of Pomegranate Farmers of Gujarat at Dhrangadhra, Surendranagar, Gujarat and field visits	Directorate of Horticulture Krushi Bhavan, Gandhinagar- (Gujarat) and ABC Agrobiotechnology, Mahemdabad, Gujarat, Vanita Agro, Kohlapur and	Feb 13, 2019	175 state horticulture officers, farmers and Agro industries
6	Field day on Pomegranate disease management and technologies available at ICAR-NRCP'	Coromandel Int. Ltd., at Paniv, Malshirus, Solapur (MS)	Feb 16, 2019	30 farmers

7	Lectures/farmer interaction during 'Lokmat Agroutsav'	Lokmat, Marathi Newspaper Solapur	Feb 16, 2019	500 farmers, stakeholders
8	Cluster seminar on Pomegranate	Centre of Excellence for Pomegranate (established under Indo Israel Action Plan) at Dhindhol -Bassi, District Jaipur	Mar 1 -2, 2019	200 farmers, Agro-industries, Scientists
9	World Honeybee Day	KVK, Baramati	May 20, 2019	500 farmers
10	Joint Inspection of pomegranate and grape orchards of the farmers at Nimgaon, Madha under NHB commercial horticulture scheme.	Nimgaon, Madha, Solapur	May 24, 2019	2 farm sites
11	Workshop on marketing, processing and production	Harshada Lawns, Sangola, Maharashtra	Aug 17, 2019	700 farmers
12	Interaction with pomegranate growers of Sangola, Solapur	ICAR-NRCP, Solapur	Aug 17, 2019	65 farmers
13	On farm training, on pomegranate cultivation in Himachal Pradesh - issues and solutions.	Regional Horticultural Research and Training Station, Bajaura Kullu, Himachal Pradesh in collaboration with Lower Kullu Kisan Avam Bagwaan Sangathan, Bhuntar	Sep 3 – 5, 2019	25 farmers at Tharas and Hurla 25 farmers at Khokhan, Bagicha and Shamshi 50 farmers at Ruwaru
14	Awareness workshop on Solapur Lal and its importance for processing	Mohite Farm, Kati, Indapur	Sep 9, 2019	200 farmers
15	Awareness programme for students of Cosmetics Technology, Solapur University on utilization of pomegranate for food, pharmaceutical and cosmetics.	Cosmetics Division of Solapur University, Solapur.	Sep 11, 2019	50 student
16	Pomegranate cultivation, problems and Prospects	Department of Agriculture, GoM and Chartapati Shivaji Shetkari Swayam Sahayata Samuha Gat, Kadlas, Sangola, Solapur	Sep 20, 2019	60 farmers
17	Most essential and advanced technologies in pomegranate protection	Organized by Director of Extention, UAS, Raichur at KVK Yadgir (Kawadimatti)	Nov 27, 2019	200 farmers, extension workers and university officers
18	Training on pomegranate processing and value addition along with KVK Solapur	ICAR-NRCP, Solapur	Dec 13, 2019	20 Womens farmers and Extension workers

SCIENTIFIC AGRO ADVISORIES

In response to queries of farmers, information on pomegranate was provided to the farmers through e-mail and phone. Scientific agro-advisories were sent to more than 2015 pomegranate growers through the "m-Kisan portal" during the period under report.

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Transfer of Technology and Entrepreneurship Development

ICAR-NRCP, Solapur organized the following trainings, workshops/ field day/ FLD, technology transfer agreement for entrepreneurs and MoU for students. In addition, ICAR-NRCP actively participated in several exhibitions besides facilitating the visit of farmers/ stakeholders to the Institute to provide information on pomegranate.

Table 1: Trainings conducted by ICAR-NRCP, Solapur

S. No.	Name of Training Programme	No. of participants	Period
	Duration: 3 or more days		
1	Propagation, model production, protection and PHM practices in Pomegranate for the students of I. Ag. Sc., Banaras Hindu University, India	15	13-16 May, 2019
2	Scientific methods of pomegranate cultivation for optimum production for farmers from ATMA, Wardha	35	20-23 May, 2019
3	Advanced production and value addition practices in pomegranate for farmers of Vijayapur, Karnataka	25	24-26 Jun., 2019
4	Model propagation and pomegranate production technologies for farmers and coordinating agencies under SCSP	32	1-3 Aug., 2019
5	Preparation and Dissemination of Agromet Advisories at Block level under Gramin Krishi Mausam Seva (GKMS) scheme" for Subject Matter Specialists (Agromet) of Krishi Vigyan Kendras (KVKs)	38	19-24 Aug., 2019
6	Model production and protection practices in pomegranate" for the extension officers of State Agri. /Hort. Department and subject matter specialists of KVK's & SAU's	20	4-8 Nov., 2019
7	Quality pomegranate production and value addition for doubling farmers' income for the farmers of Gujarat	32	18-21 Dec., 2019
8	Entrepreneurship and leadership development programme for Horticulture entrepreneurs desirous of applying to schemes of National Horticulture Board : Open field cultivation of pomegranate	5	18-24 Dec., 2019
	Duration: less than 3 days		
9	Model pomegranate production and protection practices for employees of Syngenta, India	43	4-5 Jun., 2019
10	Advanced pomegranate management practices and value addition. (Sponsored by ICCI Foundation) at ICAR-NRCP, Solapur.	20	31 Aug., 2019

"Scientific Methods of Pomegranate Cultivation for Optimum Production"; Dated:, May 20-23, 2019

Training programme on optimum pomegranate productivity using scientific method for the farmers of Wardha (MS), May 20-23, 2019

Training programme on Advanced Production and Value Addition Practices in Pomegranate for farmers of Vijayapur, Karnataka Jun. 24 -26, 2019

Model Propagation and Pomegranate Production Technologies for Farmers and Coordinating Agencies under SCSP from Aug. 01 - 03, 2019

MANAGE, Sponsored Five days Collaborative Training Programme on "Model Production and Protection Practices in Pomegranate" For the extension officers of State Agri. /Hort. Department and subject matter specialists of KVK's & SAU's from Nov. 4-8, 2019

Imparting training to the farmers of Ahmedabad district, Gujarat from Dec. 18-20, 2019 on Quality pomegranate production and value addition for doubling farmers' income

Table 2: Workshop/ Field Day/ FLD conducted

S. No.	Name of workshop/ field day/ FLD	No. of participants	Date
1	DD Kisan Multitask Training programme	28	08.03.2019
2	Training programme on advanced pomegranate management practices and value addition	24	31.08.2019
3	15th Foundation Day Ceremony of ICAR-NRCP September 25, 2019 & Kisan Goshthi on Problems and Prospects in Pomegranate Production	150	25.09.2019
4	4th Annual General Body Meeting of SARP,Foundation Day Ceremony of KVK Solapur-I and Workshop on Practices and technologies for climate resilient pomegranate production	200	24.12.2019

DD Kisan Multitask Training programme, Mar. 08, 2019

15th Foundation Day Ceremony of ICAR-NRCP Kisan Goshthi on Problems and Prospects in Pomegranate Production on Sept. 25, 2019

Workshop on Practices and Technologies for Climate Resilient Pomegranate Production on Dec. 24, 2019

AGREEMENT WITH VARIOUS STAKEHOLDERS

For Entrepreneurs

ICAR-NRCP's technologies were transferred to the following entrepreneurs through signing of Memorandum of Understanding (MoU).

Table 3: MoU with Entrepreneurs

S. No.	Technology transferred	Address of beneficiary	Date of signing MoU	Revenue received (Rs.)
1	Propagation of Pomegranate var. Solapur Lal through air layering / hardwood cutting	Mr. Sakaram Kathode A/P Ganore Tal- Akole Dist: Ahmednagar Maharashtra, India	05.07.2019	Rs.90,000/-
2	Development of pomegranate juice and ready to serve beverage	Vardayini Farmers Producer Company Ltd. A/P Pangaon Tal- Barshi Dist- Solapur Pin-413 401	30.12. 2019	88,500/-

MoU for propagation of pomegranate variety Solapur Lal though air layer/HWC, Jul. 05, 2019

Development of pomegranate juice and ready to serve beverage to M/S. Vardayini Farmers Producer Company Ltd. on Dec. 30, 2019

For Students

Table 4: MoU with Academic Institutions

S. No.	Programme	Address of beneficiary	Date	Revenue generated (Rs.)
1	PG Training Programme and PG Research	Walchand College of Arts, Science and Commerce, Solapur	01.08.2019	60000/-
2	M. Tech. (Food Technology)	MIT Art, Design and Technology University, Pune	21.09.2019	30,000/-
3	B. Tech. (Agril. Engg.)	Shriram College of Agricultural Engineer, Paniv, Ta-Malshiras, Dsit-Solapur	18.10.2020	50,000/-
4	UG Training and Project Research	Lokmangal College of Agricultural Biotechnology, Wadala	01.02.2019	30000/-
5	UG Training and Project Research	College of Agricultural Biotechnology, Sangulwadi	08.01.2019	20000/-
6	B.Tech. (Agricultural Engineering)	Shriram College of Agricultural Engineering, Paniv.	16.12.2019	20,000/-

