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SPECIAL COVER

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ICAR-National Research Centre on Pomegranate
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Preface



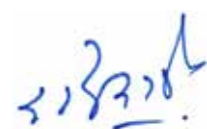
ICAR-National Research Centre on Pomegranate, Solapur, has completed 16 years of journey on September 25, 2021. The Centre has accomplished its objectives with visible outcomes during the period and is proud to be the driving force behind the sprawling pomegranate sector in India. The pomegranate sector has recorded constant increase in area, production and productivity since last 8 years. In 2020-21, the pomegranate was cultivated over 2.83 lakh ha, production of 31.25 lakh tonnes with productivity of 11.25 t/ha and in 2019-20, the export was 80,500 tonnes.

ICAR-NRCP has significantly contributed in improving pomegranate scenario in India through its technologies on combating major diseases, improving fruit yield and quality, providing quality planting material, identifying suitable pomegranate growing areas in India, developing sound package of practices, 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 Caste Sub-Plan (SCSP) by demonstrations, inputs, Soil Health Cards and technical guidance. The positive feedback from different stakeholders including farmers, is the driving force keeps us move forward with commitment.

A noteworthy achievement of this year was release of special postal cover on ICAR –NRCP , Solapur during 17th foundation day by Postal department. This year, organized an international webinar in collaboration with SARP, Solapur. A total of 47 Invited Speakers including 7 international speakers and 200 delegates from 9 countries of the world namely, Israel, Iran, Spain, USA, Turkey, Italy, South Africa, Germany, Pakistan and India have participated in this mega scientific event., webinar was conducted under the aegis of Dr CD Mayee, Former ASRB Chairman, Former DDG Dr. Krishna Kumar and Dr AK Singh, DDG (Horticulture). The institute has identified an early-maturing genotype currently under evaluation. For the first time a farmer's variety, "Sharad King" is undergoing onsite evaluation as part of the DUS center. Two varieties developed by the institute, NRCP-H4 and NRCP-H14, are also under DUS characterization. The centre has standardized the LD₅₀ for chemical mutagens to create variability through mutation in pomegranate. For the control of bacterial blight disease (BBD), developed an eco-friendly, low-cost technique called as stem solarization which has six major steps, which has been successfully demonstrated in many farmers' fields. Newly developed nematicides, Fluensulfone 2% GR and Fluopyrum 34.5% SC, have proven their effectiveness against nematodes. The centre has effectively performed wedge grafting of the Bhagwa scion onto a salinity-tolerant rootstock, making it suitable for rootstock use. Furthermore, pomegranate peel fortified and fiber enriched muffins were developed serving

as a natural antioxidant. Notably, the center has published 8 research papers, 19 book chapters and 30 popular articles. Our scientists have bestowed with several prestigious awards.

I 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. The cooperation and support rendered by all the staff members of SMD (HS) to this Centre is thankfully acknowledged. I am grateful to Hon'ble Chairman and members of RAC for guidance and keen interest shaping 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.



Dr. R.A. Marathe
Director, ICAR-NRCP



Introduction

Indian horticulture has moved from rural confines to commercial venture. In India, the scenario of horticulture crops has become very encouraging in recent times. Horticulture production in 2001-02 was only 145.8 million tonnes, 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 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 thereby 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.

Since last two decades, the 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.

Envisioning the economic importance of pomegranate for 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:

- (i) A well established, 'Field Gene bank' with 367 germplasm lines including indigenous and exotic lines established at ICAR-NRCP, Solapur which serves collection of genes for diverse characters.



- (ii) 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.
- (iii) Bio-hardened micro-propagation technology for propagation of disease free planting material.
- (iv) Novel bio-formulation for potassium fertilizer supplement, with *Penicillium pinophilum*, that reduces 70% requirement of potassium to pomegranate, saves ~Rs.40,000/ha on fertilizers cost and increases yield by 25%.
- (v) 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.
- (vi) 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 around 17.6 is a boon for processing industries.
- (vii) 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 popularized its promising technologies through licensing, consultancy, extension activities, distribution of NRCP publications, digital mobile app 'Solapur Anar', demonstrations on farmers field, providing on campus and off campus trainings to farmers and entrepreneurs and TV shows.

Due to highest BCR of pomegranate, this ancient health fruit with available technologies can be considered as 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 monetary 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-NRC on Pomegranate has developed infrastructure with the 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 Hon'ble Primer Minister of India on Digital India, Doubling Farmers' Income and Atmanirbhar Bharat.

**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

अनार के परिदृश्य में 2.83 लाख हेक्टेयर क्षेत्र में उल्लेखनीय प्रगति दर्ज की गई, 2019-20 में 31.25 लाख टन का उत्पादन और 2019-20 में 80,500 टन का निर्यात हुआ। इस फसल ने भारत के अनियमित वर्षा वाले शुष्क और अर्ध-शुष्क क्षेत्रों में किसानों की आजीविका सुरक्षा में सुधार के लिए अपना महत्व दिखाया है। आईसीएआर-राष्ट्रीय अनार अनुसंधान केंद्र, सोलापुर अनार उत्पादकों के सामने आने वाले विभिन्न शोध योग्य मुद्दों को हल करने और इस लोकप्रिय फसल की चुनौतियों का सामना करने में महत्वपूर्ण भूमिका निभा रहा है।

रिपोर्ट के तहत वर्ष के दौरान, केंद्र ने कई संस्थागत परियोजनाओं (13), बाहरी रूप से वित्त पोषित परियोजनाओं, दो अंतर-संस्थागत सहयोगात्मक परियोजनाओं, एक अनुसूचित जाति उप योजना (एससीएसपी) और एक जनजातीय उप-योजना (टीएसपी) योजना को संभाला है। प्रमुख उपलब्धियों का सारांश नीचे दिया गया है।

जननद्रव्य संसाधन:

- कुल 362 अनार जर्मप्लाज्म परिग्रहण (140 आईसी + 222 ईसी) में 140 स्वदेशी और 222 विदेशी संग्रह शामिल हैं, जिन्हें आईसीएआर-एनआरसीपी, सोलापुर में बनाए रखा गया है। जिनमें से, 98 जर्मप्लाज्म परिग्रहण (70 विदेशी, 28 स्वदेशी) का मूल्यांकन चुनौती की स्थिति के तहत बैक्टीरियल ब्लाइट रोग के प्रति उनकी आनुवंशिक प्रतिक्रिया के लिए किया गया था। एक जर्मप्लाज्म (EC-676992) मध्यम प्रतिरोधी (SG:2) और 9 परिग्रहण मध्यम रूप से अतिसंवेदनशील (SG:3) जीनोटाइप (EC-798832; EC-798740; IC-318716; EC-676975; EC-798729; EC-) पाए गए। 676994; ईसी-798763; ईसी-676931; ईसी-676930)। ये अनार प्रजनन कार्यक्रमों के लिए मूल्यवान आनुवंशिक संसाधन होंगे।
- पहले पहचानी गई छह आशाजनक प्रजनन वंशावली (शरद किंग, एनआरसीपीएस-7, बीबीएससी-1, बीबीएससी-2, बीबीएससी-3, बीबीएससी-6-1) की भी बैक्टीरियल ब्लाइट बीमारी एक्सएपी-90, 118 कल्चर (108) के प्रति उनकी आनुवंशिक प्रतिक्रिया के लिए जांच की गई थी। पीएफयू/एमएल; ओडी: 0.1031) नियंत्रित स्थिति में। रोग की गंभीरता ग्रेड के आधार पर, एनआरसीपीएस-7 (एसजी: 2.50), बीबीएससी-2 (एसजी: 2.92), बीबीएससी-3 (एसजी: 2.86), मध्यम पाए गए। अतिसंवेदनशील जबकि अन्य अतिसंवेदनशील होते हैं।
- किसान के खेत से एक "भगावा" प्रकार की पहचान की गई और उसे एकत्र किया गया जो लगभग 135-145 दिनों में पक जाता है। इस संस्करण को बीबीडी पर प्रतिक्रिया सहित अन्य डीयूएस विशेषताओं के लिए चित्रित किया जाएगा। अनार में रोग निवारण तंत्र को प्रेरित करने के लिए छह विविध अनार जीनोटाइप (गणेश, पटना -5, पी -26, जी -137, अरक्ता और मृदुला) के बीच प्रारंभिक परिपक्वता के लिए प्रजनन शुरू किया गया है। बैक्टीरियल ब्लाइट रोग के खिलाफ आशाजनक जीनोटाइप की पहचान करने के लिए एनआरसीपी एच-6 और बीसी1एफ1 पीढ़ी की 'एनआरसीपी एच-6'।
- प्रेरित उत्परिवर्तन के माध्यम से बीबीडी प्रतिरोध के लिए आनुवंशिक परिवर्तनशीलता का निर्माण किया गया है। रासायनिक उत्परिवर्तन के बीच, ईएमएस उपचार के लिए सीवी में एलडी50 मान निर्धारित किया गया है। "भगावा" (पानी में पूर्व-भिगोने के बिना 6 घंटे के लिए 1% और पानी में पूर्व-भिगोने के साथ 4 घंटे के लिए 1.4%)। अनार में बैक्टीरियल ब्लाइट रोग प्रतिरोध के लिए उन्नत आनुवंशिक अध्ययन के लिए ईएमएस के एलडी50 मान (6 घंटे के लिए 1%) के साथ इलाज की गई एम1 उत्परिवर्ती आबादी तैयार की गई है। सीवी का गामा विकिरण 'भगावा' को 4 अलग-अलग खुराकों (3 केआर, 5 केआर, 7 केआर और 9 केआर) के लिए भी किया गया था। बीज अंकुरण (%) पर डेटा पूरा हो चुका है। एलडी50 मूल्य की गणना अंकुर के जीवित रहने पर डेटा रिकॉर्ड करने के बाद एक बार की जाएगी। (%) और बीबीडी के खिलाफ स्क्रीनिंग के लिए अलग-अलग उत्परिवर्ती आबादी को बढ़ाने के लिए निर्धारित एलडी 50 मूल्य वाली आबादी को उन्नत किया जाएगा। ईएमएस और सोडियम एज़ाइड रसायनों का उपयोग करके ठोस उत्परिवर्ती विकसित करने के लिए इन विट्रो उत्परिवर्तन किया गया है। कली अंकुरण पर उनके प्रभाव के आधार पर (%), LD50 को EMS 0.5% 4 घंटे (36.67%) और SA 2mM 3 घंटे पाया गया।



- प्रथम वर्ष महाराष्ट्र के औरंगाबाद में किसान किस्म अर्थात् 'शरद किंग' का ऑन-साइट डीयूएस लक्षण वर्णन किया गया। परीक्षण की गई उम्मीदवार किस्म में संदर्भ किस्म (मध्यम, मध्यम, मध्यम और देर से पकने वाली) की तुलना में पंखुड़ी की लंबाई (लंबी), पंखुड़ी की चौड़ाई (बड़ी), एरिल लंबाई (छोटा) और फल की परिपक्वता (मध्यम) के लिए विशिष्ट विशेषताएं पाई गईं। 2021 में, दो संकर किस्में i. ई., एनआरसीपी एच-6 (सोलापुर लाल) और एनआरसीपी एच-12 (सोलापुर अनारदाना) को नई किस्मों के रूप में पौधा किस्म रजिस्ट्री, पीपीवी और एफआरए, नई दिल्ली में पंजीकृत किया गया है।
- 30 एसएसआर मार्करों का उपयोग करके जंगली और खेती दोनों प्रकार के अनार के 48 जीनोटाइप का मूल्यांकन किया गया था। अधिकतम आनुवंशिक असमानता (0.53) IC-318712 और IC-318718 के साथ-साथ IC-318712 और Acc-08 संग्रह के बीच देखी गई। तीन समूहों (जंगली प्रकार) को अभारित पड़ोसी जुड़ाव से प्राप्त किया गया था जो असमानता पर अभारित औसत के मानदंड का उपयोग करता है। बहुरूपी सूचना सामग्री 0.53 के औसत के साथ 0.12 से 8.69 तक थी। पीजीएसएसआर 54, 57 और 32 मार्करों के दिए गए सेट के साथ अत्यधिक बहुरूपी पाए गए।

किस्म सुधार:

- अनार की किस्म सोलापुर लाल का मूल्यांकन सत्तारूढ़ किस्म की तुलना में, मृग बहार में रोपण के सातवें वर्ष के दौरान भगवा ने लगभग 19.0 दिन पहले परिपक्वता दर्ज की, फल की बेहतर गुणवत्ता के अलावा भगवा की तुलना में 25.8% अधिक उपज (35.22 किग्रा / पेड़) दर्ज की गई।
- मृग बहार में रोपण के छठे वर्ष के दौरान अमलिडाना की तुलना में अनार की किस्म सोलापुर अनारदाना का मूल्यांकन किया गया। सोलापुर अनारदाना में 28.94 किलोग्राम/वृक्ष फल उपज, 4.82% अनुमापनीय अम्लता और 460.5 मिलीग्राम/100 ग्राम एंथोसायनिन दर्ज किया गया।
- रोपण के छठे वर्ष में आईसीएआर-एनआरसीपी, सोलापुर में विकसित बारह संकरों के मूल्यांकन से पता चला कि उपज 16.73-29.21 किलोग्राम/वृक्ष के बीच थी। उच्चतम उपज एचए* (29.21 किग्रा/पेड़) द्वारा दर्ज की गई, जिसका वंश 'भगवा x [(गणेश x नाना) x दारू] था, इसके बाद भगवा x पटना-5 (26.94 किग्रा/वृक्ष) था, जिसके बड़े आकार के फल (298.3 ग्राम) थे। /फल)।
- अनार संस्करण का ड्राफ्ट जीनोम अनुक्रमण। भगवा कराया गया।
- गुणसूत्र विशिष्ट एसएसआर मार्करों का वेटलैब सत्यापन।
- एंथोसायनिन संश्लेषण मार्ग: उम्मीदवार जीन आधारित मार्करों को विकसित करने के लिए, पांच जीनों (एएनएस, सीएचएस, सीएचआई, एफ3एच और डीएफआर) की पूरी लंबाई के जीन अनुक्रम, जो एंथोसायनिन जैवसंश्लेषण मार्ग का हिस्सा हैं, को ट्यूनीशिया जीनोम के लिए एनसीबीआई डेटाबेस से पुनर्प्राप्त किया गया और डाबेंजी और ताइशानहोंग के साथ तुलना की गई। जीन. एकाधिक अनुक्रम संरेखण के बाद, तीन प्रमुख जीन एएनएस (1.2 केबी), सीएचआई (2.7 केबी) और डीएफआर (1.9 केबी) में अनुक्रम भिन्नता की पहचान की गई। इसके अलावा, अनार की 10 किस्मों को बढ़ाने के लिए डिज़ाइन किए गए प्राइमर, मानकीकृत पीसीआर स्थितियां, एलील खनन के लिए फल और एरिल रंग के लिए अलग-अलग थीं।
- इन विट्रो स्थितियों के तहत, अनार संस्करण। सोलापुर लाल ने 83.6% संस्कृति स्थापना, 51.5% रूटिंग का खुलासा किया।
- आशाजनक रूटस्टॉक्स का उपयोग करके अनार में वेज ग्राफ्टिंग: लवणता और सर्टोसिस्टिस फिम्रिएटा के खिलाफ कुछ आशाजनक जीनोटाइप को वेज ग्राफ्टिंग के लिए भगवा स्कोन का उपयोग करके रूटस्टॉक के रूप में उपयोग किया गया था। ग्राफ्टिंग की सफलता 30% से 83.33% तक थी।
- भगवा वंश के ऊपर लवणता और सेराटोसिस्टिस फिम्रिएटा के खिलाफ आशाजनक 13 रूटस्टॉक्स की वेज ग्राफ्टिंग से 30.0-83.3% ग्राफ्टिंग सफलता का पता चला 676938 (83.3%), 318735 (80.0%), 676927 (70.0%), भगवा (70.0%)।

**फसल उत्पादन:**

- फलों के पतले होने के 6 स्तरों में से, अनार का हल्का पतला होना से सोलापुर लाल ने इष्टतम उपज (31.86 किग्रा/पेड़) के साथ नियंत्रण से अधिक फल का आकार (275.6 ग्राम/फल) बढ़ाया।
- भगवा में फूल आने पर 2,4-डी @20 पीपीएम का पर्ण स्प्रे और 10 डीएए न्यूनतम फूल गिरने (21.3 फूल/पेड़), उच्चतम फल गिरने (58.06%) के साथ फल गिरने के प्रबंधन के लिए अत्यधिक प्रभावी पाया गया। फलों की संख्या (96.5 फल/पेड़) और फल की उपज (25.88 किग्रा/पेड़)।
- फूल आने की प्रेरणा: अनार में फूल आने के दौरान 10 पीपीएम की दर से एनएए का पत्तियों पर छिड़काव करें। उच्चतम फल वाला भगवा (53.46%), नहीं। फल/पेड़ (98.0/पेड़) और उपज (26.87 किग्रा/पेड़)। पोटैशियम नाइट्रेट @1.0% के पत्तों पर छिड़काव के परिणामस्वरूप सबसे अधिक संख्या प्राप्त हुई। फलों की संख्या (98.2), फलों का वजन (275.4 ग्राम) और उपज (27.04 किलोग्राम/पौधा) नियंत्रण (19.79 किलोग्राम/पौधा) से अधिक है।

फसल सुरक्षा:

- स्टेम छेदक नियंत्रण के लिए, ट्रेंचिंग या ट्रेंचिंग और स्टेम इंजेक्शन @ इमामेक्टिन बेंजोएट 5% एसजी ने कीट पर 100% नियंत्रण दिया। इसी तरह, इमामेक्टिन बेंजोएट 3% + थियामेथोक्साम 12% WG ने भी 100% नियंत्रण दिया।
- ट्रेंचिंग विधि के माध्यम से अनार के शॉट होल बोरर के खिलाफ आठ अलग-अलग कीटनाशकों की जैव-प्रभावकारिता के मूल्यांकन से पता चला कि नौ उपचारों में से पौधों की 98.25% रिकवरी हुई, (इमामेक्टिन बेंजोएट 3% + थियामेथोक्साम 12% डब्ल्यूजी) @ 2 ग्राम/लीटर, साथ में प्रोपिकोनाज़ोल @ 2 मिलीलीटर/लीटर 98.25% पौधों की रिकवरी हुई।

बैक्टीरियल ब्लाइट के प्रबंधन के लिए स्टेम का सौरीकरण:

- 100% ब्लाइट नियंत्रण के साथ सामुदायिक दृष्टिकोण से बैक्टीरियल ब्लाइट का प्रबंधन करने के लिए स्टेम सोलराइजेशन तकनीक विकसित की गई। यह पर्यावरण अनुकूल, किफायती और प्रभावी तकनीक है और यदि इसे सामुदायिक दृष्टिकोण से किया जाए तो यह रोगजनक को खत्म कर सकती है। इसका उपयोग जैविक खेती वाले भूखंडों के लिए भी किया जा सकता है। 6 स्थानों पर एफएलडी प्रगति पर हैं, 3 अहमदनगर के राहता में और 3 महाराष्ट्र के सोलापुर जिले के मालशिरस में। एनआरसीपी में 3 साल के लिए फील्ड ट्रायल और अक्कलकोट में 2 साल के लिए 1 किसान के प्लॉट की सफलता को पिछली वार्षिक रिपोर्ट में 'बैक्टीरियल ब्लाइट को प्रबंधित करने के छह कदम' के रूप में रिपोर्ट किया गया है, आरएसी की सिफारिशों पर प्रौद्योगिकी का नाम बदल दिया गया है।
- फंगल रोगजनकों के खिलाफ एंडोफाइट्स का इन विट्रो मूल्यांकन: वर्तमान अध्ययन के प्रारंभिक परिणामों से संकेत मिलता है कि इन एंडोफाइट्स विशेष रूप से बीई-5 और ईबी-7 का उपयोग विभिन्न फंगल रोगजनकों के खिलाफ संभावित जैव नियंत्रण एजेंटों के रूप में किया जा सकता है।
- पॉलीहाउस स्थितियों के तहत नए नेमाटीसाइड्स का मूल्यांकन
- गमले के नीचे नई जड़ों पर निमित्ज (फ्लुएनसल्फोन 2% जीआर), वेलम प्राइम (फ्लुओपाइरम 34.48% एससी), रेक्लेमेल (फ्लुएज़ेन्डोलिज़िन 500 एससी) और वनस्पति तेल आधारित नेमाटाइड यानी रूट-नॉट नेमाटोड के खिलाफ निमोन जैसे नए नेमाटाइडल रसायनों के मूल्यांकन के लिए प्राथमिक परीक्षण 5 महीने की अवधि के लिए शर्त. परीक्षण के लिए चयनित लगभग 20 पौधे पहले से ही आरकेएन (>100 गैल्स/पौधा, उच्चतम गैलिंग इंडेक्स स्केल 5) से भारी रूप से प्रभावित थे। हमने प्रत्येक उपचार के लिए बेतरतीब ढंग से 4 पौधे दिए हैं, जिनमें से 2 की जड़ें काट दी गईं और जड़ों को उसी गमले की मिट्टी में मिला दिया गया।
- अनार के पौधों की जड़ों की छंटाई के साथ और उसके बिना भी सिफारिश के अनुसार नेमाटीसाइड्स से उपचार किया गया। सबसे कम संख्या अक्षुण्ण जड़ों वाले पौधों में रेक्लेमेल @ 2 मिली/2 लीटर (0.5 लीटर/पौधा) के साथ



वेलम प्राइम @ 2 मिली/2 लीटर (0.5 लीटर/पौधा) और निमित्त @ 10 ग्राम/पौधा से उपचारित किए गए पौधों में पित्त की मात्रा देखी गई। जड़ से काटे गए पौधों के मामले में, उपर्युक्त सांद्रता में निमित्त और वेलम प्राइम से उपचारित पौधों में कोई गॉल नहीं देखा गया।

- कटाई उपरांत प्रौद्योगिकी
- अनार के रस को फोम मैट निर्जलीकरण तकनीकी से 3 घंटे में सुखाने की प्रक्रिया को मानकीकृत।
- अनार की भगवा, गणेश और अरक्ता किस्मों की किण्वन प्रक्रिया से वाइन बनाने की प्रक्रिया का अध्ययन किया गया। संवेदी मूल्यांकन के दौरान अरक्ता के बाद भगवा और गणेश वाइन को सबसे स्वीकार्य वाइन पाया गया।
- अनार के छिलके के पाउडर से फाइबर युक्त मफिन विकसित किए गए। छिलके का पाउडर एक प्राकृतिक एंटीऑक्सीडेंट के रूप में भी कार्य करता है और ऑक्सीडेटिव और माइक्रोबियल स्थिरता प्रदान करता है।

अन्य गतिविधियाः

- केंद्र ने महाराष्ट्र, राजस्थान, छत्तीसगढ़, मध्य प्रदेश राज्यों में एससीएसपी, टीएसपी और मेरा गांव मेरा गौरव के माध्यम से प्रदर्शन, इनपुट की आपूर्ति, मृदा स्वास्थ्य कार्ड प्रदान करने, प्रशिक्षण और तकनीकी मार्गदर्शन प्रदान करके अनार की खेती को बढ़ावा दिया है, जिससे लगभग 335 किसान लोग लाभान्वित हुए हैं।
- आईसीएआर-एनआरसीपी ने उद्यमियों के लिए तीन प्रौद्योगिकियों का व्यावसायीकरण किया और तीन प्रदर्शनियों में अपनी गतिविधि प्रदर्शित की और किसानों, छात्रों और अन्य हितधारकों सहित 1000 से अधिक आगंतुकों ने जानकारी के लिए केंद्र का दौरा किया।
- आईसीएआर-एनआरसीपी के सभी कर्मचारियों ने स्वच्छ भारत अभियान, अंतर्राष्ट्रीय महिला दिवस, किसान दिवस आदि के तहत गतिविधियों में सक्रिय रूप से भाग लिया।
- केंद्र ने किसानों और अनार की खेती में शामिल विभिन्न हितधारकों के लिए कार्यशालाएं और प्रशिक्षण कार्यक्रम भी आयोजित किए। इसके अलावा, विभिन्न हितधारकों तक आईसीएआर-एनआरसीपी प्रौद्योगिकियों का प्रसार करने के लिए विभिन्न संगठनों के सहयोग से विभिन्न इंटरैक्टिव बैठकें आयोजित की गईं।
- केंद्र ने सहकर्मि समीक्षा वाली पत्रिकाओं में 8 शोध पत्र प्रकाशित किए, जिनमें से 2 NAAS रेटिंग \10 से ऊपर वाले जर्नल में थे, एक समीक्षा लेख, 19 पुस्तक अध्याय, 30 लोकप्रिय लेख, इसके अलावा सम्मेलनों में 22 प्रस्तुतियाँ और 31 पोस्टर प्रस्तुतियाँ थीं। वैज्ञानिकों को सर्वश्रेष्ठ मौखिक/पोस्टर प्रस्तुति पुरस्कारों के अलावा पेशेवर सोसायटी जैसे पुरस्कार/फैलोशिप से भी मान्यता मिली।



Executive Summary

The scenario of pomegranate recorded a significant progress in area of 2.83 lakh ha, production of 31.25 lakh tonnes in 2019-20 and export of 80,500 tonnes in 2019-20. 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 pivotal role in solving various researchable issues faced by the pomegranate growers and meeting the challenges of this popular crop.

During the year under report, the Centre has handled several Institutional Projects (13), Externally Funded Projects, two Inter-Institutional Collaborative Projects, one Schedule Caste Sub-Plan (SCSP) and one Tribal Sub-Plan (TSP) Scheme. The major achievements are summarized below.

Genetic Resources:

- In total germplasm accessions (140 IC + 222 EC) consists of 140 Indigenous and 222 Exotic collections have been maintained ICAR-NRCP, Solapur.
- Out of 98 germplasm (70 EC, 28 IC), One germplasm (EC-676992) was found moderately resistant (SG: 2) to bacterial blight besides 9 accessions as moderately susceptible, for use in pomegranate breeding programme.
- NRCP-7 (SG: 2.50), BBSC-2 (SG: 2.92), BBSC-3 (SG: 2.86), were found to be moderately susceptible to bacterial blight disease.
- Identified and collected one “Bhagawa” variant from the farmer’s field which matures in about 135-145 days. This variant will be characterized for other DUS characteristics including reaction to BBD. Breeding for early maturity, has been initiated between six diverse pomegranate genotypes (Ganesh, Patna-5, P-26, G-137, Arakta and Mridula) for inducing disease escape mechanism in pomegranate. Advanced F_2 segregant population of NRCP H-6 and BC_1F_1 generation of ‘NRCP H-6’ x ‘Bhagawa’ and ‘NRCP H-6’ x (GxNx D) has been developed to identify promising genotypes against bacterial blight.
- For creation of genetic variability for bacterial blight resistance through induced mutation, for EMS treatment fixed LD50 value in cv. “Bhagawa” (1% for 6hrs without pre-soaking with water and 1.4% for 4hrs with pre-soaking in water). M_1 mutant population treated with LD50 value of EMS (1% for 6hrs) has been generated for advanced genetic studies for bacterial blight disease resistance in pomegranate.
- Gamma irradiation of cv. ‘Bhagawa’ was carried also out for 4 different doses (3 kR, 5 kR, 7 kR, and 9 kR. The data on seed germination (%) has been completed. LD50 value will be calculated once after recording the data on seedling survival (%) and the population with the decided LD50 value will be advanced to rise the segregating mutant population for screening against BBD. *In vitro* mutagenesis for developing solid mutants has been carried using EMS and Sodium Azide chemicals. Based on their effect on bud sprouting (%), the LD50 was found to be EMS 0.5% 4 hr (36.67%) and SA 2mM 3hrs.
- First year on-site DUS characterization of farmer variety namely „Sharad King” with medium fruit maturity was carried out.
- In 2021, two hybrid varieties i. e., NRCP H-6 (Solapur Lal) and NRCP H-12 (Solapur Anardana) have been registered in the Plant Varieties Registry, PPV&FRA, New Delhi as new varieties.



Crop Improvement:

- Pomegranate variety Solapur Lal gave 25.8% higher yield (35.22kg/tree) over Bhagawa during seventh year besides better fruit quality traits. Solapur Anardana recorded 28.94 kg/tree fruit yield, 4.82% titrable acidity and 460.5 mg/100g anthocyanin.
- During sixth year of planting, assessment of 12 hybrids revealed that the yield ranged from 16.73-29.21 kg/ tree. The highest yield was recorded by HA* (29.21 kg/tree) with parentage 'Bhagawa x [(Ganesh x Nana) x Daru]', followed by Bhagawa x Patna-5 (26.94kg/tree) having the large sized fruits (298.3g/fruit)
- Draft genome sequencing of pomegranate var. Bhagawa was carried out.
- Anthocyanin synthesis pathway: To develop candidate gene based markers, full length gene sequences of five genes (ANS, CHS, CHI, F3H and DFR) that are part of Anthocyanin biosynthesis pathway were retrieved from NCBI database for Tunisia genome and compared with Dabenzi and Taishanhong genes. After multiple sequence alignment, sequence variations in three key genes ANS (1.2 Kb), CHI (2.7 Kb) and DFR (1.9 Kb) were identified.
- Under In vitro conditions, pomegranate var. Solapur Lal revealed 83.6% culture establishment, 51.5% rooting. Wedge grafting of Bhagawa scion with rootstocks tolerant to salinity / *Cercospora fimbriata* revealed success of 30% to 83.33% with highest in 676938 (83.3%)

Crop production & protection:

- Among 6 levels of fruit thinning, light thinning of pomegranate var. Solapur Lal increased the fruit size (275.6 g/fruit) over the control with optimum yield (31.86 kg/tree).
- Foliar spray of 2,4-D @20ppm in Bhagawa at flowering and 10 DAA was found to be highly effective for management of fruit drop with minimum flower drop (21.3 flowers/tree), highest fruitset (58.06%), no. of fruits (96.5 fruits/tree) and fruit yield (25.88 kg/tree).
- Induction of flowering: Foliar spray of NAA @ 10ppm during hasth bahar induced flowering in pomegranatecv. Bhagawa with highest fruitset (53.46%), no. of fruits/tree (98.0/tree) and yield (26.87kg/tree). Foliar spray of potassium nitrate@1.0% resulted in highest no. of fruits (98.2), fruit weight (275.4g) and yield (27.04kg/plant) over the control (19.79kg/plant).

Plant Protection:

- For Stem borer control, Drenching or drenching & stem injection @ Emamectin Benzoate 5%SG gave 100% control of the pest. Similarly, Emamectin Benzoate 3% + Thiamethoxam12%WG also gave 100% control.
- Evaluation of the bioefficacy of the eight different insecticides against pomegranate shot hole borer through the drenching method revealed 98.25% recovery of plants Among the nine treatments, (Emamectin Benzoate 3% + Thiamethoxam12%WG) @ 2 g/l alongwith propiconazole @ 2ml/l gave 98.25% plants recovery.
- **Stem solarization to manage bacterial blight:** Developed Stem Solarization technology to manage bacterial blight in community approach with 100% blight control & demonstrated in different locations. It is ecofriendly, economical and effective technology and can eradicate the pathogen if done in community approach. It can also be used for organic cultivation plots.



- **In vitro evaluation of endophytes against fungal pathogens :** The preliminary results of the current study indicate that these endophytes especially BE-5 and EB-7 can be used as potential biocontrol agents against different fungal pathogens.

Evaluation of newer nematicides under polyhouse conditions:

- For nematode management, Lowest no. of galls were observed in the plants with intact roots treated with Reklamel @ 2 ml/2L (0.5 liter/plant) followed by Velum Prime @ 2 ml/2L (0.5 liter/plant) and Nimitz @ 10 g/ plant. In the case of root pruned plants, no galls were observed in the plants treated with Nimitz and Velum prime.

Post-Harvest Technology:

- The process for foam mat drying of pomegranate juice has been standardized with drying time of 3 hrs.
- The studies were conducted on fermentation process of the pomegranate wine from Bhagawa, Ganesh and Arakta. The Arakta wine was found to be the best acceptable wine followed by the Bhagwa and Ganesh during sensory evaluation.
- The pomegranate peel powder fortified fiber enriched muffins were developed. Peel powder also acts as a natural antioxidant and provide oxidative and microbial stability.

Other Activities:

- The Centre has taken up promotion of 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 335 farmers.
- ICAR-NRCP commercialized three technologies to entrepreneurs and displayed its activity in three exhibitions and more than 1000 visitors including farmers, students and other stakeholders visited the center for information.
- All the staff of ICAR-NRCP actively participated in activities under Swachh Bharat Abhiyan, International Women's Day, Farmers' Day etc.
- The Centre also organized workshops and 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.
- The Centre published 8 research papers in peer reviewed journals, out of which two was in journal with NAAS rating above 10, one review article, 19 book chapters, 30 popular articles, besides 22 presentations in conferences and 31 poster presentations. The scientists also got recognitions from professional Societies viz., Awards/ Fellowships, besides best oral / poster presentation awards.



Research Programmes & Projects

INSTITUTE RESEARCH PROJECTS ONGOING

S. No.	Project title	PI	Co-PIs	Duration DoS-DoE
1.	Breeding for bacterial blight resistance in pomegranate	Dr. Shilpa P.	Dr. Jyotsana Sharma Dr. K. Dhinesh Babu Dr. Prakash G Patil Dr. NV Singh Dr.P Roopa Sowjanya	(01/08/2019-31/07/2024)
2.	Draft genome sequencing of Pomegranate (<i>Punica granatum</i> L.) cv. Bhagwa	Dr. Roopa Sowjanya P.	Dr. Shilpa P. Dr. N.V. Singh, Dr. P.G.Patil	(21/02/2017-20/01/2022)
3.	Genetic Mapping of Bacterial Blight and Fruit Quality Traits in Pomegranate	Dr. P. G. Patil	Dr. J. Sharma Dr. Shilpa P. Dr. N. V. Sing Dr. K. Dhinesh Babu	(01/01/2018-31/12/2022)
4.	Combating stresses and improving quality in pomegranate (<i>Punica granatum</i> L.) by exploiting rootstocks	Dr. N.V. Singh	Dr. Roopa Sowjanya P. Dr. Prakash G. Patil Dr. Manjunath N. Dr. K. Dhinesh Babu Dr. Somnath Pokhare	(20/08/2020-19/08/2025)
5.	Crop regulation practices for improving productivity of pomegranate	Dr. K. Dhinesh Babu	Dr, N.V. Singh Dr A. Maity Dr J. Sharma	(01/04/2018-31/03/2023)
6.	Package of practices for organic cultivation of pomegranate	Dr. A. Maity	Dr. J. Sharma Dr. Gaikwad N.N. Dr. Mallikarjun, H.	(01/08/2018-31/07/2023)
7.	Post-harvest management and value addition in pomegranate for Entrepreneurship development	Dr. Gaikwad N.N.	Dr. Namrata Giri Dr. K. Dhinesh Babu, Dr. Ashis Maity,	(01/07/2019-30/06/2024)
8.	Development of Functional food products and waste utilization from pomegranate	Dr. Namrata A Giri	Dr. Nilesh Gaikwad Dr. Ashis Maity Dr. Pinky R. Dr. Manjunatha N.	(20/08/2020-31/07/2025)
9.	Development of technologies for sustainable management of important insect pest of pomegranate	Dr. Mallikarjun	Dr. Manjunatha N Dr. Somnath S. Pokhare Dr. R.A. Marathe	(01/09/2020-31/08/2025)



S. No.	Project title	PI	Co-PIs	Duration DoS-DoE
10.	Studies on wilt complex in Pomegranate	Dr. Somnath Pokhare	Dr. Manjunatha.N Dr.Mallikarjun M.H. Dr. R.A. Marathe	(01/01/2021-31/12/2026)
11.	Epidemiology and sustainable management of economically important phylloplane diseases of pomegranate	Dr. Manjunatha N.	Dr. Jyotsana Sharma, Dr. Somnath S. Pokhare, Dr. Mallikarjun M H, Dr. Prakash G Patil, Dr. A Maity and Dr. R.A. Marathe	(01/01/2021-31/12/2026)
12.	Flagship project on Integrated approach to eradicate bacterial blight	Dr. Jyotsana Sharma	Dr. A.Maity Dr. N.V.Singh Dr. Shilpa. P Dr. K. Dhinesh Babu Dr. P.G.Patil Dr. A.Kumar, (IARI) Dr. Manjunatha N Dr. R.K.Mestha (UHSB)	(01/10/2014-31/03/2023)
13.	Biotic stress induced biochemical and epigenetic changes associated with major insect pest and diseases in diverse pomegranate (<i>Punica granatum</i> L.) genotypes.	Mr. Rahul Damale	Dr. N. V Singh Dr. K. Dhinesh Babu Dr. Shilpa Parshuram Dr. Manjunath N. Dr. Mallikarjun Harsur Dr. R.A. Marathe	(01/06/2021-31-05/2026)

INTER-INSTITUTIONAL COLLABORATIVE PROJECTS ONGOING

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



TRIBAL SUB-PLAN COMPLETED

S. No.	Project title	Chairman	Committee Members
1.	Promotion of pomegranate cultivation in tribal areas of M.P. and Chhattisgarh in collaboration with SRIJAN, India	Dr. N.V. Singh	-
2.	Tribal Sub-Plan of ICAR-NRCP, Solapur	Dr. Somnath S. Pokhare	Dr. Namrata Giri & Mr. Rahul Damale

SCHEDULED CASTES SUB-PLAN ONGOING

S. No.	Project title	Chairman	Committee Members
1.	Promotion of pomegranate cultivation and supporting SC farmers of Tikkamgarh, Alwar Barmer and Solapur in collaboration with SRIJAN, IBTADA, Gram Panchayats and KVKs	Dr. N.V. Singh	Dr. Shilpa P. Dr. Roopa Sowjanya P. Mr. Yuvraj Shinde Mr. Mahadev Gogaon
2.	Supporting SC farmers of Kalaburgi, Karnataka through training and agri-input distribution	Dr. N.V. Singh	Dr. Shilpa P. Dr. Roopa Sowjanya P. Mr. Yuvraj Shinde Mr. Mahadev Gogaon

EXTERNALLY FUNDED PROJECTS ONGOING

S. No.	Funding agency	Project	PI	Co-PIs
1.	ICAR	ICAR-All India Coordinated Research Project on Arid Zone Fruits	Dr. K. Dhinesh Babu	Dr. N.V. Singh Dr. Mallikarjun
2.	PPV&FRA, New Delhi	Establishment of DUS centre at ICAR-NRCP, Solapur	Dr. Shilpa P.	Ms. Roopa P. Sowjanya
3.	RKVY, DAC, GoI	Horticulture Crop Pest Surveillance and Advisory Project for Mango, Pomegranate & Banana	Dr. Jyotsana Sharma	Dr. Mallikarjun

**CONTRACTUAL RESEARCH PROJECTS ONGOING**

S. No.	Funding agency	Project	PI	Co-PIs	Duration DoS-DoE & Budget (Lakh)
1.	Sirius Minerals India Pvt. Ltd.	Evaluating Poly-4 as multi-nutrients fertilizer in pomegranate for yield and quality	Dr. Ashis Maity	Dr. Nilesh Gaikwad	01/08/2021-28/02/2023
2.	UPL Pvt Ltd.	Bio-efficacy evaluation of fungicides AVANCER GLOW (Azoxystrobin 8.3% + Mancozeb 66.7% WG) and CUPROFIX DISPERSS (Copper sulphate 47.15%+Mancozeb 30% WG) against disease complex of pomegranate	Dr Manjunatha N	Dr. Jyotsana Sharma, Dr. Somnath S. Pokhare, Mr. Vijay Lokhande	01/06/ 2021 to 31/08/ 2023 (31.0)
3.	Bayer Crop Science Limited	Efficacy and crop safety evaluation of Glyphosate IPA salt 41% w/wsl in pomegranate	Dr. N.V. Singh	Dr. R.A. Marathe	01/08/2021-31/07/2023
4.	Fertis India Pvt Ltd	Bio-efficacy of Ecolaid freedom microbicide on bacterial blight of pomegranate	Dr Manjunatha N	Dr. Jyotsana Sharma, Dr R.A. Marathe, Mr. Vijay Lokhande	01/06/2021 to 31/08/ 2023 (17.8)
5.	DuPont-Corteva Ltd	Efficacy of Q8U80 500SC for the management of root knot nematode on Pomegranate	Dr. Somnath S. Pokhare	Dr. Mallikarjun H. & Dr. Manjunatha N.	29/12/2020-30/06/2023

CONTRACTUAL RESEARCH PROJECTS COMPLETED

S. No.	Funding agency	Project	PI	Co-PIs	Duration DoS-DoE & Budget (Lakh)
1.	M/s. Biostadt India Ltd	To study the effect of biozyme Fruit Plus L on yield and quality parameters	Dr. N.V. Singh	-	1/12/2020 to 30/09/2021



Research Achievements

1. Genetic Resources

1.1 PROJECT: BREEDING FOR BACTERIAL BLIGHT RESISTANCE IN POMEGRANATE (*Punica granatum* L.)

(1) Study of genetic reaction of selected promising genotypes of pomegranate against bacterial blight disease

Previously identified six promising breeding lines (Sharad King, NRCPS-7, BBSC-1, BBSC-2, BBSC-3, BBSC-6-1) were evaluated for their genetic reaction to bacterial blight disease under challenge inoculation to XAP-90, 118 culture (10⁸ pfu/ml ; OD: 0.1031) during 2021-22. The disease severity grade ranged from 2.5-5 with coefficient of variation (%) of 24.99%. Based on disease severity grade, **NRCPS-7 (SG: 2.50)**, **BBSC-2 (SG: 2.92)**, **BBSC-3 (SG: 2.86)**, were found to be moderately susceptible while **BBSC-1 (SG: 3.08)**, BBSC-6-1 (SG: 3.58) and 'Sharad King' (SG: 4) are susceptible in comparison to highly susceptible variety 'Bhagawa' (SG: 5) (Fig. 1.1).

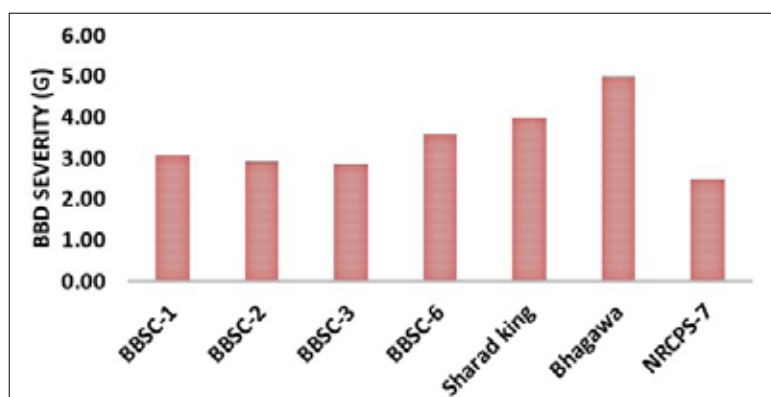


Fig.1.1: Reaction of selected promising genotypes against BBD

(2) Screening of exotic and indigenous germplasm accessions against bacterial blight disease

In total 362 pomegranate accessions maintained in field gene banks at Kegaon and Hiraj research farms of ICAR-NRCP, Solapur during 2021-22. It includes 140 Indigenous (Uttarakhand, Jammu & Kashmir, Himachal Pradesh, Maharashtra, Karnataka, Rajasthan, Tamil Nadu, Gujarat) and 222 Exotic (USA, Turkmenistan, Russia, Iran, Italy, Japan, Afghanistan, France) collections.

Out of which, **98 germplasm accessions** including **70 exotic** accessions and **28 indigenous accessions** were evaluated for their genetic reaction to bacterial blight disease under challenge inoculation to XAP-90, 118 culture (10⁸ pfu/ml; OD: 0.154) and compared with the susceptible check variety "Bhagawa". Analysis of Variance (ANOVA) using R software package 1.0.1 has showed significant differences among the accessions for BBD screening at both 5% and 1% level of significance (Fcal – 8.47; p value- < 2.2e-16 **) with mean value of 4.16, range 1.83 – 5; R² - 0.81; SEm - 27; CV - 11.36; t-value - 1.97 and LSD - 0.76). Out of 98 accessions, one germplasm

(EC-676992) found moderately resistant (SG: 2) and 9 accessions as moderately susceptible (SG: 3) genotypes (EC-798832; EC-798740; IC-318716; EC-676975; EC-798729; EC-676994; EC-798763; EC-676931; EC-676930) (Fig. 1.2). These will be valuable genetic resources for pomegranate breeding programmes.

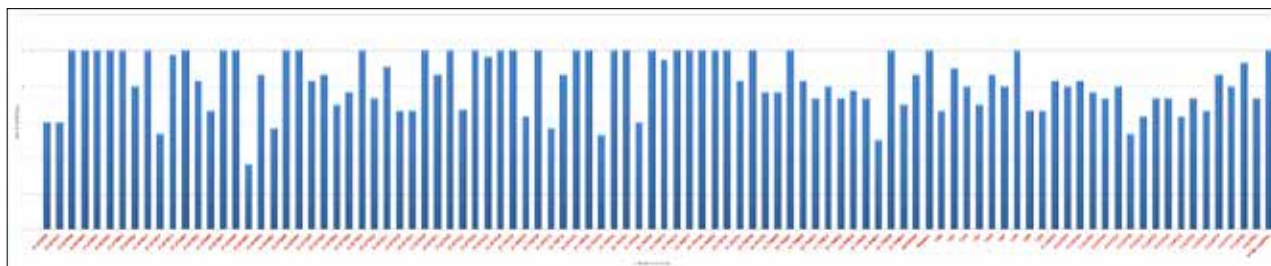


Fig. 1.2: Frequency distribution of BBD severity among 98 pomegranate accessions screened during 2021-22

(3) Development and utilization of new breeding population for identification of BBD resistance sources in pomegranate

Advanced F_2 segregant population of NRCP H-6 (459 individuals) and BC_1F_1 generation of 'NRCP H-6' X 'Bhagawa' (57 individuals) and 'NRCP H-6' X (GxNxD)' (32 individuals) has been developed. These populations will be screened for reaction to bacterial blight disease under controlled condition (Fig.1.3).



Fig. 1.3: Samplings of segregating population developed at ICAR-NRCP, Solapur

(4) Identification and development of early maturing genotypes for escaping BBD in pomegranate

- Identified and collected one "Bhagawa" variant from the farmer field which matures in about 135-145 days with all other similar characters. This variant will be characterized for other DUS characteristics including reaction to BBD (Fig. 1.4).



Fig. 1.4: Early maturing variant identified from farmer field

- At ICAR-NRCP, Solapur hybridization for developing early maturing hybrids has been initiated between six diverse pomegranate genotypes (Ganesh, Patna-5, P-26, G-137, Arakta and Mridula) for inducing disease escape mechanism in pomegranate (Fig. 1.5).



Fig. 1.5: Hybrid seeds of crosses between selected parents in pomegranate

(5) Breaking the genetic linkage of BBD through hybridization programmes

- Breeding programme for reducing the genetic susceptibility load of BBD in the crop has been initiated by crossing highly susceptible (Mridula) with moderately resistant and moderately susceptible genotypes (1205, 1203, Yellow Nana, P-26, Patna-5, Yercaud) (Fig. 1.6).