Table 5: Exhibitions

S.No.	Name of the exhibition	Organizer	Venue	No. of participants	Date
1	Global Farmers Fair	Krishi Vigyan Kendra Narayangaon	Krishi Vigyan Kendra Narayangaon, Pune.	470	3-6 Jan., 2019
2	Make arrangement of display stall on occasion of ICAR-Centre on Rabbi Sorghum QRT Meeting.	ICAR-Centre on Rabbi Sorghum	ICAR-NRCP, Solapur	57	21 Jan., 2019
3	National Horticulture fair 2019	ICAR-IIHR Bangalore	ICAR-IIHR Hissarghatta, Bangalore	1690	23-25 Jan., 2019
4	Lokmat agrotsav 2019	Lokmat News	Market yard ,Pandharpur , Dist. Solapur	950	13-16 Feb., 2019
5	Krishidham Expo 2019	ICAR-CPRI ,Meerat (UP)	ICAR-CPRI ,Meerat (UP)	1400	15-17 Feb., 2019
6	Kisan Mela under Jal Shakati Abhiyan	KVK, Baramati	Vill.Jawalarjun, Ta. Purandar Dist.Pune	500	3 Sept., 2019
7	Kisan Agri Show 2019	Kisan Pvt Ltd	Moshi, Pune	5200	11-15 Dec., 2019

Global Farmers Fair at KVK Narayangaon , Jan. 3-6, 2019

Krishidham Expo 2019 at ICAR-CPRI Meerut (UP), Feb. 15-17, 2019

Kisan Agri Show,Moshi Pune 2019, Dt Dec. 11-15, 2019

Lokmat agrotsav 2019 Market yard ,Pandharpur, Dist. Solapur, Feb. 13-16, 2019

POMEGRANATE GROWERS/ VISITORS TO ICAR-NRCP, SOLAPUR

Following beneficiaries/ visitors visited this Centre during 2019

Table 6: Visitors to ICAR-NRCP, Solapur

S. No.	Date	Organization/ Place of beneficiaries	Category	No. of beneficiaries
1	20.01.2019	Lonar area of Buldhana district	Farmers	24
2	22.01.2019	Mehakar area of Buldhana district	Farmers	14
3	22.01.2019	Vasundhara kala mahavidyalai Solapur	Students	34
4	23.01.2019	Mehakar area of Buldhana district	Farmers	14
5	30.01.2019	Morbi area of Gujarat	Farmers	45
6	28.02.2019	Tuljapur of Osmanabad district	Farmers	15
7	11.09.2019	Krishi Vigyan Kendra Babbur farm Chitradurga Karnataka	Farmers	46
8	23.09.2019	ICAR-KVK, Vijayapura, Karnataka	Farmers	50
9	30.09.2019	Department of Horticulture Bellary	Farmers	50
10	15.10.2019	ICAR-Krishi Vigyan Kendra Mangluru Karnataka	Farmers	45
11	19.10.2019	Maharshi Vivekanand Samaj kalyan Sanstha Vijayapur Karnataka	Farmers	45
12	05.11.2019	ICAR-Krishi Vigyan Kendra Mangluru Karnataka	Farmers	41
13	06.11.2019	DeputyDirector Agriculture Barwani Madhya Pradesh	Farmers	44
14	15.11.2019	Aditya Agriculture Biotechnology College Beed (MS)	Students	24
15	05.12.2019	V.D.College of agriculture biotechnology Latur (MS)	Students	30
16	05.12.2019	A.C.S.College Umdi Tal-Jat Dit-Sangli	Students	22
17	10.12.2019	College of Agriculuture Bidyanagar UAS Rauchur Karnataka	Students	49
18	11.12.2019	College of Agriculuture Bidyanagar UAS Rauchur Karnataka	Students	52
19	16.12.2019	College of Agriculuture Kalburgi UAS Rauchur Karnataka	Students	88
20	24.12.2019	K P B Mahavidyalai Pandharpur	Students	40
21	30.12.2019	Vardaiyini Farmer Producer Company	Women farmers	12

Chitradurga (D), Karnataka farmers exposures visit to ICAR-NRCP, Solapur on Sep. 11, 2019

Department of Horticulture Bellary Karnataka on Sep. 30, 2019

College of Agriculture Bidyanagar UAS Raichur Karnataka Dec. 11, 2019

UG Students of College of agriculture Nasik dated Sep. 05, 2018

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Institutional Activities

COMMITTEE MEETINGS (RAC, IRC, IMC, IJSC)

Research Advisory Committee (RAC) Meeting

The meeting of 13th Research Advisory Committee (RAC) of ICAR-National Research Centre on Pomegranate was held during Nov 22-23, 2019 at the ICAR-NRCP, Kegaon, Solapur under the Chairmanship of Dr. N. Kumar, Vice-Chancellor, Tamil Nadu Agricultural University, Coimbatore. The committee visited the experimental site of the institute and polyhouse. They interacted with scientists and provided constructive suggestions. They also visited the experimental site at Hiraj farm. The RAC team was apprised of the infrastructure development and ongoing research works under the leadership of Dr. (Mrs.) Jyotsana Sharma, Director (Acting).

Table 1: Research Advisory Committee of ICAR-NRCP, Solapur

Chairman	
Dr. N. Kumar Vice-Chancellor TNAU, Coimbatore	Dr. Madan Pal PS, ICAR-IARI New Delhi.
Member	
Dr. D.P. Waskar Director of Research VNMKV, Parbhani.	Dr. (Mrs.). J. Sharma Director Acting ICAR-NRCP, Solapur
Dr. V.V. Sulladmath Ex-PS, ICAR-IIHR Bengaluru	Mr. Shahajirao Gulchand Pawar, Progressive Farmer Mardi, North Solapur
Dr. S.K. Panda Ex-PS, OUAT Bhubaneshwar	Mr. Malsingh Shivanand Mugle, Progressive Farmer Madrup, North Solapur
	Member Secretary
Dr. R. A. Marathe* PS (Soil Sc.) ICAR-NBSS & LUP, Nagpur.	Dr. Prakash G. Patil SS (Plant Biotechnology) ICAR-NRCP, Solapur

*Not attended the meeting.

After detailed deliberations on the progress made by the Centre during 2019-20, several valuable suggestions and recommendations were given by the XIIIth RAC which is summarized below.

Recommendations of 13th RAC held during Nov., 22-23, 2019

- Intensive breeding programme against bacterial blight disease and wilt needs to be carried out by screening large population of elite genotypes.
- Development and recommendation of a suitable bio-intensive pest and disease management schedule based on validated Induced Systemic Acquired Resistance.
- Demonstration of six easy steps for management of bacterial blight disease of pomegranate in the farmer's field of Nashik.
- Commercialization of technology for pomegranate seed oil among the clients for entrepreneurship development.

13th RAC meeting of ICAR-NRCP, Nov. 22-23, 2019

Institute Research Council (IRC) Meeting

The 14th Institute Research Council (IRC) meeting of ICAR-NRC on Pomegranate was held on 27.07.2019 at ICAR-NRCP, Kegaon, Solapur under the guidance of Dr. Jyotsana Sharma, Chairperson, IRC and Director (Acting), ICAR-NRCP, Solapur with the gracious presence of Dr. Wasaka Singh Dhillon, ADG (HS-II), ICAR, New Delhi, Dr. Debi Sharma, Principal Scientist (Agril. Chemistry), IIHR, Bengaluru and Dr. Manish Srivastava, Principal Scientist (Fruit Science), ICAR-IARI, New Delhi as expert invitees. The meeting was attended by all scientists of the centre. The achievements of various ongoing projects were presented by scientists.

Table 2: Institute Research Council of ICAR-NRCP, Solapur

Chairman	
Dr.(Mrs.) Jyotsana Sharma Director (Acting) &Principal Scientist (Plant Pathology) ICAR-NRCP, Solapur	
Member	
Dr. U.R. Sangle Principal Scientist (Plant Pathology) ICAR-NRCP, Solapur	Dr. N.N. Gaikwad Senior Scientist (AS &PE), ICAR-NRCP, Solapur
Dr. D.T. Meshram Senior Scientist (L&WME) ICAR-NRCP, Solapur	Dr. Shilpa Parashuram Scientist (Plant Breeding) ICAR-NRCP Solapur
Dr. A. Maity Senior Scientist (Soil Sc.) ICAR-NRCP, Solapur	Dr. Mallikarjun Hasnur Scientist (Entomology) ICAR-NRCP, Solapur
Dr. P.G. Patil Senior Scientist (Plant Biotech) ICAR-NRCP, Solapur	Ms. Roopa Sowjanya Scientist (Pl. Breeding) ICAR-NRCP, Solapur
	Member Secretary
Dr. N.V. Singh, Senior. Scientist (Fruit Science) ICAR-NRCP, Solapur.	Dr. K. Dhinesh Babu Principal Scientist (Hort.- Fruit Sci.) ICAR-NRCP, Solapur

14th IRC meeting of ICAR-NRCP, Jul. 28, 2019

16th IMC meeting of ICAR-NRCP, Jul. 27, 2019

Institute Management Committee (IMC) Meeting

The 16th Institute Management Committee (IMC) meeting of ICAR-NRCP, Solapur was held on 27.07.2019. The members of IMC team have perused the agenda of the meeting and provided suggestions/ recommendations for better management of the institute.

Table 3: Institute Management Committee of ICAR-NRCP, Solapur

Chairperson	
Dr. (Mrs.) Jyotsana Sharma Director (Acting), ICAR-NRCP, Solapur	
Members	
Director of Horticulture Govt. of Maharashtra	Dr. Anuradha Sharma PS, ICAR-NRCG, Pune
Dr. Chitranjan M Patel, JDH Govt. of Gujarat, Gandhinagar	Dr. K. Dhinesh Babu PS, ICAR-NRCP, Solapur
Dr. Prakash K Nagare Prof. & Head, Hort. Division DPDKV, Akola	Dr. Manish Srivastava PS, Hort. Technology Division ICAR-IARI, New Delhi
Mr. Shahaji Gulchand Pawar Main Post Office, Tk.- North Solapur Dist.- Solapur	The Assistant Director General (HS-I) ICAR, KAB-II Pusa, New Delhi 110012
Mr. Malsingh Shivanand Mugle Main Post Office-Mandrup, Tk.-North Solapur, Dist.-Solapur	F & AO, ICAR-IIRR Hyderabad
Dr. S.K. Malik PS, ICAR HQ Krishi Bhavan	Sh. B.K. Sinha (S.I. Member) SAO, ICAR-NIASM, Baramati, Pune
Member Secretary	
Sh R.B. Rai Assistant Administrative Officer ICAR-NRCP, Solapur	

Institute Joint Staff Council

The Institute Joint Staff Council (IJSC) of ICAR-NRCP, Solapur consists of following members.

Table 4: Institute Joint Staff Council of ICAR-NRCP

Chairperson	
Dr. (Mrs.) Jyotsana Sharma Director (Acting) ICAR-NRCP, Solapur	
Member (Official Side)	**Member (Staff Side)**
Dr. (Mrs.) Jyotsana Sharma Principal Scientist, ICAR-NRCP	Sh. R.B. Rai, Member (CJSC) AAO, ICAR-NRCP
Dr. N.V. Singh Senior Scientist, ICAR-NRCP	Sh. Y.R. Shinde, Secretary (IJSC) Senior Tech. Asstt., ICAR-NRCP
Dr. D.T. Meshram Senior Scientist, ICAR-NRCP	Sh. Kiran Khatmode LDC, ICAR-NRCP
Dr. Nilesh Gaikwad Senior Scientist, ICAR-NRCP	Sh. S.S. Bayas SSS, ICAR-NRCP
Officer I/c Accounts ICAR-NRCP	Sh. V.S. Gangane SSS, ICAR-NRCP
Officer I/c Administration ICAR-NRCP	

MERA GAON MERA GAURAV

Under Mera Gaon Mera Gaurav (MGMG) programme different activities carried out in 16 adopted villages covering Karnataka and Maharashtra are given below.

Table 5: Activities carried out under MGMG programme

S.No.	Name of activity	No. of activities conducted	No. of farmers participated & benefitted
1	Visit to village by teams	16	211
2	Interface meeting/ Goshthies	12	60
3	Training organized	2 (one at ICAR-NRCP and one at Farmer's Farm)	50
4	Demonstrations conducted	16 (Including two FLDs)	160
5	Mobile based advisories (No of message)	30 (Downloaded Mobile application Solapur Anar to the mobiles of 30 farmers)	30
6	Literature support provided (No)	2	20
7	Awareness created (No)	16	261
8	Distribution of Soil Health Card and other activities	Soil Health Card Distributed to 73 farmers Two Workshops (Farmers from Waghdari and Nimgaon also participated) Drumstick seeds of PKM-1 distributed	100
	Total	96	892

Demonstration orchard under MGMG at Nimgaon

Distribution of Soil Health Card

Visit by Scientists under MGMG at Waghdari and Nandgaon and distribution of Drumstick seeds

International Yoga Day Celebration

ICAR-NRCP, Solapur celebrated 'Festival of Yoga and Wellbeing' on the occasion of International Yoga Day on 21st June 2019 and also conducted various programmes on Yoga theme on 19th June 2019 *viz.*, Essay competition for NRCP staff and drawing competition for school students. Total 27 participants were participated for these competitions. The inaugural ceremony and celebration of the Yoga day was held on 21st June, 2019, at 10.00 AM in Farmers Training Hall of ICAR-NRCP, Solapur by inviting Mrs. Anita Hemade, Yoga teacher, Solapur as chief Guest in presence of Director (Acting), ICAR-NRCP, Solapur. The chief guest explained the importance of celebration of Yoga Day every Year and also explained the primer importance of Yoga in day to day life to overcome mental stress and for healthy life style and distributed prize and certificates to winners of the events. Besides this she also demonstrated few important Yoga Asana along with her two assistants to all the NRCP staff including the few School students who were participated in this program. This event was coordinated by Dr. Prakash G. Patil and Dr. Shilpa P, Scientists, ICAR-NRCP, Solapur

Inaugural Ceremony of International Yoga Day at NRCP on Jun. 21, 2019

Essay competition organised for NRCP staff in view of IYD on Jun. 19, 2019

Drawing competition organised for school students in view of IYD on Jun. 19, 2019

Demonstration of Yoga Asana by the Yoga Teacher and assistants to the NRCP Staff

Distribution of prize and certificates to winners by the Yoga Teacher Mrs. Anita Hemade

हिन्दी सप्ताह

भारतीय कृषी अनुसंधान परिषद, नई दिल्ली व्दारा जारी किए गए परिपत्र के अनुसार राष्ट्रीय अनार अनुसंधान केन्द्र, सोलापुर मे दिनांक १४ से २३ सितंबर २०१६ तक हिन्दी पखवाड़ा मनाया गया तथा इस अवसर पर विभिन्न प्रतियोगीताओ (*i.e.* भाषण, सामान्यज्ञान, पत्रलेखन, सुलेखन, अनुवाद, वाद–विवाद, टंकण, कहानी लेखन, निबंध) का आयोजन भी किया गया था।

हिन्दी सप्ताह का समापन एवं पुरस्कार वितरण समारोह दिनांक २३ सितंबर २०१६ को ३.३० बजे राष्ट्रीय अनार अनुसंधान केंद्र, सोलापुर के सभागार मे आयोजित किया गया। जिसके अध्यक्ष डॉ. ज्योत्सना शर्मा, निर्देशक (प्रभारी), राष्ट्रीय अनार अनुसंधान केंद्र, सोलापुर थे। समारोह मे विभिन्न अधिकारियों व्दारा उनके विचार व्यक्त किए गए। अध्यक्ष ने अपने भाषण मे हिन्दी भाषा के असीम महत्त्व को उजाकर किया तथा हिन्दी को सीधी, आसान एवं दिलो को जोड़ने वाली भाषा बताई फिर भी अपने ही देश मे हिन्दी के प्रसार के लिए प्रतियोगिता का आयोजन किया जाता यह खेद भी जताया। उनके उपरांन्त अध्यक्ष व्दारा प्रतियोगिताओ के विजेताओ को पुरस्कार प्रदान किए गए। इस समारोह का सुत्र संचालन डॉ. डी. टी. मेश्राम, हिन्दी अधिकारी ने किया एवं डॉ. दिनेश बाबू, प्रधान वैज्ञानिक ने धन्यवाद ज्ञापन किया। विभिन्न प्रतियोगिताओ का आयोजन करने हेतु केंद्र के डॉ. ज्योत्सना शर्मा, डॉ. दिनेश बाबू, डॉ. आशीस माइती, श्री. मल्लिकार्जुन, डॉ. पी. शिल्पा, श्री. वी.ए. शिंदे और आर. बी. राय की महत्त्वपूर्ण भूमिका रही, इस समारोह मे केंद्र के सभी वैज्ञानिक तथा कर्मचारी उपस्थित थे।

उद्घटन की तस्वीर

समापण समारोह की तस्वीर

हिन्दी सप्ताह का पुरस्कार वितरण समारोह 30 अक्तूबर 2019

SWACHH BHARAT ABHIYAN

ICAR-NRCP, Solapur observed Swachh Bharat Abhiyan (SBA) during Dec. 16-31, 2019. Several programmes were conducted as part of SBA viz., Swachhta Pledge, Awareness Campaign, plantation of tree species and waste management etc. at nearby village and school to create awareness among students, farmers and citizens about SBA and report was sent to the Council.

As a part of SBA waste management including activities like utilization of organic wastes/ generation of wealth from waste, polythene free status/ composting of kitchen and home waste materials, promoting clean & green technologies and organic farming practices were undertaken in community place and on the spot redressal of issues.

Waste Management

- Composting: Conversion of kitchen waste, home waste, farm waste into compost
- Vermi-compost: Use of earthworms for decomposing waste to Vermi-compost
- Municipal compost: Conversion of municipal waste into compost

Clean Technologies

- Organic farming: Use of organic manures for manuring of crops
- Mobile app–Swachhta: to lodge complaint on litter cleaning
- Throwing litters only in the earmarked area
- Collection & discarding of polythene material

Green Technologies

- Avenue planting along roadside
- Planting of saplings in homesteads /waste lands / river banks
- Planting of saplings in communal land for food-fodder-fuel purpose

ICAR-NRCP Staff takes Swachhata Pledge

Swacchata hi Seva hai Sep. 11 - Oct. 02, 2019 at Zila Parishad Primary school keagaon Solapur

Swacchata hi Seva hai Sep. 11 - Oct. 02, 2019 Sahakar Maharshi Mohite High school Keagon Solapur

Awarness campaign on SBA to school students at Kegaon village, Solapur Dt., Dec. 27, 2019

Distribution of leaflet on Waste management, clean & green technologies under SBA to school students and staff