Fig. 1.6: Hybrid seeds of crosses carried between selected parents in pomegranate

(6) Creation of genetic variability for BBD resistance through induced mutation

6.1 Chemical mutagenesis:

- i. Fixed LD50 value for “Bhagawa” variety which found to be 1% for 6hrs for without pre-soaked water treatment and 1.4% for 4hrs with pre-soaked water treatment of seeds.
- ii. Nearly about **179 M₁** population treated with LD50 value of EMS (1% for 6hrs) has been generated and will be utilized for advanced genetic studies for bacterial blight disease resistance in pomegranate (Fig. 1.7).



Fig. 1.7: Mutagenic population of pomegranate developed through chemical mutagenesis (EMS)

6.2 Physical Mutagenesis:

- Gamma irradiation of seeds of cv. ‘Bhagawa’ was carried out for 4 different doses (3 kR, 5 kR, 7 kR, and 9 kR). The data on seed germination (%) has been completed. LD50 value will be calculated once after the data on seedling survival (%) will be recorded. The mutant population with the decided LD50 value will be advanced to rise the segregating mutant population for screening against BBD (Fig.1.8).

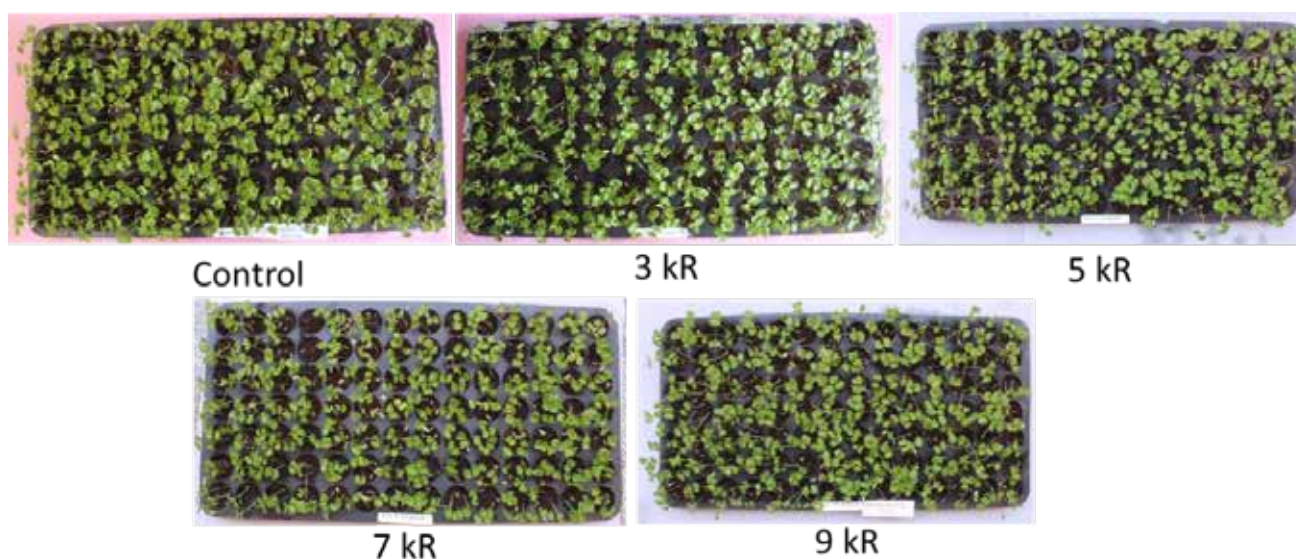


Fig. 1.8: Mutagenic population of pomegranate developed through chemical mutagenesis (EMS)

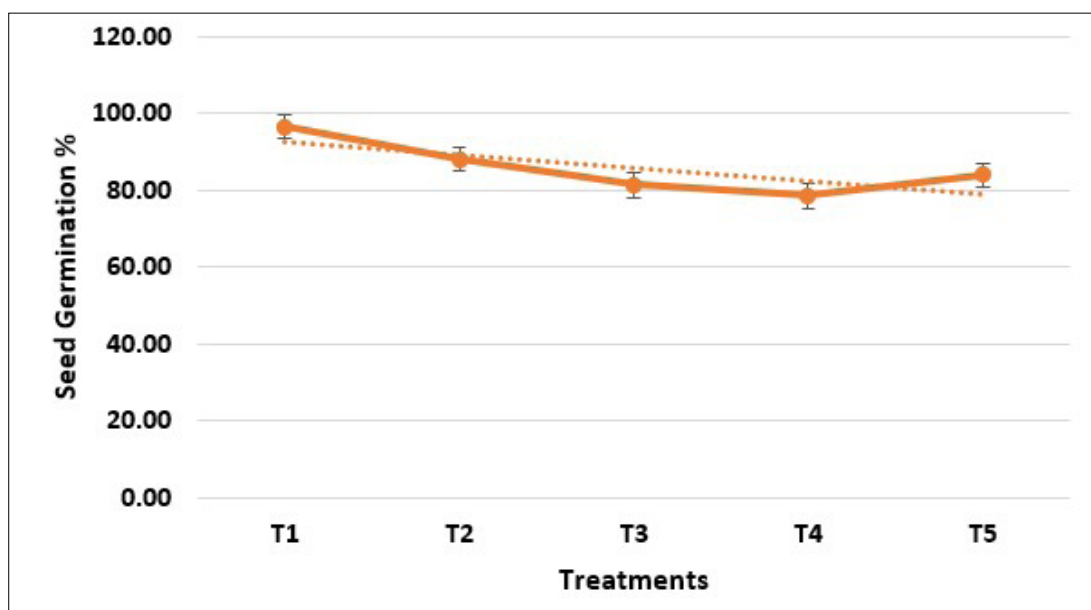


Fig. 1.9: Effect of Gamma irradiation on seed germination (%) in pomegranate

Mean	85.62 % (68.41)
Range	78.44 % - 96.46 % (64.37 - 72.09)
Fcal	() Arc Sine transformed values 0.80 ^{ns}
Coefficient of Variation (%)	9.310 (4.81)
Standard Error of Mean	3.13 (1.47)

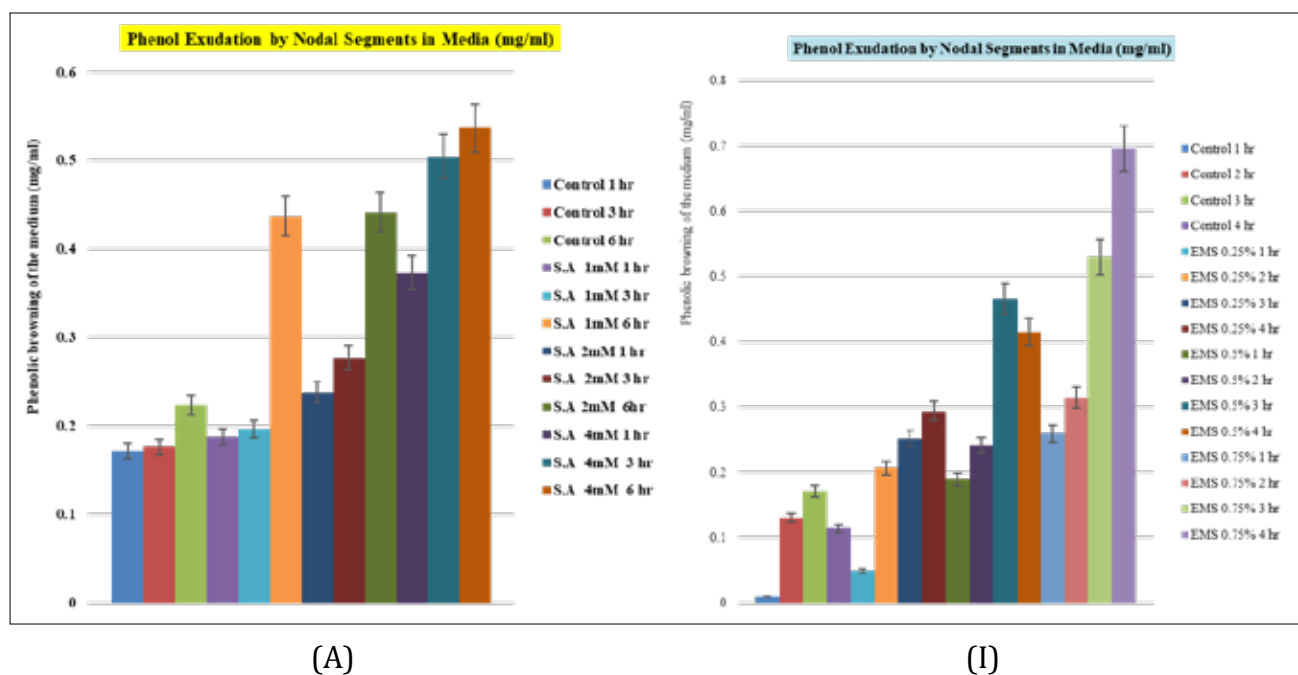
Statistical data on Gamma irradiation effect on seed germination (%) in pomegranate

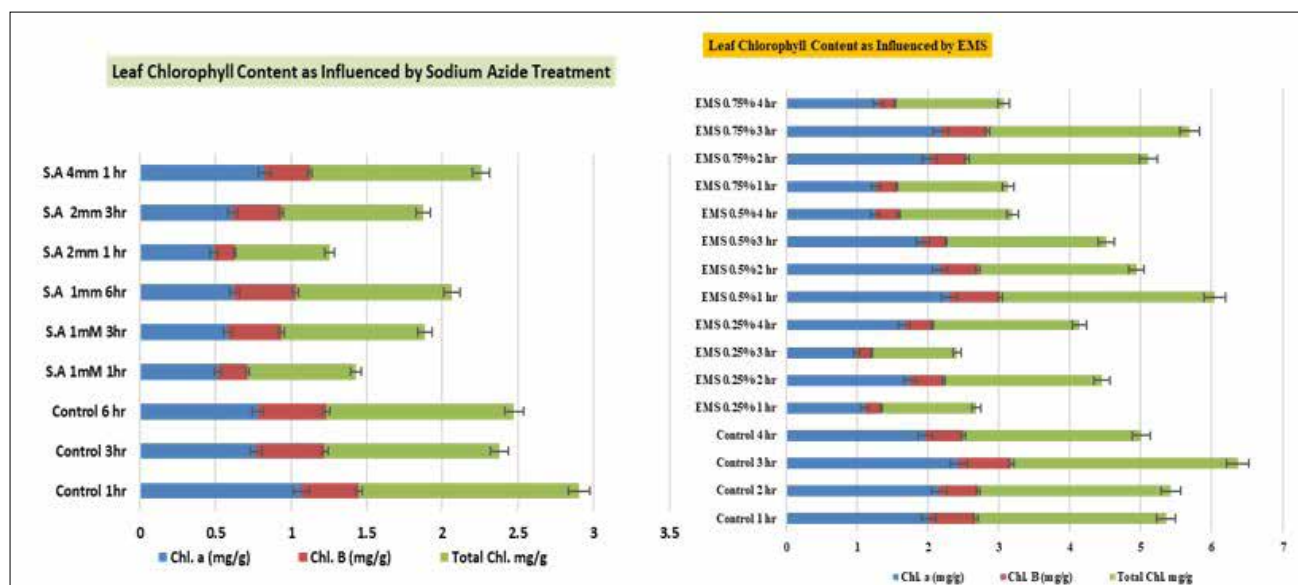
6.3 *In vitro* chemical mutagenesis in pomegranate cv. Super Bhagawa

In vitro mutagenesis for developing solid mutants has been carried using EMS and Sodium Azide chemicals. Nodal segments of Super Bhagawa variety has been treated with EMS @ 0.25, 0.5, 0.75% for 1, 2, 3 and 4 hrs and Sodium Azide @1, 2 & 4 mM @ 1, 3 and 6 hrs. Studied their effect on Bud Sprouting (%), Bud Necrosis (%), Phenol Exudation in Media (mg/ml), Chl. a (mg/g), Chl. B (mg/g), Total Chl. mg/g, Chl a/Chl b, RLWC (%), Avg. Shoot Length at 25 DAI (cm), Avg. No. Side Shoots, GI, Days to Sprout. Based on their effect on bud Sprouting (%), the LD50 was found to be EMS 0.5% 4 hr (36.67%) and SA 2mM 3hrs (Table 1.1; Fig.1.10). The experiment will be repeated and validate the data for further consideration. Then a large mutant population will be generated for the fixed LD50 values for EMS and SA, further utilized for BBD resistance breeding programmes.

Table 1.1: Bud sprouting and necrosis as influenced by *in vitro* treatment of nodal segments with EMS and Sodium Azide

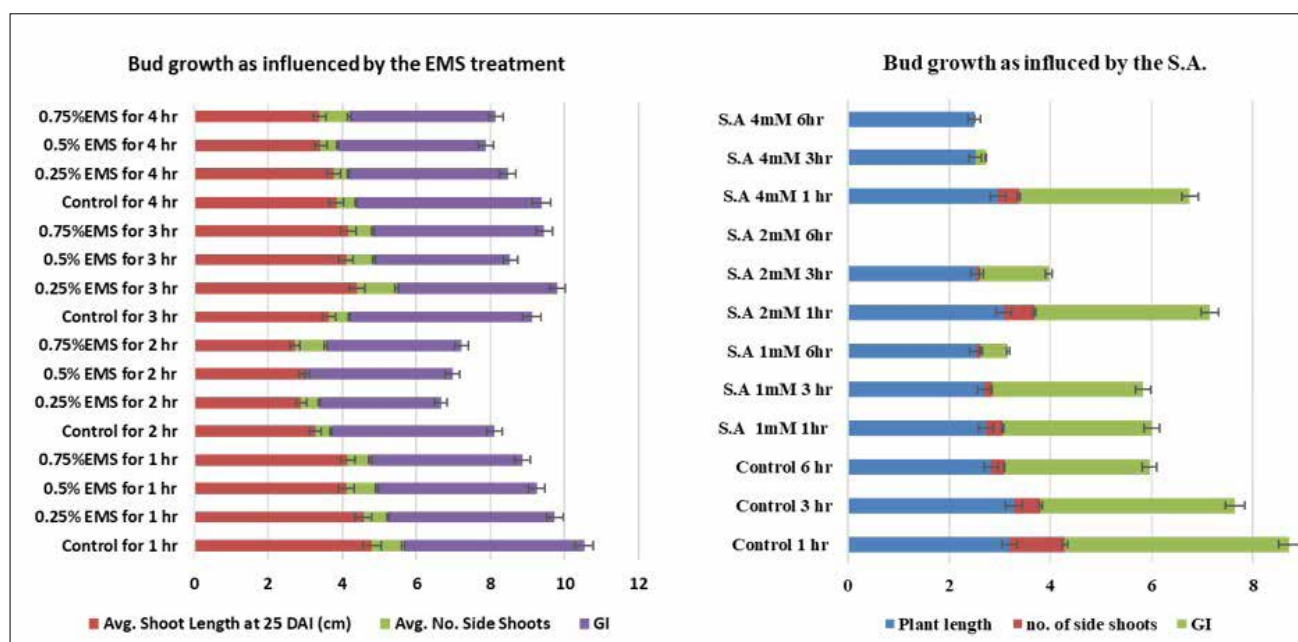
Treatment	Bud Sprouting (%)	Bud Necrosis (%)	Treatment	Sprouting (%)	Bud Necrosis (%)
Control 1 hr.	96.67 (83.32)*	3.33 (6.27)*	Control 1 hr	96.67 (81.35)	3.33 (8.65)
Control 2 hr.	80.00 (63.93)	20.00 (26.07)	Control 3 hr	93.33 (78.06)	6.67 (11.94)
Control 3 hr.	100.00 (89.82)	0.00 (0.19)	Control 6 hr	83.33 (66.26)	16.67 (23.74)
Control 4 hr.	100.00 (89.82)	0.00 (0.19)	S.A 1mM 1hr	80.00 (63.86)	20.00 (26.15)
EMS 0.25% 1 hr.	96.67 (83.73)	3.33 (6.27)	S.A 1mM 3 hr	66.67 (54.99)	33.33 (35.01)
EMS 0.25% 2 hr.	86.67 (72.72)	13.33 (17.28)	S.A 1mM 6hr	11.67 (19.50)	88.333 (70.50)
EMS 0.25% 3 hr.	70.00 (57.70)	30.00 (32.30)	S.A 2mM 1hr	93.33 (78.06)	6.67 (11.94)
EMS 0.25% 4 hr.	73.33 (59.00)	26.67 (31.00)	S.A 2mM 3hr	36.67 (37.09)	63.333 (52.91)
EMS 0.5% 1 hr.	100.00 (89.82)	0.00 (0.19)	S.A 2mM 6hr	6.67 (8.93)	93.333 (81.07)
EMS 0.5% 2 hr.	70.00 (62.15)	30.00 (27.85)	S.A 4mM 1 hr	86.67 (68.86)	13.333 (21.15)
EMS 0.5% 3 hr.	60.00 (50.77)	40.00 (39.23)	S.A 4mM 3hr	6.67 (11.94)	93.333 (78.06)
EMS 0.5% 4 hr.	36.67 (37.23)	63.33 (52.78)	S.A 4mM 6hr	00.00 (0.11)	100 (89.89)
EMS 0.75% 1 hr.	96.67 (83.73)	3.33 (6.27)	CD (p=0.05)	14.75	14.75
EMS 0.75% 2 hr.	60.00 (50.767)	40.00 (39.23)			
EMS 0.75% 3 hr.	60.00 (50.77)	40.00 (39.23)			
EMS 0.75% 4 hr.	46.67 (43.08)	53.33 (46.92)			
CD* (p=0.05)	17.04	17.04			





(B)

(II)



(C)

(III)

Fig.1.10 *In vitro* effect of Sodium Azide (A, B, C) and EMS (I, II, III) treatment in cv. Super Bhagawa on Phenol exudation by nodal segments in media (A, I); Leaf chlorophyll content (B, II) and Bud growth(C, III)

(1) Evaluation of varieties released from ICAR-NRCP

1.1 Comparative evaluation of Solapur Lal

Evaluation of pomegranate variety Solapur Lal in comparison to the ruling variety, Bhagawa during the seventh year of planting in mrig bahar recorded about 19.2 days early maturity, around 25.86% higher yield over Bhagawa besides better fruit quality traits.









			
Bearing plant	Fruit	Fruit exposing arils	Arils
Solapur Lal			
			
Bearing plant	Fruit	Fruit exposing arils	Arils
Bhagawa			

Fig 1.11. Comparative evaluation of Solapur Lal vs Bhagawa

Table 1.2. Comparative evaluation of Solapur Lal and Bhagawa

Characters	Solapur Lal	Bhagawa
Plant height (m)	2.30	2.05
Fruit maturity (days)	161.5	180.5
Fruit weight (g)	272.0	278.2
No. of fruits /tree	129.5	98.2
Yield (kg/plant)	35.22	27.31
Yield (t/ha)	26.06	20.2
Aril colour	Deep red	Red
Fruit colour	Red	Red
Rind thickness (mm)	Medium 3.42	Medium 3.38
Juice (%)	42.5	43.5
TSS (°Brix)	17.6	15.7
Titrate acidity (%)	0.4	0.46
Ascorbic acid (mg/100g)	19.2	14.8
Anthocyanin (mg/100g)	395	355
Iron (mg/100g)	1.5	0.9
Zinc (mg/100g)	0.5	0.4



1.2 Comparative evaluation of Solapur Anardana

Evaluation of pomegranate variety Solapur Anardana in comparison to Amlidana during the seventh year of planting in mrig bahar was done. Solapur Anardana recorded 28.16 kg/tree fruit yield, 4.84% titrable acidity and 460.5 mg/100g anthocyanin.

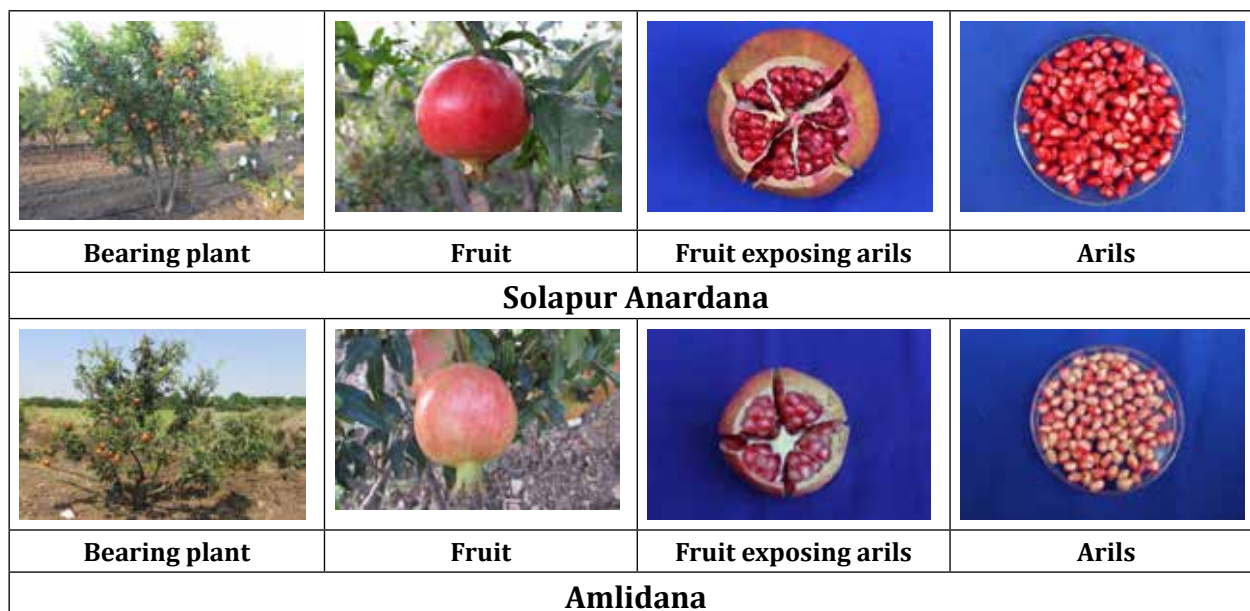


Fig 1.12. Comparative evaluation of Solapur Anardana with Amlidana

Table 1.3. Comparative evaluation of Solapur Anardana and Amlidana:

Characters	Solapur Anardana	Amlidana
Plant height (m)	2.40	1.75
Fruit maturity (days)	145.2	150.2
Fruit weight (g)	275	230.5
No. of fruits /tree	102.4	74.2
Yield (kg/plant)	28.16	17.10
Yield (t/ha)	20.83	12.65
Aril colour	Red	Light pink
Fruit colour	Red	Yellow
Seed texture	Medium	Medium
Juice (%)	41.5	40
TSS (°Brix)	16.66	15.62
Ascorbic acid (mg/100g)	17.8	14.0
Anthocyanin (mg/100g)	460.5	63.5
Titrable acidity (%)	4.84	4.16










1.3 Evaluation of hybrids developed from ICAR-NRCP:

Twelve hybrids developed at ICAR-NRCP, Solapur were evaluated for yield and quality during

sixth year of planting. The yield ranged from 16.73-29.21 kg/ tree. The highest yield was recorded by Bhagawa x [(Ganesh x Nana) x Daru] with 29.21kg/tree. This was followed by Bhagawa x Patna-5 (26.94kg/tree) and Ganesh x Nayana (26.62 kg/ tree).

Table 1.4. Evaluation of pomegranate hybrids developed by ICAR-NRCP

Hybrid	Fruit weight(g)	No. of fruits/tree	Yield (kg/tree)	TSS (°Brix)	Titration acidity (%)
Bhagawa (Check var.)	271.5	92.3	25.56	15.7	0.46
Bhagawa x Patna-5	298.3	90.3	26.94	16.6	0.35
Bhagawa x Nana	224.3	74.6	16.73	14.0	2.60
Bhagawa x Daru	252.6	84.3	21.29	17.0	2.80
Bhagawa x Kalpitiya	285.6	90.3	25.79	14.6	0.33
Bhagawa x Nayana	274.3	94.0	25.78	15.9	0.38
Bhagawa x IC-318712	240.6	88.3	21.24	14.8	2.80
Ganesh x Kalpitiya	246.3	84.6	20.84	15.7	0.46
Ganesh x Nayana	285.3	93.3	26.62	16.0	0.34
Bhagawa x [(Ganesh x Nana) x Daru]-HA*	270.5	108.0	29.21	17.2	0.38
Kalpitiya x Ruby	285.3	89.6	25.56	15.7	0.39
Nayana x Ruby	274.6	93.0	25.54	15.5	0.4
Ruby x Nayana	220.3	86.3	19.01	15.4	0.36

		
Bhagawa	Bhagawa x Patna-5	Bhagawa x Nana
		
Bhagawa x Daru	Bhagawa x Kalpitiya	Bhagawa x Nayana
		
Bhagawa x IC-318712	Ganesh x Kalpitiya	Ganesh x Nayana



Bhagawa x [(Ganesh x Nana) x Daru]-HA	Kalpitiya x Ruby	Nayana x Ruby
	Ruby x Nayana	

Fig1.13. Evaluation of pomegranate hybrids developed by ICAR-NRCP











1.4 Evaluation of pomegranate selections:

Evaluation of fourteen pomegranate selections in comparison with Bhagawa was carried out during seventh year of planting. The study was carried out for various physicochemical characters in Mrig bahar. The results revealed that yield ranged from 26.07 – 30.59 kg/tree. The yield was highest in Sln. 348 (30.59 kg/tree) closely followed by Sln. 528 (30.40 kg/tree). Total soluble solids content ranged from 15.7 to 16.7°Brix.











Table 1.5. Evaluation of pomegranate selections

Genotype	Fruit weight (g/fruit)	No. of fruits/tree	Yield (kg/tree)	TSS (°B)	Acidity (%)	Fruit Color	Aril Color
Bhagawa	276.8	96.2	26.63	15.7	0.46	Red	Red
IC-24686	272	92.3	25.11	15.9	0.43	Red	Red
Sln.934	271.2	97.3	26.39	15.9	0.37	Yellowish red	Light red
Sln.391	271.6	96	26.07	15.8	0.42	Yellowish red	Light red
Sln.528	281.5	108	30.40	15.9	0.41	Yellowish red	Red
Sln.375	281	102.3	28.75	16.7	0.4	Yellowish red	Light Red
Sln.348	282.5	108.3	30.59	15.9	0.36	Red	Red
Sln.388	274.6	101.6	27.90	16.5	0.41	Yellowish pink	Light red
Sln.317	273.2	99.3	27.13	16.6	0.39	Yellowish pink	Light red
Sln.216	276.4	96.3	26.62	16.3	0.39	Yellowish pink	Light red
	286.5	100.6	28.82	16	0.37	Red	Red
Sln.1128	283.2	99.3	28.12	15.9	0.38	Yellowish red	Light red
Sln.1129	273	98.6	26.92	15.8	0.41	Yellowish red	Light red
Sln.1121	269.8	99.3	26.79	15.9	0.39	Yellowish red	Light red
Sln.1130	273.4	103.6	28.32	15.9	0.41	Yellowish red	Red



	
Bhagawa	Bhagawa
	
IC-24686	IC-24686
	
Sln.934	Sln.934
	
Sln.391	Sln.391
	
Sln.528	Sln.528



	
Sln.375	Sln.375
	
Sln.348	Sln.348
	
Sln.388	Sln.388
	
Sln.317	Sln.317
	
Sln.216	Sln.216











	
Sln.311	Sln.311
	
Sln.1128	Sln.1128
	
Sln.1129	Sln.1129
	
Sln.1121	Sln.1121
	
Sln.1130	Sln.1130

Fig 1.14. Evaluation of pomegranate selections



1.5 Identification of promising hybrids for table and processing purpose:

Evaluation of 25 NRCP hybrids during seventh year of planting led to the identification of NRCP H-14 for table purpose and NRCP H-4 for anardana / processing purpose. The salient characters of NRCP H-14 is mentioned below.

Characters	NRCP H-14
Maturity (days)	164.5
No. of fruits/plant	121.2
Fruit weight (g)	279.8
Fruit yield (kg/plant)	33.9
100 aril weight (g)	32.8
TSS (°Brix)	17.82
Acidity (%)	0.42
Ascorbic acid (mg/100g)	19.0
Anthocyanin (mg/100g)	124.1



Fig1.15. Pomegranate hybrid NRCP H-14

Table1.6: The salient features of pomegranate hybrid NRCP H-4 is as follows.

Characters	NRCP H-4
Maturity (days)	149.5
No. of fruits/plant	112.0
Fruit weight (g)	270.2
Fruit yield (kg/plant)	29.8
100 aril weight (g)	30.26
TSS (°Brix)	16.24
Acidity (%)	5.76
Ascorbic acid (mg/100g)	18.6
Anthocyanin (mg/100g)	60.5



Fig 1.16. Pomegranate hybrid NRCP H-4

2. Crop Improvement

2.1. PROJECT: GENETIC MAPPING OF BACTERIAL BLIGHT AND FRUIT QUALITY TRAITS IN POMEGRANATE

Wet lab validation of chromosome-specific SSR markers -

For wet-lab validation of the SSRs, we screened 235 primer pairs on six pomegranate genotypes i.e. Bhagawa, Daru 17, Mridula, P-23, IC 318728, and IC 318790. As a result, 225 (94.5%) yielded the amplicons of expected size, whereas 10 remaining primer pairs did not show any amplification. A total of 221 (98.2%) SSRs were polymorphic across six pomegranate genotypes (Fig 2.1). Using SSR markers, we detected 797 alleles among six genotypes. The number of alleles for loci ranged from 1 to 8, with an average of 3.59. The observed (H_o) and expected heterozygosity (H_e) for each locus ranged from 0 to 1 (with a mean of 0.58) and 0 to 0.86 (with a mean of 0.61), respectively, and the Shannon's information index ranged from 0.00 to 2.02 with a mean of 1.08. The polymorphism information content (PIC) ranged from 0 (for HvSSRT_416) to 0.96 (HvSSRT_891) with a mean value of 0.68. A total of 187 markers had PIC values ≥ 0.5 . The frequency analysis of HvSSRT markers with respect to number of alleles showed that 78 markers had two alleles while eight alleles were obtained for two markers (Fig.2.2 A & B).

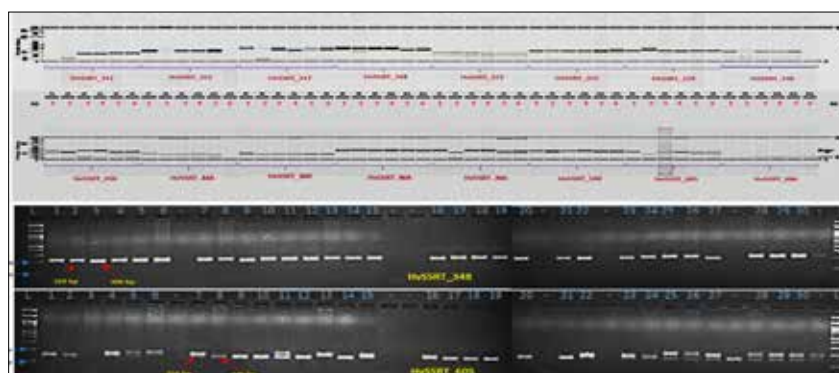


Fig 2.1 Gel images showing screening of HvSSRT markers on six pomegranate genotypes using fragment analyzer (A), HvSSRT markers 348 and 605 on 30 pomegranate genotypes on 3% metaphor gels (B).

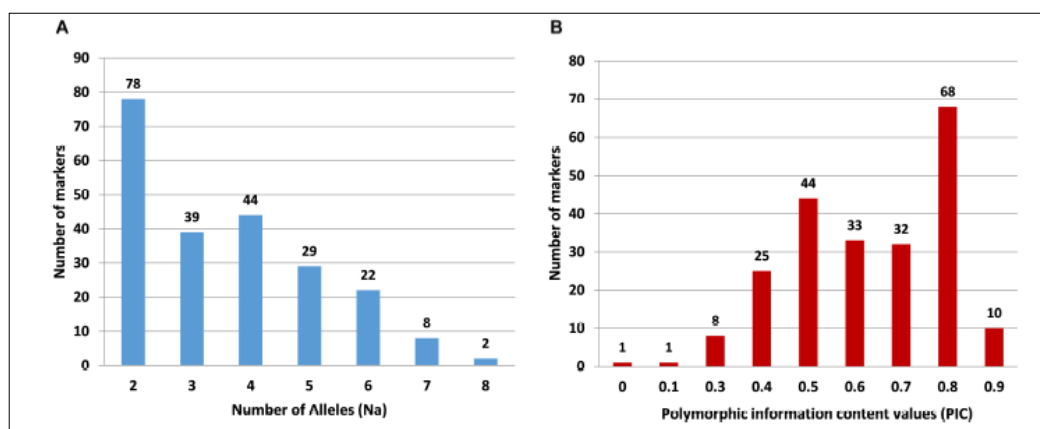


Fig.2.2 Frequency distribution of SSR with respect to number of alleles (A) and PIC values (B).



Genetic diversity analysis

A subset of 16 HvSSRs located on eight chromosomes, selected from each chromosome based on their clear amplification profiles observed on six genotypes, were tested on 30 pomegranate genotypes (**Fig.2.1B**), and a total of 34 alleles were detected with an average of 2.13 alleles across the pomegranate genotypes. The H_o ranged from 0 to 0.52, with an average number of 0.23. The PIC values ranged from 0.33 to 0.60, with an average of 0.48. In the NJ tree, all 30 pomegranate genotypes were grouped into two major clusters: cluster 1 comprised 11 while cluster 2, 19 genotypes (**Fig. 2.3A**). Cluster 1 carried 9 wild genotypes with an exceptional placement of one wild genotype (Daru 17) within cluster 2. Cluster 2 had all cultivars (18), with exception of out grouping of two cultivars Muscat and Jodhpur Red in cluster 1. Furthermore, the PCoA assigned 30 genotypes to two major clusters (**Fig. 2.3B**). The principal coordinates (PCos) 1 and 2 explained 21.16 and 12.24%, respectively, of the total variance among the genotypes and accounted for 33.84% of the total variation. Interestingly, PCo 1 clearly separated two clusters into wild and cultivar groups.

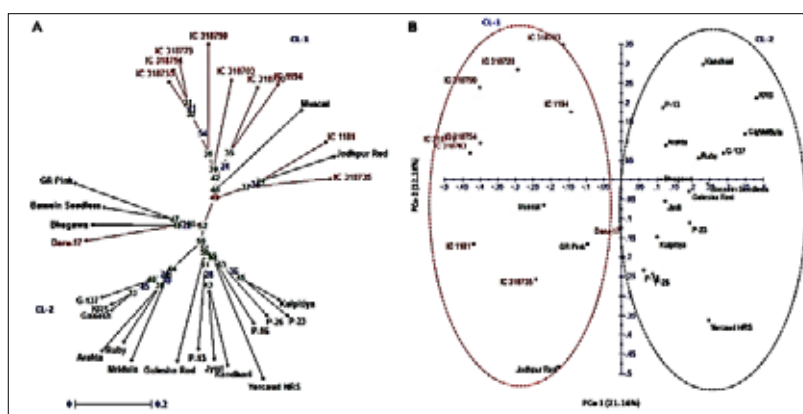


Fig. 2.3 Genetic relationships among 30 pomegranate genotypes based on 16 HvSSRT markers

Parental polymorphism study and genotyping of mapping population -

For parental polymorphism study screened 127 HvSSRT primers between Bhagawa x Daru 17 and identified 90 informative SSR markers for linkage map construction. Genotyping of F_1 mapping population (70 individuals) was initiated with 6 SSR markers i.e. HT178, HT115, HT16, P42, P13 and P19 (**Fig. 2.4**).

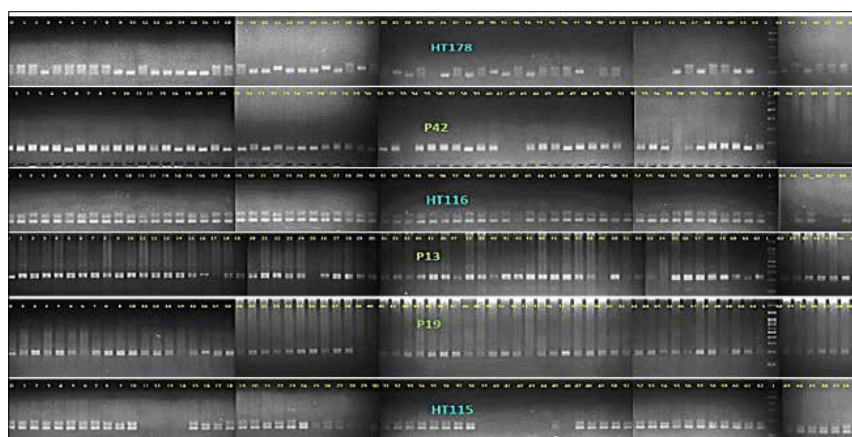


Fig.2.4 Genotyping of F_1 population Bhagawa X Daru 17 using hypervariable SSR markers

Development of mapping populations

The propagation, advancement and planting of F_1 population in the field were accomplished under Augmented Block design for mapping genes/QTLs for fruit quality traits (Fig.2.5A &B). Apart from this using 33 HvSSRs, we identified cross specific highly heterotic F_1 hybrid plants for five crosses *i.e.* Bhagawa x Daru 17, Bhagawa x Nana, Bhagawa x IC318712, Bhagawa x Nayana and Ganesh x Nayana for mapping important genes or QTLs for fruit quality traits in pomegranate (Fig. 2.6). Hybridity analysis of putative F_1 s resulted in identification of highly informative SSR primers for hybridity analysis in each of the crosses *i.e.* 14 primers for the first cross, 10 for the second, 12 for the third and 6 markers each for the fourth and fifth cross. Further, for the first cross Bhagawa x Daru 17, four primers (HvSSRT_375, NRCP_SSR9, NRCP_SSR12 and NRCP_SSR92) were found highly informative with 100% hybrid purity index, higher PIC (~0.52) and H_o (range 0.87-0.93) values, and two F_1 s namely H1 and H2 were found highly heterotic with heterozygosity index of 92.85 %. Similarly, for Bhagawa x Nana three primers (HvSSRT_375, HvSSRT_605 and NRCP_SSR19) were found highly informative with hybrid purity index (70-100%), higher PIC (0.52- 0.69) and H_o (0.75- 0.33) values, and three F_1 s H1, H2 and H4 had 70 % heterozygosity index. For Bhagawa x IC318712, four SSRs namely HvSSRT_254, HvSSRT_348, HvSSRT_826 and NRCP_SSR95 were found highly informative with higher H_o (~0.83), HPI (100%) and PIC (~0.52) values, and four F_1 s H2, H7, H9 and H10 had 91.66 % heterozygosity index. However, for Bhagawa x Nayana cross three SSRs namely HvSSRT_605, HvSSRT_826 and HvSSRT_432 and for Ganesh x Nayana, HvSSRT_375, HvSSRT_605 and HvSSRT_826 revealed co-dominant allelic patterns in the putative F_1 s to confirm true hybrids. Further, cluster and principal coordinate analysis revealed Bhagawa as female parent in combination with wild donors Daru17, Nana and IC318712 have revealed higher genetic diversity as compared to their hybrid progenies.



Fig. 2.5 Multiplication and advancement of F_1 population in the nursery (A) and planted in the field (B).

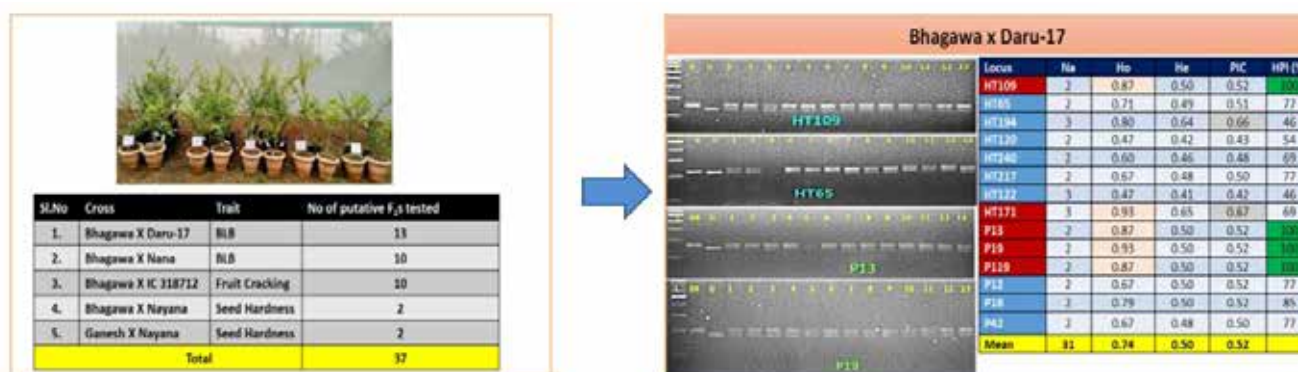
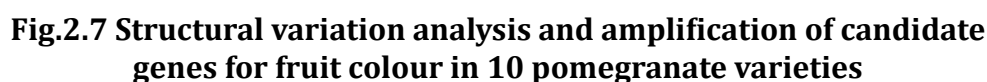
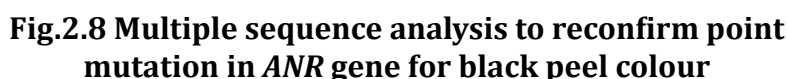


Fig. 2.6 Hybridity analysis of putative F_1 s using hypervariable SSR markers in five crosses of pomegranate

In order to develop candidate gene based markers retrieved full length gene sequences of five genes (ANS, CHS, CHI, F3H and DFR) that are part of Anthocyanin biosynthesises pathway from NCBI database for Tunisia genome and compared with Dabenzi and Taishanhong genes. After multiple sequence alignment, we identified sequence variations in three key genes ANS (1.2 Kb), CHI (2.7 Kb) and DFR (1.9 Kb), designed primers, standardized PCR conditions to amplify in 10 pomegranate varieties differed for fruit and aril colour for allele mining (**Fig. 2.7**).



Through *in silico* analysis reconfirmed that point mutation in Anthocyanidin reductase (ANR) gene could be responsible for black peel color in pomegranate (**Fig.2.8**).





2.2. DRAFT GENOME SEQUENCING OF POMEGRANATE (*PUNICA GRANATUM* L.) CV. BHAGAWA

Mapping to the reference mitochondrial genome

Mitochondrial assembly: The PacBio reads were aligned against the plant mitochondrial genomes downloaded from NCBI and then sub sampled with minimum of 1000 read length. Then, the subsampled reads were aligned against the closest reference mitochondrial genome (*Eucalyptus grandis*: NC_040010.1). In case of Illumina reads, we mapped back all the clean reads to the reference mitochondria genome (*Eucalyptus grandis*: NC_040010.1). All the libraries were passed onto BWA for the alignment.

Table 2.1: Statistics of the Reference Genome

Name	Length of Genome (bp)
<i>Eucalyptus grandis</i> mitochondrion	478813

Table 2.2: Mito Reads Mapped against *Eucalyptus grandis*

Sample	No. Of Mito Reads
PacBio	154084
Illumina	584777 (R1)

Mitochondrial genome Assembly

All the samples were further processed for mitochondrial assembly. In case of Bhagawa sample (1) the assembly was performed using hybrid approach i.e. both Illumina and PacBio reads were used by MaSuRCA (Maryland Super-Read CAbog). The hybrid assembly approach provides a way to simplify and reduce the cost of the assembly by reducing long-read coverage requirements. Masurca uses short reads to correct sequencing errors in PacBio data and then creates an assembly from the corrected reads.

However, in case of other samples having only Illumina data was used by GetOrganelle tool. The GetOrganelle uses SPAdes assembler for k-mers building the initial de Bruijn graph and on following stages it performs graph-theoretical operations which are based on graph structure, coverage and sequence lengths. Moreover, it adjusts errors iteratively.

Mitochondrial assembly statistics for the given samples

Sample	Assembly Stats	GC_Content
1 (Bhagwa)	513739	0.38
2	305899	0.46
3	308572	0.46
4	307336	0.46
5	306567	0.46
6	305167	0.46
7	299394	0.46
9	399235	0.46
11	307341	0.46



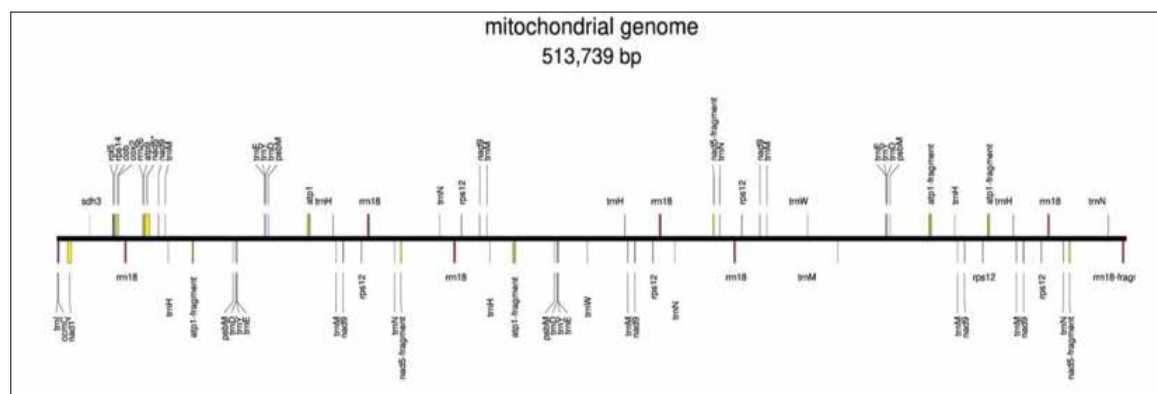
Sample	Assembly Stats	GC_Content
12	307154	0.46
20	306737	0.46
29	307053	0.46
30	306881	0.46
35	304930	0.46
37	307242	0.46
48	307176	0.46

Mitochondrial Genome Annotation

The mitochondrial genome annotation for all 16 samples was performed using GeSeq tool. The GeSeq is used for the rapid and accurate annotation of organellar genome sequences. In contrast to existing tools, GeSeq combines batch processing with a fully customizable reference sequence selection of organellar genome records from NCBI and/or references uploaded by the user. GeSeq identifies genes or other feature-encoding regions by BLAT-based homology searches and additionally, by profile HMM searches for protein and rRNA coding genes and two *denovo* predictors for tRNA genes. Below figure highlights the annotation for bhagwa sample (1).

1. Phylogenetic relationship

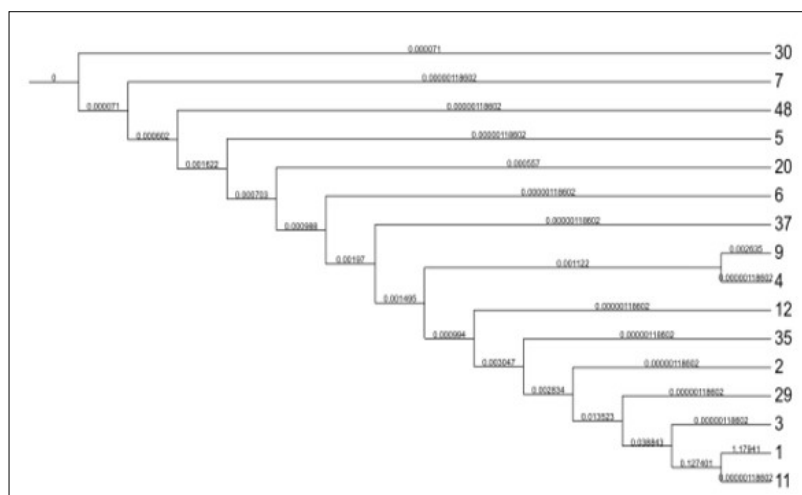
To infer orthogroups and to provide phylogenetic inference of orthologs, we have used OrthoFinder tool. It provides high accuracy orthogroup inference of orthologs, rooted gene trees, gene duplication events, the rooted species tree, and comparative genomics statistics. Finally, OrthoFinder's comprehensive phylogenetic analysis is achieved with equivalent speed and scalability to the fastest, score-based heuristic methods (Fig. 2).



2. Phylogenetic relationships between the samples

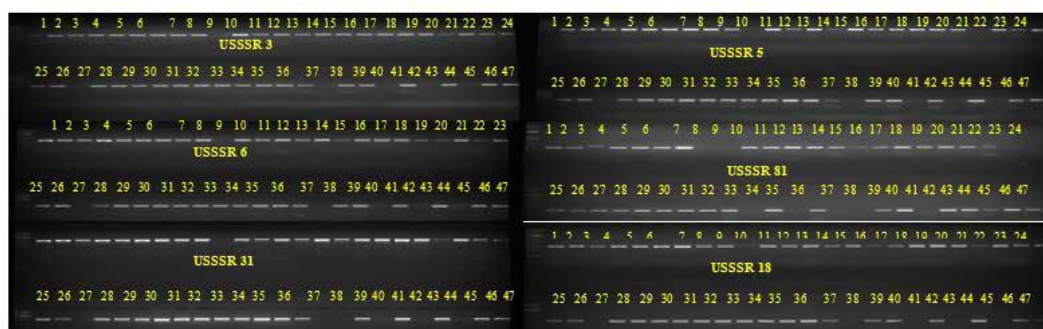
Genome wide Association mapping:

Out of 96 germplasm lines were selected based on morphological and quality trait for genome wide association mapping. In this year 48 germplasm lines has been genotyped of by using genome wide SSR markers. A total of 120 SSR markers has been screened, out of which only 35 SSR markers found to be polymorphic.

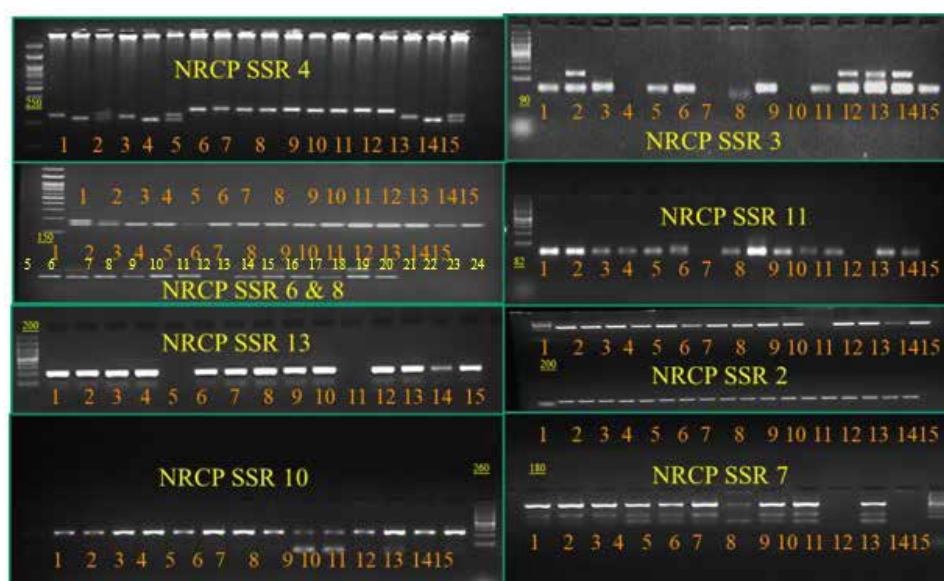


3.Validation of genomic SSR markers

On 15 selected genotypes the newly designed SSR markers has been validated. A set 30 SSR has been designed by using genome sequence of Bhagawa by using MISA and synthesised these have been validated. The results were reproducible on the genotypes studied out 30 SSR 15 were found polymorphic. The number alleles varied from 0 – 4 alleles. The PIC percent ranged from 0- 33.33. the large set of marker validation is under progress.

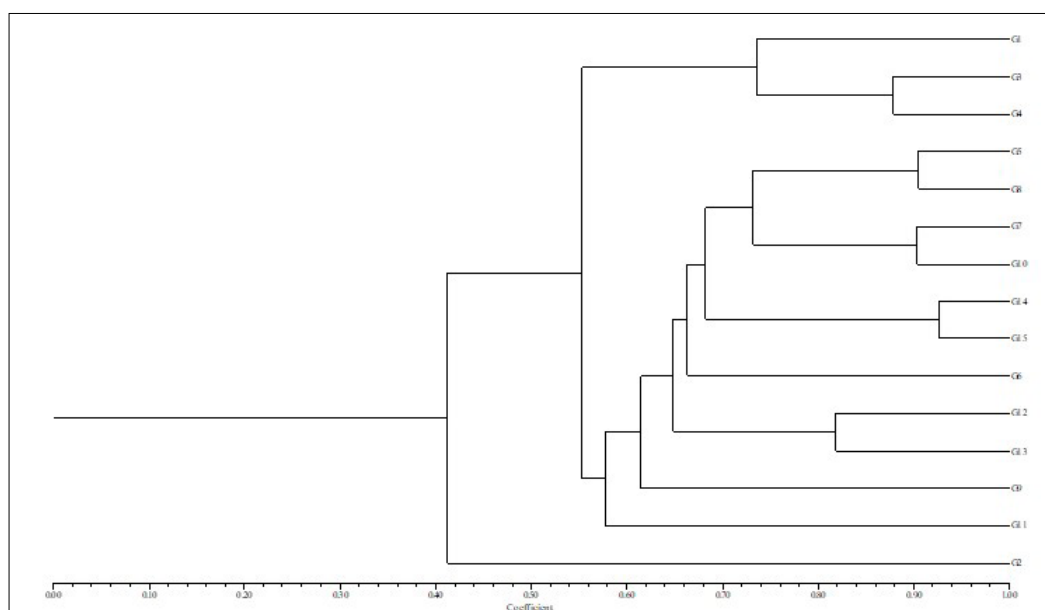


4.Validation of SSR Markers developed from Bhagawa genome sequence information





5. Cluster analysis of 15 genotypes based on new SSR markers designed by using genome sequence of Bhagawa.



3. Plant Propagation

3.1 PROJECT: COMBATING STRESSES AND IMPROVING QUALITY IN POMEGRANATE (*Punica granatum* L.) BY EXPLOITING ROOTSTOCKS

In vitro propagation of ‘Solapur Lal’: Various explant pre-treatments, basal media, growth regulator combinations and media supplement combinations were tried in experimental mode with 83.60% establishment, 3.67 proliferation and 51.54% *in vitro* rooting success, further refinement of protocol in under progress.

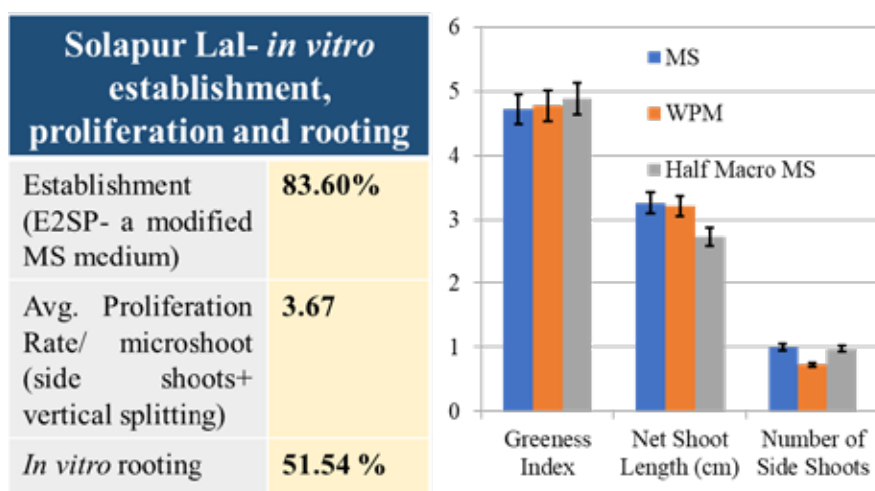


Fig.3.1 Solapur Lal- *in vitro* establishment proliferation and rooting

Refinement in *in vitro* propagation of ‘Bhagawa’ and ‘Super Bhagawa’: The maximum net shoot growth of microshoots and the average maximum side shoots were obtained on modified MS medium with proliferation rate of more than 7.32 per shoot (combining vertical splitting and side shoots).

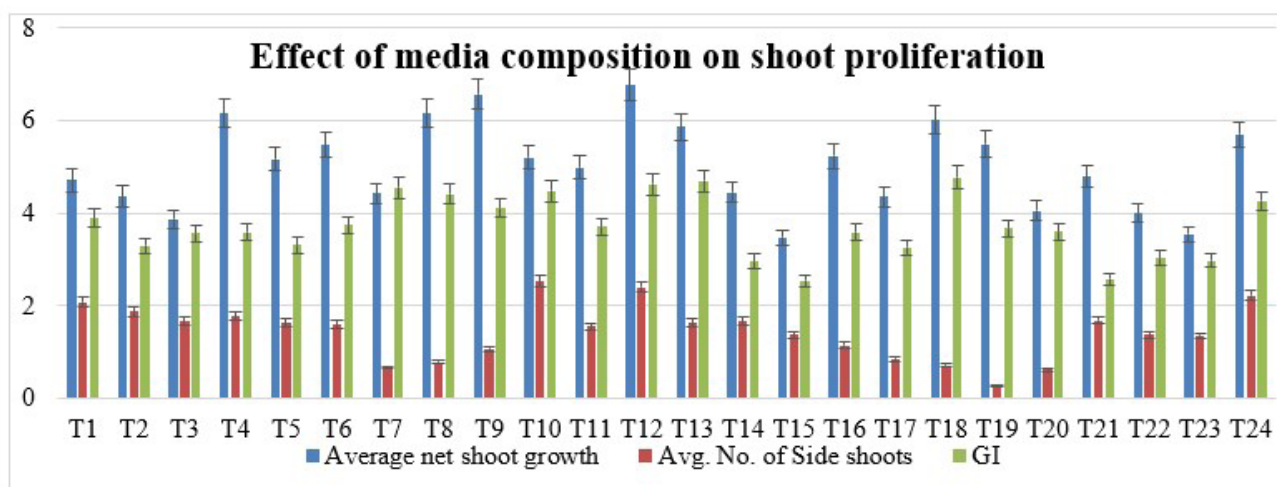


Fig.3.2 Effect of media composition on shoot proliferation



T12: WPM basal Medium + additional NH_4NO_3 + 50 mg/l Adenine Sulphate + Sodium Phosphate Monobasic + IAA 0.25 mg/l + NAA 0.1 mg/l

T10: WPM basal Medium + additional NH_4NO_3 + 50 mg/l Adenine Sulphate + IAA 0.25 mg/l + NAA 0.1 mg/l

T24: MS basal medium with additional CuSO_4 and CoCl_2 + NAA 0.15 mg/l + BAP 0.3 mg/l + 50 mg/l Adenine Sulphate + Ascorbic Acid

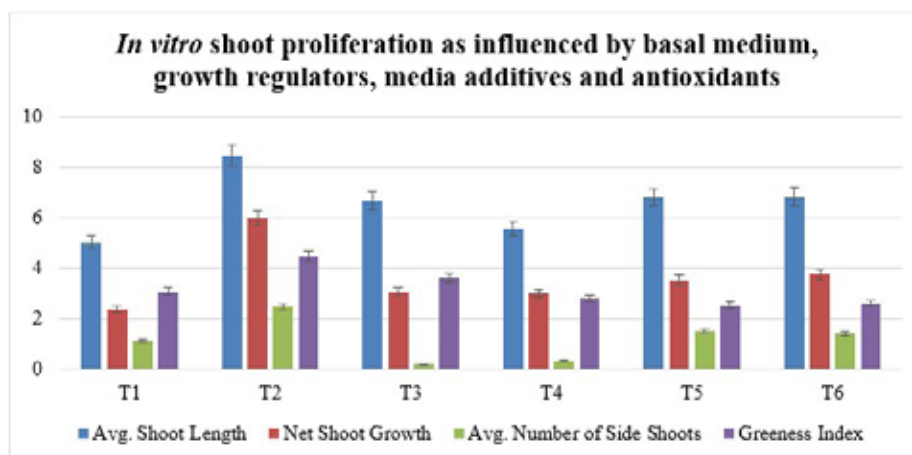


Fig.3.3 In vitro proliferation as influenced by basal medium, growth regulators, media additives and antioxidants

Treatment Details:

T1: Modified MS (Reduced NH_4NO_3 and enhanced FeSO_4 -EDTA, KI, CuSO_4 , CoCl_2 and Thiamine) + AgNO_3 + BAP (0.3)+NAA (0.15) + SPM (221) + AA (2)

T2: Modified MS (Reduced NH_4NO_3 and enhanced FeSO_4 -EDTA, KI, CuSO_4 , CoCl_2 and Thiamine) + AgNO_3 + BAP (0.3)+NAA (0.15) + SPM (221) + AA (2)

T3: DKWJ+ AgNO_3 + BAP (0.3)+NAA (0.15) + SPM (221) + AA (2)

T4: DKWJ+ AgNO_3 + BAP (0.3)+NAA (0.15) + SPM (221) + AA (4)

T5: Modified WPM with enhanced NH_4NO_3 + AgNO_3 + BAP (0.3) + NAA (0.15) + SPM (221) + AA (2)

T6: Modified WPM with enhanced NH_4NO_3 + AgNO_3 + BAP (0.3) + NAA (0.15) + SPM (221) + AA (4)



In vitro shoot proliferation

***In vitro* rooting of micro-shoots:** The average of *in vitro* rooting in different basal medium reveals the maximum *in vitro* rooting in WPM medium. The effect of addition of 5 % coconut water (v/v) to the medium was found to be very promising in enhancing *in vitro* rooting of pomegranate micro-shoots. Almost all the rooting parameters were found to be improved with the addition of coconut water as high as 100% *in vitro* rooting was observed with as low as 12.67 days to root initiation.

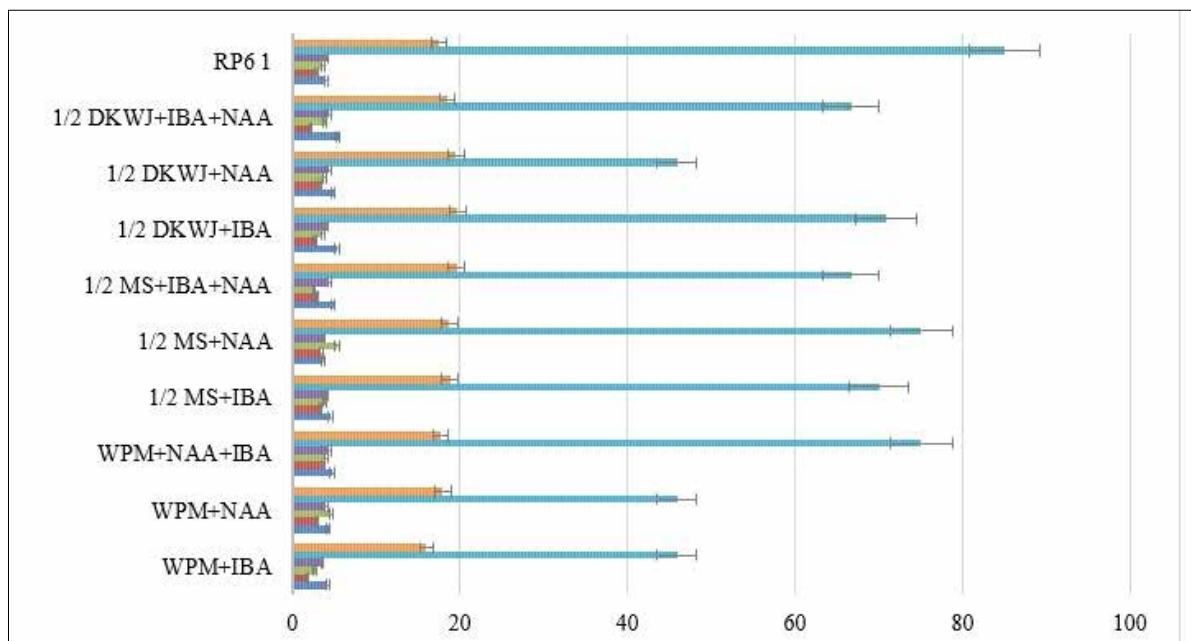


Fig. 3.4 Effect of basal media, adsorbing agents and growth regulators on *in vitro* rooting of micro-shoots

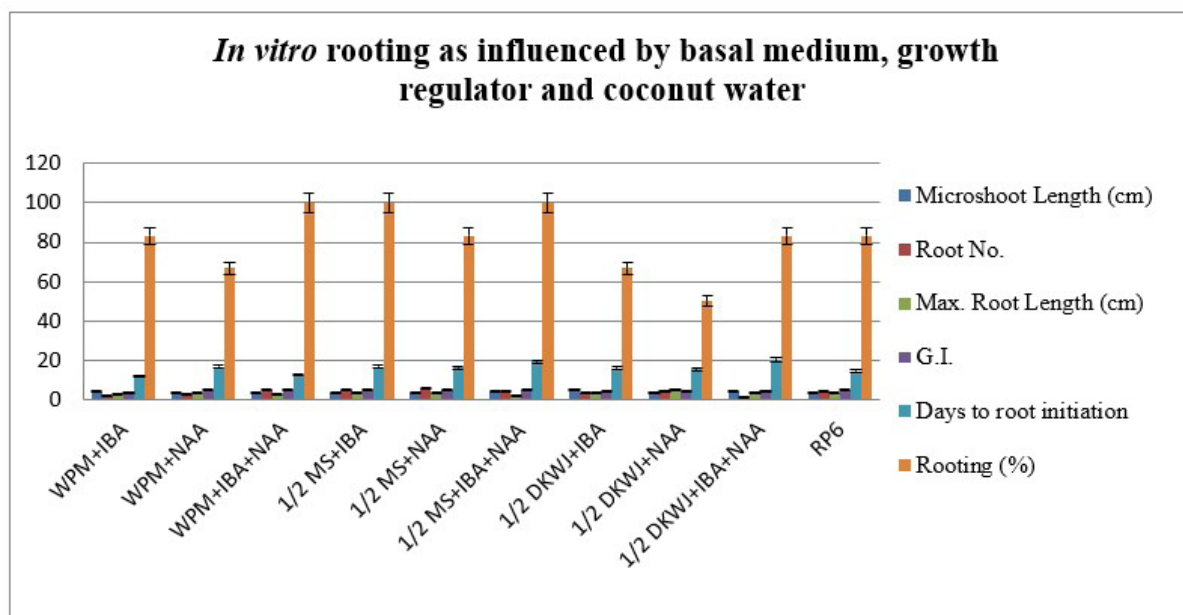


Fig. 3.5 *In vitro* rooting as influenced by basal medium, growth regulators and coconut water



Micro-cutting in pomegranate: Single nodal soft wood stem segments (4-5cm long) of 'Bhagawa' and 'Solapur Lal' were used as explant for *in vivo* micro-cutting after following sanitation protocol. The final micro-cutting success of 'Solapur Lal' and 'Bhagawa' at 45 days after planting was 18.33% and 16.67 %, respectively.

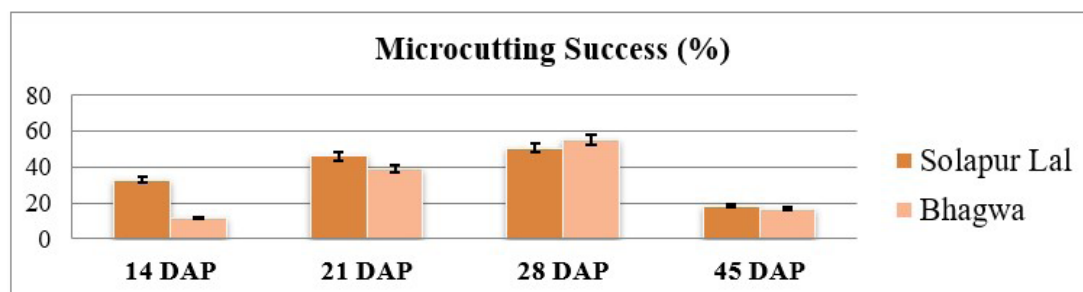


Fig. 3.6 Microcutting success (%)

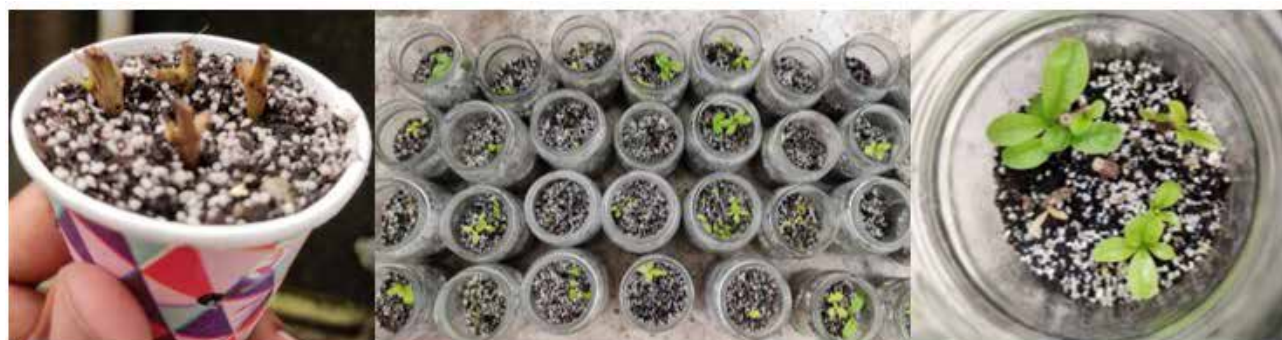


Fig. 3.7 Microcutting success

Micro-cutting in pomegranate cv. 'Bhagawa' and 'Solapur Lal'

Screening for pomegranate genotypes/cultivars/accessions against *Ceratocystis* wilt for utilizing them as rootstocks:

Disease reaction type	Pomegranate accessions/genotypes/cultivars
Slow wilting type (6 to 12 months) (Wilting started 6 month API)	EC-626968, ACC9, IC-318706, IC-318707
Early wilting type (1 to 6 months) (Wilting started 1 month API)	Bhagwa, Solapur Lal EC- 676960, 676927, 676930, 676838, 676923 IC-318718, 318754, 1181,1182, 1202, Patna 5
Note: API: after pathogen inoculation, Pathogen: <i>Ceratocystis fimbriata</i> Inoculum load: 1×10^8 cfu/ml, Number of germplasm screened (2020-2021): 20 Number of plants used for screening per genotype/cultivar/accessions:05	



Fig.3.8 Slow Wilting Types

Wilt Susceptible Types

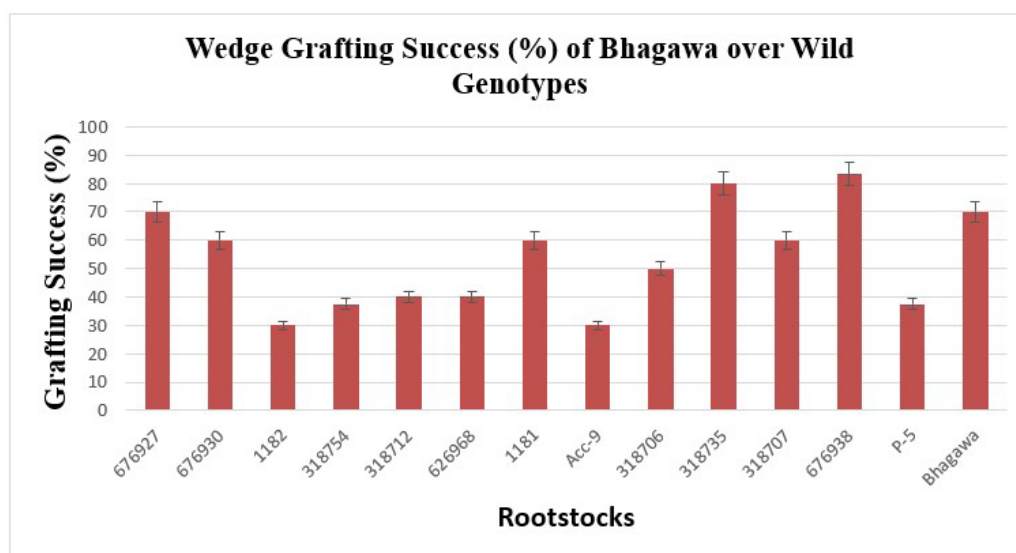


Fig.3.9 Wedge grafting success (%) of Bhagawa over wild genotypes

Wedge grafting in pomegranate by using promising rootstocks: the promising genotypes against salinity and *Certocystis fimbriata* were utilized as rootstock using Bhagawa scion and wedge grafting. The grafting success ranged from 30% to 83.33%.



4. Crop Production

4.1 PROJECT: CROP REGULATION PRACTICES FOR IMPROVING PRODUCTIVITY OF POMEGRANATE

Crop load optimization through thinning in pomegranate variety Solapur Lal:

Pomegranate variety Solapur Lal is a hybrid variety with vigorous nature. It has a tendency to produce continuous bloom, profuse flowers and overbearing of fruits throughout the tertiary branches. This often leads to medium sized fruits due to competition for nutrients. In order to improve the fruit size, the surplus fruits beyond a limit should be removed after fruitset through fruit thinning. An experiment was conducted in Solapur Lal by adopting six thinning levels viz., without thinning (control): > 135 fruits/tree; verylight thinning: 121 - 135 fruits/tree; light thinning: 106-120 fruits/tree; medium thinning: 91- 105 fruits/tree; heavy thinning: 76-90 fruits/tree and very heavy thinning: 61-75 fruits/tree. The results revealed that light thinning of fruits resulted in better fruit size (274.8g/fruit) and optimum yield (30.99kg/tree) which is superior over the control.

Thinning Level	No. of fruits/ tree	Mean fruit weight (g)	Yield (kg/ plant)	Yield (ton/ha)	TSS (°Brix)	Acidity (%)	Ascorbic acid (mg/100g)
Control (without thinning)	142.6	252.5	36.01	26.64	17.4	0.42	19.2
Very light thinning	130.3	265.2	34.56	25.57	17.5	0.42	19.2
Light thinning	115.6	275.6	31.86	23.58	17.6	0.4	19.4
Medium thinning	96.6	279.3	26.98	19.96	17.6	0.4	19.4
Heavy thinning	85.3	282.6	24.11	17.84	17.7	0.39	19.5
Very heavy thinning	72.3	284.5	20.57	15.22	17.8	0.39	19.6

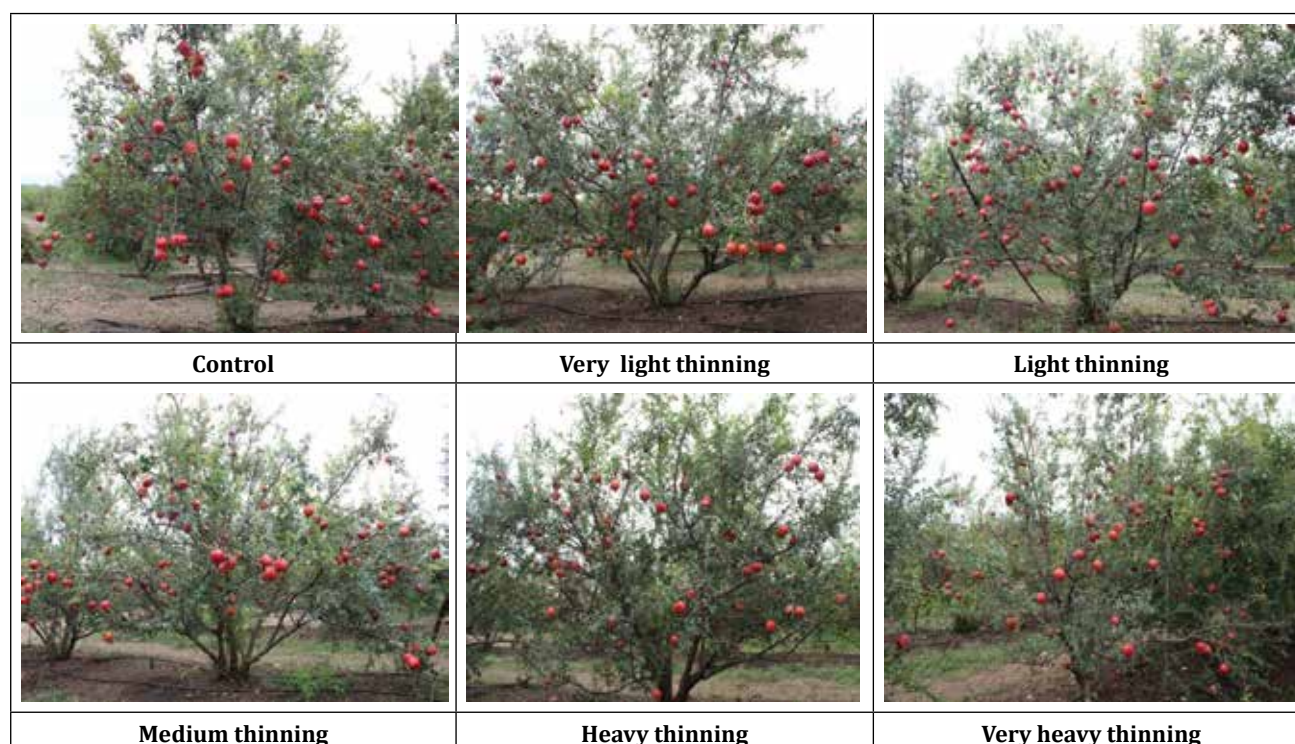


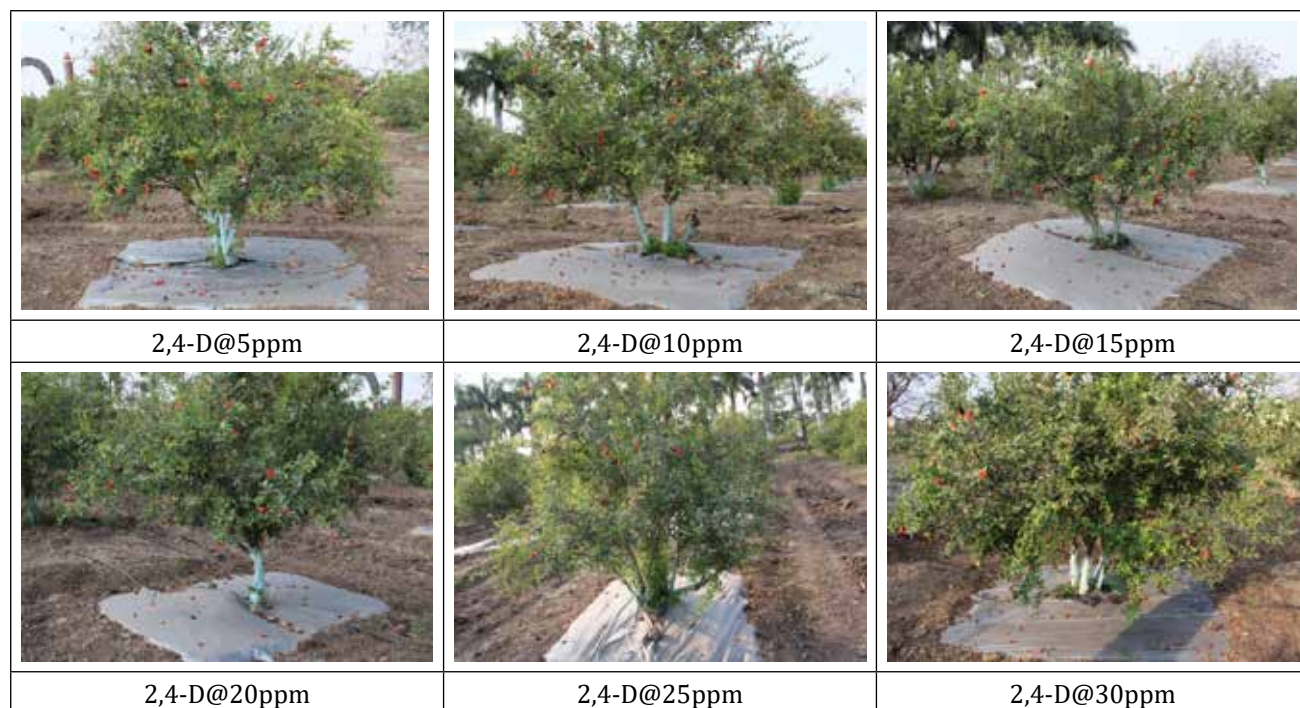
Fig4.1. Crop load optimization through thinning

Effect of 2,4 D on Flower / Fruit Drop:

In pomegranate, the crop regulation helps to produce uniform flowering and fruiting. However, there is fruitdrop during different stages of fruitgrowth, especially after fruitset. Fruit drop due to hormonal imbalance could be managed through extraneous application of suitable auxins. An experiment was conducted in pomegranate variety Bhagawa during hasthahar. Foliar spray of growth regulator: 2,4-D at six concentrations (5,10,15,20,25 and 30ppm) along with a control. The increase in concentration of 2,4-D significantly reduced the flower drop. With minimum no. of dropped flowers (21.3 flowers/tree). Hence, 2,4-D @20ppm was found to be highly beneficial for management of fruit drop.

Table 4.1 Effect of 2,4 D on Flower /Fruit Drop

Concentration of 2,4-D (ppm)	Total No. of bisexual flowers	No. of bisexual flowers dropped	No. of bisexual flowers retained	Fruitset (%)	No. of fruits/ Plant	Fruit weight (g)	Yield (kg/tree)
5 ppm	195.6	37.3	158.3	52.11	82.5	260.2	21.47
10 ppm	194.3	33.3	161.0	52.16	84.5	263.4	22.26
15 ppm	191.9	26.6	165.3	53.84	89.0	266.3	23.70
20 ppm	188.3	21.3	167.0	58.06	96.5	268.2	25.88
25 ppm	184.2	21.6	162.6	57.81	94.0	267.4	25.14
30 ppm	182.6	22.3	160.3	55.83	89.5	265.6	23.77
Control (Unsprayed)	198.3	48.0	150.3	51.42	72.0	255.2	18.37





		
	Control	

Fig 4.2 Effect of 2, 4-D on control of flower drop in pomegranate

Induction of flowering in pomegranate:

Crop regulation in pomegranate is done during different bahar viz., mrig, hath and amba bahar. Flowering in pomegranate often becomes a problem in hath bahar due to dropdown of temperature. For induction of flowering in pomegranate, an experiment was conducted during hath bahar in A4 block, Kegaon, with the following treatments viz., foliar spray of Ammonium nitrate (0.25%, 0.50%, 0.75%), Naphthalene acetic acid (5ppm, 10ppm, 15ppm) and micronutrient mixture ie. Rexolin (0.1%, 0.2%, 0.3%) along with an unsprayed control. The results revealed that NAA @ 10ppm concentration was found to be extremely useful for induction of flowering in pomegranate. It resulted in highest fruitset (53.46%), no. of fruits/tree (98.0/tree) and yield (26.87kg/tree).

Table 4.2 Induction of flowering in pomegranate

Treatment	No. of bisexual flowers / plant	No. of fruits / plant	Fruitset (%)	Fruit weight (g)	Yield (kg/ plant)	Yield (t/ha)
Ammonium Nitrate@ 0.25%	179.6	87.6	48.78	261.5	22.91	16.95
Ammonium Nitrate@ 0.50%	186.3	92.6	49.70	268.4	24.85	18.39
Ammonium Nitrate@ 0.75%	183.6	94.3	51.36	269.6	25.42	18.81
NAA@5ppm	182.6	92.3	50.55	270.4	24.96	18.47
NAA@10ppm	183.3	98.0	53.46	274.2	26.87	19.88
NAA-@15ppm	181.3	96.6	53.28	273.5	26.42	19.55
Micronutrient mixture @0.1%	180.6	88.3	48.89	261.2	23.06	17.07
Micronutrient mixture @ 0.2%	197.3	92.3	46.78	264.2	24.39	18.05
Micronutrient mixture @0.3%	190.6	93.0	48.79	264.6	24.61	18.21
Control (Unsprayed)	178.3	79.6	44.64	242.5	19.30	14.28











		
Ammonium Nitrate @0.25%	Ammonium Nitrate @0.50%	Ammonium Nitrate @0.75%
		
NAA @ 5. ppm	NAA @ 10. ppm	NAA @ 15 ppm
		
Micronutrient @0.1%	Micronutrient @0.2%	Micronutrient @0.3%
		
	Control	

Fig4.3. Induction of flowering in pomegranate

For induction of flowering in pomegranate during hasthahar, another experiment was conducted in H4 block, Hiraj with the following 8 treatments compared with a control. The Growth regulators /chemicals were foliar sprayed twice to the pomegranate trees during second fortnight of November at 15 days interval. The treatments include : IAA @20ppm, 2,4-D@10ppm, Daminozide@500ppm, Ethephon@700ppm followed by BAP@10ppm at one week later, Nitrobenzene 20% @0.2%, potassium nitrate@1.0%, silver nitrate @0.01%, Micronutrient mixture ie. Yaravita @ 0.2% along with a control. Foliar spray of potassium nitrate@1.0% resulted in highest no. of fruits (98.2), fruit weight (275.4g) and yield (27.04kg/plant). Control recorded the lowest fruit yield (19.79kg/plant).



Treatments	No. of flowers /plant	No. of fruits / plant	Fruitset (%)	Fruit weight (g)	Yield (kg/ plant)	Yield (t/ ha)
IAA @20ppm	195.6	97.5	49.85	265.6	25.90	19.16
2,4-D@10ppm	188.0	101.5	53.99	273.2	27.73	20.52
Daminozide@500ppm	184.3	102.3	55.51	274.1	28.04	20.75
Ethephon@700ppm fb. BAP@10ppm at one week later	186.0	96.6	51.94	270.2	26.10	19.31
Nitrobenzene 20% @2ml/l	190.3	97.0	50.97	269.4	26.13	19.34
Potassium Nitrate@1%	185.6	103.5	55.77	275.2	28.48	21.08
Silver nitrate @0.01%	182.3	100.3	55.02	271.2	27.20	20.13
Micronutrient mixture @0.2%	193.6	97.0	50.10	261.4	25.36	18.76
Control	180.3	83.3	46.20	244.6	20.38	15.08










		
IAA @20 ppm	2,4-D@ 10 ppm	Daminozide@ 500 ppm
		
Ethrel@1.75 ml /l + BAP@10mg/l after one week	Nitrobenzene 20 % @2ml/l	Potassium Nitrate@ 1.0%
		
Silver Nitrate@0.01%	Micronutrient mixture@0.2%	Control

Fig 4.4. Induction of flowering in pomegranate

4.2. PACKAGE OF PRACTICES FOR ORGANIC CULTIVATION OF POMEGRANATE

Effect of new micronutrient formulations (Formulation I and Formulation II) on nutritional status, flowering, fruit yield and quality of pomegranate

Two new formulations (Formulation I & II) were evaluated for the third season under field condition and compared with commercially available EDTA-micronutrient formulation. The nutritional status of trees after foliar application of Formulation I revealed that there was significant increase in Mn and Cu concentration in leaves at higher dose (@ 2.5 ml l⁻¹) while at lower dose (@ 1 ml l⁻¹) significant increase in Fe and Cu concentration was noted. The effect of formulation was seen on the flowering behavior of the tree. Significant increase in male and hermaphrodite flowers and fruit set was noticed. The highest number of hermaphrodite flowers (38.89% increase) was recorded at higher dose while the highest number of male flowers (40.41% increase) was recorded with lower dose of the formulation. An increase of 14.24-18.84% in fruit set was noticed with the formulation. Spraying of formulations increased fruit yield by 31.39-42.96% over the commercial micronutrient formulation (Grade-II) and the highest fruit yield of 20.13 kg tree⁻¹ was recorded with higher dose of the formulations. Even the yield obtained with lower dose of formulations was at par with that recorded from the use of commercial micronutrient formulation plus two sprays of gibberellic acid (@50 ppm). Significant improvement in fruit size was also noticed. About 39.51-42.77% fruit was above 250g while it was only 34.27% with commercial micronutrient formulation. Substantial improvement in aril and juice percent, 100 arils weight and rind thickness was observed with the sprays of formulations. Besides, significant improvement in phenol, anthocyanin concentration and sugar content in fruit was also noted.

Table 4.1. Effect of new formulations on fruit yield and size distribution of pomegranate

Treatment	Fruit yield (kg tree ⁻¹)	Per cent fruit weighing >250 g	Per cent fruit weighing <250 g
T1: Control	11.96 ^d	24.08 ^d	75.92 ^a
T2: EDTA micronutrient @ 1 g l ⁻¹ (three sprays)	14.08 ^c	34.27 ^c	65.73 ^b
T3: Formulation I followed by two sprays of Formulation II @ 2.5 ml l ⁻¹	20.13 ^a	42.77 ^a	57.23 ^d
T4: Formulation I followed by two sprays of Formulation II @ 1.0 ml l ⁻¹	18.50 ^b	39.51 ^b	60.49 ^c
T5: EDTA micronutrient @ 1 g l ⁻¹ (three sprays) + Gibberellic acid @ 50 ppm (two sprays)	19.08 ^b	40.63 ^b	59.37 ^c
LSD _{α_{0.05}}	0.67	1.97	2.02

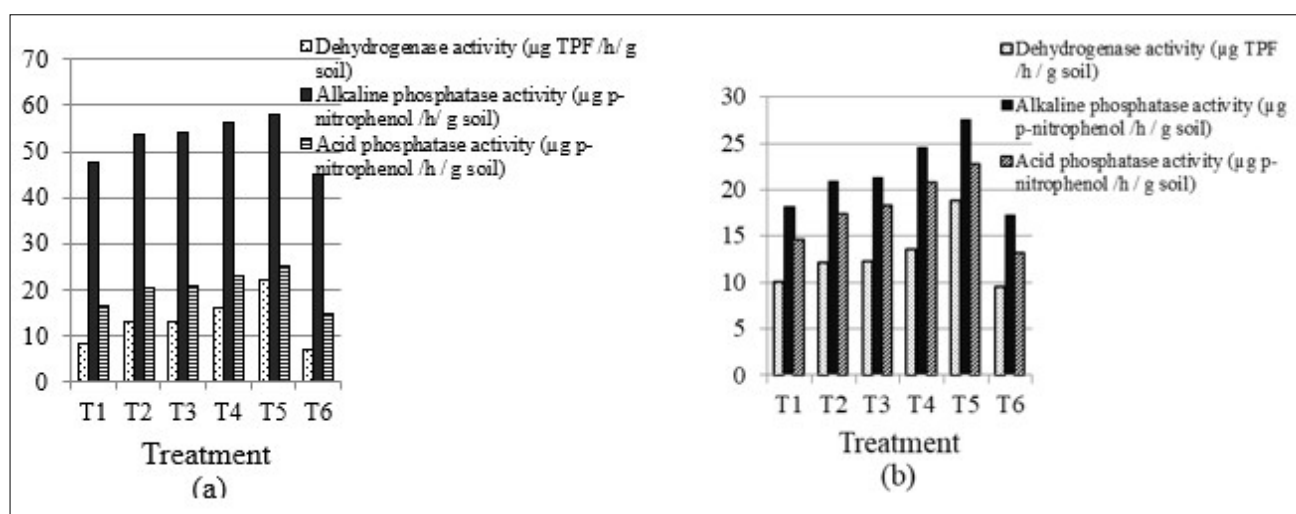
Effect of bio-organic fertilizer on biomass partitioning, soil enzyme activity, microbial biomass carbon and nutrient uptake by pomegranate

A new bio-organic product has been developed and evaluated under pot culture experiment at graded dose in pomegranate. The data revealed that application of newly developed bio-organic fertilizer significantly enhanced shoot, root and total biomass and subsequently the shoot-root ratio. The highest increase in biomass (43.46% increase in shoot, 14.48% increase in root and 35.68% increase in total biomass) was noted with the application of bio-organic fertilizer at the rate of 150 g plant⁻¹.

**Table 4.2. Effect of bio-organic fertilizer on plant biomass partitioning**

Treatment	Above ground biomass (g plant ⁻¹)	Root biomass (g plant ⁻¹)	Total biomass (g plant ⁻¹)	Shoot-root ratio
T1: Control	165.86 ^c	60.96 ^{bc}	226.82 ^c	2.73 ^c
T2: K solubilizing bio-formulation @ 20 g plant ⁻¹	219.18 ^{ab}	61.34 ^{bc}	280.52 ^{ab}	3.58 ^a
T3: Bio-organic fertilizer @ 150 g plant ⁻¹	237.95 ^a	69.79 ^a	307.74 ^a	3.41 ^{ab}
T4: Bio-organic fertilizer @ 300 g plant ⁻¹	222.37 ^{ab}	62.46 ^{abc}	284.83 ^{ab}	3.57 ^a
T5: Bio-organic fertilizer @ 600 g plant ⁻¹	211.56 ^b	57.99 ^c	269.56 ^b	3.66 ^a
T6: Recommended dose of P and K through chemical fertilizers	203.64 ^b	68.35 ^{ab}	271.98 ^b	2.98 ^{bc}
LSD α 0.05	22.20	8.22	28.66	0.48

Soil enzymes activities were assayed at 90 and 150 days after application of bio-organic fertilizer. The results indicated that application of bio-organic fertilizer significantly enhanced dehydrogenase, acid and alkaline phosphatase enzyme activities and the highest enzyme activities were recorded at the bio-organic fertilizer dose of 600 g plant⁻¹ even after 150 days of application. Similarly, microbial biomass carbon content of soil increased significantly at both the times i.e. 90 and 150 days after application of bio-organic fertilizer. Like soil enzyme activities, the highest microbial biomass carbon was recorded with the bio-organic fertilizer when applied at the dose of 600 g plant⁻¹.

**Fig 4.5. 1 Effect of bio-organic fertilizer on soil enzyme activities at (a) 90 and (b) 150 days after application**

Significant increase in uptake of N, P and K was observed with the application of bio-organic fertilizer. The highest uptake of N, P and K (N-uptake increased by 53.98%, P-uptake increased by 32.44% and K-uptake increased by 33.42%) was recorded with the application of bio-organic fertilizer at the rate of 150 g plant⁻¹ which was even significantly higher than that recorded with recommended dose of P and K fertilizers. The uptake of N, P and K with bio-organic fertilizer when applied at the rate of 150 g plant⁻¹ was even significantly higher than that recorded with the application of *Penicillium pinophilum* based K-solubilizing bio-formulation at the rate of 20 g plant⁻¹.