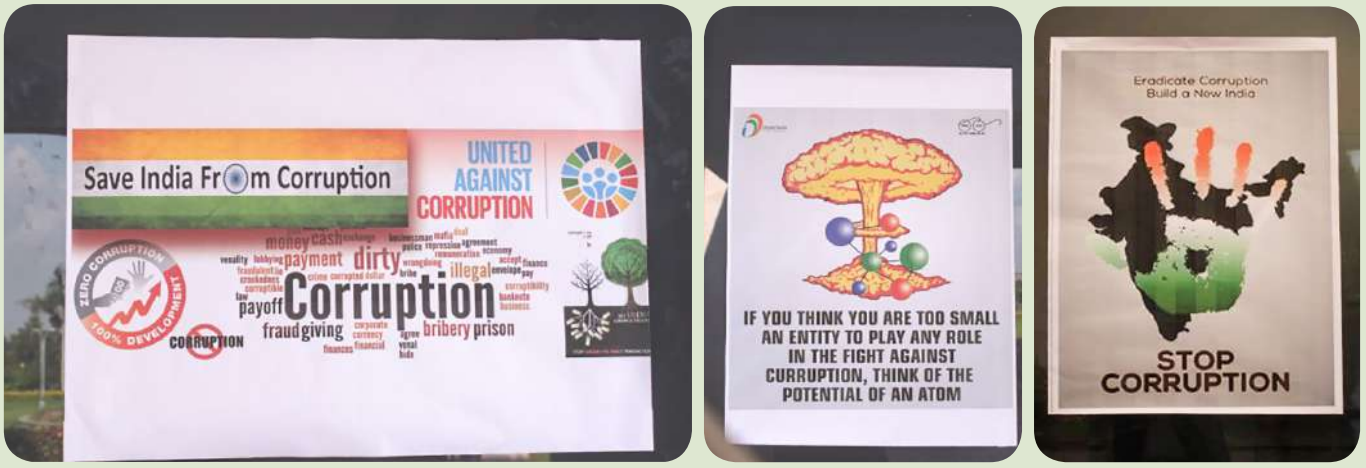
Awarness campaign on SBA in Shivajinagar Thanda, Solapur

VIGILANCE AWARENESS WEEK

ICAR-NRCP, Solapur has observed Vigilance Awareness Week from 28.10.2019 to 02.11.2019 under the guidance of Director, ICAR-NRCP, Solapur. As part of program various activities were carried out at the institute i.e. displayed posters related to eradicating corruption in the office premises, took e-pledge by the all ICAR-NRCP staffs, a wide publicity was also made through create awareness on Vigilance Week through SMS and Emails, and distributed handouts on "Honour your self-live with integrity" and "Behavior in office" among the ICAR-NRCP staff. Message on Corruption free India was disseminated through drawings through Whatsapp message to seven different groups (221 members). On 2nd Nov, closing ceremony was organized and on this occasion telecasted the panel discussion video on "Vigilance Awareness Week (Integrity: a way of life)" by Prof. J. S. Rajput (Educationist & Writer), Shri. Akhil Agarwal (Former DG, Signal & Telecom, Railway Board), Shri. Atul K. Tiwari (Additional Secretary, ministry of I&B), published by Doordarshan. They highlighted the importance of competence, commitment and performance in bringing integrity among public. This event was coordinated by Dr. Shilpa P and Dr. Prakash G. Patil Scientists, ICAR-NRCP, Solapur.

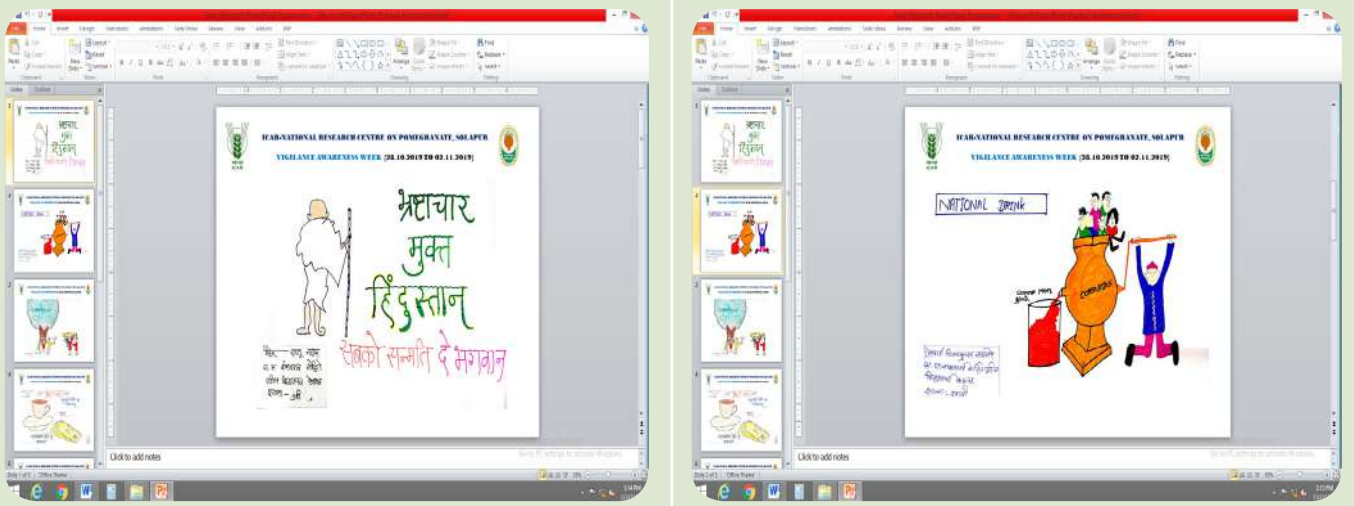
Discussion about Vigilance Awareness Week Oct. 28, 2019

Vigilance Awareness Week 2019–Integrity Pledge taken by ICAR-NRCP Staffs on Oct. 28, 2019



Posters displayed in the building of ICAR-NRCP, Solapur on Oct. 28, 2019

Distribution of handouts to promote Integrity: a way of life among ICAR-NRCP staffs on Oct. 30, 2019)



Drawing message on Corruption free India was also spread through Whatsapp on Oct. 31, 2019

Closing ceremony of Vigilance Awareness Week (Integrity: a way of life) organized on Nov. 02, 2019

DISTINGUISHED VISITORS

Visit of Mr. Kavindra Kiyawat, Horticulture commissioner, MP on Apr. 23, 2019

Visit of Mr. Suhas Divse, Commissionar Agriculture, Maharashtra on Oct. 11, 2019 to ATIC

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Human Resource Development

TRAINING ATTENDED

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

Table 1: Training attended by the staff of ICAR-NRCP, Solapur

S. No.	Name of training	Date	Venue	Name of participant
a.	**Scientific staff**			
1	Mass production technology of biological control agents	13.05.2019-15.05.2019	ICAR-National Research Centre for Integrated Pest Management, New Delhi	Dr. Ashis Maity
2	Training on use of new bio-informatics tool for analyzing chloroplast and mitochondrial genome assembly	18.05.2019-19.05.2019	Nucleome Informatics Private limited, Hyderabad, Telangana	Dr. Shilpa, P. Dr. P. G. Patil Dr. N. V. Singh
3	MDP on Priority Setting, Monitoring & Evaluation of Agricultural Research Projects	18.07.2019-23.07.2019	ICAR-NAARM Hyderabad	Dr. K. Dhinesh Babu
4	Training programme of experimental data	22.08.2019-27.08.2019	ICAR-NAARM, Hyderabad	Dr. D. T. Meshram
5	Training Workshop for Vigilance officers of ICAR Institutes	30.10.2019-01.11.2019	ICAR-NAARM Hyderabad	Dr. K. Dhinesh Babu
6	Prospects of emerging agro-based processing techniques and business opportunities	14.11.2019-04.12.2019	ICAR-Central Institute of Agril. Engg., Bhopal	Dr. N. N. Gaikwad
7	Climate smart agricultural technologies for resource conservation and increasing farmer's income	19.11.2019-09.12.2019	ICAR-National Institute of Abiotic Stress Management, Baramati	Dr. Ashis Maity
8	Novel techniques in mass culturing of smart microbial bio-control agents for the development of bio-pesticides	03.12.2019-23.12.2019	ICAR-NBAII, Bengaluru	Dr. Mallikarjun H.

b.	**Technical staff**			
9	Motivation, Positive Thinking and Communication skill.	13.03.2019-19.03.2019	ICAR-IISWC Dehradun	Mr. D.T. Chaudhary
10	Pesticide application techniques and safety measures	15.07.2019-19.07.2019	NIPHM, Hyderabad	Mr. Vijay Lokhande Mr. Govind A. Salunke
c.	**Administrative staff**			
11	Assets Management	06.11.2019-08.11.2019	ICAR-IARI, New Delhi	Mr. R.B. Rai
12	Capacity building programme towards secure and resilient work place at ICAR	25.11.2019-27.11.2019	ICAR-CPRI, Shimla	Mr. R.B. Rai

CONFERENCES, WORKSHOPS AND MEETINGS ATTENDED

The scientists of the Centre participated in conferences, workshops and meetings conducted by various organizations in India besides the meetings mentioned in the chapter on institutional activities. Conferences, seminars, symposia, workshops and important meetings attended by the scientists are enlisted below.