Table 4.3. Effect of bio-organic fertilizer on nutrient uptake by the plant

Treatment	Nutrient uptake (mg plant ⁻¹)		
	Nitrogen	Phosphorus	Potassium
T1: Control	1729.41 ^e	940.78 ^e	259.05 ^d
T2: K solubilizing bio-formulation @ 20 g plant ⁻¹	2470.32 ^b	1105.54 ^c	311.88 ^b
T3: Bio-organic fertilizer @ 150 g plant ⁻¹	2663.00 ^a	1245.95 ^a	345.63 ^a
T4: Bio-organic fertilizer @ 300 g plant ⁻¹	2238.90 ^c	1059.75 ^d	313.34 ^b
T5: Bio-organic fertilizer @ 600 g plant ⁻¹	2058.62 ^d	1074.57 ^{cd}	290.21 ^c
T6: Recommended dose of P and K through chemical fertilizers	2097.57 ^d	1171.48 ^b	311.44 ^b
LSD α 0.05	44.45	38.85	17.02

Effect of bio-organic fertilizer on temporal changes of nutrients in leaves and soil

Leaves samples were collected at 30, 90 and 140 days after flowering (DAF) to assess the nutritional status of pomegranate trees in response to the application of bio-organic fertilizer. The data revealed that trees treated with bio-organic fertilizer @ 300 and 600 g tree⁻¹ showed significant increase in leaf N concentration only at 30 DAF while at 90 and 140 DAF, no significant increase in leaf N concentration was noticed. Significant changes in leaf P concentration were noted in response to bio-organic fertilizer application. Application of *Penicillium pinophilum* based K-solubilizing bio-formulation and bio-organic fertilizer significantly increased leaf P concentration at 30 and 90 DAF and the leaf P concentration was even at par with that recorded in trees treated with chemical P and K fertilizers at recommended dose. While, application of bio-organic fertilizer @ 600 g tree⁻¹ could significantly enhance leaf P concentration at 140 DAF which was at par with that recorded in trees treated with chemical P and K fertilizers at recommended dose. Although, application of K-solubilizing bio-formulation did not significantly enhanced leaf K concentration at 30 and 90 DAF, application of bio-organic fertilizer significantly increased leaf K concentration at all the sampling date i.e. 30, 90 and 140 DAF. At 30 DAF, the highest leaf K concentration was noted with the application of bio-organic fertilizer @ 600 g tree⁻¹ which was at par with that recorded in trees treated with chemical P and K fertilizers at recommended dose. While the highest leaf K concentration at 90 and 140 DAF was recorded with the application of bio-organic fertilizer at the rate of 300 g tree⁻¹ which was even significantly higher than that recorded with the chemical P and K fertilizers at recommended dose.

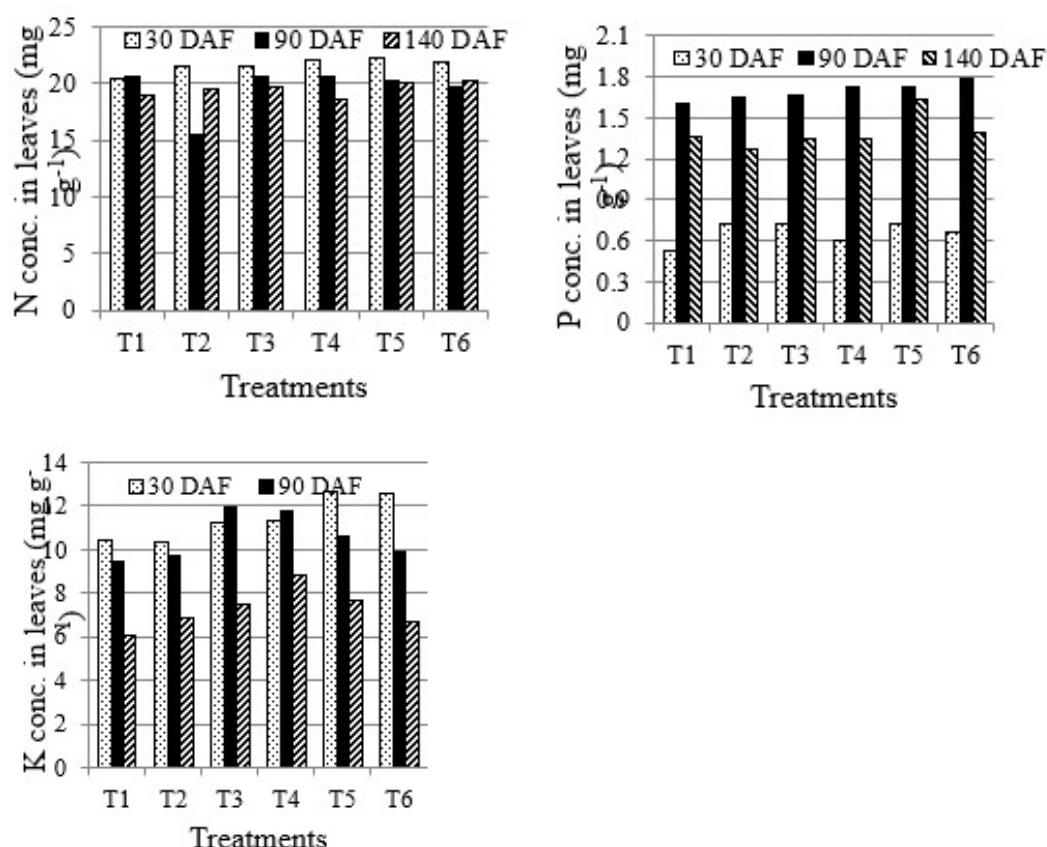


Fig. 4.6 Effect of bio-organic fertilizer on temporal changes of N, P and K concentration in leaves during the fruit growth and development period.

Soil available nutrient status was evaluated periodically at 30, 60, 90 and 120 DAF to monitor the changes in soil fertility in response to bio-organic fertilizer application. Significant increase in available N content was observed at 60, 90 and 120 DAF in bio-organic fertilizer treated soil. The highest available N content at 60 DAF was recorded with the application of bio-organic fertilizer @ 150 g tree⁻¹ which was at par with that recorded in chemical P and K fertilizers application at recommended dose. While at 90 and 120 DAF, the highest available N content was observed with the application of bio-organic fertilizer @ 300 g tree⁻¹ which was even higher than that recorded with chemical P and K fertilizers at recommended dose.

Unlike available N, significant increase in soil available P content was noted in bio-organic fertilizer treated soil at 30, 60 and 90 DAF. However, no significant improvement in available P content was observed at 120 DAF in response to bio-organic fertilizer application. The highest available P content at 30 DAF was recorded with bio-organic fertilizer applied at the rate of 150 g tree⁻¹ and 600 g tree⁻¹ which were at par with each other. At 60 DAF all the bio-organic fertilizer and K-solubilizing bio-formulation treated soil showed significantly higher available P content and they were all at par with each other. Application of bio-organic fertilizer @ 300 and 600 g tree⁻¹ registered significantly higher available P content in soil at 90 DAF. So the effect of bio-organic fertilizer on available P content was seen as early as 30 DAF and lasted up to 90 DAF. Significant increase in available K content was noted with the application of bio-organic fertilizer at 30, 90 and 120 DAF. But the highest available K content in soil was recorded with the

application of chemical P and K fertilizers at recommended dose. Application of K-solubilizing bio-formulation and bio-organic fertilizer significantly increased available S content at 60 DAF and the highest available S content was noted with the application of bio-organic fertilizer @ 150 g tree⁻¹. While application of K-solubilizing bio-formulation, bio-organic fertilizer @ 150 g tree⁻¹ and chemical P and K fertilizer at recommended dose resulted significant increase in available S content in soil at 30 DAF and the highest available S content was recorded with chemical P and K fertilizers applied at recommended dose.

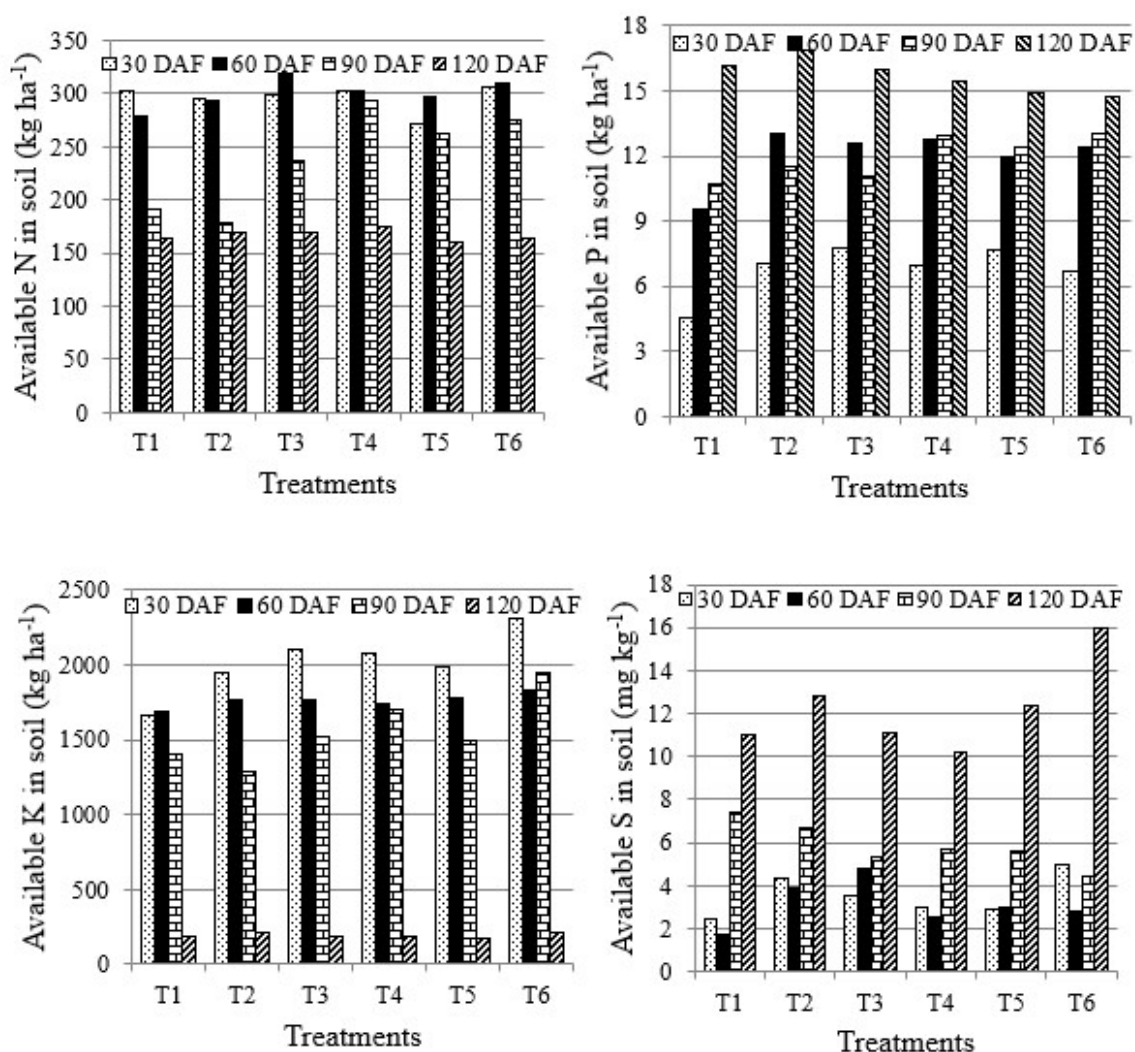


Fig. 4.7 Effect of bio-organic fertilizer on temporal changes of soil available N, P, K and S content during the fruit growth and development period.

Effect of bio-organic fertilizer on flowering, fruit yield and quality

A field experiment was conducted to evaluate the efficacy of bio-organic fertilizer in influencing flowering, fruit yield and quality of pomegranate. The data indicated that application of bio-organic fertilizer significantly increased number of male and hermaphrodite flowers and fruit set per cent. The highest number of hermaphrodite flowers was recorded with the chemical P and K fertilizers at recommended dose, while the highest per cent fruit set (69.90%) was noted



with the application of bio-organic fertilizer when applied at the rate of 300 and 600 g tree⁻¹ which were at par with each other. Application of bio-organic fertilizer significantly increased fruit yield by 48.23-55.32% over the *Penicillium pinophilum* based K-solubilizing bio-formulation application @ 20 g tree⁻¹. There was no significant difference in fruit yield with different doses of bio-organic fertilizer application. Even, the fruit yield obtained with the use of bio-organic fertilizer was significantly higher than recorded with the application of P and K chemical fertilizers at recommended dose. Significant improvement in fruit size was also observed with the application of bio-organic fertilizer. The per cent of fruits above 250 g weight ranged from 38.94-46.47% and the highest per cent of fruits weighing more than 250 g was obtained with the application of bio-organic fertilizer at the rate of 150 g tree⁻¹. While only 27.86% fruits was above 250 g weight in K-solubilizing bio-formulation treated trees.

Substantial increase in fruit attributes viz. aril and juice per cent and 100 arils test weight was noted with the application of bio-organic fertilizer. Significant improvement in juice acidity, ascorbic acid and anthocyanin concentration was recorded with the application of bio-organic fertilizer at the rate of 150-300 g tree⁻¹.

Table 4.4. Effect of bio-organic fertilizer on flowering, fruit set, yield and fruit size distribution

Treatments	Flowers (Nos.)			Fruit set (%)	Yield (kg tree ⁻¹)	Per cent fruit >250 g	Per cent fruit <250 g
	Male	Herma-phrodite	Total				
T1: Control	96 ^d	98 ^c	194 ^d	49.58 ^e	9.86 ^d	25.76 ^d	74.24 ^a
T2: K solubilizing bio-formulation @ 20 g tree ⁻¹	107 ^c	100 ^c	207 ^c	59.42 ^c	12.98 ^c	27.86 ^d	72.14 ^a
T3: Bio-organic fertilizer @ 150 g tree ⁻¹	153 ^a	132 ^b	285 ^a	66.21 ^b	20.16 ^a	46.47 ^a	53.53 ^d
T4: Bio-organic fertilizer @ 300 g tree ⁻¹	133 ^b	128 ^b	261 ^b	69.90 ^a	20.09 ^a	43.34 ^b	56.66 ^c
T5: Bio-organic fertilizer @ 600 g tree ⁻¹	137 ^b	128 ^b	264 ^b	69.56 ^a	19.24 ^a	38.94 ^c	61.06 ^b
T6: Recommended dose of P and K through chemical fertilizers	150 ^a	140 ^a	288 ^a	57.17 ^d	17.45 ^b	44.31 ^{ab}	55.69 ^{cd}
LSD _{α_{0.05}}	4.70	4.97	6.65	1.63	1.33	2.29	2.86

Evaluation of bio-efficacy of bio-pesticides in combination with insecticides against fruit borer and sucking pest of pomegranate

The combination of the two insecticides and three bio-pesticides were field evaluated for the for their bio-efficacy against the pomegranate sucking pests and pomegranate fruit borer. The treatment T1 (Spinosad+ Neem oil) recorded the least pest population at 3 and 7 days after spray and the results are consistent in all the three spays with 1.62, 0.87, 4.0 and 2.54, 0.87 and 3.16 at 3 and 7 days after spray respectively. The treatment T4 (Spinetoram+ Neem oil) in all the three recorded the 1.83, 1.0, 3.95 and 3.83, 0.83, 3.91 average no. of thrips in 3days after and 7 days after spray respectively (Table 1). The result indicates the neem oil is best compatible bio-pesticides with insecticide Spinosad and Spinetoram. The best combination will be further evaluated for further for the detailed study.

**Table. 4.5 Bio-efficacy evaluation of the insecticides and bio-pesticide combinations against the sucking pests and pomegranate fruit borer**

Treatments details	Dose ml/l	Pre-population count (Avg)	I st spray		II nd spray		III rd spray	
			3DAS	7DAS	3DAS	7DAS	3DAS	7DAS
Spinosad+ Neem oil (T1)	0.5+3.0	7.62	1.62	2.54	0.83	0.87	4.00	3.16
Spinosad+ Karanja oil (T2)	0.5+3.0	7.12	2.25	2.91	0.91	1.00	4.91	3.66
Spinosad+ Mustard oil (T3)	0.5+3.0	6.75	1.58	3.41	0.95	0.70	4.00	3.87
Spinetoram+ Neem oil (T4)	1.0+ 3.0	6.12	1.83	3.83	1.00	0.83	3.95	3.91
Spinetoram+ Karanja oil (T5)	1.0+3.0	4.62	2.12	5.04	1.16	1.04	4.25	4.20
Spinetoram+ Mustard oil (T6)	1.0+3.0	7.87	2.91	6.79	1.70	1.04	4.95	4.25
Control (T7)	--	8.37	4.33	8.37	4.12	4.25	10.70	9.25



5. Crop Protection

5.1 PROJECT: DEVELOPMENT AND REFINEMENT OF INTEGRATED CROP PROTECTION TECHNOLOGIES FOR IMPROVED PRODUCTIVITY OF POMEGRANATE

1. Bioefficacy evaluation of newer insecticides formulations against pomegranate stem borer (*Coelosterna spinator*)

An experiment was conducted to evaluate the bioefficacy of the six different insecticides against pomegranate stem borer in 3 different treatment methods viz., Stem injecting, Drenching, and, Stem injecting + Drenching (Fig.1) at 2ml/g/l water (Table 5.1).

Stem injecting: Among the seven treatments by injecting method, treatments T1 and T7 gave 66.67% plant recovery and in all remaining treatments it was 33.33%, and in control, no plant recovery was recorded.

Drenching: Among the seven treatments by drenching method, treatments T1 and T7 gave 100% plant recovery and in the other remaining treatments it is 66.67% the lowest (33.33%) was recorded in treatment T2 and in control, no plants recovered.

Stem injecting+ Drenching: Among the seven treatments by stem injecting+drenching method, treatment 7 gave 100% control and in all others, its 33.33% recovery was recorded. In the control treatment, no plants recovery was recorded

Conclusion: The treatment T1 and T7 were found to be promising for the management of pomegranate stem borer in different methods of treatment at the dose of 2g/l water.

Table 5.1. Bioefficacy evaluation of different insecticide stem borer (*C. spinator*)

Treatments	Treatment details	Dosage
T1	Emamectin benzoate 5% SG	2 g/l
T2	Imidacloprid 30.5% SC	2 ml/l
T3	Thiamethoxam 25 % WG	2 g/l
T4	Tolfenpyrad 15 % EC	2 ml/l
T5	Afidopyropen 50 g/L DC	2 ml/l
T6	Flonicamid 50 WG	2 g/l
T7	Emamectin benzoate 3%+ Thiamethoxam 12% WG	2 g/l
T8	Control	Water

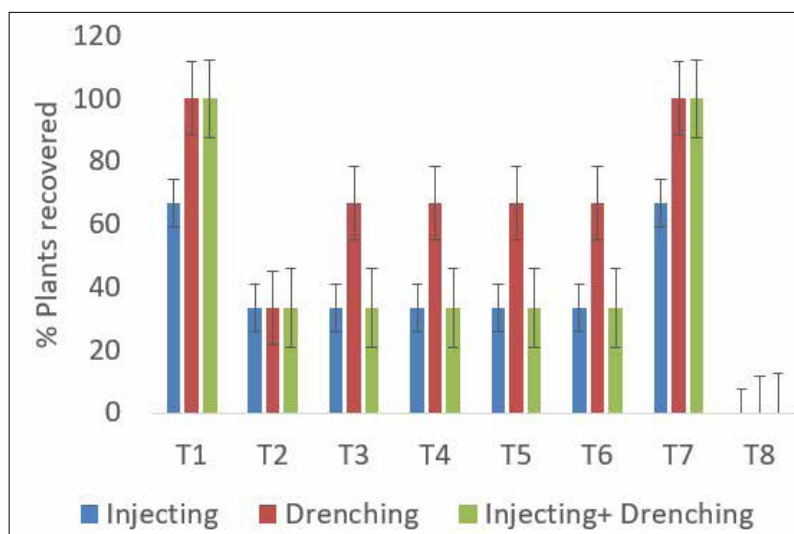


Fig. 5.1. Bioefficacy of newer insecticides against pomegranate stem borer in three different methods of treatment

2 . Bioefficacy evaluation of newer insecticides formulations against pomegranate shot hole borer

An experiment was conducted to evaluate the bioefficacy of the eight different insecticides against pomegranate shot hole borer at two doses (1 and 2ml/l water) through the drenching method (Table.5.2). Among the nine treatments, treatment T7 gave 66.45 and 98.25% plants recovery in 1 and 2ml dose respectively. The next best treatment was T1 gave 56.5 and 97.5% plant recovery in 1 and 2ml doses respectively. The standard check treatment T8 48.25 and 67.25% plants recovery was recorded respectively. The lowest % Plant recovery of 30.0 and 35.25% was recorded in treatment T5 and nil plant recovery was recorded in the control treatment. From the above experiments, it concludes that Treatment T7 and T1 are found to be best for the management of shot hole borer in pomegranate as a curative measure.

Table 5.2. Bioefficacy Evaluation of different insecticides against pomegranate shot hole borer (SHB)

Treatment	Treatment details	Dosage/g/ ml/Lit	Dosage/g/ ml/l
T1	Emamectin benzoate 5% SG+ Propiconazole 25% EC	1gm + 1 ml	2+2
T2	Imidacloprid 30.5% SC + Propiconazole 25% EC	1ml + 1 ml	2+2
T3	Thiamethoxam 25 % WG+ Propiconazole 25% EC	1gm + 1 ml	2+2
T4	Tolfenpyrad 15 % EC + Propiconazole 25% EC	1ml + 1 ml	2+2
T5	Afidopyropen 50 g/L DC + Propiconazole 25% EC	1 ml + 1 ml	2+2
T6	Flonicamid 50 WG + Propiconazole 25% EC	1gm + 1 ml	2+2
T7	(Emamectin benzoate 3%+ Thiamethoxam 12% WG) + Propiconazole 25% EC	1 gm + 1 ml	2+2
T8	Chlorpyriphos 20% EC (Check) + Propiconazole 25% EC	1ml+ 1 ml	2+2
T9	Control	Water + Sticker	Water + Sticker

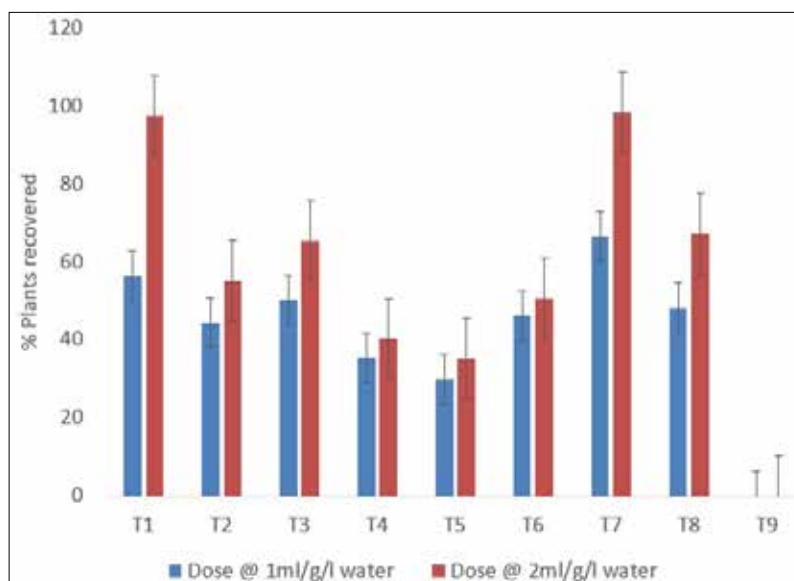


Fig. 5.2: Bioefficacy evaluation of different insecticides against pomegranate SHB

3: Record of relative susceptibility of pomegranate varieties to Shot hole borer (SHB) infestation

Table 5.3. Differential susceptibility of pomegranate varieties to SHB infestation

Variety	Total no. of plants	Total no. of plants infested by SHB	% Infested pants
Ganesh	58	54	53.45
S. Bhagawa	58	26	44.83
Arakta	56	34	60.71
Mridula	54	28	51.85
G-137	58	22	37.93
Bhagawa	351	138	33.62
Total	635	302	40.79
Ganesh	58	31	93.10
S. Bhagawa	58	26	44.83
Arakta	56	34	60.71
Mridula	54	28	51.85
G-137	58	22	37.93
Bhagawa	351	118	39.32
Total	635	259	47.56

The different cultivated commercial varieties of pomegranate were recorded with differential susceptibility to shot hole borer infestation. The data on the incidence of shot hole borer is recorded at 15 days intervals. Among the different varieties, the level of susceptibility at the

first observation in the ascending order was Arakta > Ganesh >Mridula>S. Bahgawa>G-137> Bahgawa. The second observation of the level of susceptibility was Ganesh> Arakta>Mridula>S. Bahgawa> Bhagawa> G-137. The average percent infestation in the first and second observations was 40.79 and 47.56% (Table 5.3)



Fig. 5.3. The flooding of the experiment block H-24 due to heavy and extended rainfall

Level of Susceptibility-I: Arakta > Ganesh >Mridula>S. Bhagawa>G-137> Bhagawa
Level of susceptibility-II: Ganesh> Arakta >Mridula >S. Bhagawa> Bhagawa> G-137

Ganesh		G-137	
Range	Avg.	Range	Avg.
6.5-78.5	51.52	6-129	41.95



Fig. 5.4 SHB damage on pomegranate

4. Bioefficacy evaluation of newer insecticides and combi formulations against pomegranate thrips and fruit borer:

The treatment T5 (Flonicamid 50% W/W)) recorded the highest percentage (87.72%) of fruits free from thrips damage followed by T4 (Tolfenpyrad 15 % EC) (80.95%) and T9 (Spinetoram 11.7% SC) (80.51%) the and least was observed in T8 (Difenthiuron 40.1% + Acetamiprid 3.9% WP) (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.

5. Bioefficacy evaluation of newer insecticides against Invasive mealybugs:

The treatment T1 (Thiamethoxam 12.6 % +Lambda cyhalothrin 9.5% ZC)) recorded the highest % Reduction over control (68.37%) of fruits free from thrips damage followed by T7 (Emamectin benzoate 3%+ Thiamethoxam 12% WG) (66.26%) and T9 (Spinetoram 11.7% SC) (80.51%) the and least was observed in T5 (Afidopyrofen 50G/L DC) (75.78%) wherein control it was 34.25%.



6. Isolation of Entomopathogens through soil baiting technique:

Though soil baiting techniques 1- Entomopathogenic nematode-1, Entomopathogenic Bacteria-4, and Entomopathogenic Fungi-1 was isolated.



Fig. 5.5 Isolated Entomopathogens

7. Invitro evaluation of native entomopathogenic nematodes against pentatomid bugs

Table 5.4. Invitro evaluation of native EPN against pentatomid bugs and pomegranate fruit borer

IJs/2 Nymphs/ adult	Avg. % mortality Nymphs HAI		Avg. % mortality of adult HAI	
	48	72	48	72
10	25.25	27.35	20.20	22.25
50	28.50	33.55	23.45	25.35
100	35.50	40.15	30.55	38.15
150	42.25	60.45	41.45	58.45
200	55.42	74.55	46.24	62.54
250	62.25	98.55	52.52	65.52
300	65.55	99.15	55.25	67.18

IJs-Infective Juveniles

HAI=Hours after inoculation



Fig. 5.6. The green stink bug infested by EPN

The inoculation of 250 infective juveniles (IJs/ 2 bugs nymphs recorded 62.25 and 98.55 avg. % mortality of nymphs at 48 and 72 hours after inoculation.

- The inoculation of 300 infective juveniles (IJs/2 nymphs recorded 65.55 and 99.15 avg. % mortality of nymphs at 48 and 72 hours after inoculation.
- The inoculation of 300 infective juveniles (IJs/ adults recorded 52.52 and 65.52 avg. % mortality of adults at 48 and 72 hours after inoculation.
- The inoculation of 300 infective juveniles (IJs/ 2 adults recorded 55.25 and 67.18 avg. % mortality of adults at 48 and 72 hours after inoculation.

8. Evaluation of new mustard powder against scale insect in the Net house

Table 5.5. Evaluation of new mustard powder against scale insect in the Net house

Trts.	Dose g/l water + 0.25 ml sticker	Avg. Pre-population count /5cm shoot	Total No. dead 3DAS	% Dead	Total no. dead 7 DAS	% Dead
T1	1	23.0	20.0	86.9	20.0	86.9
T2	1.5	10.0	8.5	85.0	8.5	85.0
T3	2.5	16.0	13.0	81.2	13.0	81.2
T4	5	12.5	12.5	100.0	12.5	100.0
T5	Control	12.0	2.0	16.00	2.0	16.0



Fig. 5.7. Invitro evaluation of Solar light against fruit-sucking moths

The mustard powder @ 5 g/l water + 0.25 ml sticker gave 100% mortality of wax scale insect 3 days after and 7 days after treatment. Invitro Bioefficacy evaluation of brown Mustard powder alone and in combination with Neem and Pongamia oil against thrips: The combination of mustard powder and neem oil (10000ppm) @ 15+ 5 g and ml gave 76.87 and 78.36 % mortality 24 and 48 hours after treatment respectively.

**Table5. 6. Invitro evaluation of Solar light against fruit-sucking moths**

Time (pm)	No. of moth attracted	Male	Female
6.30	2	2	0
7.30	3	2	1
8.30	4	3	1
9.30	4	3	1
9.30	5	4	1
10.30	6	5	1
11.30	5	4	1
12.00	5	5	1

- The two light traps evaluated for their efficacy for attracting the fruit piercing moths were evaluated under Invitro conditions both the traps are having - 230 volts AC.
- Trap-1 has the main light source violet smd UV Led 3.2 volt 395nm wavelength and it attracted the 34 moths (28 males and 6 females). The Trap-2 having the water led blue led 3.2 volts 465nm wavelength no attract of moth was observed. Total no of moths attracted in trap-1= 34 Total no of moths attracted in trap-2= 0

5.2 PROJECT: FLAGSHIP PROJECT ON INTEGRATED APPROACH TO ERADICATE BACTERIAL BLIGHT

(a) Stem solarization to manage bacterial blight

Developed Stem Solarization technology to manage bacterial blight in community approach with 100% blight control. It is ecofriendly, economical and effective technology and can eradicate the pathogen if done in community approach. It can also be used for organic cultivation plots. FLDs at 6 locations are in progress 3 at Rahata in Ahemadnagar and 3 in Malshirus at Solapur district in Maharashtra. The success of field trials at NRCP for 3 years and 1 farmer's plot at Akkalkot for 2 years have been reported in previous annuals reports as 'Six Steps to Manage Bacterial Blight', on the recommendations of RAC the technology name has been changed.

(b) Bacteriophages from blight control

Bacteriophages from pomegranate tree phylloplane were found effective in bacterial blight pathogen *Xanthomonas axonopodis* pv *punicae* of pomegranate *in vitro* trials. Studies are in progress for making formulation with UV protectants and long shelf life to take field trials.

(c) Weather-based prediction model

Work was initiated on weather-based prediction model for bacterial blight in pomegranate in collaboration with ICAR-CRIDA and weekly blight data for 10 years has been provided by NRCP.



5.3 EPIDEMIOLOGY AND SUSTAINABLE MANAGEMENT OF ECONOMICALLY IMPORTANT PHYLLOPLANE DISEASES OF POMEGRANATE

Survey of phylloplane diseases on pomegranate during 2020-21

A detailed roving survey was conducted (approx.1200 acres) to assess the disease severity/disease incidence of major diseases of pomegranate in different districts of Karnataka, Maharashtra and Madhya Pradesh during 2020-21 (Table 5.7). The maximum disease severity (0 to 100 %) of phylloplane diseases (bacterial blight, leaf spots caused by *Cercospora* and *Alternaria*, anthracnose (fruit rot) and scab) was observed in Solapur district of Maharashtra. The severity of leafspots and fruit rot was observed in all the areas surveyed. Similarly, A detailed roving survey was also conducted to assess the disease severity/disease incidence of wilt disease of pomegranate caused by *Ceratocystis fimbriata*, Root-Knot Nematode and Shot/Pin hole borer in different districts of Maharashtra, Karnataka, and Madhya Pradesh and surveyed data presented in the table. Numbers in parenthesis indicates number taluks covered during survey; DS: Disease severity. CF: *Ceratocystis fimbriata*; Root-knot nematode was present in the 70-90% of the orchards having wilt disease; from 5 to 80% root infection.

Table 5.7: Status of economically important phylloplane disease of pomegranate in different districts of Karnataka, Maharashtra and Madhya Pradesh

State	Districts	Area covered (acre)	Disease severity (%)				
			BBD	FR	CR	AR*	SB
Karnataka	Bijapur (3)	75.75	0.4-2.1	0.2-1.0	0-65	0-4.0	0-19.15
	Bagalkot (4)	135.45	0.0	0.1-0.5	0-46.2	0-4.0	0-0.40
	Koppal (2)	49.5	0.0	0.0	1.85-34.4	1-3.80	0.0
	Bangalore rural (2)	25.7	0-25	0-2.0	0 to 5.0	0.0	0.0
	Bangalore urban (1)	10.0	0.0	0-8.7	0-4.0	0.0	0.0
	Chikkaballapur (3)	56.0	0-5.0	1 to 13	0.5 -3.0	0.0	0.5- 5
	Total area/ DS (%)	352.4	0-25	0-13	0-65	0-4.0	0-19.15
Maharashtra	Pune (2)	8.5	0-15	0.0	0-48	0-2.15	0.0
	Ahmednagar (2)	41.25	0.6-20	0-31	0-80	0.0	0.0
	Solapur (10)	725.75	0-71	0-63	0-100	0-2.25	0-100
	Sangli (1)	21.80	0-6.0	0-8.5	1 -100	0.2-0.3	2.1-100
	Satara (1)	49.5	0-40	0.3-4.3	1-63	0.0	0-51
	Total area/ DS (%)	846.8	0-71	0-63	0-100	0-4.0	0-100
Madhya Pradesh	Chindwada (1)	9.5	0-13.5	0.0	0.0	2.00	0.0

Numbers in parenthesis indicates number of taluks covered during survey; DS: Disease severity; BBD: Bacterial blight; FR: Fruit rot/Anthracnose; CR: *Cercospora*; AR: *Alternaria* on leaves; SB: Scab.



Table 5.8: Status of wilt disease, Root knot nematode and shot hole borer on pomegranate in different districts of Karnataka, Maharashtra and Madhya Pradesh

State	Districts	Area covered (acre)	Wilt Disease incidence (%) CF	Shot/Pin hole borer (SHB)
Maharashtra	Pune (2)	8.5	0-36	0.0
	Ahmednagar (2)	41.25	2-100	8.95-25.8
	Solapur (10)	725.75	0-57	0-59.42
	Sangli (1)	21.80	0-21	-
	Satara (1)	49.5	0-17	-
	Total area/ DS (%)	846.8	0-100	0-59.42
Karnataka	Bijapur (3)	75.75	0-8	0
	Bagalkot (4)	135.45	0-5	0
	Koppal (2)	49.5	0	0
	Bangalore rural (2)	25.7	0.5-17	-
	Bangalore urban (1)	10.0	1-5	-
	Chikkaballapur (3)	56.0	2-30	-
	Total area/ DS (%)	352.4	0-30	0
Madhya Pradesh	Chindwada (1)	9.5	0	1-2.5

***In-vitro* bio-efficacy of bactronol against fungal pathogens of pomegranate**

Bactronol, chemically known as bronopol (95 % 2-Bromo-2-Nitro-1, 3-Propanediol), is a commonly used bactericide to control bacterial diseases of various vegetables and fruit crops. However, its efficacy against fungal pathogens is less studied. Therefore, in the current study, *in-vitro* 'Poison Food Technique' was used to test bio-efficacy of different concentrations (0.25 g/L, 0.50 g/L and 0.75 g/L) of bactronol against three economically important fungal pathogens of pomegranate (Figure 1). These included *Alternaria alternata* causing heart rot and leaf spot/blight in pomegranate, *Colletotricum gloeosporioides* (the anthracnose pathogen) and *Ceratocystis fimbriata* (the pomegranate wilt pathogen). All the concentrations checked the pathogen growth above 64 % at lower concentration (0.25 g/L). The radial was completely arrested (100 % inhibition) at 0.75 g/L in all tested fungi. The *in vitro* tests were encouraging; however, studies that are more elaborate are required to affirm the final concentration for field conditions.

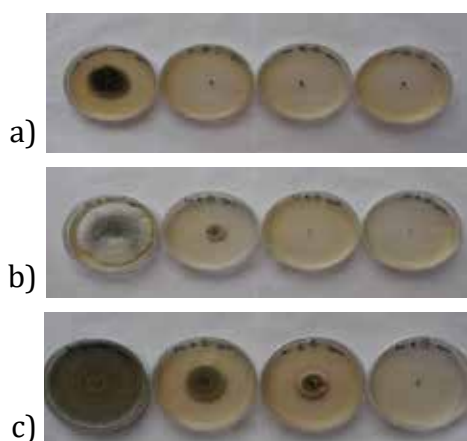


Figure 5.8: Radial growth of different pathogens at different concentrations of bactronol on potato dextrose agar media

***In-vitro* bio-efficacy of mustard formulation against fungal pathogens of pomegranate**

The modified new mustard formulation prepared at CIPHET, Ludhiana was tested against three fungal pathogens of pomegranate viz. *Alternaria alternata* causing heart rot and leaf spot/blight in pomegranate, *Colletotricum gloeosporioides* the anthracnose pathogen and *Ceratocystis fimbriata* pomegranate wilt pathogen. All the 3 pathogens cause severe losses under favorable weather conditions and are cause of concern to the pomegranate farmers. Though promising chemicals for the control of these diseases are available, yet farmers opting for organic pomegranate cultivation face problems once the disease appears, hence the mustard formulation was tested in vitro at 3 doses (1, 2.5 and 5 ml per litre) using 'Poison Food Technique' against these pathogens. All the doses of mustard formulation used checked the pathogen growth above 37%, however highest inhibition was achieved at 5ml/l dose with 53.77% inhibition of *A. alternata* and 50.68 % inhibition of *C. gloeosporioides* and 79.07% of *C. fimbriata*. The in vitro tests were encouraging; however, the formulation will be tested in polyhouse and field trials before arriving at final conclusion. In case the formulation is found effective in field trials in checking these pathogens, it will be a promising formulation for organic pomegranate production.

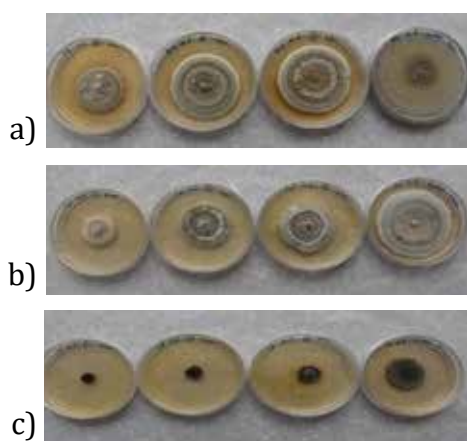


Figure 5.9: Radial growth of different pathogens a) *Alternaria alternata* b) *Colletotricum gloeosporioides* c) *Ceratocystis fimbriata* on PDA with different concentrations of mustard formulation (1) 5 ml/l (2) 2.5 ml/l (3) 1 ml/l (4) Control

***In vitro* evaluation of endophytes against fungal pathogens of pomegranate**

Fifty endophytes were isolated from different medicinal plants (from different geographical locations) as well as tissue cultured pomegranate plants. These endophytes belonged to different taxonomic groups such as bacteria, fungi, actinobacteria and Trichoderma. They were tested *in vitro* for their inhibitory effect on growth of fungal pathogens: *Alternaria alternata*, *Colletotrichum gloeosporioides* and *Ceratocystis fimbriata* using dual culture technique. The endophytes were grouped according to their ability to inhibit growth of the fungal pathogen: 0-50% inhibition, 51-75% inhibition and more than 75% inhibition. Two endophytic isolates (BE-5 and EB-7) were found to inhibit upto 51-75% growth of all three pathogens. Seventeen isolates (TC-6, TC-Y, EBO-1, EBO-2, EBO-6, EBO-8, EBO-11, EBO-14, EBO-16, EBO-17, BE-4, E-7, EB-9, PG-10, PG-12, VADGAON, E2 BHAGAWA) were found to be the most effective endophytes against *Ceratocystis* showing more than 75% inhibition of the pathogen growth. Only three isolates (TC-4, TC-10 and PG-6) exhibited more than 75% growth inhibition of *Colletotrichum* while none of the isolates could show such a response against *Alternaria*. The preliminary results of the current study indicate that these endophytes especially BE-5 and EB-7 can be used as potential biocontrol agents against different fungal pathogens, however only after more elaborated field studies.

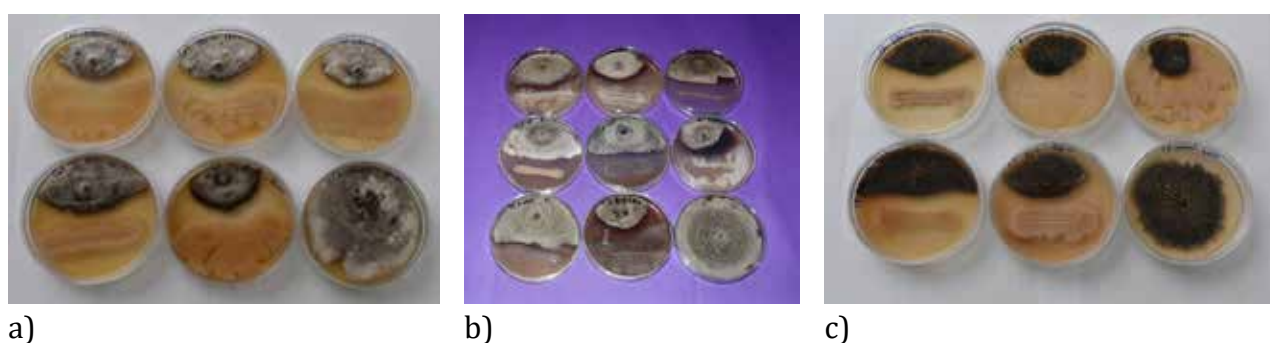





Figure 5.10: In-vitro inhibitory effect of endophytes on growth of fungal pathogens a) *Alternaria alternata*, b) *Colletotrichum gloeosporioides* c) *Ceratocystis fimbriata*

Field demonstration of Stem solarization-Six-Step to control bacterial blight

ICAR-NRC on Pomegranate, Solapur developed Stem Solarization-Six-Step disease management schedule with continuous research to make it as an eco-friendly, cost-effective and effective management strategy. Stem solarisation of naked stem kills all pathogenic bacteria giving 100% control if untimely rains are not there. Most significant feature of this technology is that farmers in arid and semi-arid regions facing losses due to bacterial blight disease can take the 'mrig bahar' and late 'mrig bahar' crop (rainy season) of pomegranate successfully. This has been successfully demonstrated for 3 years at ICAR-NRCP and in 1 farmers' orchard in 2018 and 2019 and in 3 farmers' orchards in 2020-21. With this technology antibiotics will not be required and arid and semi-arid regions can successfully take rainy season crop. Moreover, this technology can be used for organic pomegranate production also. The technology has been demonstrated in 3 farmers' plots in 2021.

Stem Solarization: Six Steps to Manage Bacterial Blight in Rainy Season Crop					
					
Step 1 Main Pruning & fertilizer application Dec/Jan			Step 2 Irrigate the crop till <u>mid March</u>		Steps 3 Put crop on stress for complete defoliation till April
 Dried tips					
Steps 4 Stem Solarization for 10-20 days in May			Steps 5 Light <u>pruning</u> , <u>INM</u> , take rainy season crop.		Steps 6 During crop season follow recommended practices
  					
Harvest Bacterial Blight Free Pomegranate Produce from Heavily Blight affected Orchard in Previous Years					

Technology Demonstration in Farmers Plots (2021)						
Particulars	Farmer 2		Farmer 3		Farmer 4	
Farmer Name and Location	Bira Waghmode, Malshirus, Solapur		Vijay Narute, Malshirus, Solapur		(Tannaji Navadkar), Malshirus, Solapur	
Year of demonstration	2020-21		2020-21		2020-21	
Area (acres)	4.5		2.5		4.0	
Technology demonstration	Before	After	Before	After	Before	After
Yield Loss Due to Bacterial Blight (%)	60	2	70	5	80	10
Total Yield (tonnes)	5	21.6	3.75	22	6.0	14
Input cost (Rs. Lakhs)	4.5	4.6	6.5	8	3.4	3.5
Income (Rs. Lakhs)	4.2	15.54	5.10	36.30	9.5	16
Profit (Rs. Lakhs)	* Loss	13.94	** Loss	28.30	6.1	12.5
Benefit: Cost	* Loss	3.03:1	** Loss	3.54:1	1.79: 1	3.57:1
Note: BBD: bacterial blight disease; *Rs 30,000 loss, ** Rs.1.4 lakh loss; BD/AD: before demonstration/after demonstration						

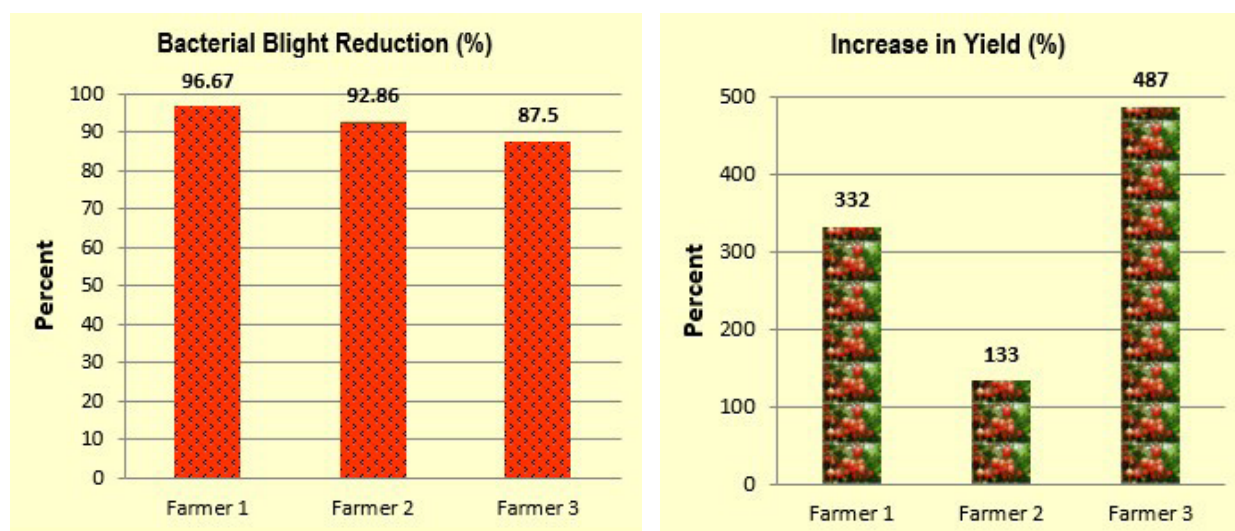


Figure 5.11: Effect of stem solarization on bacterial blight control and increase in yield on farmers' plots in 2019-20 to 2020-21

Streptomycin and copper sensitivity in *Xanthomonas axonopodis* pv. *punicae*

Sensitivity to streptomycin was checked for all the isolates *in vitro*. These isolates could grow on media containing 250 ppm to 1500 ppm streptomycin. The zone of inhibition (ZOI) at the highest concentration (1500ppm) was below 50% (ranged between 26.3% to 37.8%) indicating a lower sensitivity to the antibiotic. Notably, 7 isolates had less than 30% growth inhibition indicating the lowest sensitivity in these isolates. A positive correlation was found between the concentration of streptomycin and ZOI *i.e.*, as the concentration increased the ZOI also increased indicating higher sensitivity at higher concentration of the antibiotic. To analyse the molecular basis of the observed lower sensitivity to antibiotic, the presence of *strAB* gene pair was confirmed through



PCR amplification using gene specific primers. Ninety percent isolates showed the presence of either of the gene *strA-strB* of which 60% isolates showed the presence of the complete gene pair *strAB*.

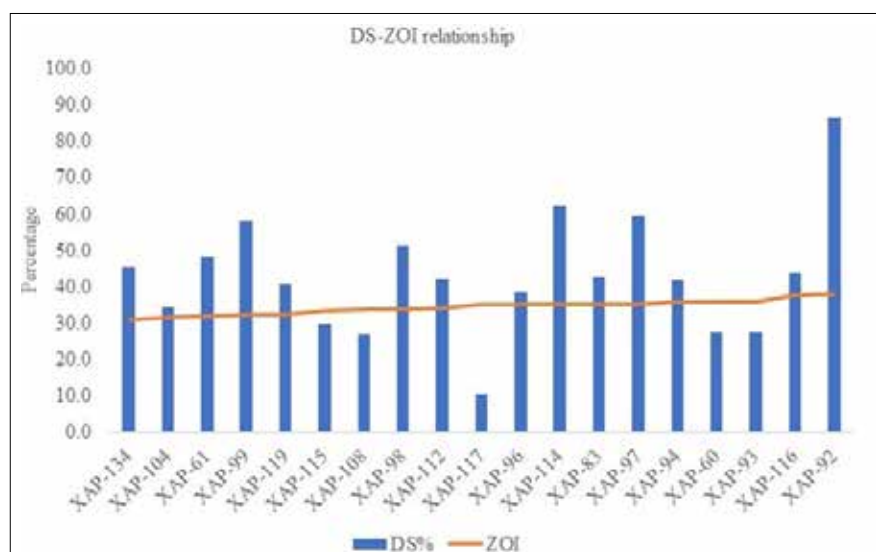


Figure 5.12 Relationship between percent disease severity (%DS) observed after 6 weeks and zone of inhibition (ZOI) at the highest concentration (1500ppm).

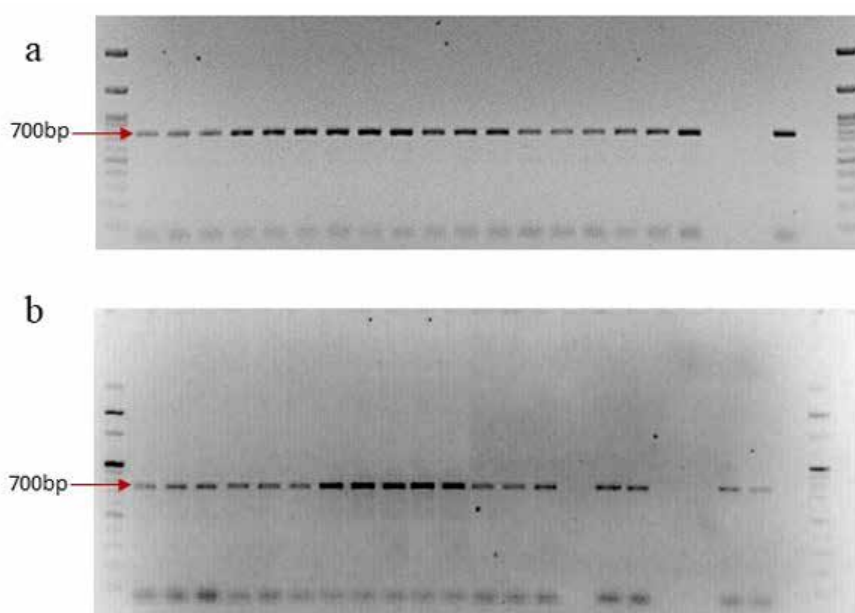


Figure 5.13: Gel electrophoresis image showing amplification of *strA* (a) and *strB* (b) genes in isolates of Xap

Genetic diversity of *Xanthomonas axonopodis* pv. *punicae* (Xap) using SSR markers

Genetic diversity amongst Xap isolates (n= 20) was analyzed using SSR markers (n=18). Based on the results, isolates could be grouped into two major clusters. Cluster I contained 5 isolates and cluster II contained remaining 15 isolates. Xap-97 and Xap-116 displayed the maximum value for Jaccards similarity coefficient (0.80) indicating that these two isolates are highly similar.

The disease severity exhibited by the two isolates also did not show much of a difference. On the other hand, Xap-60 and Xap-92 displayed minimum Jaccards similarity coefficient (0.13) and were grouped into two different clusters indicating high diversity between them. These two isolates also highly differed in their level of pathogenicity in terms of disease severity, Xap-92 being highly pathogenic (86.7%) while Xap-60 displayed low pathogenicity (27.3%).

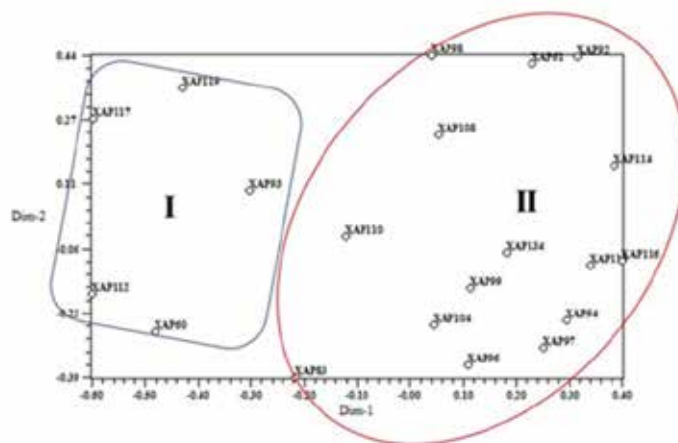


Figure 5.14: Dendrogram showing genetic diversity amongst Xap isolates on the basis of SSRs

Evaluation of potential bio agents and new chemicals for their bio efficacy against wilt disease

During the survey of pomegranate orchards, we have collected the soil samples and from that we have isolated the *Trichoderma* and other bioagents coded as KA-40 and KA-54 from Bagalkot area of Karnataka. This species was tested under in-vitro dual plate technique against the wilt causing fungi, *Ceratocystis fimbriata*. The newly isolate KA-40 species gives highest *Ceratocystis fimbriata* inhibition (93.47%) followed by KA-54 species (84.78%) under in-vitro condition.

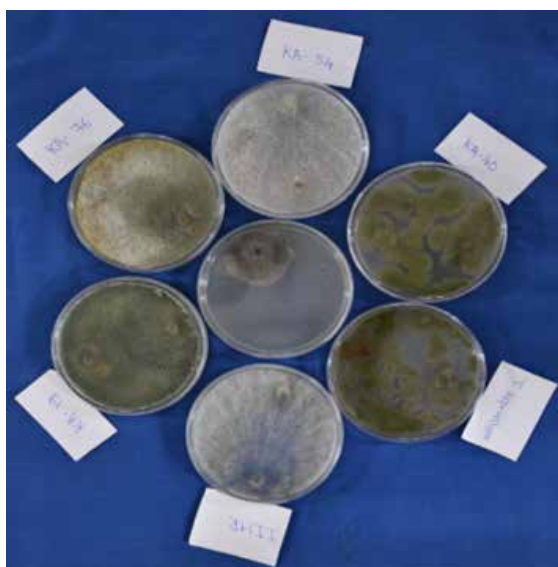


Figure 5.15: Bio-efficacy of bioagents against *Ceratocystis fimbriata* under *in-vitro* conditions



S.N.	Bioagent	Mean radial growth (cm)	% inhibition
1	IIHR <i>Trichoderma</i>	0.6	73.91
2	KA- 76	0.85	63.04
3	KA- 54	0.35	84.78
4	KA-19	0.45	80.43
5	KA-40	0.15	93.47
6	<i>T. asperellum</i>	0.15	93.47
7	Control	2.3	0.00

The cultural filtrate of the KA-54 species was also tested against Root-Knot Nematode under *in-vitro* condition. The results indicated that filtrate concentration of 25% can cause 31% death in 24 hrs. of exposure while 56.88% mortality occurs after juveniles were exposed for 48 hrs. at 25% concentration.

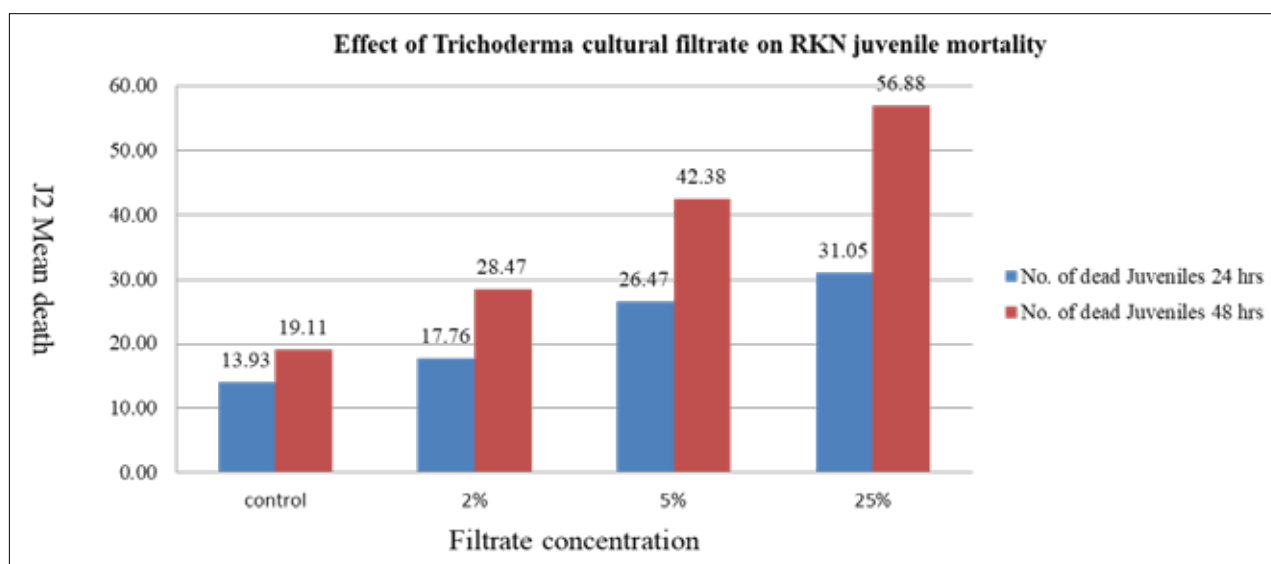


Figure 5.16: Mortality of RKN juveniles after treatment of KA-54 cultural filtrate

Evaluation of newer nematicides under polyhouse conditions

Primary trial for the evaluation of newer nematicidal chemicals like Nimitz (Fluensulfone 2% GR), Velum Prime (Fluopyrum 34.48% SC), Reklamel (fluazaindolizine 500 SC) and Vegetable oil based nematicide *i.e.* Nemon against Root-Knot Nematode on new roots under pot condition for the period of 5 months. About 20 selected plants for trial were already heavily infested by RKN (>100 galls/plant, highest galling index scale 5). We have randomly assigned 4 plants per treatment out of which 2 were root pruned and root were mixed in the same pot soil. Treatments with nematicides were given as recommended with and without root pruning of the pomegranate plants. Lowest no. of galls were observed in the plants with intact roots treated with Reklamel @ 2 ml/2L (0.5 liter/plant) followed by Velum Prime @ 2 ml/2L (0.5 liter/plant) and Nimitz @ 10 g/ plant. In the case of root pruned plants, no galls were observed in the plants treated with Nimitz and Velum prime in the above-mentioned concentrations.

Treat ment	Nemati- cide	Rec. dose	Dose taken per pot	Galls on New white roots	
				Plants with intact roots	Plants with pruned roots
T1	Nimitz	10g/dripper (Max 40 gm/plant)	10 g/ plant	25 galls	No galls
T2	Reklemel	2ml/2L	0.5 liter/plant	18 galls	Plant dead
T3	Suzan	4 ml/2L	0.5 liter/plant	43 galls	10 galls
T4	Velum Prime	2ml/2L	0.5 liter/plant	21 galls	No galls
T5	Nemon	200 µl/2L	0.5 liter/plant	27 galls	Plant dead
T6	Control	0.5 liter/plant	0.5 liter/plant	80 galls	15 galls

Figure 5.17: Testing of Nematicides under pot condition with and without root punning of heavily infested pomegranate plants

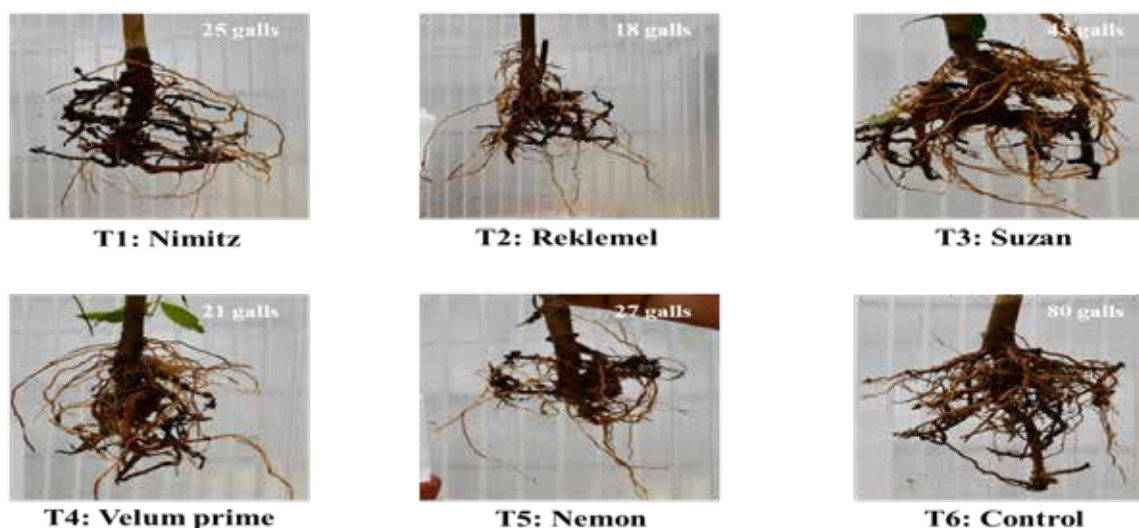


Figure 5.18: Effect of nematicides treatment of galls caused by Root-Knot Nematode in the plants with intact root system.



6. Post Harvest Management and Value Addition

6.1 PROJECT: POST HARVEST MANAGEMENT AND VALUE ADDITION IN POMEGRANATE FOR ENTREPRENEURSHIP DEVELOPMENT

A. Foam mat drying of pomegranate juice

Pomegranate juice is well known for health benefits owing to presence of various bioactive compounds. However, the seasonality of the fruits, and susceptibility of the pomegranate juice for microbial contamination curtails its accessibility to masses. Further, transportation of pure juice to distant markets is costly affair due to larger volume. The above mentioned factors are important impediment for the marketing of pomegranate juice in distant markets. The Foam mat drying is an innovative approach for the drying of the juices especially with higher sugars. It is a process of drying liquid - solid foods by being mixed with foaming agent and or stabilizing agent to produce stable foam, which undergoes air drying. Thus experiment was planned to study the effect of level of Whey Protein Isolate (WPI) as foaming agent and Carboxymethyl Cellulose (CMC) as stabilizing agent on foam expansion (FE) and foam drainage volume (FDV) of juice foam, drying behavior and quality of dried powder and reconstituted juice.

The pomegranate juice is extracted from the fruits of the cv. Bhagawa. The biochemical properties of the fresh juice were determined and tabulated in table 1.

Table 6.1. Fresh Juice Biochemical Properties

Parameters	Means (\pm SD)
pH	3.44 \pm 0.01
TSS ($^{\circ}$Brix)	15.55 \pm 0.06
Colour	
L*	7.81 \pm 0.03
a*	22.74 \pm 0.15
b*	10.42 \pm 0.08
Density	1.03
Titrateable acidity (%)	0.55 \pm 0.04
Ascorbic acid (mg/100ml)	17.5 \pm 0.00
Total phenolic content (g/lit of GAE)	2787.2 \pm 5.00
Antioxidant Capacity (mg/100 ml AAE)	47.29 \pm 0.19
Total monomeric anthocyanin content (mg/100 ml)	32.90 \pm 0.67
Total sugar (%)	14.95 \pm 0.51
Reducing sugar (%)	13.764 \pm 0.22
Non reducing sugar (%)	1.186 \pm 0.44

The effect of different percentages of the whey protein isolate (WPI) (5, 7.5, and 10%) as foaming agent and carboxy methyl cellulose (CMC) (0, 0.25, 0.5 and 0.75 %) as stabilizing agent were observed on foam expansion, foam density and foam drainage volume. About 100ml of pomegranate juice was taken in 500ml glass beaker. The requisite amount WPI and CMC is added and whipping was done using a blender at high speed for 2 mins. The various parameters for the

foam were measured. The pomegranate foam is then poured into a suitable measuring cylinder without breaking the foam structure at all and also without trapping the air bubbles. The weight and the volume of the foam were then noted down. The density of the pomegranate juice was calculated before and after foaming by dividing the measured weight by the volume.

$$\text{Foam Density (\%)} = \frac{\text{Mass of the foam (g)}}{\text{Volume of the foam (ml)}}$$

Foam expansion denotes the percentage increase in volume of the juice. Foam expansion indicates the amount of air incorporated into the juice during whipping was calculated using the difference in the volume of juice before and after foaming.

$$\text{Foam Expansion (\%)} = \frac{(V_1 - V_0) \times 100}{V_0}$$

Where, V_1 is the volume of juice after foaming (cm^3) and V_0 is the volume of juice before foaming (cm^3). Foam drainage volume (FDV) was used to determine the stability of foam. It gives us the rate at which liquid drains from the foam. Some of the foam was transferred to a Büchner funnel (110 mm) placed on a 100 mL measuring cylinder, and the weight of the foam was recorded. Then, the volume of liquid drained from the foam was determined at the end of 30 min. The drainage volume was calculated for 50 g of foam.

Table 6.2. Effect of WPI and CMC on FE, FD and FDV

Treatment	WPI %	CMC %	FE %	FD %	FDV %
T1	5	0	424.40 ±7.80bc	0.2050±0.0078de	65.59±1.93a
T2	5	0.25	449.07 ±7.91a	0.1940±0.0044fg	58.36±1.76b
T3	5	0.5	340.70 ±9.45f	0.2470±0.0075b	40.72±1.19c
T4	5	0.75	285.73±8.22g	0.2820±0.0075a	34.85±0.92d
T5	7.5	0	431.91±8.31b	0.2020±0.0052ef	34.19±0.73d
T6	7.5	0.25	425.23 ±8.66bc	0.2050±0.0040de	29.46±0.62e
T7	7.5	0.5	413.00 ±8.10cd	0.2100±0.0026de	27.01±0.11f
T8	7.5	0.75	405.18 ±9.02d	0.2140±0.0085d	22.29±0.42g
T9	10	0	457.07 ±7.91a	0.1880±0.0026g	22.31±1.16g
T10	10	0.25	455.28±2.11a	0.2030±0.005g	20.10±0.02h
T11	10	0.5	417.85 ±2.26cd	0.2080±0.0062de	20.07±0.05h
T12	10	0.75	390.77 ±4.19e	0.2210±0.0075cd	18.76±0.21h

The FE values were found to be in the range of 285.73–457.07% (table 2) during the present experimental studies. This data reveals that WPI and CMC affected the foam expansion. It is evident from the table 2 that the FE increased with increase in concentration of WPI. The FE of 424.40%, 431.91% and 457.07 % were observed with 5, 7.5 and 10% of WPI respectively. However, the addition of the CMC% which is being added as stabilization agent affected negatively to the foam expansion. At 5% WPI the variation in the CMC from 0% to 0.75% has led to reduction in foam expansion by 138.67 %. Similarly at 7.5 % and 10% WPI this reduction in foam expansion due to addition of CMC was 25.16% and 66.30 % respectively. Similar to FD, the increased concentration of WPI at constant whipping time showed a gradual rise in foam volume followed by a slow decreasing trend.



FD was measured after incorporating the air into the pomegranate juice by whipping. The FD for the series of WPI and CMC treated experiments varied from 0.188 to 0.282 g/cc. The density of fresh pomegranate juice was found to be 1.03 g/cc. The significant reduction in the foam density has been observed due to the use WPI and CMC. The FD of 0.205, 0.202 and 0.188 g/cc were observed with 5, 7.5 and 10% of WPI respectively. This shows the decrease in the foam density with increase in WPI which is in line with results for foam expansion.

The stability of any foam can very well be judged by the rate at which the liquid drains from the foam. In present investigation FDV ranged from 18.76 to 65.59 ml (table 2). Higher value of FDV implied lower water holding capacity of foam. It has been observed that the FDV has been decreased with increase in concentration of WPI from 5 to 10%. The high concentration of foaming agents increases the stability by increasing viscosity and yield stress of the liquid phase and or increasing thickness (or strength) of the interface. It is also observed from Table 2 that the absence of foam stabilizer showed a greater degree of foam expansion. The incorporation of CMC as foam stabilizer did improved the foam stability by reducing the FDV at particular concentration of foaming agent.

Foam Mat Drying

The pomegranate juice foam produced using 10% WPI and 0.25% CMC owing to its high FE (455.28 %) and low FDV (20.10 ml) was selected for foam mat drying experiments. The drying experiments were conducted at 50, 60 and 70 °C, and foam thickness of 3 mm and 6 mm (table 3). The drying experiments were conducted up to the moisture content of 4 % (db). The approximate instantaneous moisture content at different drying temperature and thickness of the foam were depicted in table 3. The drying time required for drying of foam at 70°C was 120 and 180 minutes (Fig. 1), at 60°C it was 180 and 240 minutes (Fig. 2), and at 50 °C it was 210 and 300 minutes (Fig. 3) respectively for 3- and 6-mm thickness. The drying time decreases with the increase in drying temperature. Further, at 6 mm thickness additional 60 minutes are required for drying when compared with 3 mm thickness at 70°C and 60 °C. However, at low temperature of 50 °C the increase in drying time is 90 minutes at 6 mm thickness as compared to that of 3 mm thickness.

Table 6.3 Effect of drying temperature and thickness of foam on instantaneous moisture content (db) and drying time.

Drying Time (min.)	Drying Temperature (°C)					
	70		60		50	
	Thickness (mm)					
	3 mm	6 mm	3 mm	6 mm	3 mm	6 mm
0	354.5455	354.5455	354.5455	354.5455	354.5455	354.5455
60	82.82828	125.7576	32.323	144.9495	112.6263	183.3333
90	9.59596	24.74747	13.63636	58.08081	32.32323	92.17172
120	4.040404	7.828283	4.545455	18.56061	11.11111	57.19697
150		5.555556	6.565657	13.63636	7.070707	27.39899
180		4.419192	4.292929	7.070707	3.838384	13.13131
210				4.671717	4.69697	7.19697
240				4.419192		5.808081
270						5.176768
300						4.545455

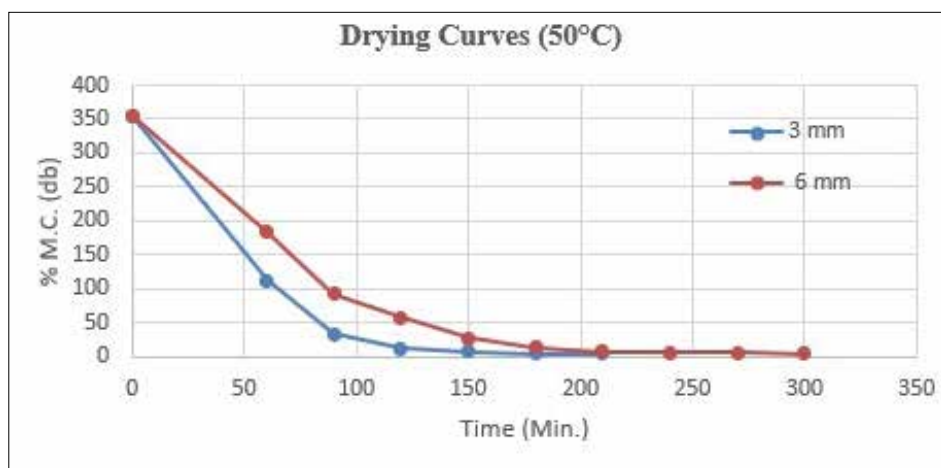


Fig. 6.1. Drying curves for foam mat drying at 50°C and different thickness of foam

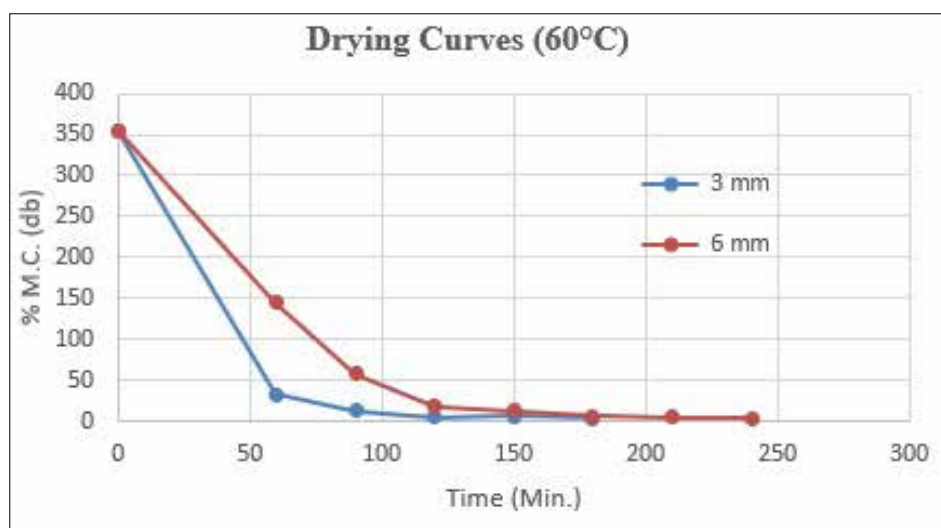


Fig.6.2. Drying curves for foam mat drying at 60°C and different thickness of foam

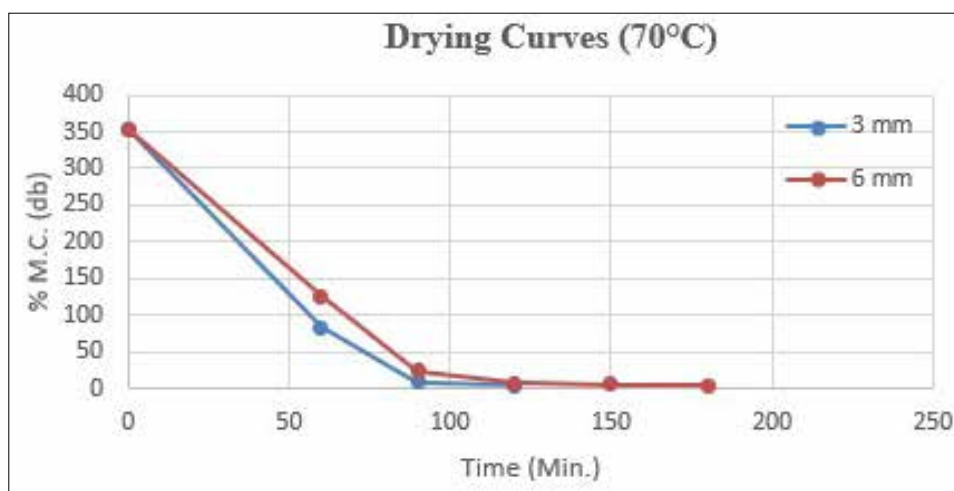


Fig. 6.3. Drying curves for foam mat drying at 70°C and different thickness of foam



Colour of Foam Mat Dried Powder

The L^* , a^* and b^* values of foam mat dried pomegranate powder for different drying conditions is depicted in table 4. The lightness value indicates a measure of colour in light-dark axis, which in turn denotes that the sample turned dark at reduced L^* value. The L^* value ranged from 48.56 to 52.12. It has been observed that L^* value which shows the lightness of the sample decreased with drying temperature and increase in the thickness. Furthermore, the foaming process increased the lightness in pomegranate powders due to the incorporation of air into it. The reduction in a^* and b^* value is evident from table 4. The reduction in a^* value shows the decrease in red colour of the powder with increase in temperature of drying and thickness of the drying.

Table 6.4 Colour values of foam mat dried pomegranate powder for different drying conditions

Treatment	Colour of foam mat dried powder		
	L^*	a^*	b^*
70°C 3mm	51.35±0.76	8.6±0.33	17.61±0.64
70°C 6mm	51.27±0.83	8.21±0.38	16.96±0.84
60°C 3mm	53.12±0.84	8.09±0.28	16.32±0.50
60°C 6mm	51.62±2.55	7.6±0.64	15.05±0.61
50°C 3mm	50.63±1.00	8.39±0.20	17.3±0.24
50°C 6mm	48.56±1.12	8.47±0.24	16.05±0.15

Bulk density, tapped density, carr's index and Hausner's ratio of foam mat dried pomegranate powder

Bulk density is defined as the mass of solid particles plus moisture divided by the total volume engaged by the particles, surface moisture, and all pores are closed or open, in the surrounding atmosphere. Bulk density is a parameter of the powder product which represent for economical and practical reason. Bulk density of foam mat dried pomegranate powders was ranged between 0.43–0.53 g/cm³ (table 5). The tapped density of the foam mat dried samples at different conditions was ranged from 0.45–0.56 g/cm³. The bulk density at 3 mm is lower as compared to that for 6mm thickness. This is because of the faster drying at low thickness leading to porous dried powder. The carr's index for all the samples was less than 10 and Hausner's ratio was within 1.00 to 1.11 (table 5) thereby showing that the foam mat dried powder developed in all the treatments is having excellent flow characteristics.

Table 6.5 Bulk density, tapped density, carr's index and Hausner's ratio of foam mat dried pomegranate powder for different drying conditions

Samples	Bulk density(g/cm3)	Tapped Density(g/cm3)	Carr's index	Hausner's ratio
70°C 3mm	0.51	0.56	5.26	1.06
70°C 6mm	0.53	0.56	9.09	1.10
60°C3mm	0.43	0.45	4.35	1.05
60°C6mm	0.49	0.51	4.85	1.05
50°C 3mm	0.43	0.46	5.22	1.06
50°C 6mm	0.51	0.53	4.04	1.04

Biochemical Analysis

TSS, pH, Acidity, Colour

The TSS, pH, titratable acidity and sugars of the reconstituted foam mat-dried pomegranate juice powder dried under different conditions are given in the table 6a. The TSS of the sample were shown in table found to be 15.3 and 15.4 for all the samples. The titratable acidity of the samples was ranged in between 0.70 to 1.40. Similarly, the pH values ranged in between 4.71 to 4.81.

Table6. 6a. Quality of reconstituted juice

Sr. No.	Samples	pH	Titratable Acidity	TSS	%Total sugar	%Reducing sugar	%Non-Reducing Sugar
1	70°C 3mm	4.78(±0.00)	0.82(±0.02)	15.3(±0.06)	13.76(±0.00)	11.36(±0.00)	2.40(±0.00)
2	70°C 6mm	4.71±0.00)	0.7(±0.04)	15.4(±0.00)	13.28(±0.41)	10.95(±0.14)	2.33(±0.27)
3	60°C3mm	4.81(±0.00)	1.15(±0.24)	15.3(±0.06)	14.60(±0.00)	12.50(±0.00)	2.10(±0.00)
4	60°C6mm	4.77(±0.01)	0.88(±0.06)	15.4(±0.00)	14.05(±0.45)	11.90(±0.00)	2.14(±0.45)
5	50°C 3mm	4.77(±0.01)	1.4(±0.22)	15.4(±0.06)	14.91(±0.51)	13.05(±0.19)	1.87(±0.44)
6	50°C 6mm	4.75(±0.00)	0.82(±0.02)	15.3(±0.06)	13.84(±0.00)	12.82(±0.00)	1.01(±0.00)

All the bioactive compounds viz. total phenolic content, antioxidant capacity, anthocyanin and ascorbic acid had shown similar trend showing reduction in bioactive with increase in the drying temperature and thickness of the foam. The drying temperature directly affects the bioactive compounds present. In case of the thickness of the foam the effect is indirect in nature. The increase in thickness leads to the increase in drying time and thereby exposing the foam to drying process for longer duration leading to loss of bioactive compounds. Further, it has been observed that the advantage of decrease in drying temperature in terms of reduction in the losses in bioactive is comparatively lower when temperature of drying is reduced from 60°C to 50°C as compared to reduction from 70°C to 60°C (table 6b). In other words, for 3 mm foam thickness when temperature has been increased from 50°C to 60°C the loss of phenols was 92 mg/ml and for increase from 60°C to 70°C its 326.34. Thus, the losses are higher at 70°C when compared at 60 °C. Similar is the case for 6 mm thickness. It can be seen from the table 3.6 that the significant loss in antioxidant activity can be observed for the increase in temperature from 60 °C to 70°C as compared to that for 50°C to 60°C. The similar trend as that of the total phenol and antioxidant activity was evident in case of anthocyanin content. Further the ascorbic acid being thermo labile in nature has shown losses in ascorbic acid for increase in temperature as well as increase in thickness of drying.

Table6. 6b. Quality of reconstituted juice

Treatment	Phenol (g/L GAE)	Antioxidant capacity (mg/100ml AAE)	Anthocyanin (mg/100ml)	Ascorbic acid (mg/100 ml)
70°C 3mm	2352.53±16.62e	40.35±0.44b	23.43±0.48c	13.33±1.44bc
70°C 6mm	2251.53±15.28f	38.39±0.69c	22.43±1.18c	12.50±0.00c
60°C 3mm	2678.87±5.77c	41.19±0.08ab	24.60±0.26b	14.17±1.44abc
60°C 6mm	2494.53±67.49d	40.53±0.62b	23.10±0.70c	12.50±0.00c
50°C 3mm	2770.87±12.66a	41.96±0.34a	28.83±0.19a	15.83±1.44a
50°C 6mm	2731.87±43.02b	41.73±0.27a	28.17±0.10a	15.00±0.00ab



The results leads to the following conclusions for the experiments conducted for foam mat drying. In foaming experiment the 10 % whey protein isolate and 0.25 % of CMC has shown the best results in terms of foam expansion, foam density and foam drainage volume of 455.28 %, 0.2030 g/cc and 20.10 ml respectively. This optimum combination arrived at after foaming experiments has been used for the drying experiments. The drying time required for drying of foam at 70°C was 120 and 180 minutes, at 60°C it was 180 and 240 minutes, and at 50 °C it was 210 and 300 minutes respectively for 3 and 6 mm thickness. Thus, it can be observed that drying time increases with decrease in temperature and increase in foam thickness. Further, data on biochemical analysis reveals that the bioactive compounds have shown the higher losses when temperature rose to 70°C from 60°C when compared with increase from 50°C to 60°C. Thus, keeping in mind, the drying time required and bioactive compound retention the 60°C temperature and 3 mm drying thickness seems to be the best combination for lower drying time of 180 minutes with optimum retention of the bioactive compounds during drying process.

B. Comparative studies on fermentation process in wine development from pomegranate juice of Bhagawa, Ganesh and Arakta varieties.

The experiments were conducted for comparative evaluation of the fermentation process and quality of the wine from pomegranate juice of Bhagawa, Ganesh and Arakta varieties.

Biochemical Profile of Pomegranate Juices

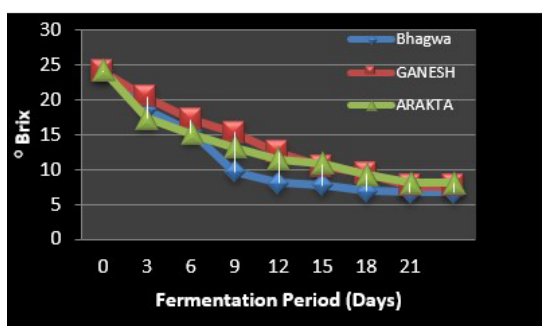
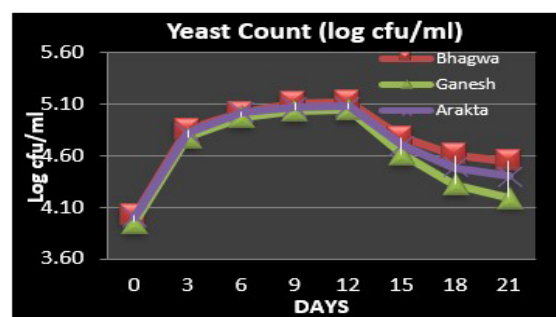
Biochemical and bioactive compounds of pomegranate juices of different varieties were tabulated in Table 1 and 2. It has been clear from critical difference values (Table 1) that TSS, acidity, pH and reducing sugars were significantly different for all the three varieties namely Bhagwa, Ganesh, and Arakta. The difference in anthocyanin concentrations of the three varieties studied was statistically significant with Arakta being richest in anthocyanin followed by Bhagwa and Ganesh. The Arakta has significantly higher total phenols than Bhagwa and Ganesh. The phenol content in Bhagwa and Ganesh were not significantly different. The antioxidant capacity of the pomegranate juice has been contributed by total phenols, anthocyanin content and ascorbic acid content. Since, Arakta has highest content of the phenolics and anthocyanin as compared to Bhagwa and Ganesh making it rich source of antioxidants. In present study the pomegranate juice of Arakta had the highest total flavonoid contents of 81.42, followed by 75.36 in Bhagwa and 65.06 mg QuE/L in Ganesh varieties respectively.

Table 6.7. Biochemical profile for pomegranate juice of different varieties

Pomegranate Variety	TSS (°B)	Acidity (%)	pH	Reducing sugar (%)	Total sugar (%)	Non Reducing Sugar (%)
Bhagwa	16.10	0.32	3.49	15.31	15.80	0.49
Ganesh	17.10	0.35	3.17	16.49	16.73	0.24
Arakta	15.80	0.38	3.54	14.15	15.74	1.59
C.D.	0.10	0.02	0.02	0.56	0.43	0.41
SE(m)	0.03	0.01	0.01	0.16	0.12	0.12
SE(d)	0.04	0.01	0.01	0.22	0.17	0.17
C.V.	0.31	2.43	0.30	1.78	1.30	22.73

Table 6.8: Bioactive compounds for pomegranate juice of different varieties

Pomegranate Variety	Anthocyanine (mg cyanidine /100ml)	Total phenol (mg/L GAE)	Antioxidant capacity (mg/100ml AAE)	Total Flavonoid contents (mg QuE /L)
Bhagwa	24.04	2730.10	37.37	75.36
Ganesh	13.65	2702.77	26.37	65.06
Arakta	29.54	2862.10	41.03	81.42
C.D.	0.40	46.61	2.04	7.53
SE(m)	0.16	13.21	0.58	2.14
SE(d)	0.16	18.68	0.82	3.02
C.V.	0.89	0.83	2.86	5.00


Fig. 6.5. Temporal changes in TSS during fermentation

Fig. 6.6. Yeast count (log CFU/ml) during fermentation

Changes in TSS and Yeast Count (cfu/ml)

The changes in total soluble solids (TSS) of three varieties were presented (Fig.3). The TSS adjusted to 24 °B. It has been observed that TSS has been reduced progressively during fermentation period up to 21 days (Fig 1). It has also been observed that major reduction in TSS was during initial 6 days. The 49.71, 41.81 and 55.97 % of the TSS reduction was observed during first six days for Bhagwa, Ganesh and Arakta varieties and remaining reduction was seen during last fifteen days. Further, the data on yeast count (Fig 2) shows that it exponentially increased up to sixth day and thereafter there was slow growth up to twelfth day followed by reduction in the yeast cell count. It can be concluded from the data that, the increase in the yeast count can be correlated to the corresponding fast utilization of TSS which comprises mainly sugars. Further, the reduction in rate of consumption of the sugars can be correlated to the quick dying of the yeast cells.

Biochemical Profile of the Wines of Different Varieties

Biochemical parameters of the developed wines were tabulated (Table 3). The TSS (°B) for different varieties for pomegranate wine namely Bhagwa, Ganesh and Arakta were 6.7, 7.5 and 8.1 respectively. The pH values for different varieties of pomegranate wine were from 3.65, 3.66 and 3.59 of Bhagwa, Ganesh and Arakta wines respectively. The TSS values for all the wines were statistically significantly different from each other and was highest for Arakta followed by Ganesh and Bhagwa. The residual sugars in the pomegranate wine were depicted by total sugars, reducing sugar and non-reducing sugars. The different wine varieties have shown significantly



different residual total sugars (Table 3). The total sugars were mainly composed of reducing sugars similar to the juice. The reducing sugars in the wines are mainly composed of the fructose followed by glucose. The ethanol content in different varieties for pomegranate wine were 13.65, 13.65 and 13.27 % for Bhagwa, Ganesh and Arakta respectively. Thus it can be seen that the Ganesh and Bhagwa had highest ethanol content. Based on the residual sugar content the pomegranate wines developed can be categorized as sweet wines.

Bhagwa, Ganesh, and Arakta wines had total phenolics of 1980.43, 1716.10, and 1986.10 mg/LGAE, respectively. When compared with the total phenols present in the juice (Table 2) the phenols were found to be degraded during the process of the fermentation. This might be due to the decrease in the ellagitannins which are hydrolysable tannins present in the juice and were undergo hydrolysis during fermentation process.

The anthocyanin content has been decreased during the fermentation process. The table 2 and 4 shows that the reduction in the total anthocyanin content was 5.11, 6.88 and 21.40% respectively for Bhagwa, Ganesh and Arakta respectively. The reduction of anthocyanins in wines, might be due to the reactions of polymerization with acetaldehyde, generated by the metabolic activity of yeasts, with the formation of complex compounds causing losses of the red color. The total flavonoids in the juice were also reduced during the fermentation process.

Table 6.9 Biochemical profile of pomegranate wines of different varieties

Pomegranate Variety	TSS (°B)	Total Acid (%)	Malic Acid (%)	pH	Reducing sugar (%)	Total sugar (%)	Non Reducing Sugar (%)	Ethanol (%)
Bhagwa	6.70	4.50	3.65	3.65	6.25	6.81	0.56	13.65
Ganesh	7.50	4.50	3.65	3.66	7.14	7.55	0.41	13.65
Arakta	8.10	4.25	3.15	3.59	7.92	8.42	0.50	13.27
C.D.	0.003	0.059	0.102	0.015	0.017	0.024	0.029	0.108
SE(m)	0.001	0.017	0.029	0.004	0.005	0.007	0.008	0.031
SE(d)	0.001	0.024	0.041	0.006	0.007	0.010	0.012	0.043
C.V.	0.020	0.654	1.435	0.199	0.116	0.157	2.909	0.392

Table 6.10. Bioactive compounds for pomegranate wine of different varieties

Pomegranate Variety	Anthocyanin (mg/100ml of cyanidine)	Total Phenol Content (mg/L GAE)	Antioxidant capacity (mg/100ml AAE)	Total Flavonoid Content (mg QE/L)
Bhagwa	22.81	1980.43	28.70	61.73
Ganesh	12.79	1716.10	21.03	46.58
Arakta	23.22	1986.10	31.03	66.27
C.D.	0.316	25.521	4.016	7.880
SE(m)	0.090	7.234	1.139	2.234
SE(d)	0.127	10.231	1.610	3.159
C.V.	0.792	0.662	7.325	6.648

Color and Sensory Analysis

During fermentation the L^* and b^* values were increased for all wines during fermentation with and corresponding increased lightness and yellowness. The a^* values (redness) in wines were increased for Bhagwa and Arakta and decreased for Ganesh as compared to initial values for juice. The results of the sensory evaluation of the three varieties namely Bhagwa, Ganesh and Arakta were depicted in Fig.3 In all the sensory quality parameters viz. color, aroma, taste, style the Arakta wine was found to be the best acceptable wine followed by the Bhagwa and Ganesh (Fig. 4).

Table 6.11. Color of pomegranate juice and wine

Pomegranate Variety	Juice			Wine		
	L^*	a^*	b^*	L^*	a^*	b^*
Bhagwa	14.41	18.37	6.04	17.47	40.38	27.02
Ganesh	35.28	42.18	18.14	43.24	21.77	30.32
Arakta	15.10	11.87	3.22	22.13	32.30	16.01



Fig. 6.7 Radar plot for sensory score of pomegranate wines of Bhagwa, Ganesh and Arakta

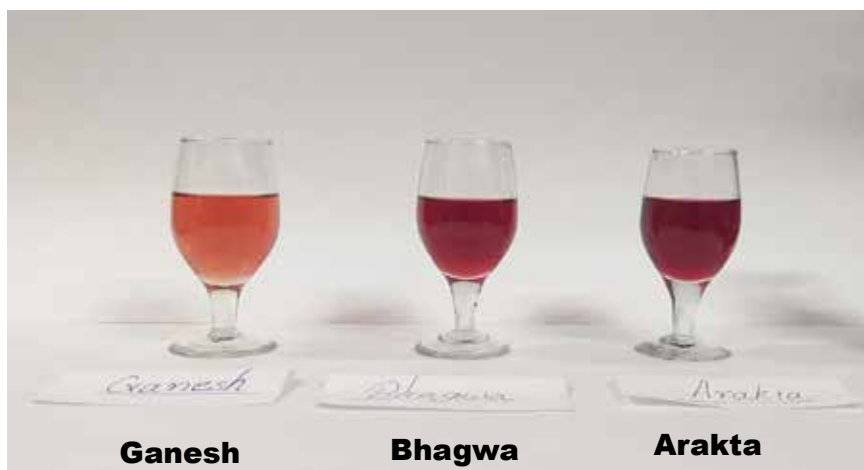


Fig. 6.8. Pomegranate wines of Bhagwa, Ganesh and Arakta varieties



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 at 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. 6.12 Maturity indices for pomegranate variety Solapur Lal

Stage of fruit development (Days after anthesis)	Fruit weight (g)	TSS (°Brix)	Titration acidity (%)	TSS/Acid ratio
90 days	170.6	13.0	0.58	22.41
105 days	196.2	14.2	0.52	27.30
120 days	222.8	15.3	0.49	31.22
135 days	245.2	16.1	0.46	35.00
150 days	263.2	16.9	0.43	39.30
160 days	271.6	17.6	0.40	44.00
165 days	272.5	17.8	0.40	44.50

6.1.3. Determination of anardana recovery:

Anardana is the dried form of arils. Arils are 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 from 17.5-21.2%B. Anardana recovery was highest in Solapur Anardana (21.2%) closely followed by NRCP H-4 (20.8%). The recovery was lowest in Amlidana (17.5%).

Table 6.13. Anardana recovery from pomegranate hybrids

S.No.	Variety/ Hybrid	Anardana recovery from arils (%)
1	NRCP H-1	19.8
3	NRCP H-3	18.8
4	NRCP H-4	20.8
5	NRCP H-11	20.4
6	NRCP H-12 (Solapur Anardana)	21.2
7	NRCP H-15	20.6
8	6/4	19.4
9	6/5	18.6
10	Hybrid A	20.2
11	Amlidana	17.5

6.2 DEVELOPMENT OF FUNCTIONAL FOOD PRODUCTS AND WASTE UTILIZATION FROM POMEGRANATE

Activity 1: Development and evaluation of **Low calorie pomegranate fruit drink** using natural and artificial sweeteners

- Low calorie pomegranate Ready-To-Serve (RTS) drink was prepared using natural (stevia) and artificial sweeteners (sucralose and aspartame) by substituting sucrose (refined white sugar) at the rate of 0, 25%, 50%, 75% and 100%. RTS drink was prepared as per the FSSAI Specification as Juice: 20%, T.S.S.: 15% and Acidity: 0.375%. The sweeteners were added within the limit as described by FSSAI.
- The physicochemical properties of the low calorie pomegranate RTS drink were evaluated with respect to total sugar, energy value, T.S.S., acidity, pH, colour, total phenol content, antioxidant activity, ascorbic acid content and sensory properties.
- The total sugar content of RTS was significantly reduced from 15.03% to 4.5% due to use of non-calorific sweeteners. The energy value was also reduced from 60.12 kcal/100ml to 18 kcal/100ml (Fig.1a and 1b). The developed RTS drink is suitable for the consumers on low calorie diet and also for patient with type II diabetics.