Table 2: Conference/ Seminar/ Symposia

S. No.	Title of Conference/ Seminar/ Symposia	Date	Venue	Name of the participant(s)
1	XXVII Plant and Animal Genome Conference, San Diego, California, USA from 12-16 Jan, 2019	12.01.2019-16.01.2019	San Diego, California, USA	Dr. N.V. Singh
2	Agri-based entrepreneurship development through processing and value addition' District level Mahila Mela, Org. by KVK Solapur	18.01.2019	KVK Solapur	Dr. J. Sharma
3	'Contemporary Research in Life Sciences and Cancer Biology' organised by Department of Biotechnology, V.G.Shivdare College of Arts, Commerce and Science, Solapur Jan 19, 2019	19.01.2019	Solapur	Dr. J. Sharma
4	ICAR Directors Conference	31.01.2019-01.02.2019	ICAR, New Delhi	Dr. J. Sharma
5	Farmer friendly soil and water conservation technologies for mitigating climate change impact	31.01.2019-02.02.2019	Gem Park, Ooty	Dr. D.T. Meshram
6	"International Symposium on, "Edible Alliums: Challenges and Opportunities"	09.02.2019	YASHADA, Baner, Pune.	Dr. J. Sharma
7	Advances in Agrometeorology for Managing Climate Risks of Farmers (INAGMET-2019)	11.02.2019-13.02.2019	JNU, New Dehli	Dr. D.T. Meshram
8	'Transforming the Life of Pomegranate Farmers of Gujarat' organised jointly by ABC Agrobiotechnology, Ahmedabad, Vanita Agro, Kohlapur and Directorate of Horticulture Krushi Bhavan, Gandhinagar- (Gujarat)	13.02.2019	Framers field, Dhrangadrha, Dist. Surendranagar Gujarat	Dr. J. Sharma
9	Field day for pomegranate farmers organized by Coromandel Int. Ltd., at Paniv, Malshirus, Solapur (MS)	16.02.2019	Paneev, Akluj, Solapur	Dr. J. Sharma Dr. N. N. Gaikwad
10	Lokmat Agro Exhibition and seminar on Problems and prospects in pomegranate cultivation organized by Lokmat Agroutsav 2019	16.02.2019	Pandharpur, Solapur	Dr. J. Sharma Dr. N. N. Gaikwad

11	Cluster development seminar on Pomegranate at Centre of Excellence for Pomegranate (established under Indo Israel Action Plan)	01.03.2019 -02.03.2019	Dhindhol -Bassi, District Jaipur	Dr. J. Sharma
12	International Conference on Innovative Horticulture and Value Chain Management	28.05.19-29.05.19	GBPUAT, Pant Nagar, Uttarkhand	Dr. K. D. Babu, Dr. J. Sharma
13	47th Joint AGRESCO Meet-2019	29.05.2019-31.05.2019	MPKV, Rahuri	Dr. N.V. Singh
14	International Conference of Centres of Excellence	18.06.2019 20.06.2019	Dindigul Tamil Nadu	Dr. J. Sharma, Dr. Mallikarjun H.
15	International Conference on Plant Protection in Horticulture - Advances and Challenges (ICPPH-2019)	24.07.2019-27.07.2019	IIHR, Bengaluru	Dr. J. Sharma Dr. Mallikarjun H.
16	5th International conference on "Plant Genetics and Genomics (Germplasm to Genome Engineering)"	17.10.2019-18.10.2019	NASC complex, New Delhi	Dr. Shilpa, P. Dr. P. G. Patil
17	Soil and Water Resources Management for Climate Smart Agriculture, Global Food and Livelihood Security	05.11.2019-09.11.2019	NASC, New Dehli	Dr. D.T. Meshram
18	XIX International Plant Protection Congress IPPC 2019	10.11.2019 - 14.11. 2019	Patancheru, Hyderabad, Telangana	Dr. J. Sharma
19	National Conference on Arid Fruits- 'A Way Forward for Sustainable Production and Nutritional Security	28.11.2019-30.11.2019	UAS, Raichur	Dr. J. Sharma Dr. N.V. Singh Dr. P.G. Patil

Table 3: Workshops

S. No.	Title of Workshop	Date	Venue	Name of Participant(s)
1	Inaugural Ceremony and Farmers Fair of "Agriculture Technology Week - 2019" 29-31 January, 2019 organized by KVK, Solapur	29.01.2019	Solapur	Dr. J. Sharma
2	National level stakeholder consultation on mango, pomegranate and banana organized by NHB	23.04.2019-24.04.2019	NASC, New Delhi	Dr. N.V. Singh Dr. N.N. Gaikwad
3	Workshop for Horticulture Training Institutes organized by NHB	06.08.2019	KVK Baramati	Dr. N.V. Singh
4	Marketing, processing and production of pomegranate	17.08.2019	Harshada Lawns, Sangola	Dr. N.N. Gaikwad
5	Kisan Goshthi on problems and prospectus in pomegranate production organized by ICAR-NRCP on the occasion of 15th Foundation Day	25.09.2019	ICAR-NRCP, Solapur	Staff of ICAR-NRCP
6	'Pomegranate cultivation, problems and Prospects' organized by Department of Agriculture, GoM, Chartapati Shivaji Shetkari Swayam Sahayata Samuha Gat, Kadlas	28.09.2019	Sangola	Dr J. Sharma, Dr. N. N. Gaikwad
7	Advance technologies in pomegranate production and protection	27.11.2019	KVK, Yaddgir, Karnataka	Dr. J. Sharma Dr. N.V. Singh Dr. P.G. Patil
8	Practices and technologies for climate resilient pomegranate production	24.12.2019	ICAR-NRCP, Solapur	Staff of ICAR-NRCP

Table 4: Meetings

S. No.	Title of meeting	Date	Venue	Name of participant(s)
1	Foundation Day of ICAR-NIASM, Baramati and Meeting with DG, ICAR	22.02.2019	Baramati	Dr. J. Sharma
2	XXIII Research Workers Annual Group Meet, AICRP on Arid Zone Fruits	23.02.2019-25.02.2019	VNMKV, Parbhani	Dr. K. Dhinesh Babu
3	Meeting of Standing Committee on Agriculture	27.02.2019-28.02.2019	ICAR-NRCG, Pune	Dr. J. Sharma Dr. N.N. Gaikwad Dr. N.V. Singh Dr. Mallikarjun H.
4	Scientific Advisory Committee Meeting	05.03.2019	SKP, KVK, Solapur	Dr. D.T. Meshram
5	DPC meeting under the Chairmanship of Dr. H. P. Singh, former DDG (HS), ICAR	11.03. 2019	NIASM, Baramati	Dr. J. Sharma
6	Golden Jubilee Celebration programme of MPKV Rahuri	29.03.2019	MPKV Rahuri	Dr. J. Sharma
7	Stakeholders meet on pomegranate and banana value chain called by Add. Project Director, SMART Project, GoM	03.04.2019	VAMNICOM, Pune, MS	Dr. N. N. Gaikwad
8	Final colloquium of Ph.D Student Mr. Malikarjun,' as committee member and co-advisor for thesis entitled, 'Isolation, Identification and Field Evaluation of Pheromone Compounds of Fruit Piercing Moth with Special Reference to *Eudocima materna* Linnaeus (Lepidoptera: Erebidae)'.	05.04.2019	GKVK, Bengaluru	Dr. J. Sharma
9	Investigation committee meet for NIASM, Baramati under the Chairmanship of the Director ICAR-DOGR, Rajgurunagar, Pune.	26.04.2019	Rajgurunagar, Pune	Dr. J Sharma
10	15th Review Meeting of DUS test centres: Kharif crops-2019"	25.04.2019-26.04.2019	PPV&FRA, NASC Complex, New Delhi	Dr. Shilpa, P.
11	1St Steering Committee Meeting on "Crop Pest Surveillance and Advisory Project (CROPSAP) 2019-20	03.05.2019	Sakhar Sankul Shivajinagar Pune Maharashtra	Dr. Mallikarjun H.
12	Project screening committee meeting for NMPB funded project entitled Utilization of pomegranate for development of functional medical ingredient	11.05.2019	NMPB office , Red Cross Road, New Delhi	Dr. N.N. Gaikwad
13	Brainstorming session on "Technology Innovation and Strategies for Farmer's Prosperity in Rajasthan"	13.07.2019	ICAR, New Delhi	Dr. J. Sharma Dr. N. N. Gaikwad
14	ICAR-Foundation Day and Award Ceremony	16.07.2019	ICAR, New Delhi	Dr. J. Sharma
15	Scientific Advisory Committee Meeting	19.08.2019	SKP, KVK, Solapur	Dr. D.T. Meshram
16	XXV ICAR Regional Committee Meeting No. VII	09.08.2019-10.09.2019	ICAR-NBSS & LUP, Nagpur	Dr. J. Sharma Dr. N.V. Singh
17	Brainstorming on Horti millet researchable issues and way forward	13.09.2019	ICAR-IIMR, Hyderabad	Dr. N. N. Gaikwad
18	Open defence meet for Ph. D thesis,' "Studies on microbial control of downy mildew in grapes" of Shri. Mahesh R Ghule	20.09.2019	Shivaji University, Kolhapur	Dr. J. Sharma
19	"Development of protocol for export of pomegranate by sea to long distance markets" at APEDA office. Organised by APEDA with different stakeholders	30.09.2019	APEDA, New Delhi	Dr. N.N. Gaikwad

20	Meeting on issues related to the registration of the insecticides and registration act 1968	22.10.2019	Krishi Bhawan, New Delhi	Dr. Mallikarjun H.
21	2nd steering committee meeting of the CROPSAP project 2019-20	23.10.2019	Sakhar Sankul Shivajinagar Pune Maharashtra	Dr. Mallikarjun H.
22	Meeting on finalization of pomegranate cluster in Maharashtra	30.10.2019	District collector office Solapur, Maharashtra	Dr. Mallikarjun H.
23	Meeting for formulation of proposal on precision farming under MoU of ICAR-CSIR	09.12.2019	NASC Complex, New Dehli	Dr. D.T. Meshram
24	4th AGM meeting of the SARP	24.12.2019	ICAR-NRCP	ICAR-NRCP Scientists and Life Members of SARP