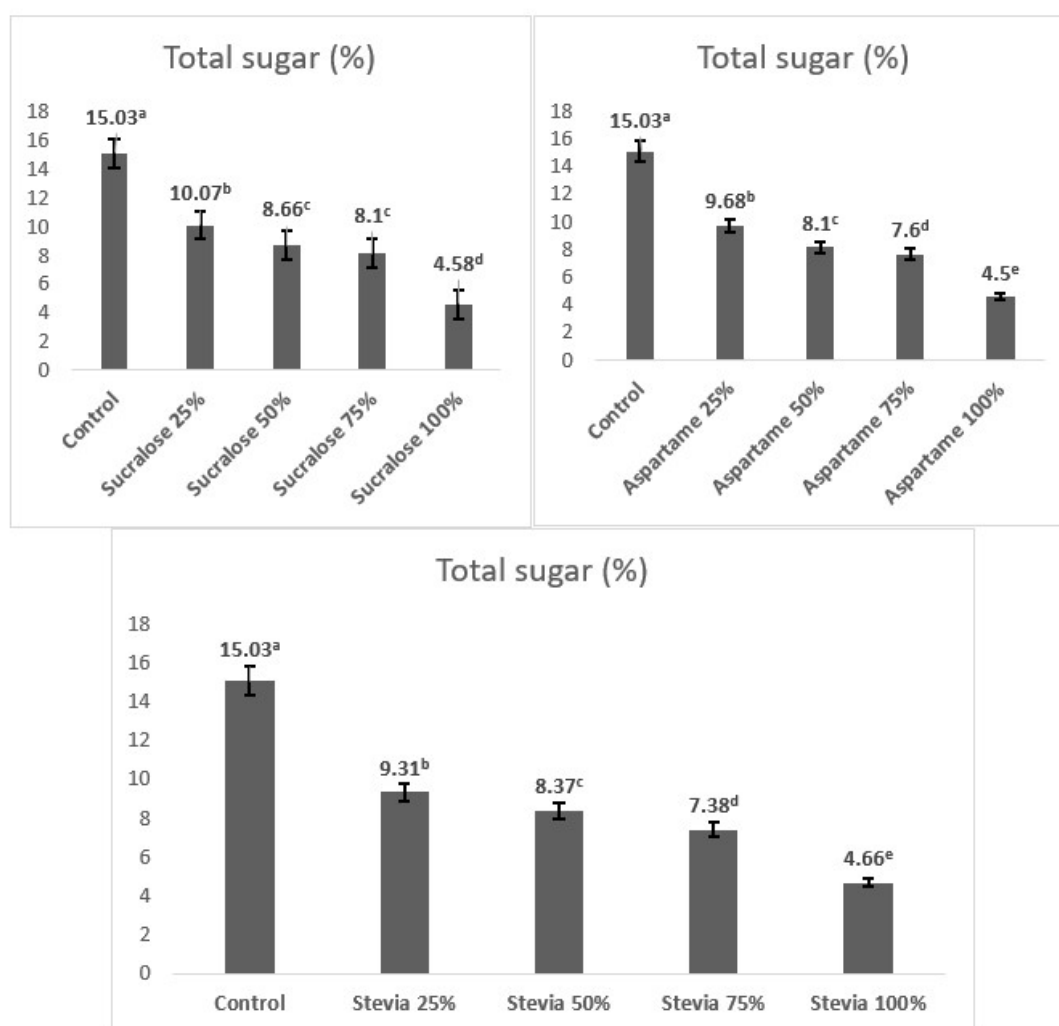


Fig 6.9 (a) Total sugar content of low-calorie pomegranate fruit drink with different sweeteners

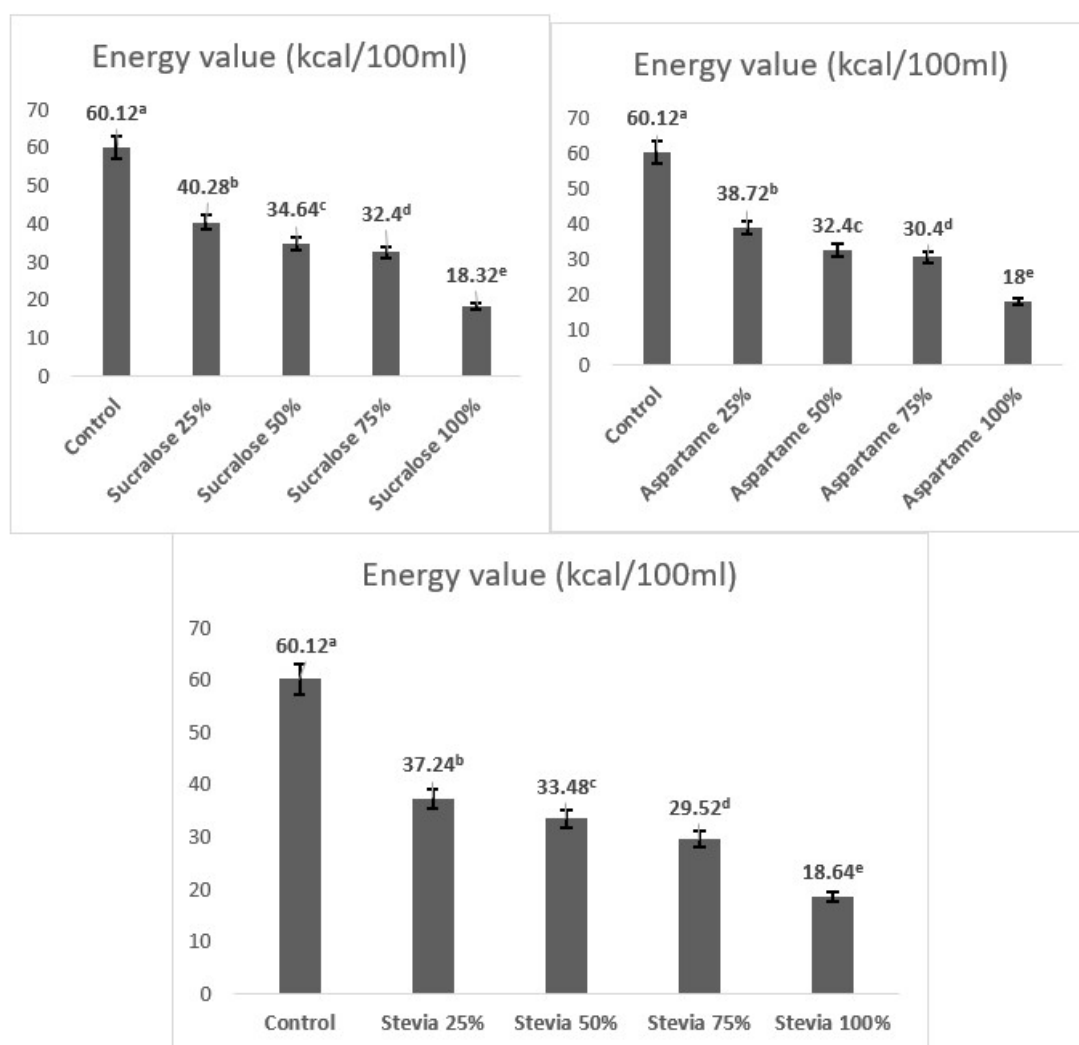


Fig.6.9 (b) Energy value of low-calorie pomegranate fruit drink with different sweeteners

- The chemical composition and physico-chemical properties of low-calorie pomegranate fruit drink is given in Table 1 and 2 respectively. The substitution of white refined sugar with natural and artificial sweeteners at different levels significantly affected on chemical composition, T.S.S, colour value and overall acceptability.
- The sensory evaluation resulted to acceptable score to the low calorie pomegranate fruit drink with 75% replacement of refined sugar with natural and artificial sweeteners.

Table 6.14. Chemical composition of low calorie pomegranate fruit RTS drink

Treatments	Reducing sugar (%)	Non reducing sugar (%)	Total sugar (%)	Energy value (kcal/100ml)	Ascorbic acid (mg/100ml)	Total phenols (mg GAE/100ml)	In-vitro Antioxidant activity (%)	Antioxidant capacity (mg/100ml)	Total anthocyanin (mg/100ml)
RTS with Sucralose sweeteners									
Control	3.62±0.1 ^a	11.41±0.3 ^a	15.03±0.1 ^a	60.12±0.2 ^a	6.25±0.3 ^d	0.15±0.3 ^a	92.85±0.1 ^a	2.44±0.3 ^a	43.584±0.1 ^a
Sucralose 25%	3.67±0.2 ^a	6.4±0.3 ^b	10.07±0.1 ^b	40.28±0.2 ^b	6.25±0.3 ^d	0.148±0.3 ^b	88.21±0.1 ^b	2.23±0.3 ^b	39.91±0.2 ^b
Sucralose 50%	3.7±0.1 ^a	4.96±0.2 ^c	8.66±0.2 ^c	34.64±0.3 ^c	8.12±0.2 ^c	0.132±0.2 ^c	81.84±0.2 ^c	1.93±0.2 ^c	39.91±0.2 ^b
Sucralose 75%	3.67±0.3 ^a	4.43±0.2 ^d	8.1±0.2 ^d	32.4±0.3 ^d	11.87±0.2 ^b	0.122±0.1 ^d	75.65±0.2 ^d	1.56±0.2 ^d	38.24±0.3 ^c
Sucralose 100%	3.67±0.2 ^a	0.91±0.3 ^e	4.58±0.3 ^e	18.32±0.1 ^e	12.5±0.1 ^a	0.113±0.1 ^e	65.31±0.1 ^e	1.4±0.1 ^e	38.073±0.1 ^c
RTS with Aspartame sweeteners									
Control	3.62±0.1 ^a	11.41±0.3 ^a	15.03±0.1 ^a	60.12±0.2 ^a	6.25±0.3 ^e	0.15±0.3 ^a	92.85±0.1 ^a	2.44±0.3 ^a	43.584±0.1 ^a
Aspartame 25%	3.67±0.1 ^a	6.01±0.1 ^b	9.68±0.3 ^b	38.72±0.1 ^b	6.87±0.1 ^d	0.122±0.2 ^b	89.86±0.1 ^b	2.13±0.1 ^b	38.908±0.1 ^b
Aspartame 50%	3.7±0.1 ^a	4.4±0.1 ^c	8.1±0.2 ^c	32.4±0.1 ^c	7.5±0.2 ^c	0.119±0.2 ^c	87.05±0.1 ^c	1.82±0.2 ^c	37.571±0.1 ^c
Aspartame 75%	3.7±0.3 ^a	3.9±0.2 ^d	7.6±0.1 ^d	30.4±0.2 ^d	10±0.2 ^b	0.113±0.1 ^d	83.09±0.2 ^d	1.48±0.2 ^d	36.239±0.2 ^d
Aspartame 100%	3.67±0.2 ^a	0.83±0.4 ^e	4.5±0.1 ^e	18±0.3 ^e	12.5±0.1 ^a	0.11±0.2 ^d	74.98±0.3 ^e	1.36±0.1 ^e	36.06±0.3 ^d
RTS with Stevia sweeteners									
Control	3.62±0.1 ^a	11.41±0.3 ^a	15.03±0.1 ^a	60.12±0.2 ^a	6.25±0.3 ^d	0.15±0.3 ^a	92.85±0.1 ^a	2.44±0.3 ^a	43.584±0.1 ^a
Stevia 25%	3.64±0.1 ^a	5.67±0.1 ^b	9.31±0.2 ^b	37.24±0.2 ^b	7.5±0.3 ^c	0.119±0.1 ^b	86.28±0.2 ^b	2.06±0.1 ^b	39.50±0.1 ^b
Stevia 50%	3.7±0.1 ^a	4.67±0.2 ^c	8.37±0.1 ^c	33.48±0.2 ^c	7.5±0.3 ^c	0.117±0.2 ^c	78.55±0.2 ^c	1.74±0.1 ^c	38.572±0.2 ^c
Stevia 75%	3.7±0.2 ^a	3.68±0.2 ^d	7.38±0.2 ^d	29.52±0.1 ^d	11.87±0.1 ^b	0.113±0.3 ^d	63.29±0.1 ^d	1.35±0.2 ^d	37.576±0.2 ^d
Stevia 100%	3.67±0.2 ^a	0.99±0.2 ^e	4.66±0.1 ^e	18.64±0.1 ^e	12.5±0.1 ^a	0.11±0.3 ^d	53.24±0.1 ^e	1.29±0.2 ^e	37.574±0.3 ^d

Values are expressed as mean ± SD of three independent determinations. Values in columns followed by the same letter are not significantly different at $p \leq 0.05$ as measured by Duncan's test



Table 6.15. Physico-chemical properties and overall acceptability of low calorie pomegranate fruit RTS drink

Treatments	T.S.S. (°BX)	Acidity (%)	pH	L	a	b	Hue	Croma	ΔE	Overall acceptability
RTS with sucralose sweeteners										
Control	16.07±0.06 ^a	0.353±0.35 ^d	2.653±2.65 ^a	34.30±0.01 ^e	49.23±0.01 ^b	30.23±0.01 ^a	31.55±0.01 ^a	57.77 ±0.01 ^a	0	8.70±0.17 ^a
Sucralose 25%	13.23±0.06 ^b	0.353±0 ^d	2.643±0.01 ^{ab}	34.75± 0.01 ^d	49.28±0.01 ^a	29.31±0.01 ^b	30.75± 0.01 ^b	57.34 ±0.01 ^b	1.03±0.01 ^d	8.30±0.17 ^b
Sucralose 50%	9.27±0.06 ^c	0.362±0 ^c	2.643±0.01 ^{ab}	36.08±0.01 ^b	48.67 ±0.01 ^d	28.15± 0.01 ^d	30.03 ±0.01 ^d	56.23 ±0.01 ^d	2.80± 0.01 ^b	8.30±0.17 ^b
Sucralose 75%	7.63±0.06 ^d	0.368±0 ^b	2.633±0.01 ^b	36.02± 0.01 ^c	49.14 ±0.01 ^c	28.79 ±0.01 ^c	30.37 ±0.01 ^c	56.95 ±0.01 ^c	2.25 ±0.01 ^c	8.30±0.17 ^b
Sucralose 100%	4.63±0.06 ^e	0.374±0 ^a	2.633±0.01 ^b	36.76± 0.01 ^a	48.57±0.01 ^e	27.57 ±0.01 ^e	29.63±0.01 ^e	55.85 ±0.01 ^e	3.68 ±0.01 ^a	7.80±0.17 ^c
RTS with Aspartame sweeteners										
Control	16.07±0.06 ^a	0.353±0.35 ^d	2.653±2.65 ^a	34.30±0.01 ^e	49.23±0.01 ^a	30.23±0.01 ^a	31.55±0.01 ^a	57.77 ±0.01 ^a	0	8.70±0.17 ^a
Aspartame 25%	12.70±0.06 ^b	0.361±0 ^c	2.643±0.01 ^{ab}	35.62±0.01 ^d	48.83±0.01 ^b	27.97± 0.01 ^b	29.82± 0.01 ^b	56.27±0.01 ^b	2.65± 0.01 ^d	8.13±0.25 ^b
Aspartame 50%	10.10±0.06 ^c	0.368±0 ^b	2.643±0.01 ^{ab}	36.43± 0.01 ^c	48.35± 0.01 ^d	26.88±0.01 ^c	29.07±0.01 ^c	55.32± 0.01 ^c	4.07± 0.01 ^c	8.13±0.25 ^b
Aspartame 75%	7.50±0.06 ^d	0.373±0 ^{ab}	2.643±0.01 ^{ab}	36.68±0.01 ^b	48.39± 0.01 ^c	26.73± 0.01 ^d	28.93± 0.01 ^d	55.28± 0.01 ^d	4.32±0.01 ^b	8.13±0.25 ^b
Aspartame 100%	4.60±0.06 ^e	0.375±0 ^a	2.633±0.01 ^b	37.05±0.01 ^a	48.02±0.01 ^e	26.49± 0.01 ^e	28.93±0.01 ^d	54.84± 0.01 ^e	4.83± 0.01 ^a	7.56±0.25 ^c
RTS with stevia sweeteners										
Control	16.07±0.06 ^a	0.353±0.35 ^d	2.653±2.65 ^a	34.30±0.01 ^e	49.23±0.01 ^b	30.23±0.01 ^a	31.55±0.01 ^a	57.77 ±0.01 ^a	0	8.70±0.17 ^a
Stevia 25%	13.10±0.06 ^b	0.365±0 ^c	2.633±0.01 ^b	34.88± 0.01 ^d	49.39± 0.01 ^a	28.73±0.01 ^b	30.20± 0.01 ^b	57.14±0.01 ^b	1.62± 0.01 ^d	8.60±0.25 ^a
Stevia 50%	10.90±0.06 ^c	0.369±0 ^{bc}	2.623±0.01 ^{bc}	35.46±0.01 ^c	49.08±0.01 ^c	28.54±0.01 ^c	30.16± 0.01 ^c	56.78± 0.01 ^d	2.06±0.01 ^c	8.16±0.25 ^{ab}
Stevia 75%	8.46±0.06 ^d	0.372±0 ^b	2.623±0.01 ^{bc}	35.59±0.01 ^b	49.23±0.01 ^b	28.43± 0.01 ^d	29.99±0.01 ^d	56.83±0.01 ^c	2.24±0.01 ^b	8.16±0.25 ^{ab}
Stevia 100%	5.73±0.06 ^e	0.379±0 ^a	2.633±0.01 ^c	35.89±0.01 ^a	48.86±0.01 ^d	26.87± 0.01 ^e	28.81± 0.01 ^e	55.76±0.01 ^e	3.74± 0.01 ^a	7.66±0.25 ^b

Values are expressed as mean ± SD of three independent determinations. Values in columns followed by the same letter are not significantly different at $p \leq 0.05$ as measured by Duncan's test

Activity 1. Oxidative stability of muffins incorporated with pomegranate peel powder

➤ Experiment 1. Phytochemical, nutritional, thermal and functional properties of pomegranate peel powder and its extract

- The studies were carried out to evaluate the effect of different drying methods (cabinet tray drying and sun drying) and particle size (260µm, 710µm and 2000µm) of the pomegranate peel powder (Fig.2) on the biochemical composition of the pomegranate peel powder and its extract for its further utilization as natural preservative for oxidative and microbial stability in food products.
- The surface disinfection of pomegranate peel was done by washing with sodium hypochloride (80 ppm, pH 7) followed by drying at 50°C for 24-48h till get moisture content about 5 to 7% using cabinet tray dryer. Moreover, sun drying was also applied for preparation of pomegranate peel powder. The dried pomegranate peel was pulverized into powder with varying particle size of 260µm, 710µm and 2000µm. The pomegranate peel extract was prepared using already standardized aqueous method and further concentrated by rotary evaporator.
- A significant variation was observed with respect to biochemical composition of pomegranate peel extract of different particle size of pomegranate peel powder (PPP). The highest total phenol content (1988.33 mg/L GAE) and antioxidant activity (67.77% radical scavenging activity) of peel powder revealed with smallest particle size (260µm) and vice versa. But, no significant different was observed in protein and fiber content of peel powder with respect to variation in particle size (Table 3).
- The minerals content of peel powder showed slight variation but not significant when there is variation in particle size of the powder. The phosphorus (0.31%), potassium (1.51%), calcium (1.80%), magnesium (0.14 %), iron (445 mg/100g) and manganese (101 mg/100g) was found higher in sample with 260µm whereas, higher amount of copper (96mg/kg), zinc (161mg/kg) was noted in peel powder with 2000µm (Table 3).

Table 6.16. Phytochemical and nutritional properties of pomegranate peel powder of different particle size

Parameters	Particle size of pomegranate peel powder		
	260um	710um	2000um
Total phenols (mg GAE/L)	1988.33±0.05 ^a	1601.36±0.05 ^b	1559.54±0.03 ^c
Antioxidant activity FRAP (mg/100ml AAE)	41.10±0.03 ^a	39.87±0.03 ^b	33.21±0.05 ^c
Antioxidant activity DPPH (%)	67.77±0.01 ^a	56.99±0.01 ^b	37.77±0.01 ^c
Total tannin content (mg GAE/L)	-	-	231±0.04 ^a
Protein (%)	2.53±0.03 ^a	2.45±0.03 ^a	2.39±0.03 ^a
Fiber content (%)	12.2±0.02 ^a	11.57±0.05 ^a	12.22±0.05 ^a
P%	0.31±0.01 ^a	0.28±0.01 ^a	0.31±0.01 ^a
K%	1.51±0.03 ^a	1.235±0.03 ^a	1.215±0.05 ^a
Calcium (%)	1.80±0.02 ^a	1.60±0.05 ^a	1.60±0.05 ^a
Magnesium(%)	0.14±0.01 ^a	0.10±0.01 ^a	0.10±0.01 ^a
Iron (mg/100g)	445±0.07 ^a	365±0.02 ^b	355±0.06 ^c



Parameters	Particle size of pomegranate peel powder		
	260um	710um	2000um
Mn (mg/100g)	101±0.03 ^a	58±0.06 ^b	53±0.01 ^c
Cu (mg/100g)	83±0.02 ^c	92±0.03 ^b	96±0.02 ^a
Zinc (mg/100g)	139±0.01 ^c	158±0.02 ^b	161±0.02 ^a

Values are expressed as mean ± SD of three independent determinations. Values in rows followed by the same letter are not significantly different at $p \leq 0.05$ as measured by Duncan's test

- The functional properties such as water absorption capacity (340%), oil absorption capacity (260%), bulk density (0.48g/ml), foaming capacity (1%) and stability (40%), emulsification



Fig 6.10. Dried pomegranate peel and powder

capacity (78.57%), swelling capacity (44ml) and dispersibility (52%) of pomegranate peel powder has been evaluated. There was no significant difference was observed for functional properties of cabinet tray and sun dried pomegranate peel powder. Thermal properties of food materials give an idea about the quality of food components under the effect of high temperature. The thermal properties of cabinet tray dried peel powder was recorded significantly higher especially peak temperature and conclusion temperature. Whereas, enthalpy of sundried peel powder was found as 3.848 J/g which was slightly higher than cabinet tray dried peel powder (3.070J/g) (Table 6.17).

Table 6.17. Functional and thermal properties of pomegranate peel powder

Parameters	Pomegranate peel powder	
	Sun dried	Cabinet Tray dried
Water absorption capacity (%)	340±0.3 ^a	340±0.1 ^a
Oil absorption capacity (%)	260±0.5 ^a	260±0.5 ^a
Bulk density (g/ml)	0.49±0.5 ^a	0.48±0.5 ^a
Foaming capacity (%)	1±0.1 ^a	1±0.1 ^a
Foam stability (%)	40±0.1 ^a	40±0.1 ^a
Emulsification capacity (%)	78.57±0.5 ^a	78.57±0.5 ^a

Parameters	Pomegranate peel powder	
	Sun dried	Cabinet Tray dried
Swelling capacity (ml)	42±0.3 ^b	44±0.3 ^a
Dispersibility (%)	51±0.3 ^b	52±0.3 ^a
Onset temperature (To)	40±0.1 ^a	40.2±0.1 ^a
Peak temperature (Tp)	63.9±0.1 ^b	67.1±0.2 ^a
Conclusion temperature (Tc)	93.3±0.2 ^b	95.2±0.1 ^a
Enthalpy (ΔH) (J/g)	3.84±0.2 ^a	3.07±0.2 ^b

Values are expressed as mean ± SD of three independent determinations. Values in rows followed by the same letter are not significantly different at $p \leq 0.05$ as measured by Duncan's test

- Thermogravimetric analysis (TGA) was done for sun dried and cabinet tray dried pomegranate peel powder samples to know the thermal stability of the material and its fraction of volatile components by monitoring the weight change that occurs when sample is heated at constant rate. The sample was heated at a constant rate of 10°C/min from 35 °C to 800 °C. From TGA curve, it can be seen that as temperature increases there was decrease in mass of the sample due to thermal treatment. The loss in mass at initial stage of sundried pomegranate peel powder was 13.99% and for cabinet tray dried peel powder as 9.89% which was increased to 48.28% and 41.52% respectively. The residual mass recorded as 3.69% and 28.81% for sundried and cabinet tray dried pomegranate peel powder respectively (Fig 6.11).

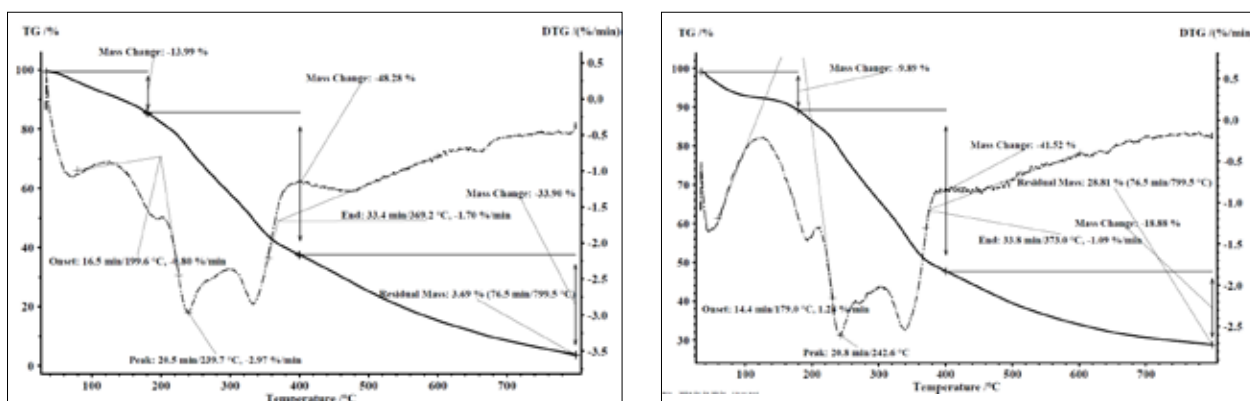


Fig.6.11 The TGA curve for sundried and cabinet tray dried pomegranate peel powder

➤ Experiment 2: Development and evaluation of pomegranate peel powder fortified muffins

- The cabinet tray dried pomegranate peel powder were utilized as a natural preservative to evaluate the oxidative stability of muffins. The pomegranate peel powder was incorporated at the rate of 0, 2, 4, 6, 8 and 10% by substituting refined wheat flour in the formulations (Table 5.5). The process including the level of different ingredients, baking temperature, baking time etc. were standardized for the development of muffins (Fig 6.4).
- The physical, nutritional, pasting, sensorial and microbial properties of developed muffins with pomegranate peel powder along with control (without pomegranates peel powder) samples were evaluated.



Table 6.18. Formulation for the development of muffins fortified with pomegranate peel powder (PPP)

Ingredients (%)	Control	2%PPP	4%PPP	6%PPP	8%PPP	10%PPP
Refined wheat flour	26	24	22	20	18	16
Pomegranate peel powder	--	2	4	6	8	10
Refined Sugar	26	26	26	26	26	26
Sunflower oil	12	12	12	12	12	12
Egg	22	22	22	22	22	22
Milk	13	13	13	13	13	13
Baking powder	1	1	1	1	1	1

Table 6.19. Nutritional compositions of muffins fortified with pomegranate peel powder

Treat-ments	Moisture (%)	Fat (%)	Protein (%)	Fiber (%)	Carbohydrates (%)	Energy value (Kcal/100g)	Antioxidant activity (%)	Total phenols (mg GAE/100g)
Control	16.68±0.01 ^f	12.66±0.01 ^a	7.37±0.01 ^a	4.39±0.43 ^f	57.09±0.42 ^b	371.85±0.42 ^a	75.94±0.01 ^f	0.443±0.01 ^f
2%PPP	17.38±0.01 ^e	10.76±0.01 ^b	7.00±0.01 ^b	5.09±0.06 ^e	57.83±0.08 ^a	356.20±0.26 ^b	78.89±0.01 ^e	21.08±0.0 ^e
4%PPP	18.03±0.01 ^d	9.63±0.01 ^c	6.82±0.01 ^c	6.23±0.30 ^d	56.88±0.29 ^b	341.54±0.18 ^c	85.31±0.01 ^d	23.93±0.0 ^d
6%PPP	18.38±0.01 ^c	9.17±0.01 ^d	6.39±0.01 ^d	7.32±0.12 ^c	56.06±0.12 ^c	332.40±0.50 ^d	89.47±0.01 ^c	34.96±0.0 ^c
8%PPP	18.67±0.01 ^b	8.09±0.01 ^e	6.33±0.06 ^e	8.43±0.47 ^b	55.70±0.44 ^c	320.99±0.47 ^e	98.55±0.01 ^b	48.15±0.0 ^b
10%PPP	19.08±0.01 ^a	7.74±0.01 ^f	5.86±0.01 ^f	10.66±0.30 ^a	53.81±0.29 ^d	308.38±0.19 ^f	99.36±0.01 ^a	48.53±0.06 ^a

- Values are expressed as mean ± SD of three independent determinations. Values in columns followed by the same letter are not significantly different at $p \leq 0.05$ as measured by Duncan's test.



Fig.6.12 Muffins fortified with pomegranate peel powder

- The muffins fortified with pomegranate peel powder resulted to increase in fiber content from 4.39% to 10.66%, total phenols from 0.443 mg GAE/100g to 48.53 mg GAE/100g and antioxidant activity from 75.94% to 99.36%. On positive sides, for consumers on low calorie diet, can prefer the muffins with pomegranate peel powder which showed the reduction in energy values from 371.85 kcal/100g to 308.38kcal/100g (Table 6).
- The significant changes were recorded in the physical properties of muffin batter as well as muffins incorporated with pomegranate peel powder. The significant reduction in the height, volume and specific volume of muffins was found with increase in the level of pomegranate

peel powder. Moreover, the specific gravity and viscosity of muffins batter increased with incorporation of pomegranate peel powder. The substitution of refined wheat flour with pomegranate peel powder resulted to dilution in gluten content which is responsible for the desirable physical properties of muffins and higher fiber content of pomegranate peel powder leads to higher moisture absorption caused increase in the viscosity of batter (Table 7).

Table 6.20. Physical properties of muffin batter and muffins fortified with pomegranate peel powder

Treatments	Height of muffins (mm)	Weight (g)	Volume (cm ³)	Specific volume (cm ³ /g)	Weight loss (g/100g)	Viscosity of muffin batter (cP)	Specific gravity of muffin batter
Control	37.43±0.06 ^a	31.28±0.01 ^e	62.33±0.48 ^a	1.99±0.02 ^a	11.73±0 ^a	8240.3±0.58 ^f	1.056±0.01 ^f
2%PPP	33.36±0.01 ^b	31.42±0.01 ^d	60.33±0.48 ^b	1.92±0.02 ^b	11.71±0 ^b	9272.4±0.51 ^e	1.268±0 ^e
4%PPP	32.68±0.01 ^c	31.58±0.01 ^c	59.33±0.48 ^b	1.88±0.02 ^c	11.46±0.01 ^c	10019.7±0.58 ^d	1.360±0 ^d
6%PPP	31.14±0.01 ^d	31.65±0.01 ^b	55.33±0.45 ^c	1.75±0.02 ^d	10.96±0.01 ^d	11024.8±0.40 ^c	1.438±0 ^c
8%PPP	28.01±0.01 ^e	31.68±0.01 ^b	53.33±0.45 ^d	1.68±0.02 ^e	10.79±0.01 ^e	12027.3±0.58 ^b	1.462±0 ^b
10%PPP	26.62±0.01 ^f	32.03±0.06 ^a	50.33±0.30 ^e	1.57±0.02 ^f	10.14±0.01 ^f	13019.7±0.40 ^a	1.481±0 ^a

Values are expressed as mean ± SD of three independent determinations. Values in columns followed by the same letter are not significantly different at $p \leq 0.05$ as measured by Duncan's test

- The organoleptic properties of the muffins fortified with pomegranate peel powder were assessed using 9-point hedonic scale and the significant variation was recorded in pomegranate peel powder muffins with respect to sensorial properties especially texture, taste and mouthfeel when compared with control sample. The increase in level of pomegranate peel powder resulted to increase in the hardness and slightly grittiness. The fortification levels up to 8% in muffin was within acceptable range by the panel members.
- The shelf life of muffins was evaluated by storage at room temperature and low temperature (5°C) using high density polyethylene (HDPE) as packaging material. The effect of fortification of pomegranate peel powder on oxidative and microbial stability of muffins were investigated during the storage period of 4 weeks at different storage conditions. The moisture content, free fatty acid content, peroxide value, texture profile analysis and microbial analysis were carried out for all the treatments.
- The muffins sample stored at room temperature showed visible microbial growth during 3rd week of the storage and parameters recorded at the interval of each week. The moisture content of muffins decreased during storage period (3weeks) from 16.68% to 11.62% (control) and 19.08% to 14.11% (10%PPP). The oxidative stability of muffins was measured in terms of free fatty acid content (%) and peroxide value (meq.of O₂/kg of oil). The free fatty acid content was significantly increased from 0.27% to 1.36% in control sample and 0.18% to 0.71% in muffin with pomegranate peel powder. The increase in free fatty acid content in pomegranate peel powder fortified muffins was significantly lower when compared with control. Similarly peroxide value was increased from 3.04 to 6.08 meq.of O₂/kg of oil (control) and 2.50 to 3.15 meq.of O₂/kg of oil (10%PPP). The muffins fortified with pomegranate peel powder showed higher oxidative stability when compared with control sample due to high phenols content and antioxidant activity.
- Similar trends with respect to moisture content, free fatty acids and peroxide value were observed for the muffins stored at low temperature (5°C). In both the cases muffins with pomegranate peel powder showed significantly higher oxidative stability in comparison with control. The shelf life of muffins at low temperature (5°C) recorded as 4 weeks.



- Microscopy images of muffin batter**

Micrograph obtained for the control batter, and for the batter with 2%, 4%, 6%, 8% and 10% pomegranate peel powder as shown in Fig 5. When refined wheat flour was replaced by increasing quantities of pomegranate peel powder, a change in air bubble size and quantity was observed. There was decrease in the number of air cell with increase in the level of pomegranate peel powder but the radius of air cell (μm) was recorded as increased. Bigger air cell in pomegranate peel powder added muffin batter was observed as compared to control.

Table 6.21. Air cells of pomegranate peel powder fortified muffins batter observed under light microscopy

Treatments	Control	2%PPP	4%PPP	6%PPP	8%PPP	10%PPP
No. of air cells	11	11	8	8	7	5
Air cells radius range (μm)	8.01 to 33.58	18.65 to 42.84	19.92 to 44.02	20.57 to 44.07	28.32 to 44.32	49.36 to 70.14
Area range (μm^2)	201.46 to 3540.71	1092.16 to 4996.4	1245.97 to 6084.56	1666.57 to 6094.4	2518.35 to 6167.78	7650.32 to 15447.61

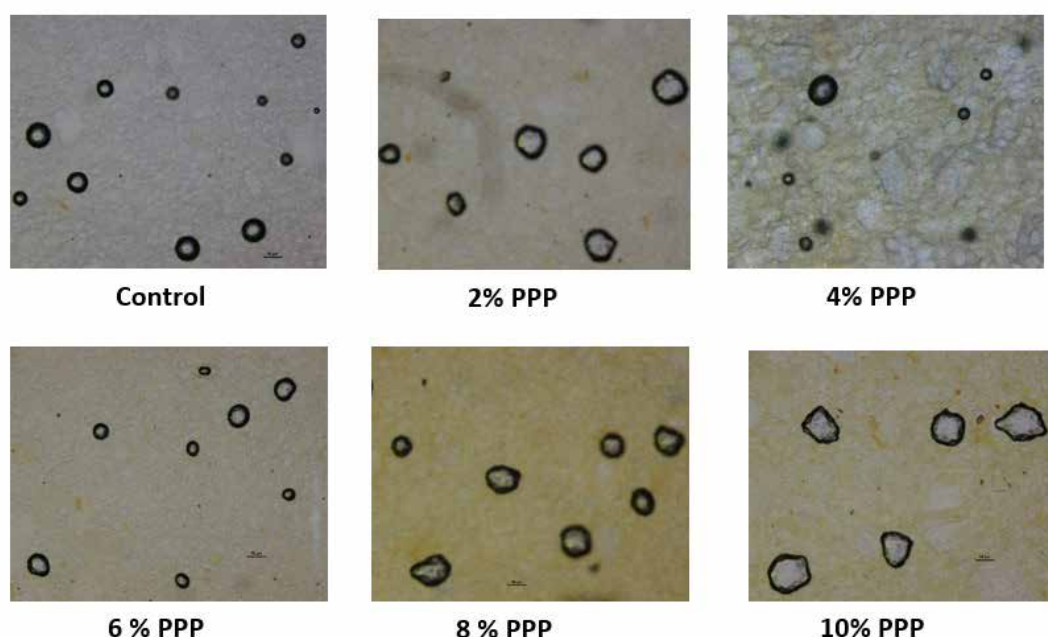


Fig 6.13. Micrographs for the muffin batter prepared with pomegranate peel powder obtained with light microscopy

- Pasting properties of flour blend for muffins incorporated with pomegranate peel powder**

The pasting properties of muffins flour blend fortified with pomegranate peel powder was evaluated using Rapid Visco Analyzer (RVA Tech Master, Perten Instruments, Australia) and it measured the pasting temperature, peak viscosity, trough, breakdown viscosity, final viscosity, set back viscosity and peak time. The RVA graph for the control sample along with sample containing pomegranate peel powder is shown in Fig 6. The increase in the level

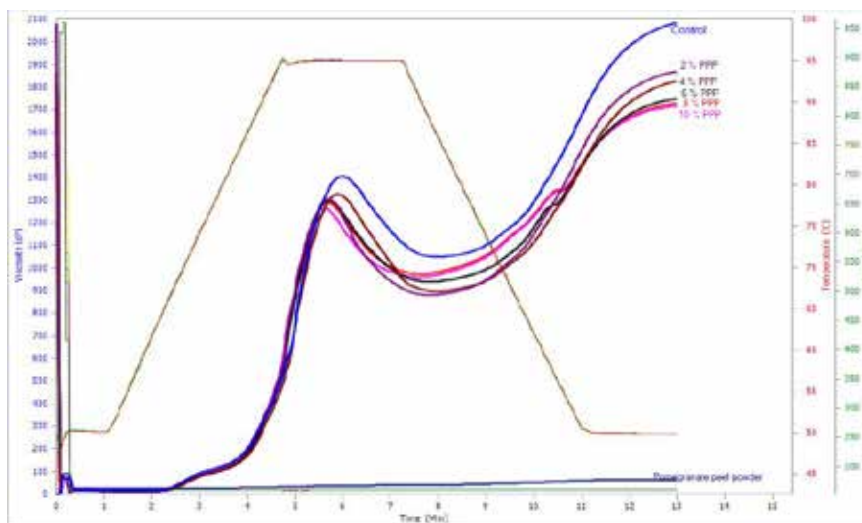


Fig 6.14. RVA graph for the muffins flour blend fortified with different levels of pomegranate peel powder

of pomegranate peel powder in muffins resulted to significant reduction in peak viscosity, trough viscosity and final viscosity. The peak viscosity attained during the heating portion of tests indicates the water binding capacity of the mixture.

• **Rheological properties of the muffins flour blend fortified with different levels of pomegranate peel powder by rheometer**

In dynamic oscillation measurements, the potential energy that is dissipated as heat is separated into storage modulus and loss modulus. Storage dynamic modulus (G') is a measure of the energy stored in the material and recovered from it per cycle while the loss modulus (G'') is a measure of the energy dissipated or lost per cycle of sinusoidal deformation. In dynamic oscillation measurements, the frequency sweep of the two moduli (G' and G''), used to distinguish between the elastic and viscous properties of a material over a spectrum of times. When the viscous properties dominate, G'' exceeds G' , and *vice versa* ($G' > G''$) when the elastic properties prevail. The dynamic rheological properties (storage modulus, loss modulus and phase angle) for the 10% (w/v) gel suspension of the muffin batter samples obtained from RVA studies were determined using Rheoplus MCR 51 Rheometer (M/s Anton Paar GmbH, Germany) at 30°C, using a parallel plate geometry system (PP20-SN5912, 1mm diameter) at 1 mm gap. The following experimental conditions were selected: frequency 1 to 10 Hz; strain of 1 per cent (%). For each treatment, storage modulus (G'), loss modulus (G''), complex modulus (G_{max}), phase angle (δ) were recorded and the measurements were conducted in duplicates.

The frequency dependence of storage modulus (G'), loss modulus (G'') and complex modulus (G_{max}) were increased with increase in the value of frequency from 0 to 10 Hz and with increase in the level of pomegranate peel powder. The value for loss modulus (G'') of sample was greater than value of storage modulus (G') in the frequency range studied, showing a predominantly viscous behavior of the muffin batter. The phase angle for all the sample showed sharp increase at initial frequency range of 0 to 5 Hz and tends to constant at 5 to 10 Hz (Fig.7).

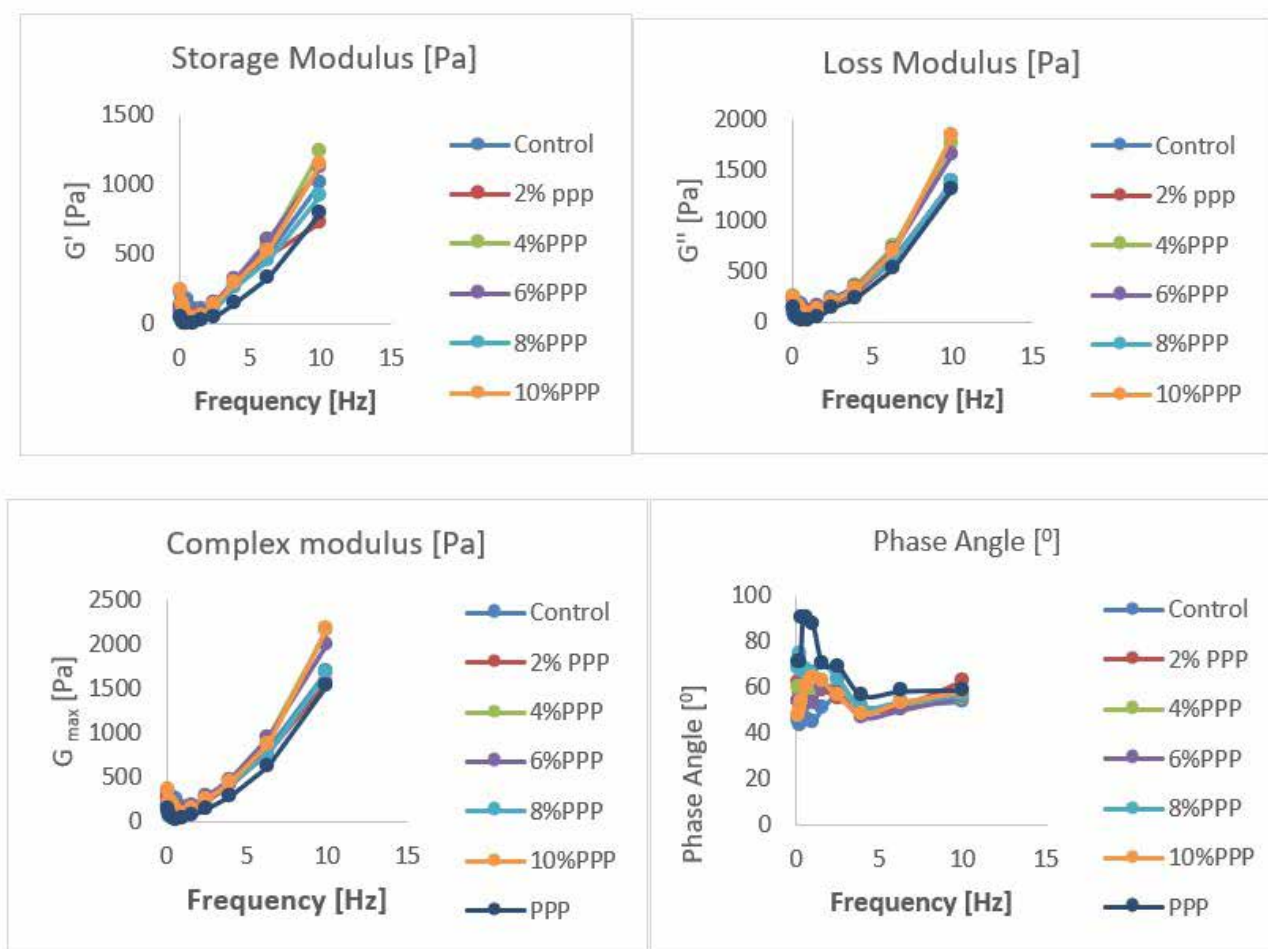


Fig 6.15. Storage modulus, loss modulus, complex modulus and phase angle of control batter and batters fortified with pomegranate peel powder

7. Externally Funded/ Collaborative Projects

7.1 PROJECT: ESTABLISHMENT OF DUS CENTRE ON POMEGRANATE AT ICAR- NRCP, SOLAPUR

(1) On-Site DUS characterization of farmer variety ‘Sharad king’

First year on-site DUS characterization of farmer variety namely ‘Sharad king’ was carried out in 2021-22 at Tupewadi (V), Aurangabad (D), Maharashtra and it was compared with the reference variety (Bhagawa) for 36 DUS characters (Fig. 17). The tested candidate variety was found to have distinctive characteristic features for petal length (long), petal width (large), Aril length (short) and fruit maturity (medium) in comparison to reference variety (medium, medium, medium and late maturity) (Fig. 18).

The two years consolidated report of the two hybrid varieties (NRCP H-4 and NRCP H-14) has showed that the NRCP H-14 is having vigorous plant growth habit with yellow with red tinge fruits, pink very sweet arils and hard seeds. While, NRCP H-4 also observed to be a vigorous hybrid variety whose fruit rind is yellow with red tinge colored, arils are pink with acidic juice embedded with hard seeds. All these are medium duration varieties takes about 140-165 days to mature after anthesis. In 2021, two hybrid varieties i. e., NRCP H-6 (Solapur Lal) and NRCP H-12 (Solapur Anardana) have been registered in the Plant Varieties Registry, PPV&FRA, New Delhi as new varieties.



Fig. 7.1: On-site DUS characterization of farmer variety (“Sharad King”) at Aurangabad, Maharashtra

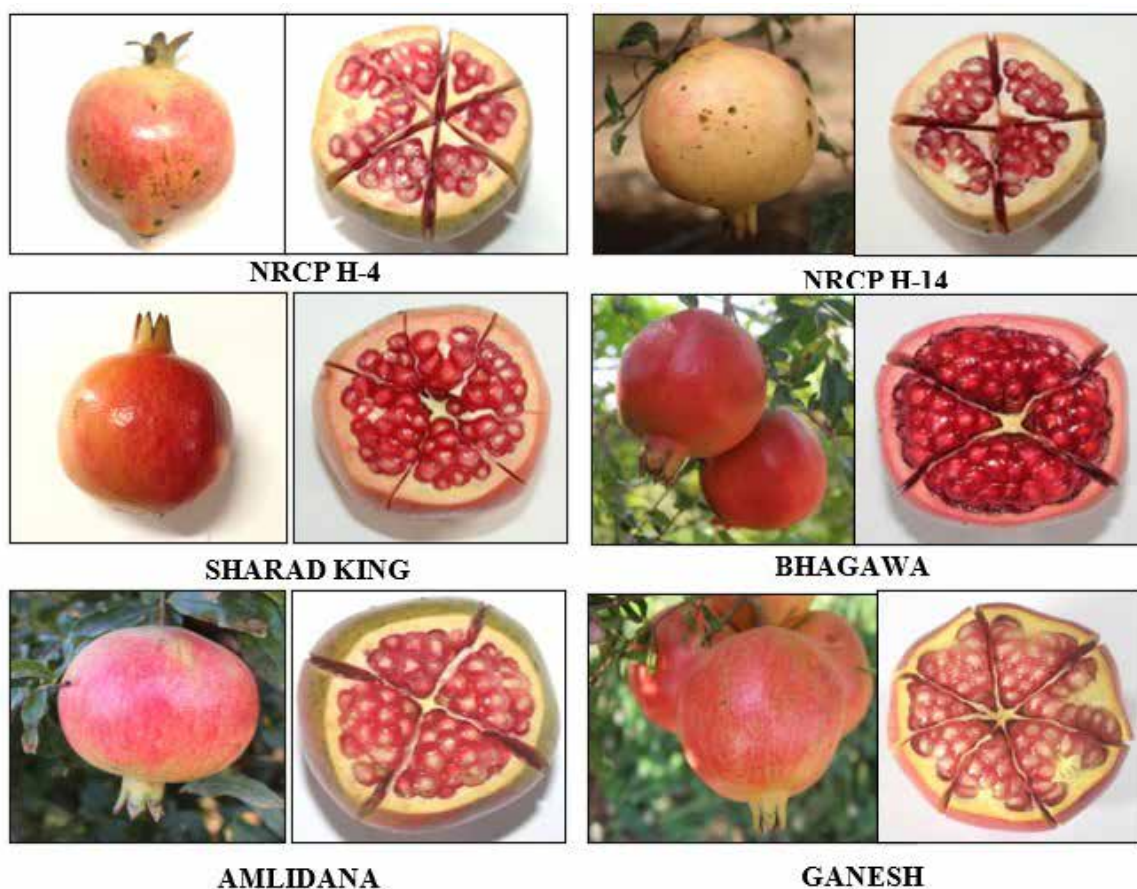


Fig. 7.2: Glimpses of pomegranate varieties characterized for DUS traits during 2021-22

(2) Molecular characterization of pomegranate germplasm accessions:

48 pomegranate genotypes consist of both wild and cultivated types were assessed by using 30 SSR markers. All the 48 genotypes genotypic data was scored and analyzed. The number of alleles of loci was varied from 2 to 4. Total of 40 alleles were found in the studied genotypes. DARwin ver.2.0 was used to analyze the data. Maximum genetic dissimilarity (0.53) was observed between IC-318712 and IC-318718 as well as IC-318712 and Acc-08 collection, while non-significant/lower dissimilarity was observed between Acc-11 and IC-318702 (0.09). Three clusters (wild types) were derived from unweighted neighbour joining which uses a criterion of unweighted average on dissimilarity. The polymorphic information content ranged from 0.12 to 8.69 with an average of 0.53. The clustering analysis was well supported by principle component analysis (PCA). The first two axis of PCA with positive two values 0.0197 and 0.0122 accounted for 46.71% of the total variation. The first axis has accounted 28.76%, whereas second axis covered 17.95% of variance. The molecular with high Polymorphic information content will help in future molecular diversity studies. The pgssr 54, 57 and 32 were found to be highly polymorphic with given set of markers (Fig 19).

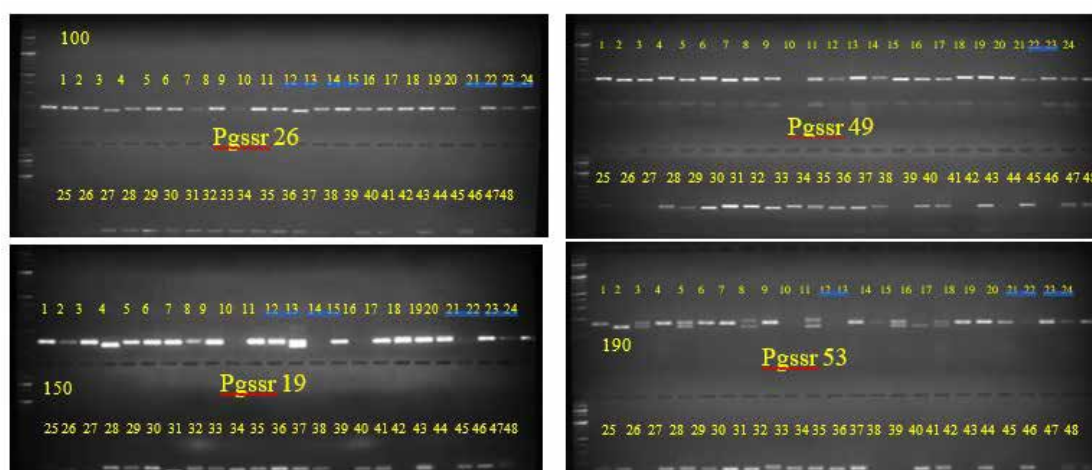


Fig7.3. Molecular diversity analysis of germplasm lines by using SSR markers (1: IC-318706; 2: IC-318743; 3: IC-318764 ; 4: IC-318734; 5: IC-318724; 6: IC-318762; 7: IC-318703; 8: IC-318744; 9: IC-318749; 10: IC-318733; 11: IC-318702 ; 12: IC-318707; 13: IC-318740; 14: IC-318716 ; 15: IC-318712; 16: IC-318793 ; 17: 1185; 18: 1197; 19: Acc. No.-1; 20: Mukteshwar; 21: 1184 ; 22: EC-676951; 23: Acc. No.-5; 24: Acc. No.-2 ; 25: Acc. No.-4; 26: 1181; 27: 1195; 28: 1252; 29: BBSC-6(3); 30: 1255; 31: Almoda; 32: 1180; 33: IC-318749; 34: IC-318733; 35: IC-318702; 36: IC-318707; 37: IC-318740; 38: IC-318716; 39: IC-318712; 40: IC-318793; 41: 1185; 42: 1197; 43: Acc. No.-1; 44: Mukteshwar; 45: 1185; 46: EC-676951; 47: Acc. No.-5; 48: Acc. No.-2.

PROJECT : ALL INDIA COORDINATED RESEARCH PROJECT ON ARID ZONE FRUITS

MLT on Evaluation of sweet type variety 'Solapur Lal':

Multi-locational trial on pomegranate variety Solapur Lal was conducted in Lead Centre Solapur besides four other coordinating centres under All India Coordinated Research Project on Arid Zone Fruits during 2020-21. The planting material distributed to other centres for MLT include, HRS – APHU, Ananthapuram; ICAR-CIAH, Bikaner, ICAR-IIHR, Bengaluru and MPKV, Rahuri.

At ICAR-NRC on Pomegranate, Solapur the trial was initiated by planting the air-layer progenies in C2 block, Kegaon Experimental Farm, during Nov 2018.

Design : Randomized Block Design
Treatments : Ganesh, Solapur Lal, Phule Bhagawa Super, Bhagawa (04)
Replications : Seven (07)
Unit : Two (02)

The data on vegetative growth parameters viz., plant height (cm), plant spread (East West), plant spread (North South), and stem girth were recorded at two years after planting (Table).

The results revealed that sweet type varieties differed significantly with respect to different growth parameters. Among four varieties, Solapur Lal recorded the highest value for plant height (167.9cm), E-W spread (160.0cm), N-S spread (152.1cm) and stem girth (12.9cm) due to its hybrid vigour. This was closely followed by Ganesh and performance of Solapur Lal and Ganesh were found to be on par. The check variety, Bhagawa recorded the lowest value for different growth parameters.



Table 7.1. Growth performance of pomegranate varieties during second year under Solapur condition

Variety	Plant height (cm)	Plant spread East-West (cm)	Plant spread North-South (cm)	Stem girth (cm)
Ganesh	156.4	149.3	144.3	12.3
Solapur Lal	167.9	160.0	152.1	12.9
Phule Bhagawa Super	140.7	136.4	130.7	9.6
Bhagawa (Check variety)	136.4	131.4	125.7	9.0
CD (5%)	6.75	4.14	6.04	0.73

MLT on Evaluation of sour type variety “Solapur Anardana”:

Multi-locational trial on pomegranate variety Solapur Anardana was conducted in Lead Centre Solapur besides four other coordinating centres under All India Coordinated Research Project on Arid Zond Fruits during 2020-21. The planting material distributed to other centres for MLT include, HRS, Ananthapuram; ICAR-CIAH, Bikaner, ICAR-IIHR, Bengaluru & MPKV, Rahuri.

At ICAR-NRC on Pomegranate, Solapur the trial was initiated by planting the air-layer progenies in C2 block, Kegaon Experimental Farm, during Nov 2018.

Design : Randomized Block Design

Treatments : IC-1181, Solapur Anardana, Amlidana (03)

Replications : Seven (03)

Unit : Two (02)

The data on vegetative growth parameters viz., plant height (cm), plant spread (East West), plant spread (North South), and stem girth were recorded at two years after planting (Table 7.2).

The results revealed that sour type varieties differed significantly with respect to different growth parameters. Among three varieties, Solapur Anardana recorded the highest value for plant height (175.0cm), E-W spread (165.7 cm), N-S spread (158.6cm) and stem girth (12.5cm) due to its hybrid vigour. This was followed by IC-1181. The check variety, Amlidana recorded the lowest value for different growth parameters.

Table 7.2. Growth performance of pomegranate varieties during second year under Solapur condition

Variety	Plant height (cm)	Plant spread East-West (cm)	Plant spread North-South (cm)	Stem girth (cm)
IC-1181	145.7	138.6	132.1	11.5
Solapur Anardana	175.0	165.7	158.6	12.5
Amlidana	98.6	95.0	92.5	3.40
CD (5%)	3.36	4.12	3.40	0.60

Brief report on insect pests of pomegranate:

1. Report of Pomegranate a new host for the invasive mealybug *Pseudococcus jackbeardsleyi* (Newstead)

Mealybugs were found scattered on the leaves, fruits and trunks and were observed sucking the sap from various parts of the pomegranate plants including leaves, stems, flowers and fruits (Fig. 1). The mealybug was identified as *P. jackbeardsleyi* (Gimpel and Miller), at the National Bureau of Agriculturally Important Insects, Bengaluru through slide mounting techniques. The invasive mealybug is greyish; thin filaments around the body, caudal pair about one half of the length of the body, and ovisac covering hind part of the body. 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 25-30 if timely proper management practices were not taken its infestation may increase further. The shoots infested by mealybugs exhibits the stunted growth, yellowing of leaves with no or poor flower induction and dropping of flower and drop of young fruits. Symptoms on the maturing, developing and ripening fruits indicates the eruptions, reddening of the rind deformation in shape and browning of arils was recorded.



Fig. 7.4 Mealybug infestation on ripening pomegranate fruits

2. Report of scale insect *Hemiberlesia lataniae* (Signoret) and *Ceroplastes sp.* damage on pomegranate

The diapsid and Coccidae scales *Hemiberlesia lataniae* (Signoret) and *Ceroplastes sp.* occasionally infest on a pomegranate but they are of minor status. The hard scales generally infest fruits and twigs and if allowed to multiply unchecked they will affect the fruit quality and they can kill the terminal growth, and in the case of young trees may threaten their vitality.

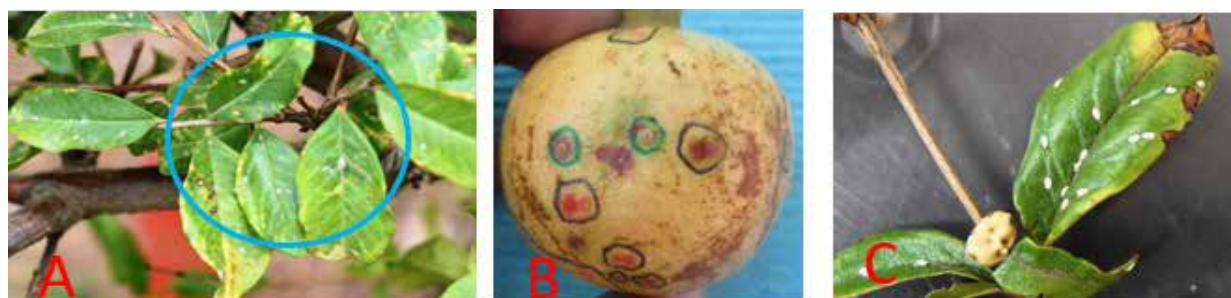


Fig. 7.5. *Hemiberlesia lataniae* infestation on leaf
B. *H. lataniae* on fruit and C. *Ceroplastes sp.* on the leaf and twig



Report of Leaf eating caterpillar's damages on pomegranate

The damage is mainly caused by caterpillars and the adult moths have been recorded as a secondary feeder on the pomegranate fruits. The caterpillars feed voraciously on pomegranate leaves. Feeding on the edges inwards, leaving behind only the midrib and the stalk. The damage is maximum during Mrig and hasta bahar crops.

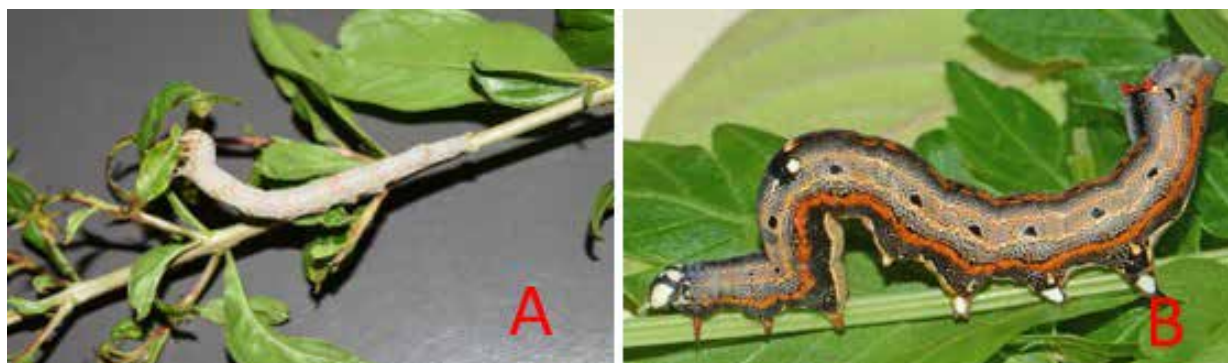


Fig. 7.6. *Ophusia tirhaca* B. *Achaea janata* damage Symptoms

7.3 PROJECT: HORTICULTURE CROP PEST SURVEILLANCE AND ADVISORY PROJECT (HORTSAP) SUB SCHEME UNDER CROP SURVEILLANCE AND ADVISORY PROJECT FOR MANGO, POMEGRANATE & BANANA (CROPSAP) SCHEME

The survey of insect pest of pomegranate was carried out in Maharashtra in an area of 530.75 care covering the 3 districts and 13 talukas and major incidence reported was Thrips, fruit sucking moth, shot hole borer, stem borer and green stink bug and in Karnataka in an area of 314.15 acres covering the 4 districts and 13 talukas. The major incidence was Thrips, green stink bug and stem borer (Table-1). Report of pomegranate fruit borer natural enemies: *Brachymeria* sp. has been collected from the field-infested pupae. The percent pupal parasitization recorded was 13-14.

Table 7.3: Occurrence (% incidence) of important insect pests on pomegranate in different districts of Karnataka, Maharashtra and Madhya Pradesh

State	District	Area surveyed (Acre)	Average % incidence					
			Thrips	FB	FSM	SHB	SB	GSB
M.H	Pune (1)	8.5	7.75-16.15	1.0-1.85	1.5-2.0	0.0	0.0	1.5-4.8
	Solapur (10)	504.5	15.5-75.24	2.5-11.58	0-20.75	0-59.42	4.5-12.8	0-36.5
	A.nagar (2)	17.75	0-66.55	1.5-3.5	0.0	8.95-25.8	3.5-11.95	5.5-15.45
	Total area/ %Incidence	530.75	0-75.24	1.0-11.58	0-20.75	0-59.42	0-12.8	0-36.5



State	District	Area surveyed (Acre)	Average % incidence					
			Thrips	FB	FSM	SHB	SB	GSB
K.A	Kalaburgi (1)	20.0	1.5-15.44	1.25-4.5	0.0	0.0	-	1-2.0
	Vijapur (3)	69.75	0-71.25	2.33-5.6	0.0	0.0	1.5-3.8	0.0
	Bagalkot (6)	133.2	15.33-56.75	2.5-6.45	0.0	0.0	2.5-4.2	1.5 – 25.5
	Koppal (3)	91.2	13.45-46.45	2.25-5.5	0.0	0.0	0-2.5	0.0
	Total area/ % Incidence	314.15	0-71.25	1.25-6.45	0.0	0.0	0.0	0-25.5
M.P	Chindwada (1)	9.5	0-5.6	0.0	0.0	1-2.5	0.0	0.0

Numbers in parenthesis indicate the number of taluks covered during the survey; T= Twigs F= Fruits FB= Fruit borer FSM= Fruit sucking moth SHB=Shot hole borer SB=Stem borer GSB= Green stink bug

7.4 PROJECT: UNRAVELING MECHANISM AND DEVELOPING MITIGATION STRATEGIES FOR ARIL BROWNING AND FRUIT CRACKING IN POMEGRANATE

Biochemical characterization of healthy and brown arils

Based on the previous results 10 germplasm were selected for study

S. No.	More browning (above 10%)	Less browning (below 10%)
1.	Ganesh	Yodhpur collection
2.	Bassein seedless	IC-318754
3.	1205	IC-318720
4.	G-137	IC-318723
5.	P-16	Bedana thin skin

Aril browning is one of the major physiological disorders of pomegranate that hampers its quality and hence exports of fruits. Germplasm was grouped into a less severity group (LSG; less than 10% browning) and high severity group (HSG; more than 10% browning) based on the severity of browning. Five germplasm viz. Yodhpur collection, IC-318754, IC-318720, IC-318723, Bedana thin skin were selected under LSG and five germplasm viz. Ganesh, Bassein seedless, 1205, G-137, P-16 selected under HSG. For the present study, both normal and brown arils were collected from the same fruits and dried in oven. The raisins formed after drying were used for biochemical evaluations. Results are presented as the average under both severity groups.



- Results showed that the HSG germplasm exhibited more proline content i.e 27 mg/100g DW compared to the LSG germplasm that contained 21 mg/100g DW proline in dried pomegranate raisins.

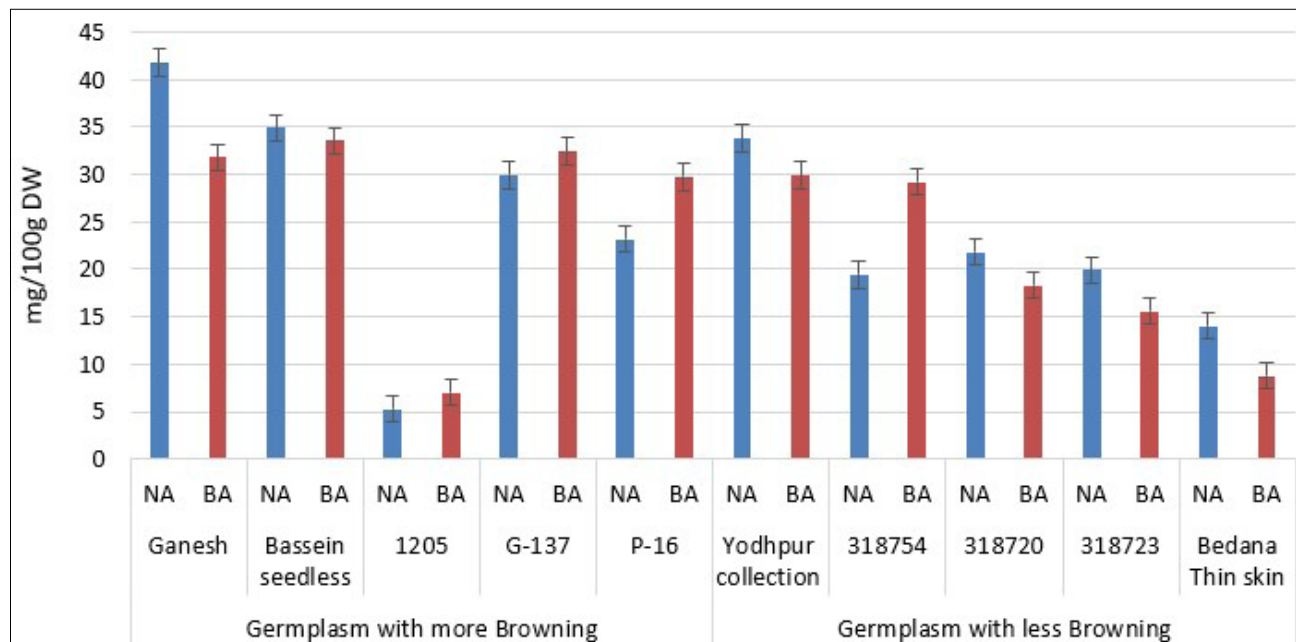


Fig 7.8 Difference in Proline Content in healthy and brown arils (NA: normal aril; BA brown aril)

Coefficient of Variation	17.803		
CD (0.01)	9.479	Value range	5.33-41.67
CD (0.05)	7.085	Mean	24.117
F cal	17.157**	SE means	1.38

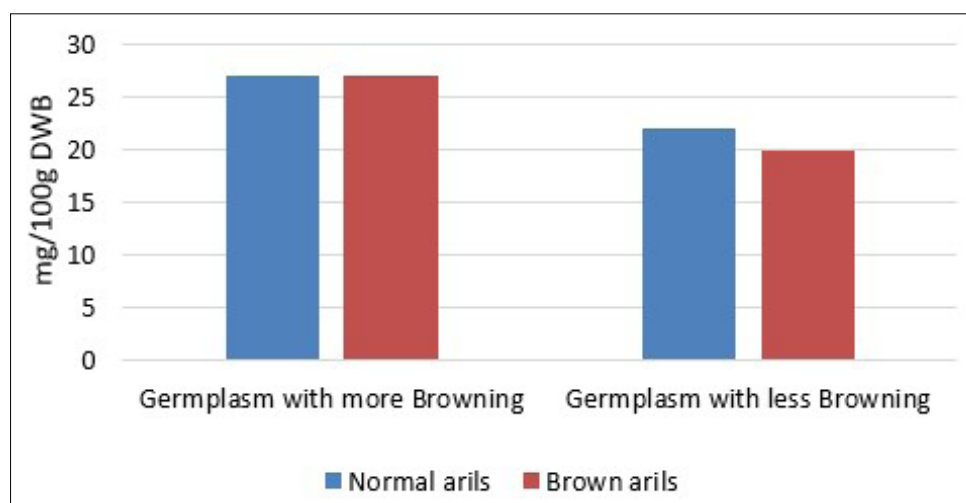


Fig 7.8 Comparison of Proline content in more and less browning group

- Malondialdehyde, a stress indicator also followed same pattern as proline does. Malondialdehyde was high in the HSG ($7.14 \text{ nmol.ml}^{-1}$) than in the LSG germplasm ($5.95 \text{ nmol.ml}^{-1}$).

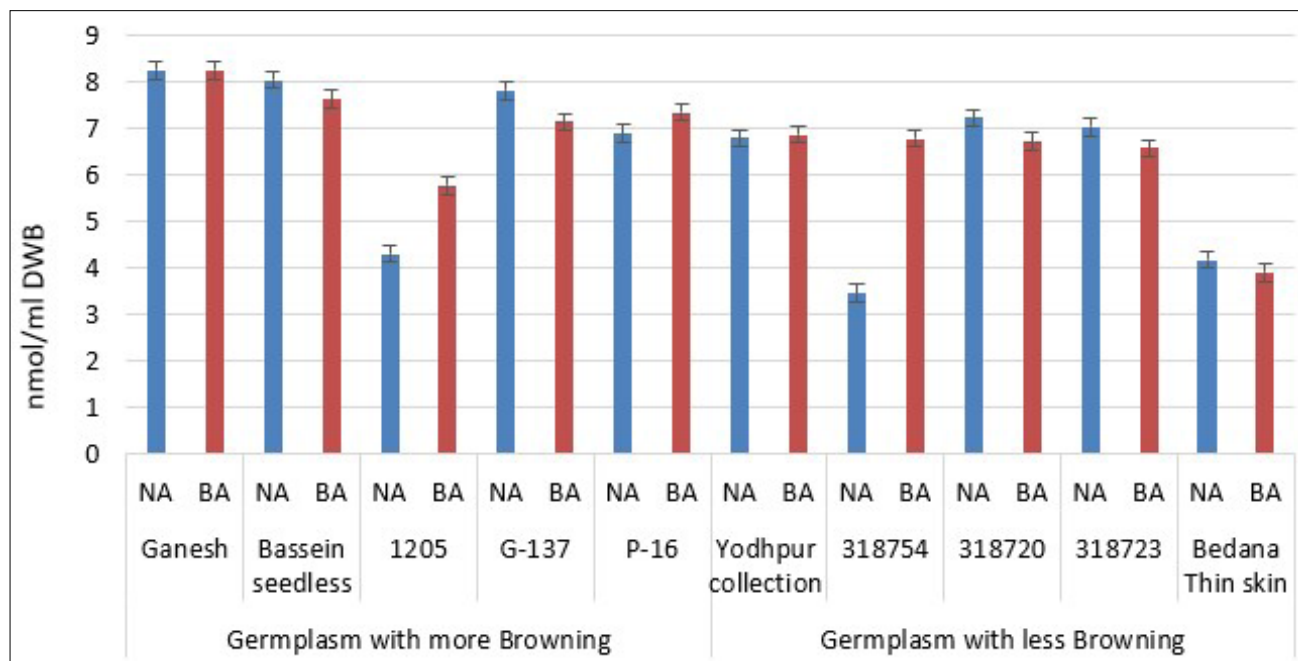


Fig 7.9 Difference in Malondialdehyde Content in healthy and brown arils (NA: normal aril; BA brown aril)

Coefficient of Variation	3.52		
CD (0.01)	0.509	Value range	3.45-8.25
CD (0.05)	0.381	Mean	6.55
F cal	120.79**	SE means	0.187

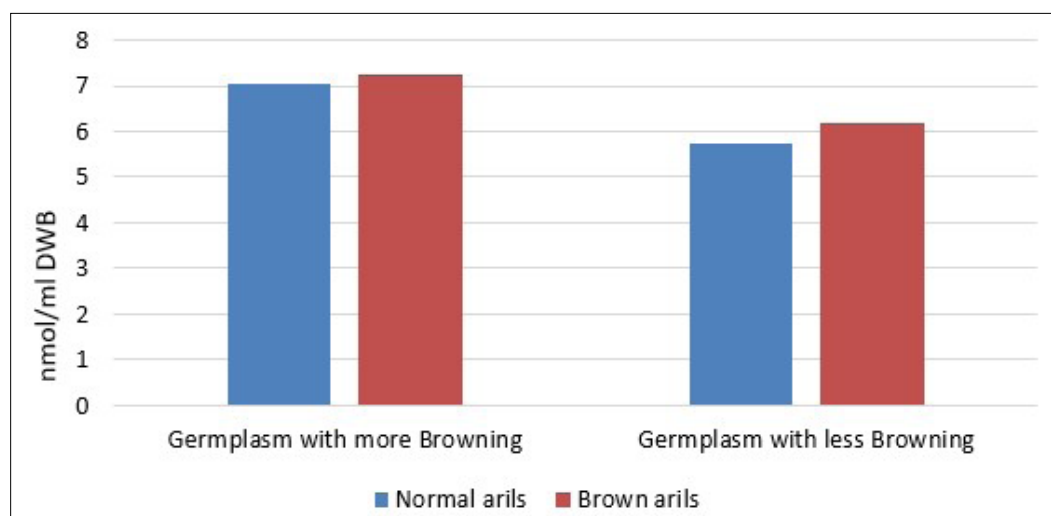


Fig 7.10 Comparison of total soluble protein in more and less browning group



- Protein content was 52.6 mg/g DW in LSG and 55.2 mg/g DW in HSG germplasm. More protein in HSG germplasm could be due to the activation of a certain group of proteins under stress conditions.

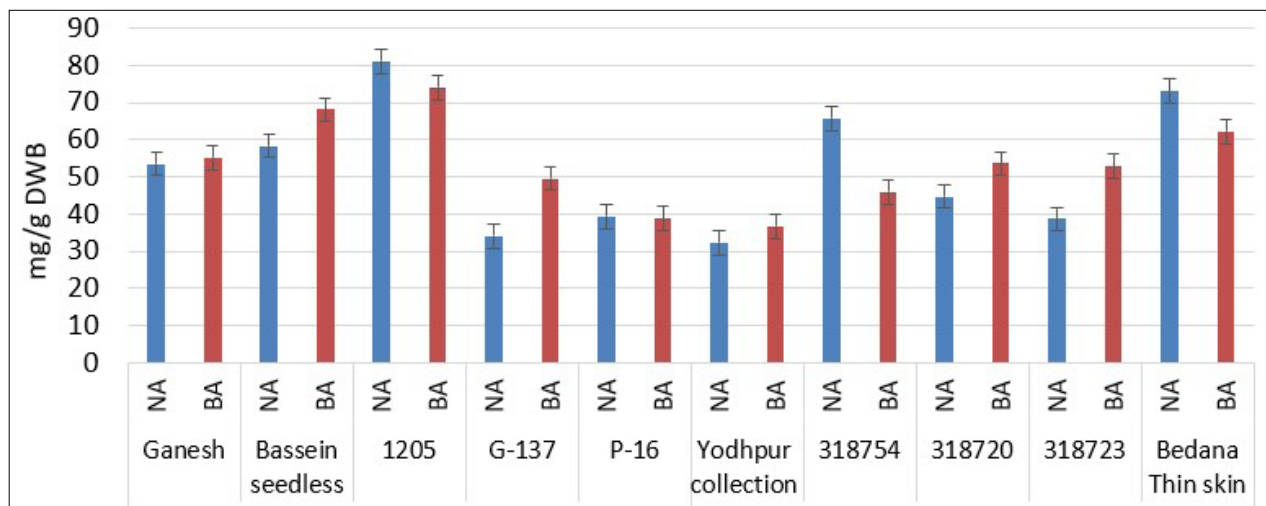


Fig 7.11 Difference in Total Soluble Protein Content in healthy and brown arils (NA: normal aril; BA brown aril)

Coefficient of Variation	9.334		
CD (0.01)	10.902	Value range	32-80
CD (0.05)	8.148	Mean	53
F cal	25.466**	SE means	3.203

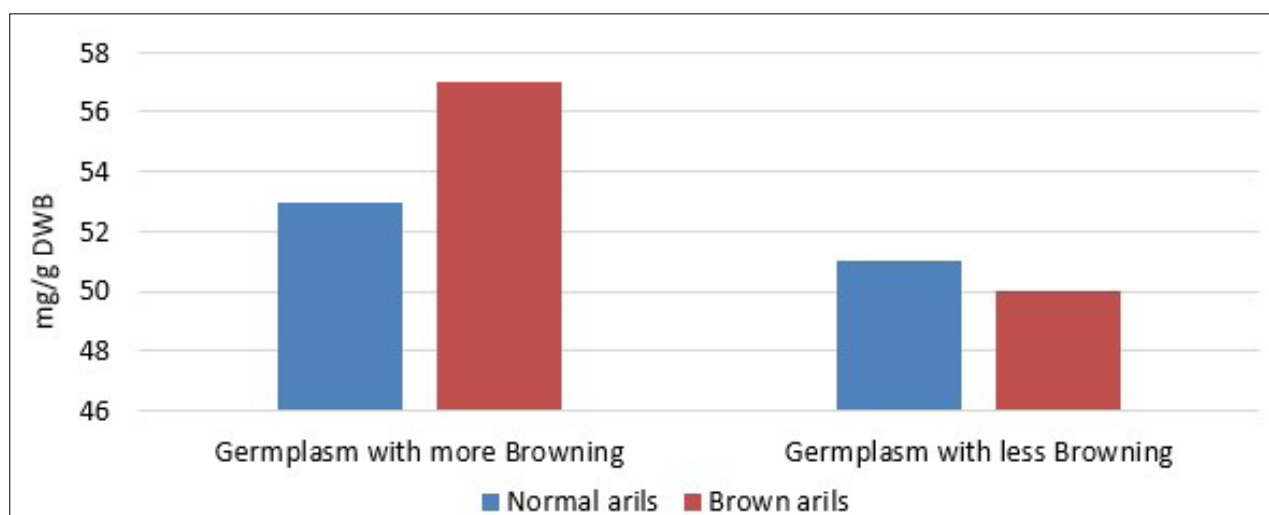


Fig.7.12 Comparison of total soluble protein in more and less browning group

- Ascorbic acid showed similar trend as protein, and was more in HSG (2.34 mg/g DW) and lower in LSG germplasm (2.08 mg/g DW).

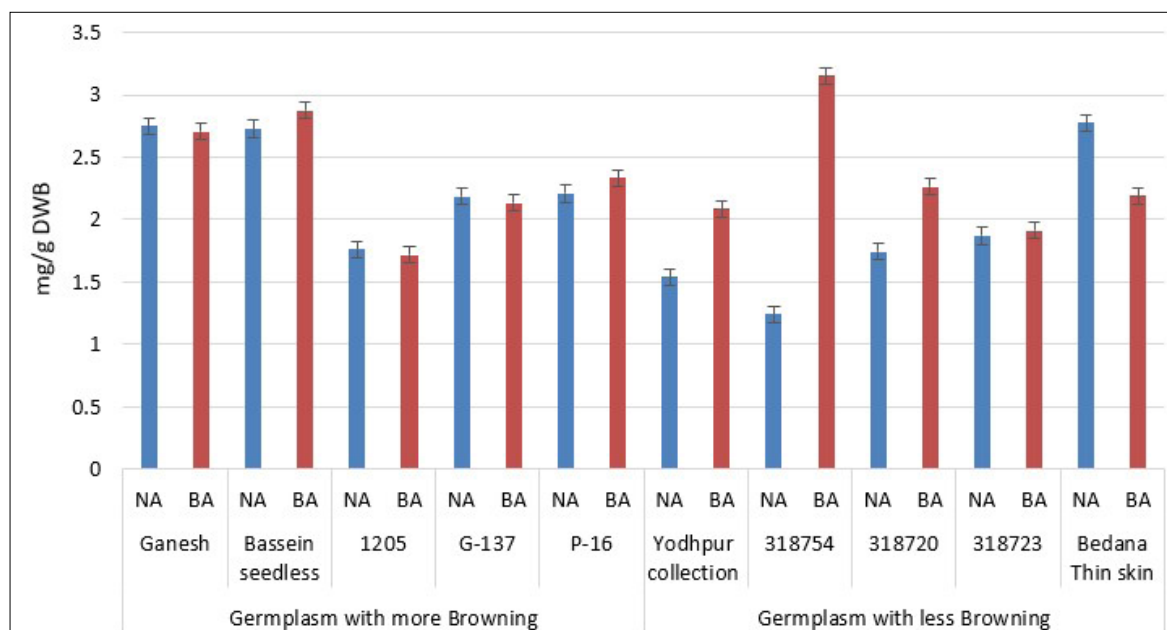


Fig 7.13 Difference in Ascorbic acid content in healthy and brown arils (NA: normal aril; BA brown aril)

Coefficient of Variation		7.111		
CD (0.01)	0.347	Value range	1.24-3.15	
CD (0.05)	0.259	Mean	2.208	
F cal	30.511**	SE means	0.066	

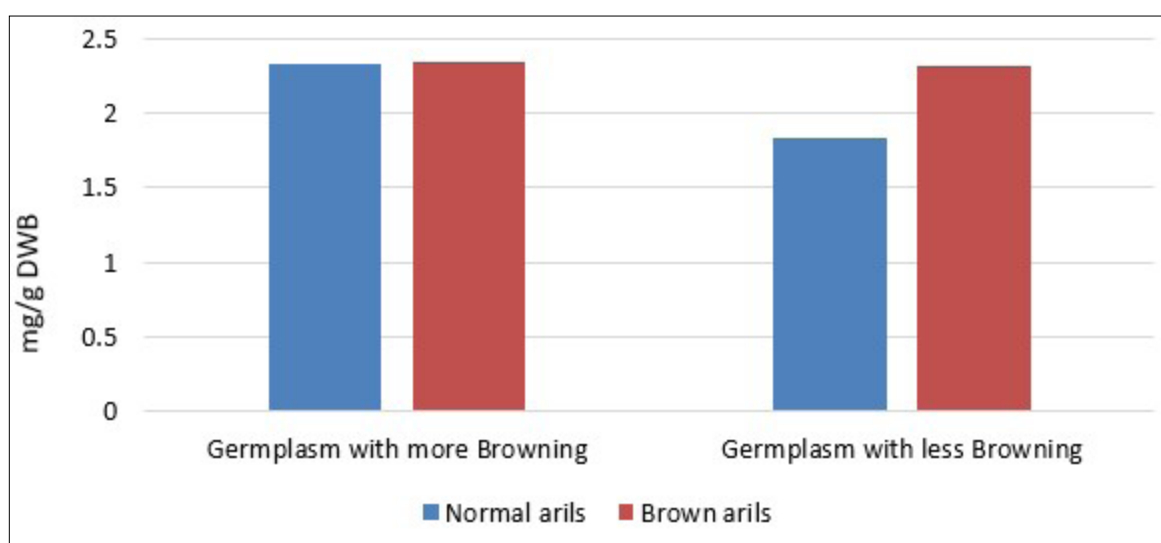


Fig 7.14 Comparison of Ascorbic acid content in more and less browning group



- Total phenolics decreased in HSG (8.3 mg/g DW) and was 8.6 mg/g DW in LSG.

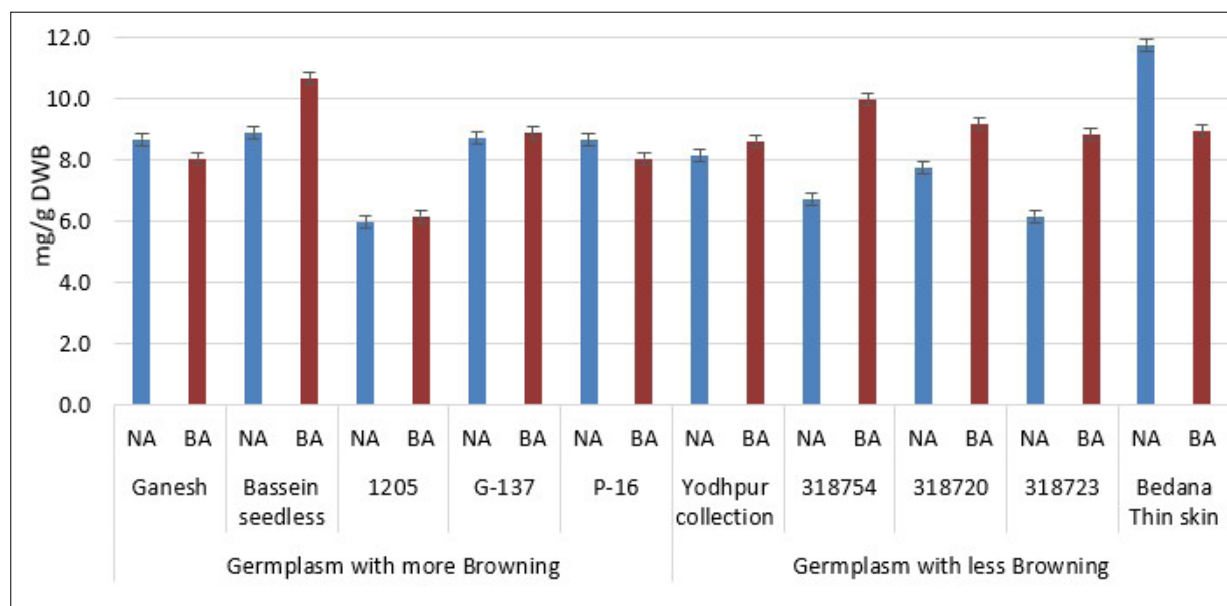


Fig 7.15 Difference in Total polyphenols Content in healthy and brown arils (NA: normal aril; BA brown aril)

Coefficient of Variation	9.206		
CD (0.01)	1.715	Value range	5.97-11.77
CD (0.05)	1.282	Mean	8.44
F cal	10.494**	SE means	0.202

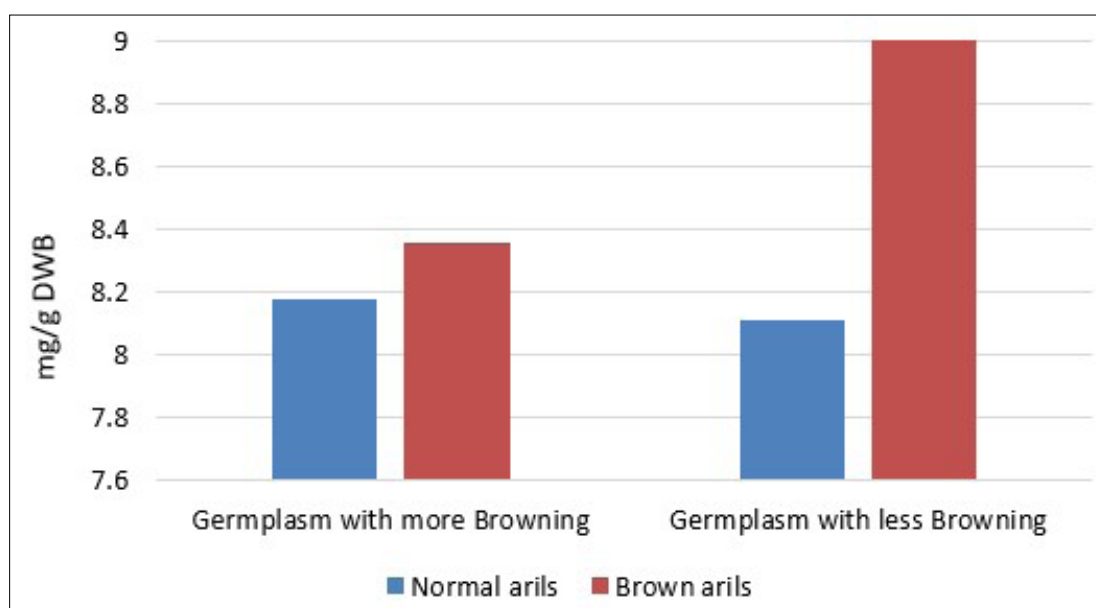


Fig 7.16 Comparison of total polyphenols in more and less browning group

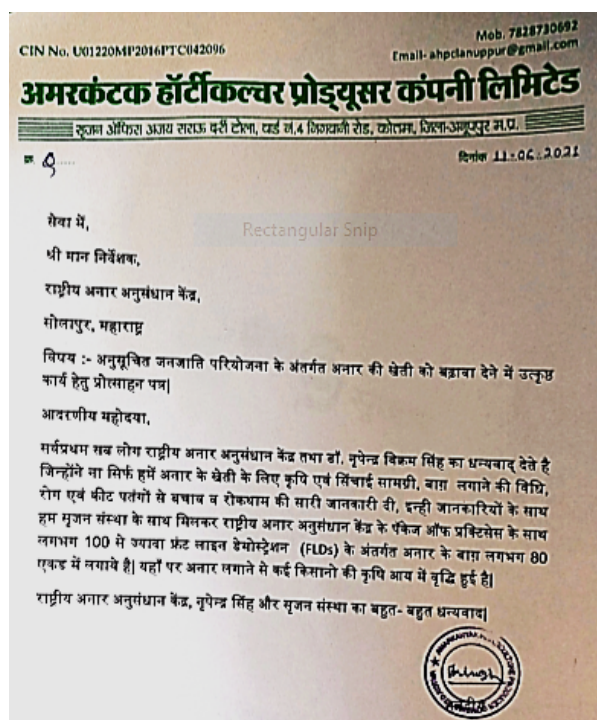
Activities under Tribal Sub-plan / STC

Table 1: Tribal farmers adopted by ICAR-NRCP, Solapur under TSP/STC

State	District	Sub-district	Village	ST population benefit-ed	Year of adoption	Status as on 31.12.2021
Madhya Pradesh	Anuppur	Kotma	Manmari Reusa Baskhala Baskhali Chaka Changeri Reula Behratola Jamunia Chapani Chhauhari Chapani Kadmaha Pathroudi Thouda	115 (including family members)	2017-18	Pomegranate orchards established & in bearing stage Agri-input and technical support provided Capacity building programmes organized Master trainers groomed
Chhatisgarh	Koriya	Manendragarh	Kerabehara Dorki	10 (including family members)	2017-18	Pomegranate orchards established & in bearing stage Agri-input and technical support provided Capacity building programmes organized Master trainers groomed



Agri-input distribution to ST farmers by the SDM at Jatara, Anuppur under STC/ TSP scheme of ICAR-NRCP



Adopted orchard visit by the SDM Jatara and Letter of Appreciation by the FPC

Activities under SCSP

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

State	District	Sub-district	Village	SC population benefitted	Year of adoption	Status as on 31.12.2021
M.P.	Tikkamgarh	Jatara	Tal Lidhora Barmadang Dor	85 (including family members)	2019-20	Pomegranate orchards established and are in bearing stage Agri-input and technical support provided Capacity building programmes organized
Karnataka	Kalaburgi	Aland	Santanur Vaijapur	15 (including family members)	2020-21	Technical and agri-input support provided Trainings organized Agri-input and technical support provided Capacity building programmes organized

Maharashtra	Solapur	Madha	Nimgaon and Solankarwadi	20 (including family members)	2019 and 2021	Pomegranate orchards established and are in bearing stage
						Agri-input and technical support provided Capacity building programmes organized
Rajasthan	Barmer and Alwar	Balotra and Rampur	Rajeshwar Nagar, Roopbas, Sherpur	20 (including family members)	2019	Pomegranate orchards established and are in bearing stage Agri-input and technical support provided Capacity building programmes organized



टीकमगढ़ भास्कर 08-08-2021

कृषि • राष्ट्रीय कृषि अनार अनुसंधान केन्द्र सोलापुर के कृषि वैज्ञानिक दे रहे प्रशिक्षण नई तकनीक से किसान अनार की खेती से कमा रहे हैं लाभ

भास्कर संवाददाता | जलारा

अनार की खेती को बढ़ावा देने के लिए भारत सरकार की अनुसूचित जाति परियोजना राष्ट्रीय अनार अनुसंधान केन्द्र किसानों को अनार की खेती से अधिक फायदा पहुंचाने के लिए काम कर रहा है। राष्ट्रीय अनार अनुसंधान केन्द्र सोलापुर के वरिष्ठ वैज्ञानिक डॉ. नृपेन्द्र विक्रम सिंह ने बताया कि ब्लॉक जलारा के 16 अनुसूचित जाति के किसानों को अनार फसल संबंधित दवाई, खाद, कीट नियंत्रण संबंधित सामग्री उपलब्ध कराई गई है। जिससे किसानों ने इसकी खेती कर लाभ लिया है। किसानों को नई तकनीक



कम लागत में ज्यादा उत्पादन के लिए प्रोत्साहित किया जा रहा है। डॉ. एनवी के सिंह वरिष्ठ वैज्ञानिक

राष्ट्रीय अनुसंधान संस्था केन्द्र सोलापुर के द्वारा बुन्देलखंड के 500 किसानों को अभी तक अनार

की खेती को बढ़ावा देने के लिए प्रशिक्षण दिया जा चुका है। जिससे किसानों को अधिक लाभ हो रहा है।