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Publications

Table 1: Papers in research journals

S. No.	Research paper	NAAS Rating
1	Marathe, R.A., **Sharma, J.** and Chaudhari, D.T. 2019. Evaluation of micro irrigation methods in pomegranate under semi- arid tropical climate of India. *Journal of Environmental Biology* 40 (5), 1029-1035	6.73
2	**Maity, A.**, **Gaikwad, N., Babu, K. D., More, A. K.** and Sarkar. A. 2019. Physico-chemical and nutritional characteristics of main pomegranate (*Punica granatum* L.) cultivars grown in Deccan Plateau of India. *Agrochimica*, 63(2), 105-12.	6.69
3	**Meshram, D.T., Babu, K.D.**, Nair, A.K., Panigrahi, P and **Wadne S.S.** 2019. Response of Pomegranate (*Punicca granatum* L.) to deficit irrigation system under field conditions, India. *Journal of Agrometeorology* (Accepted).	6.56
4	**Mallikarjun, H.**, Bhanu, K.R.M., Thippaiah, M., Raghavendra, A., **Jyotsana Sharma** and AK Chakravarthy. 2019. Role of fruit volatiles and sex pheromone components in mate recognition in fruit piercing moth Eudocima materna Linnaeus (Lepidoptera: Erebidae). *Journal of Entomology and Zoology Studies* 7(3), 1381-1387.	5.53
5	Bachake, S.S., Jadhav, V.B., Deshpande, P.P., Tele, A.A., Banda, M.A., Adki, V.S., Gopika, M.K., Karanjule, P.G., Birajdar, S.B., Karwa, N.N., **Mundhewadikar, D.M.** and **Singh, N.V.** 2019. Standardization of *in vitro* propagation protocol for pomegranate cv. Super Bhagwa. *Journal Pharmacognosy and Phytochemistry* 8(3), 2548-2553.	5.21
6	Tele, A.A., Banda, M.A., Bachake, S.S., Jadhav, V.B., Deshpande, P.P.,Adki, V.S., Gopika, M.K., Shinde, N.A., **Sharma, J**., **Parashuram, S**., Sangnure, V.R., **Mundiwadikar, D.M.** and **Singh, N.V.** 2019. Quality RNA isolation, cDNA synthesis and qPCR validation of differentially expressed gene in *Punica granatum* L. under influence of *Xanthomonas axanopodis* pv. *punicae. Journal Pharmacognosy and Phytochemistry* 8(3), 2542-2547.	5.21
7	Marathe, R.A., **Chaudhari, D.T**. and Murali, S. 2019. Feasibility of micro-sprinklers in pomegranate (*Punica granatum* L.) orchards grown on light textured soils of central India. *Indian Journal of Soil Conservation* 47(2), 180-185.	5.20
8	**Meshram, D.T.**, Gorantiwar, S.D., Bake, N. and **Wadne, S.R.** 2019. Forecasting of air temperature of western part of Maharashtra, India. *International Journal of Science, Environment and Technology* 8(1), 201-217.	3.98
9	**Mallikarjun, M.H.** and Thippaiah, M. 2019, Electroantennographic responses of female fruit piercing moth *Eudocima materna* Linnaeus (lepidoptera: Erebidae) to fruit extracts of host plants. *Mysore Journal of agricultural Sciences*, 53(2), 62-65.	3.93

10	**Babu, K.D., Singh, N.V., Gaikwad, N., Maity A.**, Marathe, R.A., **Meshram, D.T., Patil, P.G., Shilpa, P., Sharma, J**. and Pal, R.K. 2019. Determination of maturity indices for harvesting of pomegranate cv. Bhagawa. *Indian Journal of Arid Horticulture* 1 (1), 69-72.	2.84
11	**Meshram, D.T.**, Gorantiwar, S.D. and **Wadne, S.R.** 2019. Crop coefficient and evapotranspiration pomegranate (*Punica granatum* L.) for western part of Maharashtra, India. *ACTA Scientific Agriculture* 3(7), 218-223.	-

S. No.	BOOK CHAPTERS
1	**Meshram, D.T.,** Gorantiwar, S.D., **Wadne, S.S.** and Arun Kumar K.C. 2019. Planning, Designing and Construction of Series of Check Dams for Soil and Water Conservation in a Micro-Watershed of Gujarat, India. *Springer Publication*. 337-343
2	**Meshram, D.T., Jyostana Sharma and Wadne, S.S**. 2019. Novel ways to Use Water for "Per Drop More Pomegranates (*Punicca granatum* L.). Soil and Water Conservation Bulletin. Dehradun. 4:49-51.
3	Ferrara, G., Palasciano, M., Sarkhosh, A., Cossio, F., **Babu, K.D**., Mazzeo, A. 2019 Orchard Establishment and Tree Management. In : The Pomegranate: Botany, Production and Uses (Eds Sarkhosh, A., Yavari, A. and Zamani, Z) CABI Publishing – Wallingford OX10 8DE, United Kingdom (in press).
4	**Sharma, J.**, Manjunath, G., Xavier, K.V. and Vallad, G.E. 2019. Diseases and Management. In: The Pomegranate: Botany, Production and Uses (Eds. Sarkhosh, A., Yavari, A. and Zamani, Z) CABI Publishing – Wallingford OX10 8DE, United Kingdom (in press).
5	**Singh, N.V**., Karimi, H.R., **Sharma, J.** and **Babu, K.D**. 2019.Propagation Techniques and Nursery Management. In: The Pomegranate: Botany, Production and Uses (Eds. Sarkhosh, A., Yavari, A. and Zamani, Z) CABI Publishing – Wallingford OX10 8DE, United Kingdom (in press).
6	Chater, J.M., Yavari,A. M., Sarkhosh, A., Jia, Z., Merhaut, D.J., Preece, J.E., Cossio, F., Qin G., Liu, C., Li, J., **Shilpa, P., Babu, K. D., Sharma, J.**, Yilmaz, C., Bartual, J., Mustafayeva, Z., Saeedi, M.A., Awd, N.A, Moersfelder, J. and Hou, L. 2019. World Pomegranate Cultivars. In: The Pomegranate: Botany, Production and Uses (Eds Sarkhosh, A., Yavari, A. and Zamani, Z) CABI Publishing – Wallingford OX10 8DE, United Kingdom (in press).
7	**Maity, A.**, Khayyat, M., Azarmi-Atajan, F., Agehara, S. and Sarkhosh, A. 2019.Soil and Nutrition. In: The Pomegranate: Botany, Production and Uses (Eds. Sarkhosh, A., Yavari, A. and Zamani, Z) CABI Publishing – Wallingford OX10 8DE, United Kingdom (in press).
8	Massimino Cocuzza, G.E., Goldansaz, S.H. and **Mallikarjun, H.** 2019.Arthropod Pests and Their Management. In: The Pomegranate: Botany, Production and Uses (Eds. Sarkhosh, A., Yavari, A. and Zamani, Z) CABI Publishing – Wallingford OX10 8DE, United Kingdom (in press).
9	**Gaikwad, N.N., Patil, P.**, Patil, N., Cano-Lamadrid, M. and Carbonell-Barrachina, Á.A. 2019. Processing and Industrialization. In: The Pomegranate: Botany, Production and Uses (Eds. Sarkhosh, A., Yavari, A. and Zamani, Z) CABI Publishing – Wallingford OX10 8DE, United Kingdom (in press).
10	**Shilpa, P., Babu, K. D. and Jyotsana Sharma**, 2019. Important Pomegranate varieties of India. In: The Pomegranate: Botany, Production and Uses (Eds. Sarkhosh, A., Yavari, A. and Zamani, Z) CABI Publishing – Wallingford OX10 8DE, United Kingdom (in press).

S. No.	POPULAR ARTICLES
1	Sharma, J., Singh, N.V., Maity, A., Shinde, Y.R. and Gharate, R. 2019. "*Dalimbavaril telyarogani vyavasthapan*". In: Shetkarimasik. March, 2019 (In Marathi).
2	Mallikarjun, Shinde, Y. and Sharma, J. 2019. Dalimbatil khod bhungecha adal va tyache vyavastapan. P 27-28
3	Mallikarjun, Shinde, Y. and Bajolge, R. 2019. Khod kidicha adal tyache va vyavastapan. October-December, 2019 p.29.
4	Sharma, J., Maity, A., Shinde, Y., Singh, N.V. 2019. Dalimba: Naya bagechi lagbod b vyavastapan. Setkari 54 (2), 20.
5	Sharma, J., Maity, A., Shinde, Y. Gharate, R. 2019. Dalimb baget bharadramayan karabyachi masagtiche kame. Setkari 54(1), 23.

6	Singh, N.V., Sharma, J., Maity, A., Shinde, Y., Gharate, R., Chaudhari, D.T. 2019. Dalimbacha nabin bageche lagbod tantragan b tabryl teliya rogache babasthapan. Baliraja, June, 64-72.
7	Sharma, J., Shinde, Y., Chaudhari, D. 2019. Janun gya dalimb bagetil mar rogachi lakshane", Agrowon 13.06.2019 page no 11.
8	Sharma J., Shinde Y., Chaudhari, D. and Gharate, R. (2019) *Dalimb bagetil mar rogachi niyantran*", Agrowon 14.06.2019 page no 11.

PRESENTATIONS IN CONFERENCES/ SYMPOSIA/ SEMINAR/ OTHER FORA

S. No.	ORAL PRESENTATION
1	**Sharma, J**. 2019. Pomegranate "Ancient fruit in modern horticulture. International Conference on Innovative Horticulture and Value Chain Management, May 28-30, 2019, organized by Confederation of Horticulture Associations of India, GBPUAT, Pant Nagar, Uttarakhand.
2	**Sharma, J**. 2019. Pomegranate Bacterial Blight: Recent Scenario and Research Developments. International Conference on Plant Protection in Horticulture - Advances and Challenges (ICPPH-2019) July 24-27, 2019 at IIHR, Bengaluru.
3	**Sharma, J**. 2019. Economically important diseases affecting pomegranate and their management (Keynote address). National Conference on Arid Fruits- 'A Way Forward for Sustainable Production and Nutritional Security, Nov. 28-30, 2019 at UAS, Raichur.
4	**Babu, K.D.,** Singh, N.V., Maity, A., Shilpa, P., Sharma, J. 2019. Bio-fortified pomegranate variety Solapur Lal. International Conference on Innovative Horticulture and Value Chain Management, 28-30 May 2019, organized by Confederation of Horticulture Associations of India, GBPUAT, Pant Nagar, Uttarakhand.
5	**Singh, N.V.** 2019. Challenges in Pomegranate Production. In**:** National Level Stakeholder Consultation on Mango, Pomegranate and Banana organized by NHB on 23rd April, 2019
6	**Singh, N.V.** 2019. Abiotic Stresses and their Management in Pomegranate w.r.t. Abiotic Fruit Cracking and Aril Browning. In**:** Workshop **on Practices and Technologies for Climate Resilient Pomegranate Production on 24**th December, 2019.
7	**Singh, N.V.** 2019. Innovative Propagation Techniques and Methods for Sustainable and Climate Resilient Pomegranate Production. In: National Conference on Arid Fruits- 'A Way Forward for Sustainable Production and Nutritional Security 28th November, 2019.
8	**Singh, N.V.** 2019. Presentation on research achievements of ICAR-NRCP. In: 47th Joint AGRESCO Meet-2019 at MPKV, Rahuri on 29th May, 2019.
9	**Singh, N.V.** 2019. Propagation Methods and Techniques in Pomegranate to Mitigate Abiotic and Biotic Stresses. In: 21 days winter school on Climate Smart Agricultural Technologies for Resource Conservation and Increasing Farmers' Income at ICAR-NIASM on 08.12.2019
10	**Gaikwad, N.N.** 2019**.** Pomegranate processing and likely strategy for integration of pomegranate and millets for value addition in Brainstorming on Horti millet researchable issues and way forward on 13th Sep. 2019 at ICAR-IIMR, Hyderabad.
11	**Mallikarjun, M.H., Sharma, J**., Badiger, K., Chakravarthy, A. K. and Mallesh, S. B. 2019. Bio-efficacy evaluation of novel nematicide MCW-2 (Fluensulfone 2% w/w GR) against root-knot nematodes (*Meloidogyne incognita*) of pomegranate (*Punica granatum* L.). In: Souvenir and abstract proceedings book (ICPPH-2019), International conference on plant protection in horticulture: Advances and challenges, 24-27th July, 2019, organize by AAPMHE, ICAR-IIHR, ICAR-IARI and NIPHM, at ICAR-IIHR, Bengaluru, India p.85.
12	**Patil, P.G., Singh, N.V., Parashuram, S**., Bohra, A., **Mundewadikar, D.M**., **Sangnure, V.R.**, **Babu, K.D**. and **Sharma, J**. 2019. *In silico* mining and characterization of novel miRNA-SSRs for genetic improvement of pomegranate. Lead paper presented at National Conference on Arid Fruits: A way forward for sustainable production and Nutritional Security, Department of Horticulture, University of Agricultural Sciences, Raichur, Karnataka, India, 28th -30th Nov 2019.

S. No.	POSTERS PRESENTATION
1	**Gaikwad N.N**., Kalal, A.Y., **Babu, K.D**. 2019. "Pomegranate utilization for food, pharmaceutical and cosmetic enterprises". in Souvenir cum abstract compendium of National Conference on Arid fruits: A way forward for sustainable production and nutritional security, UAS, Raichur, 28-30th November, 2019 p. 232-233.
2	**Gaikwad N.N**., Kalal, A.Y., **Babu, K.D**. 2019. "Studies on active modified atmospheric packaging of pomegranate arils". in Souvenir cum abstract compendium of National Conference on Arid fruits: A way forward for sustainable production and nutritional security, UAS, Raichur, 28-30th November, 2019 p. 211.
3	Kalal A.Y., and **Gaikwad N.N**. 2019 "Encapsulation of sensitive ingredients" in Souvenir cum abstract compendium of National Conference on Arid fruits: A way forward for sustainable production and nutritional security, UAS, Raichur, 28-30th November, 2019 p. 213.
4	**Shilpa, P., Roopa Sowjanya, P., Singh, N.V., Patil, P.G., Babu, K.D., Sharma, J.**, Pal, R. K., Kothandaraman, H., Tripathi, A. and Baghel, D.S. 2019. Finished Genome Assembly of Indian Pomegranate cv. "Bhagawa" (*Punica granatum* L.). In: E-souvenir- 5th International conference on "Plant Genetics and Genomics (Germplasm to Genome Engineering)" organized by Select Biosciences India Private Limited at NASC complex, New Delhi, 17th-18th Oct. 2019, p. 101.
5	**Patil, P.G., Singh, N.V., Shilpa, P**., Bohra, A., **Mundewadikar, D.M., Sangnure, V. R**., **Babu, K. D**. and **Sharma, J.** 2019. Genome-Wide Mining, Characterization and Development of miRNA-SSRs in Pomegranate. In: E-souvenir- 5th International conference on "Plant Genetics and Genomics (Germplasm to Genome Engineering)" organized by Select Biosciences India Private Limited at NASC complex, New Delhi, 17th-18th Oct. 2019, p. 96.

S. No.	TECHNICAL/ EXTENSION BULLETINS & FOLDERS
1	**Meshram, D.T. and Babu, K.D.** 2019. Partial root zone drying irrigation (PRZDI) techniques in Pomegranate. Folder/ ICAR-NRCP/ Extn./ 2019/01.

S. No.	MANUAL/ COMPENDIUM / ANNUAL REPORT
1	Singh, N.V., Chandra, R., Babu, K.D., Meshram, D.T., Maity, A., Gaikwad, N.N., Shilpa, P., Mallikarjun, M.H., Patil, P.G. and Sharma, J. 2019. Training programme on Model Pomegranate Production and Protection Practices for employees of Syngenta India Ltd. 4th -5th June, 2019, ICAR-NRC on Pomegranate, Solapur, Maharashtra, India, 79 p.
2	Singh, N.V., Chandra, R., Babu, K.D., Meshram, D.T., Maity, A., Gaikwad, N.N., Shilpa, P., Mallikarjun, M.H., Patil, P.G. and Sharma, J. 2019. Training Manual on Model Prapagation and Pomegranate Production Technologies for SC farmers and coordinating agencies under SCSP Programme". 1st-3rd August, 2019, ICAR-NRC on Pomegranate, Solapur, Maharashtra, India, e-Training Manual No. NRCP/2019/3, 73 p.
3	Singh, N.V., Chandra, R., Babu, K.D., Meshram, D.T., Maity, A., Gaikwad, N.N., Shilpa, P., Mallikarjun, M.H. and Sharma, J. 2019. Training Manual on Six days training on Entrepreneurship and Leadership Development Programme for Horticulture Entrepreneurs Desirous of Applying to Schemes of National Horticulture Board (NHB) : Open Field Cultivation of Pomegranate". 18th-24th December, 2019, ICAR-NRC on Pomegranate, Solapur, Maharashtra, India, e-Training Manual No. NRCP/NHB/2019/1, 95p.
4	Mallikarjun, M.H., Sharma, J., Babu, K. D., Meshram, D. T., Maity, A., Singh, N.V., Gaikwad, N. and Shilpa, P. 2019. E-Training Manual on "Model Production and Protection Practices in Pomegranate" For the extension officers of State Agri. /Hort. Department and subject matter specialists of KVK's & SAU's from November 04-8, 2019 at ICAR-National Research Centre on Pomegranate, Solapur, Maharashtra, India. (E-Training Manual No. NRCP/2019-20/2) 105 p.
5	Babu, K.D., Maity, A., Singh, N.V., Patil, P.G. and Gaikwad, N. 2019. ICAR-NRCP Annual Report 2018-19, ICAR-National Research Centre on Pomegranate, Solapur – 413 255, Maharashtra. p.114.

S. No.	PROCEEDINGS
1	Singh, N.V., Meshram, D.T., Gaikwad, N.N., Babu, K.D., Shilpa, P., Mallikarjun, M.H. and Sharma, J. 2019. Proceedings of Second National Seminar-cum- Farmers' Fair - Pomegranate for Health Growth and Prosperity, Published by SARP, Solapur, 4p.
2	Singh, N.V., Meshram, D.T., Babu, K.D., Maity, A., Shilpa, P., Mallikarjun, M.H. and Sharma, J. 2019. Proceedings of Third Annual General Body Meeting of SARP and One day Workshop on Quality Production and Processing in Pomegranate: Issues and Strategies, Published by SARP, Solapur, 4p.

S. No.	VIDEOS
	DD Kisan Programs Aired During 2019
1	Sharma J. (2019) राष्ट्रीय अनार अनुसंधान केंद्र किसानों की सेवा में. DD Kisan, May 31, 2019 https://www.youtube.com/watch?v=i3BJkdAUazE&t=958s
2	Sharma, J. (2019) बोर्डो मिश्रण की विधि. DD Kisan, Nov 6, 2019 https://www.youtube.com/watch?v=-kjr7MI38eU&t=242s
3	Gaikwad, N. (2019) अतिरिक्तआय के लिए अनार का प्रसंस्करण DD Kisan (Nov 28, 2019) https://www.youtube.com/watch?v=91Ux1q8HY6M
4	Sharma, J., Gaikwad , N. Maity A. And Singh, N. V. (2019) विचर विमरस – अनार की खेती, DD Kisan April 30, 2019 https://www.youtube.com/watch?v=eg_yxOdYVm4&t=8s (1,012 views)
5	Shilpa P. (2019) अनार की उन्नत किस्मे– डी डी किसान, DD Kisan Jul 1, 2019 https://www.youtube.com/watch?v=zeHrLdSvG9c&t=63s
6	Babu, K. D. (2019) Khet Khalihaan - Pomegranate Farming special, DD Kisan Jun 14, 2019 https://www.youtube.com/watch?v=laMk5s0IBj4&t=107s
7	Sharma, J. (2019) कैसे करें अनार में रोगों की रोकथाम Khet Khaliyan, DD Kisan Nov 4, 2019 https://www.youtube.com/watch?time_continue=546&v=yHRyXoE_FL8&feature=emb_logo
	ICAR-NRCP Videos
1	Gaikwad, N (2019) राष्ट्रीय अनार अनुसंधान केंद्र की अनार प्रसंस्करण प्रौद्योगिकियां https://www.youtube.com/watch?v=ptMu6qwfMOM (Video in Marathi, Hindi and English)
2	Singh N. V. (2019) Preparation of Quality Planting Material in Pomegranate. http://nrcpomegranate.icar.gov.in/Farmeryoutubevideo?page=4

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Awards and Recognition

AWARDS

S. No.	Name of Scientist	Name of award	Year	Awarding organization
Fellowship/ Associateship/ Young Scientist/ other awards				
1	Dr. Jyotsana Sharma	Fellow of CHAI -2019	2019	Confederation of Horticulture Associations of India, New Delhi
2	ICAR-National Research Centre on Pomegranate received by Dr. Jyotsana Sharma	Innovative Agriculture Award (Consolation) for Best Working Innovative Technology in Agriculture (category for Institutions ICAR/ SAUs/CAUs)	2019	Dhanuka Agritech Limited, New Delhi
3	Dr. K. Dhinesh Babu	Fellow of Society for Horticulture Research & Development - 2018	2019	Society for Horticulture Research & Development Ghaziabad
4	Dr. K. Dhinesh Babu	Fellow of Confederation of Horticulture Associations of India – 2019	2019	Confederation of Horticulture Associations of India, New Delhi
5	Dr. D.T. Meshram	SCSI Leadership Award	2019	SCSI, New Dehli
6	Dr. D.T. Meshram	Vasantrao Naik Krishi Prerana Purshakar	2019	Agrocare Krishimanch Nashik
7	**Dr. N.N. Gaikwad,** Miss. A.Y. Kalal, Dr. K.D. Babu	Best poster award on "Studies on active modified atmospheric packaging of pomegranate arils" in National Conference on Arid fruits: A way forward for sustainable production and nutritional security.	2019	UAS, Raichur, 28-30th Nov.
8	**Dr. Shilpa, P.,** Roopa Sowjanya, P., Dr. N.V. Singh, , Dr. P.G. Patil, Dr. K.D. Babu, Dr. J. Sharma, Dr. R. K. Pal, H. Kothandaraman, A. Tripathi and D.S. Baghel	Best poster award on "Finished Genome Assembly of Indian Pomegranate cv. "Bhagawa" (*Punica granatum* L.)" in 5th International conference on "Plant Genetics and Genomics (Germplasm to Genome Engineering)"	2019	Select Biosciences India Private Limited, 17th-18th Oct.

9	**Dr. P.G. Patil,** Dr. N.V. Singh, Dr. S. Parashuram, Dr. A. Bohra, D.M. Mundewadikar, V.R. Sangnure, Dr. K.D. Babu and Dr. J. Sharma	Best oral presentation award on "*In silico* mining and characterization of novel miRNA-SSRs for genetic improvement of pomegranate" in National Conference on 'Arid Fruits: A way forward for sustainable production and nutritional security'	2019	UAS, Raichur, 28-30th Nov.
10	**Dr. D.T. Meshram,** Dr. S.D. Gorantiwar, Dr. K. D. Babu and S.S. Wadne	Best oral presentation award on "Efficient Irrigation Management for Optimization of Pomegranate (*Punica granatum* L.) Production" in 28th National conference on "Farmer friendly soil and water conservation technologies for mitigating climate change impact"	2019	SCSI, New Delhi, 31 Jan. – 02 Feb.

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Budget Estimate

Table 1: Financial outlay in 2019-20

Head of account	Rupees (in lakhs)	
	2019-20	
	Govt. Grant	
	RE	Expenditure
(A) Recurring		
Establishment charge	332.00	328.95
T.A.	12.85	12.85
Other charges	279.15	343.23
Total A	624.00	685.03
(B) Non-recurring		
Equipment	15.59	15.58
Minor works	103.05	39.33
Library	0.47	0.47
Furniture	0.00	0.00
Information technology	0.89	0.89
Total B	120.00	56.27
(C) Loan & advances	70.00	24.40
(D) Pension	33.00	29.75
(E) Vehicles & vessels	0.00	0.00
Grand total (A+B+C+D)	777.00	771.05

Table 2: Revenue receipt in 2019-20

S. No.	Items	Amount (Rs.)
1	Income from farm produce	458403.00
2	Income from royalty and publications	79328.00
3	Income from other sources	20774.00
4	Interest on loans and advances	31613.00
5	Interest earned on short term deposits	277876.00
6	Recovery of loans and advances	140450.00
7	Training programs	190000.00
8	Analytical testing fee	16649.00
9	License fee/ Guest house	86696.00
	Total revenue receipt	1301789.00

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Staff Position, Personnel, Joining/ Promotion/ Relieving

Staff Position

Category	Sanctioned during XIIIth 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	25	5

Personnel

RMP	
-	
Scientific staff	
Dr. (Mrs.) Jyotsana Sharma Principal Scientist and Director (Acting)	Dr. K. Dhinesh Babu Principal Scientist (Hort.-Fruit Science)
Dr. U.R. Sangle Principal Scientist (Plant Pathology)	Dr. D.T. Meshram Senior Scientist (Land and Water Management Engg.)
Dr. Ashis Maity Senior Scientist (Soil Science-Pedology)	Dr. N.V. Singh Senior Scientist (Hort.-Fruit Science)
Dr. Prakash G. Patil Senior Scientist (Plant Biotechnology)	Dr. N.N. Gaikwad Senior Scientist (Agril. Structures and Process Engg.)
Dr. (Mrs.) Shilpa P. Scientist (Genetics & Plant Breeding)	Dr. Mallikarjun Scientist (Agril. Entomology)
Ms. Roopa Sowjanya P. Scientist (Genetics & Plant Breeding)	

Technical staff		
Sh. D.T. Chaudhari Technical Officer	Sh. Yuvaraj Shinde Senior Technical Officer	Sh. Diwakar Sawji Senior Technical Officer
Sh. Mahadev Gogaon Senior Technician	Sh. Govind Salunke Senior Technician	Sh. Vijay Lokhande Senior Technician
Administrative staff		
Sh. R.B. Rai AAO	Sh. V.A. Shinde AF&AO	
Sh. Kiran Khatmode LDC	Sh. A.S. Babar LDC	Sh. Vipin Dagar LDC
Supporting staff		
Sh. Shailesh Bayas SSS	Sh. Vishal Gangane SSS	

JOINING: NIL

PROMOTION

Dr. Nilesh Nivrutti Gaikwad, Scientist (Agril. Structures and Process Engineering) was promoted as Senior Scientist (Agril. Structures and Process Engineering) w.e.f. 23.06.2018.

Dr. Prakash G Patil, Scientist (Plant Biotechnology) was promoted to Senior Scientist (Plant Biotechnology) w.e.f. 08.01.2018.

Dr. Shilpa P, Scientist (Genetics & Plant Breeding) was promoted to Scientist with GP Rs. 7000 (Genetics & Plant Breeding) w.e.f. 01.01.2019.

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Outreach activities of ICAR-NRCP in India

POPOM / IDIPM-Practices for Pomegranate Orchard Management / Integrated management of diseases and Insect pest in Pomegranate

TCP-Tissue Culture Raised Bio-Hardened Plants

HWCP-Hard Wood Cutting Plants

RTS&J-Ready to Serve Drink and Juice

MPA-Minimal Processing of Arils

CB-Capacity Building

SL-Solapur Lal (new variety)

SONAAR- Potassium solubilizing bio-formulation

MOU (BSC / MSC / Ph.D students)- Training to students

MGMG / SCSP / TSP- Mera Gaon Mera Gaurav / Scheduled Caste Sub Plan / Tribal Sub Plan

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

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