किसान ने पिछले साल 8 क्विंटल अनार बेचे

कुमार शाक्य सहित राष्ट्रीय कृषि अनार अनुसंधान केन्द्र सोलापुर के कृषि वैज्ञानिकों द्वारा समय-समय पर प्रशिक्षण एवं मार्गदर्शन दिया गया है। जिससे जलारा क्षेत्र के किसानों को फायदा हो रहा है। किसान बालचन्द्र अहिरवार ग्राम लिथीय ताल ने बताया कि संस्थान के सहयोग से प्रशिक्षण दिया गया है। जिससे मुझे अनार की खेती में फायदा मिलने लगा है। पिछले साल अहिरवार ने 8 क्विंटल अनार बेचे थे और इस साल भी अनार के फल तैयार होने लगे हैं।



Agri-input distribution to SCSP beneficiary during training programme



Agri-input distribution and orientation programme for SC beneficiary farmers of Kalaburgi and demonstration plot at Barmer



Adopted pomegranate orchards at Alwar under SCSP scheme

Table 2. Training programmes/ workshop/farmers' field day organized for tribal and SC farmers under SCSP / STC

S. 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, TSP and MGMG	ICAR-NRCP (Virtual mode)	11 th -13 th Jan, 2021	33
2.	Material distribution and orientation programme for SC beneficiary farmers of Vaijapur and Santanur	ICAR-NRCP, Solapur	25 th March, 2021	5
3.	Model propagation and orchard management practices for sustainable pomegranate production for farmers and coordinating agencies under SCSP	ICAR-NRCP, Solapur	26 th -29 th Oct, 2021	30



Release of technical bulletin during inaugural session of the training programme for SCSP beneficiary farmers



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	Name of organizers	Date	No. of participants
Training:					
1.	Quality pomegranate production value addition for doubling farmer's income.	ICAR-NRCP, Solapur	Course Director- Dr. J.S.Sharma, Course co-ordinator-Dr. A. Maity, Dr. Somnath Pokare	15-17 Feb.2021	26
2.	Training program on "Good Agricultural Practices for export quality pomegranate production" to farmers of S. Solapur Tehsil, Solapur during 10-12 January 2022.	ICAR-NRCP	Training Coordinator- Dr. K.Dhinesh Babu, Co-cordinator- Mr. Rahul Damale	10.01.2022- 12.01.2022	30 farmers of South Solapur Taluk, Solapur Dist, MS.
3.	Four days MANAGE, Hyderabad sponsored collaborative online training program on "Modern practices for export quality pomegranate production and value addition" for extension officers of State Agri./Hort.	ICAR-NRCP	Dr. N.V.Singh	28-31 st July, 2021	49
4.	Model Propagation and Pomegranate Production Technologies for Farmers and Coordinating Agencies under SCSP, TSP and MGMG	ICAR-NRCP (Virtual mode)	Dr. N.V.Singh	11 th -13 th Jan, 2021	33
5.	Material distribution and orientation programme for SC beneficiary farmers of Vaijapur and Santanur	ICAR-NRCP, Solapur	Dr. N.V. Singh	25 th March, 2021	05



S. No.	Title of Trainings/ Workshops/ Farmers Fair/ Field Day/ FLD	Venue	Name of organizers	Date	No. of participants
6.	Model propagation and orchard management practices for sustainable pomegranate production for farmers and coordinating agencies under SCSP	ICAR-NRCP, Solapur	Dr. N.V.Singh	26 th -29 th October, 2021	30
7.	Conducted one day training programme of SC/Sub-project of at Malumbra, Tuljapur on 16th March 2021.	ICAR-NRCP, Solapur	Dr. N.V. Singh	16 th March 2021.	30
Workshop:					
1.	Workshop on Insect pest disease management of Pomegranate, at Sangewadi, Sangola	Sangewadi, Sangola		27.07.2021	78
2.	Workshop on Insect pest disease management of Pomegranate, at Kadalas, Sangola	Kadalas, Sangola		04.08.2021	60
3.	Organized International webinar on Pomegranate ancient fruit in modern horticulture, ICAR-NRCP, Solapur,	ICAR-NRCP, Solapur		25-27th August 2021	
4.	Organized Webinar on "Pomegranate production in dry land region: An alternative for higher income" under <i>Azadi Ka Amrit Mahotsav</i>	ICAR-NRCP, Solapur		16 th July 2021	
5.	Organized Webinar on "Pomegranate Nutrition and its Therapeutic Utility" under <i>Azadi Ka Amrit Mahotsav</i>	ICAR-NRCP, Solapur		8 th Sep. 2021	
6.	Organized Webinar on "Solapur Lal and Solapur Anardana: NRCP Contribution in Bio fortified Food" under <i>Azadi Ka Amrit Mahotsav</i>	ICAR-NRCP, Solapur		16 th Sep. 2021	
7.	Organized Webinar on "Pomegranate miracle health fruit for livelihood and nutrition for women" under <i>Azadi Ka Amrit Mahotsav</i>	ICAR-NRCP, Solapur		16 th Oct. 2021	



S. No.	Title of Trainings/ Workshops/ Farmers Fair/ Field Day/ FLD	Venue	Name of organizers	Date	No. of participants
8.	Organized Webinar on “Pomegranate Value addition: NRCP contribution in technologies and entrepreneurship development” under <i>Azadi Ka Amrit Mahotsav</i>	ICAR-NRCP, Solapur		16 th Oct. 2021	
9.	Organized Webinar on “Entrepreneurship Opportunities for small land holding pomegranate farmers” under <i>Azadi Ka Amrit Mahotsav</i>	ICAR-NRCP, Solapur		28 th Dec. 2021	
10.	Organized Webinar on “Hi- tech Pomegranate Cultivation for Higher Productivity and Income” under <i>Azadi Ka Amrit Mahotsav</i>	ICAR-NRCP, Solapur		4 th Jan. 2022	
11.	Organized Webinar on “Smart Cities and Vertical Gardening” under <i>Azadi Ka Amrit Mahotsav</i>	ICAR-NRCP, Solapur		8 th Feb. 2022	
Farmers fair:					
1.	Field day cum farmer fair on impact of “Stem Solarization – Six Step Technology for the Management of Bacterial Blight Disease in Pomegranate”	Village - Tamsheewadi, Malshiras, Solapur	Dr. J.Sharma Dr.Somnath Pokhare	November 13, 2021	A total of 150 farmers were actively participated in the field day.
2.	Agrovision	ICAR-CCRI, Nagpur	Mr.B.V. Naikwadi Mr.G.A. Salunke	24-27 Dec.2021	500
Field Day:					
1.	Participated in Farmers scientists’ interaction on Climate Resilient varieties, technologies and practices at ICAR-NRCP, Solapur	ICAR-NRCP, Solapur	Dr. Nilesh Gaikwad	28 th December 2021	Around 50 farmers were present for this interaction.
2.	Pomegranate Field Day organized on the occasion of the first harvest to of the demonstration plot H13	ICAR-NRCP	Dr. N.V.Singh	26 th March, 2021	30
3.	Field day on Management of Bacterial blight and Wilt in Pomegranate on jointly organized by ICAR-NIASM, Baramati and ICAR-NRCP, Solapur at NIASM, Baramati.	ICAR-NIASM, Baramati	Dr. Somnath Pokhare	21 st October 2021	60 farmers



S. No.	Title of Trainings/ Workshops/ Farmers Fair/ Field Day/ FLD	Venue	Name of organizers	Date	No. of participants
4.	Farmer-Scientist Interface meet: live webcasting of Hon'ble Prime Minister's programme of Dedication of 35 Crop Varieties and establishment of ICAR – National Institute of Biotic Stress Management, Raipur to the Nation and Farmer-Scientist Interface meet	ICAR-NRCP, Solapur	Dr. Somnath Pokhare	28 th September 2021	80 farmers and institute staff members



Farmers trainee from S.Solapur Tk, Solapur



Certificate distribution to trainee, 12.01.2022



Live webcasting of Hon'ble Prime Minister's programme and Famer-Scientist Interation meet on 28th september 2021



Field day cum farmer fair on impact of “Stem Solarization – Six Step Technology for the Management of Bacterial Blight Disease in Pomegranate” at Tamsheewadi, Malshiras, Solapur on November 13, 2021

SCIENTIFIC AGRO ADVISORIES

Likewise every , this year (2021) five bimonthly scientific agro-advisories were published on office website, Dalimbmitra-a social digital platform and daily newspaper for the benefit of farmers regulating three bahars in English, Hindi, Marathi, Kannada language for updating their knowledge.

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 4961 pomegranate growers through the “m-Kisan portal” during the period under report.

Providing inputs to stakeholders through Dalimb Mitra platform and other social media platforms.





Transfer of Technology and Entrepreneurship Development

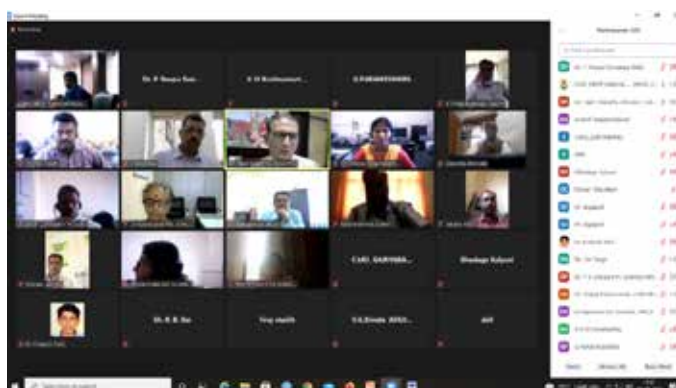
ICAR-NRCP, Solapur organized the following trainings, workshops/ field day/ FLD, technology transfer agreement for entrepreneurs and MoU for students. In addition, ICAR-NRCP actively participated in several exhibitions besides facilitating the visit of farmers/ stakeholders to the Institute to provide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

Table 1: Trainings conducted by ICAR-NRCP, Solapur

S. No.	Name of Training Programmes (Duration: 3 or more days)	No. of participants	Name of organizers	Period
1	Quality pomegranate production value addition for doubling farmer's income.	30	Dr. J.Sharma, Dr.A.Maity, Dr.Somnath Pokhare	15-17 Feb,2021
2	Four days MANAGE, Hyderabad sponsored a collaborative online training program on "Modern practices for export quality pomegranate production and value addition" for extension officers of State Agri./Hort.	49	Dr. N.V. Singh	28-31 July, 2021
3	Training program on 'Quality pomegranate production and value addition for doubling farmer's income' for bio squad team of Valagro Pvt. Ltd.	27	Dr. J.Sharma, Dr.Somnath Pokhare	15-17 Feb, 2021



Quality pomegranate production value addition for doubling farmer's income. (15-17 Feb 2021)



**Address by Dr. Rajiv Marathe,
Director ICAR-NRCP, Solapur**



**Lecture by Dr. Mallikarjun, on Insect
pest management in pomegranate**

Training title, date: **“Modern practices for export quality pomegranate production and value addition” 28-31st July 2021.**

• **Workshop/ Field day/FLD conducted**

S. No.	Name of Training Programme	No of Participants	Date
1.	Webinar on “Balanced Use of Fertilizers”	85	18.06. 2021
2.	Workshop on Insect pest disease management of Pomegranate, at Sangewadi, Sangola	78	27.07.2021
3.	Workshop on Insect pest disease management of Pomegranate, at Kadalas, Sangola	60	04.08.2021
4.	Field day cum Farmers fair Tamshedwadi Tal, Malshiras	102	13.09.2021
5.	Programme on celebration of International year of millets at ICAR-NRCP	25	17.09.2021
6.	Field visit cum-training programme on Short hole borer management in Pomegranate, Ajanale, Sangola	250	25.09.2021
7.	Scientist- farmers interactive training programme on occasion of PM’s web based Live telecast , at ICAR-NRCP	57	28.09.2021
8.	Interacted with the pomegranate farmers on various pomegranate issues and surveyed orchards at Chikka-sanshi, Tal. Bagalkot, Dist. Bagalkot. and at Anagawadi, Aheri & Shindagi, Tal Shindagi Dist. Vijayapur	35	26-27 Dec, 2021

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.	Process of minimal processing and shelf-life extension of minimally processed arils licensed to for	M/S Gnamam Foods, Bhuj- Bhachau Highway, RS NO 426, Opp. Essar pump, Village-Morgar, Tal- Bhachau, District- Kutch, State- Gujarat, 370140	20 th July 2021.	Rs. 1,18,000/-



Process of minimal processing and shelf life extension of minimally processed arils licensed to M/S Gnamam Foods, Bhuj- Bhachau, Gujarat on 20.7.2021

FOR STUDENTS**Table 4: MoU with Academic Institutions**

S. No.	Programme	Address of beneficiary	Date	Revenue generated (Rs.)
1	B.Sc./B.Tech./M.Sc./M.Tech./Ph.D.	Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani, MS	February 7th 2021	Nil

Table 5: Exhibitions

S. No.	Name of the exhibition	Organizer	Venue	No. of visitors	Date
1	Field day cum farmers fair Tamshedwadi Tal, Malshiras	ICAR-NRCP Solapur	Tamshedwadi Tal, Malshiras Dist Pune	102	13Nov. 2021
2	Agrovision	Agrovision Foundation	ICAR-CCRI Nagpur	500	24-27 Dec.2021

POMEGRANATE GROWERS/ VISITORS TO ICAR-NRCP, SOLAPUR

Following beneficiaries/ visitors visited this Centre during 2021

Table 6: Visitors to ICAR-NRCP, Solapur

S. No.	Date	Organization/ Place of beneficiaries	Category	No. of beneficiaries
1.	16.09.2021	Farmers exposure visit from Department of Agriculture Badmer, Rajasthan		50
2.	29.09.2021	State Agriculture Department Gadchiroli (MS)		52 Farmers
3.	16.12.2021	KVK Mohol under DEASI project		40 Agri input dealers
4.	17.12.2021	KVK Mohol Solapur		27 Farmers
5.	30.12.2021	State Agriculture Department		25 Farmers
6.	26.03.2022	Farmers' exposure visit to ICAR-NRCP, Solapur coordinated by KVK, Bidar, Karnataka.	Farmers	50



Farmers exposure visit from Department of Agriculture Badmer, Rajasthan, visited ICAR-NRCP, 16/09/2021

S. No.	Date	Organization/ Place of beneficiaries	Category	No. of beneficiaries
			Student	
1	08.09.2021	Dnyaan prabhodini krushi tantra vidyalai Harali Osmanabad.(MS)		40 students
2	29.10.2021	AD, college of agriculture ,Dapoli (MS)		89 Students
3	25.11.2021	PG students of Aahilyabai holkar University Solapur.		58 Students



S. No.	Date	Organization/ Place of beneficiaries	Category	No. of beneficiaries
4	02.12.2021	College of agriculture Karkere Hasan, Karnataka		60 Students
5	15.07.2021	Virtual tour- College of Agriculture, Hassan, Karnataka	Final year B. Tech (Biotechnology)	60
6	05.12.2021	College of Agriculture, Hassan, Karnataka	III rd year B. Tech (Biotechnology)	59



PG students of Aahilyabai holkar University, Solapur visited NRCP farm 25/11/2021



Institutional Activities

COMMITTEE MEETINGS (RAC, IRC, IMC, IJSC)

Research Advisory Committee (RAC) Meeting

The fifteenth Research Advisory Committee (RAC) meeting of ICAR- National Research Centre on Pomegranate was held from November 29th-30th, 2021, at ICAR-NRCP, Kegaon, Solapur under the Chairmanship of Dr. N Kumar, Vice Chancellor, TNAU, Coimbatore, Tamil Nadu. The Progressive Pomegranate Farmer (MS) Shri. M.S. Mugle, could not attend the meeting due to pre-occupation elsewhere. The RAC members and scientists of ICAR-NRCP, Solapur who participated in the meeting are given below:

Chairman

- | | |
|---|---|
| 1. Dr. N. Kumar
Vice- Chancellor
TNAU, Coimbatore | 5. Dr. V.V. Sulladmath
Ex-PS, ICAR-IIHR
Bengaluru |
|---|---|

Members

- | | |
|---|---|
| 2. Dr. D.P.Waskar
Director of Research
VNMKV, Parbhani. | 6. Dr. R.A.Marathe
Director,
ICAR-NRCP, Solapur. |
| 3. Dr. S. K.Panda
Ex-Head, OUAT Bhubaneshwar | 7. Mr. Shahajirao Gulchand Pawar, Progressive
Farmer
Mardi, North Solapur |

Ic /Member Secretary

- | | |
|--|--|
| 4. Dr. Madan Pal
PS, ICAR-IARI,
New Delhi. | 8. Dr.Prakash G.Patil
Sr.Scientist (Plant Biotech.)
ICAR-NRCP, Solapur |
|--|--|

The technical meeting on Nov 29, 2021 started at 10.30 am in the Director's Board Room. Dr. Prakash G. Patil, Sr. Scientist (Plant Biotech) & I/c Member Secretary extended a warm welcome to the Hon'ble chairman and esteemed members of the RAC. The RAC team was felicitated with ICAR-NRCP product basket by the honourable Director, ICAR-NRCP, Dr. R. A. Marathe. Then the all the ICAR-NRCP scientists gave their self-introduction to RAC members with their specialization and area of research work on pomegranate. Then Director, ICAR-NRCP briefed all the members about 16 Years Journey of ICAR-NRCP with success stories at Solapur through a brief presentation. The major research achievements highlighted by the Director included, germplasm conservation, protection of 'Solapur Lal' and 'Solapur Anardana' varieties under PPV&FRA, New Delhi, DUS testing of new varieties, finished genome assembly of Bhagawa, mapping of suitable areas of pomegranate cultivation, tissue culture and bio-hardening and technology transfer, novel bio formulations for K supplement, special micronutrient formulations for pomegranate, amino acid based supplements, water management, organic cultivation, development of modified IDIPM, Six step management of BBD and its success stories. Similarly, large-scale screening of germplasm lines against *Ceratocystis fimbriata* and root knot nematode *Meloidogyne incognita* and identification EC-676923 and ACC-2 as showing resistance to wilt. Development of novel genomic hybervariable SSR and micro RNA markers for seed hardness, fruit colour, bacterial blight, fruit size traits, technologies developed for value added products, pome mat drying for Juice powder preparation, Pomegranate Probiotics, functional beverage at ICAR-NRCP and their



cost benefit ratios, patent filed for seed oil extraction, technology transfer, infrastructure, mobile app, publications, and capacity building programs organized at ICAR-NRCP. The overall research efforts made by the Centre.

The in-charge member secretary presented the 'Action Taken Report' in front of RAC committee on the recommendations of 14th RAC meeting held through virtual mode from November 6-7, 2020. At the end of the opening session, the Chairman addressed the house and appreciated the research effort made by ICAR-NRCP. The technical sessions started thereafter with the presentation on detailed work done during 2020-21 by the Principal Investigators of 13 projects. The Chairman and all members of RAC interacted with the scientists on each project. After detailed deliberations on the progress made by the Centre, several valuable suggestions and recommendations as listed below were given by the RAC members.

Recommendations of 15th RAC held during Nov., 29th-30th, 2021

- Integration of different biomolecules and successful demonstration of a bio-intensive plant protection schedule for management of diseases and insect pests.
- Efforts should be made to create variability through intraspecific hybridization programme and interspecific hybridization after introduction of *Punica protopunica* from Socotra Island.
- Focused breeding programme to develop varieties resistant to bacterial blight and wilt by screening germplasm lines, advanced F2 segregating populations and mutation breeding etc.
- Work on high density planting, canopy management, new fertigation schedule for cost effective crop management and production in pomegranate.
- Popularization and commercialization of NRCP technologies for successful entrepreneurship development and revenue generation among stakeholders.

The meeting ended with vote of thanks by Dr. Prakash G. Patil, I/c Member Secretary, RAC.





Institute Research Council (IRC) Meeting

The meeting of sixteenth Institute Research Council (IRC) of ICAR- National Research Centre on Pomegranate was held on November 24th, 2021, at ICAR-NRCP, Solapur under the Chairmanship of Dr. R. A. Marathe, Director, ICAR-NRCP, Solapur. The following Scientists/IRC members attended the meeting.

Table. Institute Research Council of ICAR-NRCP, Solapur

	Chairman IRC		
1	Dr. R. A. Marathe, Director, ICAR-NRCP, Solapur (MS)	9	Dr. Somnath Pokhare, Scientist (Nematology), ICAR-NRCP
	Members	10.	Dr. Shilpa Parashuram, Scientist (Plant Breeding), ICAR-NRCP
2	Dr. Jyotsana Sharma, Pr. Scientist (Plant Pathology), ICAR-NRCP	11.	Dr. Namrata Giri, Scientist (Food Technology), ICAR-NRCP
3	Dr. P. S. Shirgure, Pr. Scientist (L&W Mg.Engg), ICAR-NRCP	12.	Dr. Chandrakant Awachare, Scientist (Hort.-Fruit Sc.), ICAR-NRCP
4	Dr. Ashis Maity, Sr. Sci. (Soil Sc.-Pedo), ICAR-NRCP	13.	Dr. Mallikarjun Harsur, Scientist (Entomology), ICAR-NRCP
5	Dr. N.V. Singh, Sr. Scientist (Hort.-Fruit Sc.), ICAR-NRCP	14.	Dr. Roopa Sowjanya P, Scientist (Plant Breeding), ICAR-NRCP
6	Dr. Nilesh N. Gaikwad, Sr. Scientist (AS & PE), ICAR-NRCP	15	Mr. Rahul Damale, Scientist (Plant Biochemistry), ICAR-NRCP
7	Dr. Pinky Raigond, Sr. Scientist (Plant Physiology), ICAR-NRCP		I/c Member Secretary
8	Dr. Manjunatha N, Scientist (Plant Pathology), ICAR-NRCP	16	Dr. Prakash G. Patil, Sr. Scientist (Plant Biotech), ICAR-NRCP

The IRC meeting was started on Nov 24th, 2021 at 9.30 am in the Director's Board Room. Dr. Prakash G. Patil, Sr. Scientist, I/c Member Secretary IRC extended a warm welcome to Hon'ble Chairman Dr. R.A Marathe, Director, ICAR-NRCP, Solapur and all the members. Then presentations on salient achievements of 17 ongoing research projects besides 2 new research project proposal and future line of work were made by each scientist.

Suggestions & Recommendations:

General

- All the Scientists were asked to submit hard copy of their research project RPPs eight days before the commencement of IRC meeting, this will helps to thoroughly review, evaluate the progress of each projects and documentation purpose also for further improvements by the Chairman.
- Scientists asked to submit their project RPP II in time to the PME for record.
- It was decided by the chairman that the extended IRC may be arranged or during RAC all the new projects proposals will be reviewed.
- Scientists were asked to keep good balance between applied and basic research which can address most of the field oriented problems of pomegranate farmers.



- Scientists were asked to submit RPF-II of their projects and information in short for their project achievements presented in IRC to the publication committee for compiling and printing of Annual Report 2020-21.
- It was decided that progress of externally funded projects may be also presented and reviewed during each IRC.
- All the experimental results and tables presenting in the IRC should have proper statistical analysis.
- It was observed that Scientists are including/excluding the names of Co-PIs as per their own. This should be strictly avoided and any inclusion/exclusion of Co-PIs will be decided as per approved in IRC only.

The meeting ended with vote of thanks by Dr. Prakash G. Patil, I/c Member Secretary, IRC.





OTHER ACTIVITIES

Following visitors visited ICAR-NRC on Pomegranate, Solapur during 2021

Distinguished Visitors:



**EX VC Dr Dhavan VNMKV Parbhani
visited NRCP 07.02.2021**



**Dr. Smt Poonam Malakondaiah SPL Chief
Secretary visited to NRCP, 03.03.2021**



**Ms G Madhumita Das IPoS and Sh Milind
Shambharkar DM Solapur 26.08.2021**



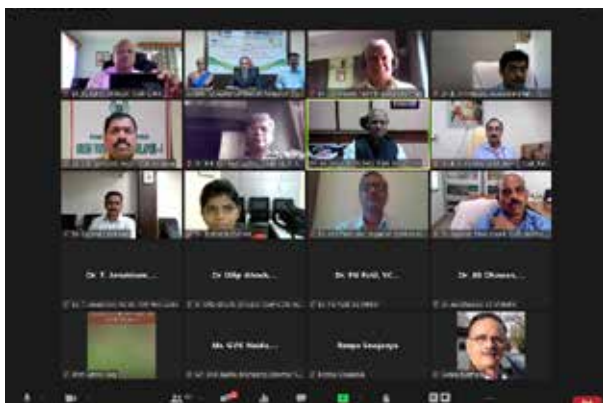
**Sh. Ankush Shinde Ex CP Solapur
24.09.2021**



**Team Bhartiya Agrow Economic
Research centre New Delhi 15.11.2021**



NABAARD Officer 20.12.2021



Sl No	Date	Events conducted	Coordinator	Team	No of beneficiary
1.	23.03.2021	Co-organized and hosted 'Dalimb Mitra' launch Programme on	Dr. Mallikarjun	Dr. Mallikarjun Dr. Nilesh Gaikwad Dr. N. V. Singh	50
2.	25 th August -27 th August, 2021	International Webinar on Pomegranate: Ancient Fruit in Modern Horticulture	Dr. R.A. Marathe- Convener Dr. Jyotsana Sharma- Joint Convener Dr. P.S Shergure & Dr. K.D. Babu: Co-Convener Dr. N.V. Singh- Organizing Secretary	All Scientists	200



“International Webinar on “Pomegranate: Ancient Fruit in Modern Horticulture”, August 25-27, 2021



The ICAR–National Research Centre on Pomegranate has organized an International Webinar on “Pomegranate: Ancient Fruit in Modern Horticulture” during August 25-27, 2021 in collaboration with Society for Advancement of Research on Pomegranate, Solapur and ICAR-CIAH, Bikaner.

A total of 47 Invited Speakers including 7 international speakers and 200 delegates from 9 countries of the world namely, Israel, Iran, Spain, USA, Turkey, Italy, South Africa, Germany, Pakistan and India have participated in this mega scientific event. In this webinar representatives of many MNCs like UPL, ICL, Jain Irrigations, Sam AgriTech, Coromandel, Bayer, Corteva, etc., also participated. The Padma Shri awardee pomegranate farmer Sh. Genabhai Dargabhai Patel has also shared his experiences to inspire the other pomegranate growers.

The Inaugural program of the International Webinar was chaired by Dr. CD Mayee, Former Chairman, ASRB and Dr. AK Singh, DDG, HS. The webinar also witnessed the august presence of by Dr. NK Krishna Kumar, Former DDG HS; Dr. PL Saroj, Director, ICAR-CIAH, Bikaner; Dr. T Jankiram, VC, Dr. YSRHU (AP); Dr. AS Dhawan VC, VNMKV, Prabhani; Dr. PG Patil VC, MPKV, Rahuri, Dr. DK Ghosh, Director, ICAR-CCRI, Nagpur; Dr. BK Pandey, ADG (HS-II), ICAR, New Delhi; Dr. RT Patil, Former Director, ICAR-CIPHET; Dr. RK Pal, Former Director, ICAR-NRCP and Dr. VI Benagi, Ex-VC, UAS Dharwad. The International Webinar was convened by Dr. RA Marathe and coordinated by Dr. NV Singh.



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.	Completed online training workshop on "Response Surface Methodology"	24-26 August, 2021	(Online) Organized by ICAR-NAARM, Hyderabad	Dr. Namrata A. Giri
2.	Training Programme on Analysis of Experimental Data	17-22 Jan, 2022	Online-NRCP, Solapur	Awachare Chandrakant Mahadev
3.	Online workshop on "response surface methodology"	24-26 Aug, 2021	Online -NRCP, Solapur	Dr. Namrata Giri
4.	Advances in applications of phenomic tools for assessment of abiotic stress responses in crop plants	28 Feb to 9 March, 2022	Baramati NIASM, Baramati	Dr. Roopa Sowjanya
5.	Competency Enhancement Program for Effective Implementation of Training Functions by HRD Nodal Officers of ICAR	21-23 Feb, 2022	Online -NRCP, Solapur	Dr. Mallikarjun
6.	Training Programme on "Quality pomegranate production and value addition for doubling farmer's income" for Valagro Biosciences organized by ICAR-NRC on Pomegranate, Solapur.	15-17 Feb, 2021	ICAR-NRCP	Dr. N.V. Singh
7.	A Four days Collaborative Training Programme on "Modern practices for export quality pomegranate production and value addition" jointly organized by MANAGE and ICAR-NRCP.	28-31 July, 2021	ICAR-NRCP and MANAGE	Dr. N.V. Singh
8.	Online Training Programme on "DUS Testing" conducted by PPV&FRA, New Delhi.	1 July, 2021	On-line	Dr. Shilpa Parashuram
9.	Virtual Training Programme on 'Plant Genetic Resources Management and Utilization' organized by ICAR-National Bureau of Plant Genetic Resources, New Delhi.	19 July to 1 Aug, 2021	On-line	Dr. Shilpa Parashuram
10.	On-line training programme on "Advanced statistical techniques for data analysis using R" organized by ICAR - Indian Institute of Rice Research and Society for Advancement of Rice Research, Hyderabad, Telangana.	3-15 Jan, 2022	On-line	Dr. Shilpa Parashuram



S. No.	Name of training	Date	Venue	Name of participant
11.	Attended virtual training on “Analysis of Experimental data” organized by ICAR-NAARM, Hyderabad, during 17th to 22nd January, 2022.	17 th to 22 nd January, 2022	ICAR-NAARM, Hyderabad (Virtual mode)	Mr. Chandrakant Awachare
12.	Virtual training course on “ Management of Fruit Genetic Resources ” organized by ICAR- NBPGR, New Delhi, ICAR- AICRP (F) and ICAR-IIHR, Bangalore during	Feb., 1-2, 2021	Virtual mode	Mr. Chandrakant Awachare

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, etc. attended

S. No.	Title of Conference/ Seminar/ Symposia	Date	Venue	Name of the participant(s)
1.	International Webinar on “Pomegranate: Ancient fruit in modern horticulture”	25-27 Aug, 2021	ICAR-NRCP, Solapur	Dr. Ashis Maity
2.	4 th Global Meet of Science and Technology for staying healthy and feeding ever-growing population world- wide”	12-13 Sept, 2021	SVP University of Agriculture and Technology, Meerut	Dr. Ashis Maity
3.	National Seminar on “Managing soils in a changing climate”	24-26 March, 2022	ICAR-NBSS & LUP, Nagpur	Dr. Ashis Maity
4.	International e-Conference on Postharvest disease management and value addition of horticultural crops.	18-20 August, 2021	ICAR-IARI, New Delhi. (Online)	Dr. Namrata Ankush Giri
5.	International Webinar on Pomegranate: Ancient fruit in Modern Horticulture.	25-27 August, 2021	ICAR-NRC on Pomegranate, Solapur in collaboration with ICAR-CIAH, Bikaner.	Dr. Namrata Ankush Giri
6.	National conference on “Oil Palm- A right choice towards self-sufficiency in edible oil production”.	6 September, 2021	(Online) ICAR-Indian Institute of Oil Palm Research, Pedavegi, A.P.	Dr. Namrata Ankush Giri
7.	International webinar on “Fighting the hunger using smart technology”.	26 October, 2021	(Online) ICAR-Indian Institute of Oil Palm Research, Pedavegi, A.P.	Dr. Namrata Ankush Giri



S. No.	Title of Conference/ Seminar/ Symposia	Date	Venue	Name of the participant(s)
8.	Webinar on Prospects of underutilized fruits in India for nutritional security & entrepreneurship	24.05.2021	SKNAU, Jobner, Online	K.Dhinesh Babu
9.	International Webinar on Pomegranate : An ancient fruit to modern horticulture	25-27 Aug, 2021	ICAR-NRCP Solapur Online	K. Dhinesh Babu / All staff
11.	9 th Indian Horticulture Congress, organized by IAHS, New Delhi	18-21 Nov, 2021	CSAUA&T, Kanpur	K.Dhinesh Babu
12.	International Webinar on Pomegranate: Ancient Fruit in Modern Horticulture, NRCP, Solapur, India	25-27 Aug, 2021	NRCP, Solapur, India	Dr. Manjunatha N
13.	International Webinar on “Pomegranate: Ancient Fruit in Modern Horticulture” organized by ICAR-NRC on pomegranate and SARP, Solapur.	25-27 Aug, 2021	NRCP, Solapur	Dr. Mallikarjun
14.	<i>National Agricultural Scientist Conclave on “Sustainable Agriculture Through Integrated Inputs” at JNKVV, Jabalpur, Madhya Pradesh organized by Bhartiya Agro- Economic Research Centre, New Delhi,</i>	9-12 Dec, 2021	JNKVV, Jabalpur, Madhya Pradesh	Dr. Mallikarjun
15.	Online webinar on “Smart Cities and Vertical Gardening” organized by ICAR-NRCP, Solapur	08 Feb, 2022	NRCP, Solapur	Dr. Mallikarjun
16.	Attended the lecture on Containing Malnutrition through Horticulture- by Dr. Anand Kumar Singh, DDG (Hort. Sci), ICAR	5 April, 2021	Online NRCP, Solapur	Dr. Mallikarjun
17.	Online National webinar on the use of Nontechnology in Agriculture: Nano fertilizer jointly organized by ICAR-Research Complex for Eastern Region, Patna, and Indian farmers, fertilizer Cooperative limited Patna, Bihar.	23 Sept, 2021	Online NRCP, Solapur	Dr. Mallikarjun
18.	Attended The Virtual Workshop On Science Communication December Organized By ICAR-IIHR, Bengaluru.	29 Dec, 2021	Online NRCP, Solapur	Dr. Mallikarjun
19.	International E Conference on post-harvest disease management and value addition of horticultural crops. Delivered Invited oral paper Gaikwad N.N., Giri, N.A. and Marathe, R.A. 2021. Pomegranate utilization for food, pharmaceutical and cosmetic industry	18-20 Aug, 2021	ICAR-IARI, New Delhi, India I(S06B)04.	Gaikwad N.N., Giri, N.A. and Marathe, R.A.
20.	Virtual Webinar on Increasing the Yield, Quality and Income of Pomegranate Farmers organized by Dhanuka Group in partnership with the University of Horticultural Sciences, Bagalkot, Karnataka	24 July, 2021	UHS Bagalkot	Dr. N.V. Singh



S. No.	Title of Conference/ Seminar/ Symposia	Date	Venue	Name of the participant(s)
21.	International Webinar on Pomegranate-Ancient Fruit in Modern Horticulture	25-27 Aug, 2021	ICAR-NRCP (Hybrid Mode)	Dr. N.V. Singh
22.	National Agricultural Scientists Conclave on Sustainable Agriculture through integrated inputs organized by Bhartiya Agro-Economic Research Center in Collaboration with Bhartiya Kisan Sangh. The conclave will be held at JNKVV, Jabalpur	10-11 Dec, 2021	JNKVV, Jabalpur	Dr. N.V. Singh
23.	13 th Swadesh Prem Jagriti Sangosthi International Conference on Innovative Approaches for Enhancing Water Productivity in Agriculture including Horticulture, PJTSAU, Rajendranagar, Hyderabad, Telangana, India	16-19 Sept, 2021	PJTSAU, Rajendranagar	Dr. N.V. Singh
24.	International web conference on Innovative & Current Advances in Agri & Allied Sciences	19-21 July, 2021	Society for Scientific Development in Agriculture & Technology (SSDAT), Meerut, India	Mr. Rahul Damale
25.	Attended the International webinar on “Exchange of Post PVP Control Measures” organized by PPV&FRA, New Delhi.	8th April, 2021	On-line	Dr. Shilpa Parashuram
26.	One day National webinar on ‘IPR & Patents’ organised by V. G. Shivdare College of Arts, Commerce & Science, Solapur .	19 June 2021	On-line	Dr. Shilpa Parashuram
27.	International Webinar on Pomegranate: Ancient Fruit in Modern Horticulture organised by ICAR-NRCP, Solapur; ICAR-CIAH, Bikaner and SARP, Solapur	25-27 Aug, 2021	On-line	Dr. Shilpa Parashuram
28.	International Webinar on “Pomegranate: Ancient Fruit in Modern Horticulture” organized by SARP and NRCP, Solapur	25-27 Aug, 2021	NRCP, Solapur, India	Dr. Somnath S. Pokhare
29.	National Webinar on “Nematodes A Continuing Bottleneck in Crop Production : Available Technologies and Recent Advances” organized by Department of Nematology, Rajasthan College of Agriculture, Maharana Pratap University of Agriculture and Technology, Udaipur, Rajasthan.	6 April, 2021	Online platform	Dr. Somnath S. Pokhare

**Table 3. WORKSHOPS ATTENDED**

S. No.	Title of Workshop	Date	Venue	Name of Participant(S)
1.	Pest and disease management in Pomegranate, KVK, Vijayapura, Karnataka	26 th June, 2021	KVK, Vijayapura, Karnataka	Dr Manjunatha N
2.	Review and sensitization workshop of ZTMUs/ITMUs/PMEs under NAIF.	6 th Oct, 2021	Online	Dr. Gaikwad Nilesh N.
3.	One day online Awareness Programme on “Germplasm registration in Horticultural Crops” organized by Germplasm Advisory Committee, ICAR-IIHR Bengaluru	1 st Oct, 2021	On-line	Dr. Shilpa Parashuram
4.	Attended as Expert in One day workshop on ‘Wilt and Nematode management in Pomegranate’. At Kadlas, Sangola, Maharashtra organised by Adama India Limited on 12/02/2021. Experts: Dr. Jyotsana Sharma, Dr. Somnath Pokhare and Dr. Mallikarjun. More than 300 farmers were participated in this workshop.	12 Feb, 2021	At Kadlas, Sangola, Maharashtra	300 farmers

Table 4. MEETINGS ATTENDED

S. No.	Title of meeting	Date	Venue	Name of participant(s)
1.	26 th Research Workers Annual Group Meet, AICRP on Arid Zone Fruits	28-30 th April, 2021	ANDUAT, Kumarganj, Ayodhya	K.Dhinesh Babu
2.	Farmer interface meeting on management of shot hole borer and pomegranate at Ajnale, Sangola	-	Ajnale, Sangola	Dr Manjunatha N
3.	Outreach Programme at Nagpur organized by APEDA, Ministry of Commerce and Industries, GOI and Agrovision, Nagpur. Delivered lecture on “cultivation and value addition of pomegranate for improvement in export” as Invited Speaker in session on “Cultivation Practices & Export Quality production of Pomegranate”	9 th October 2021	Nagpur	Dr. Gaikwad Nilesh N.
4.	Board of studies, Cosmetic Technology department, Solapur University for designing and finalization of the course wise syllabus, marking system etc. for B.Tech (Cosmetic Technology)	13 th May 2021	Solapur	Dr. Gaikwad Nilesh N.



S. No.	Title of meeting	Date	Venue	Name of participant(s)
5.	Gap assessment in infrastructure & processing facilities for development of potential value chains for perishable products under Operation Greens Scheme of MoFPI for Pomegranate organized by Deloit for Ministry of Food Processing Industries GOI.	14 th July 2021	Online	Dr. Gaikwad Nilesh N.
6.	College Development Committee Meeting of DSTS Mandal's College of Pharmacy, Solapur as Member on 26th November 2021.	26 th Nov. 2021	Solapur	Dr. Gaikwad Nilesh N.
7.	13 th Foundation Day Function of ICAR-NIASM, Baramati and Panel Discussion	18-19 th Feb, 2021	ICAR-NIASM, Baramati	Dr. N.V. Singh
8.	Discussion session organized by Maharashtra Pomegranate Growers' Research Association, Pune on the occasion of Foundation Day of MPGRA, Pune.	5-10 th June, 2021	Online Mode, MPGRA, Pune	Dr. N.V. Singh
9.	Webinar Organized for officers of Telangana State Government on Pomegranate cultivation	6 th May, 2021	Virtual Mode (Telangana Government)	Dr. N.V. Singh
10.	Three-Day Farmers' Training Programme Organized by VNMKV, Parbhani	1-3 May, 2021	Virtual mode (KVK Aurangabad, VNMKV)	Dr. N.V. Singh
11.	16 th Foundation Day Ceremony of ICAR-NRCP	25 th Sept, 2021	ICAR-NRCP (Hybrid Mode)	Dr. N.V. Singh
12.	Tree plantation campaign. Theme- Har med par ped, organized by ICAR-CAFRI, Jhansi	16 th July, 2021	ICAR-CAFRI, Jhansi	Dr. N.V. Singh
13.	Review meeting of DUS centres under the Chairmanship of Dr. K. V. Prabhu, Chairperson of PPV&FRA, New Delhi.	10 th June, 2021	On-line	Dr. Shilpa Parashuram
14.	Scientists-Farmer interaction meeting organized by ICAR-National Research Centre on Pomegranate, Solapur in the eve of 17th Foundation Day	25 th Sept, 2021	ICAR-NRCP, Solapur	Dr. Shilpa Parashuram



Publications

Research articles

S. No.	Research paper	NAAS Rating
1.	Patil, P. G., Singh, N. V., Bohra, A., Sowjanya, R., Raghvendra, K.P., Mane, R., <i>et al.</i> 2021. Comprehensive characterization and validation of chromosome-specific highly polymorphic SSR markers from pomegranate (<i>Punica granatum</i> L.) cv. Tunisia genome. <i>Frontiers in Plant Science</i> 12: 645055. doi: 10.3389/fpls.2021.645055	11.75
2.	Gaikwad NN, Kalal AY, Suryavanshi SK, Patil PG, Sharma D, Sharma J. 2021. Process optimization by response surface methodology for microencapsulation of pomegranate seed oil. <i>Journal of Food Processing and Preservation</i> . 45 (6) e15561. https://doi.org/10.1111/jfpp.15561 .	7.41
3.	Kumar, R.A., Rajpurohit, V.S., Gaikwad N. N. 2021. Image dataset of pomegranate fruits (<i>Punica granatum</i>) for various machine vision applications. <i>Data in Brief</i> . 37:107249 https://doi.org/10.1016/j.dib.2021.107249 .	7.70
4.	Singh, N.V., Karwa, N.N., Birajdar, S.B., Parashuram, S., Patil, P.G., Babu, K.D. <i>et al.</i> 2021. Evaluation of plant beneficial microbes for bio-hardening of in-vitro raised pomegranate saplings. <i>Indian Journal of Agricultural Sciences</i> 91(1): 29-33.	6.37
5.	Singh, N.V., Patil, P.G., Sowjanya, P.R., Shilpa, P., Natarjan, P., Reddy, U.K., Babu, K.D., Pal, R.K. and Sharma J. 2021. Chloroplast Genome Sequencing, Comparative Analysis and Discovery of Unique Cytoplasmic Variants in Pomegranate (<i>Punica granatum</i> L.). <i>Frontiers in Genetics</i> , doi: 10.3389/fgene.2021.704075	10.60
6.	K.J. Jeyabaskaran, P.S. Shirgure, Vikramaditya Pandey, A.K. Srivastava and S. Uma. 2021. Fertigation in Horticulture : A Guarantee to Economized Quality Production. <i>Indian Journal of Fertilisers</i> 17 (4) : 364-383	4.76
Review Article		
1.	Babu KD, Sharma J, Maity A, Singh NV, Patil PG, Shilpa P, and Marathe, RA. 2021. Pomegranate: An ancient fruit for health and nutrition. <i>Progressive Horticulture</i> . 53 (1): 3-13.	4.49

S.No.	BOOK CHAPTERS
1.	Maity, A. and Marathe, R. 2021. Nutrient Management. In: Good management practices in pomegranate (Eds. Pokhare, S.S., Sharma, J., Patil, P.G., Manjunatha, N., Mallikarjun, M.H.), Technical Manual No. 1/NRCP/2021, ICAR-National Research Centre on Pomegranate, Solapur-413255 (Maharashtra), India, pp.44-59.
2.	Sowjanya, R.P., Sharma, J. Maity, A. and Marathe, R.A. 2021. Abiotic stresses of pomegranate and their management. In: Good management practices in pomegranate (Eds. Pokhare, S.S., Sharma, J., Patil, P.G., Manjunatha, N., Mallikarjun, M.H.), Technical Manual No. 1/NRCP/2021, ICAR-National Research Centre on Pomegranate, Solapur-413255 (Maharashtra), India, pp. 114-120.
3.	Nilesh N. Gaikwad, K. Dhinesh Babu and Namrata Giri 2021. Harvesting and Post-Harvest Handling, In Good Management Practices in Pomegranate, Eds. R A Marathe, S. Pokhare, J. Sharma, PG Patil, N. Manjunatha, Mallikarjun, M.H., Technical Manual No.1/NRCP/2021 ICAR-National Research Centre on Pomegranate, Solapur-413255 (Maharashtra), India, 121-128.



4.	Nilesh N. Gaikwad, Namrata Giri and K. Dhinesh Babu 2021. Processing and Value addition, In Good Management Practices in Pomegranate, Eds. R A Marathe, S. Pokhare, J. Sharma, PG Patil, N. Manjunatha, Mallikarjun, M.H., Technical Manual No.1/NRCP/2021 ICAR-National Research Centre on Pomegranate, Solapur-413255 (Maharashtra), India, 129-132.
5.	Namrata Ankush Giri, Sajeev M.S., Bansode V.V., Krishnakumar T. and Pradeepika Chintla. 2021. Sweet potato (<i>Ipomoea batatas</i> L.): Nutritional importance and value addition In: Recent Advances in Root and Tuber Crops, Brillion Publishers, New Delhi, 355-376.
6.	Krishnakumar, T, Sajeev M.S and Namrata Giri. 2021. Tapioca: Processing and Storage. In: Recent Advances in Root and Tuber Crops, Brillion Publishers, New Delhi, 341-353.
7.	Sajeev M.S., Namrata A. Giri, Krishnakumar T. and Bansode V. 2021. Primary and Secondary Processed Value Added Food Products from Cassava. In: Recent Advances in Root and Tuber Crops, Brillion Publishers, New Delhi, 319-340.
8.	Bansode V.V., Namrata A. Giri, Sajeev M.S., Chauhan V.B.S., Nedunchezhiyan M., Kalidas Pati. 2021. Nutritional importance and value addition of Elephant Foot yam and Taro. In: Recent Advances in Root and Tuber Crops, Brillion Publishers, New Delhi, 377-389.
9.	Sankaran, M, Babu, KD, Jai Prakash, Karale, AR. 2021. Pomegranate. In: Fruits : Tropical & subtropical. Vol.2 (Eds. Parthasarathy VA, Bose TK, Mitra SK, Bhosh B, Chakraborty I, Sanyal D) . Daya Publishing House, N.Delhi. pp.165-242.
10.	Ferrara, G., Palasciano, M., Sarkhosh, A., Cossio, F., Babu, K.D., Mazzeo, A. 2021. 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. 247-284.
11.	Singh, N.V., Karimi, H.R., Sharma, J. and Babu, K.D. 2021. 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. 196-224.
12.	Carter JM, Yavari A, Sarkhosh A, Jia Z, Merhaut DJ, Preece JE, Cossio F, Qin G, Liu C., Li J, Shilpa P, Babu K.D., Sharma J, Yilmaz C, Bartual J, Mustafayeva Z, Saeedi, MA., Awd NA, Moersfelder J and Hou L. 2021. 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. 157-195.
13.	Mallikarjun H., 2021. Insect and non-insect pests and their management. Technical Manual No.1/NRCP/2021 on Good Management Practices in Pomegranate, published by ICAR-NRC on Pomegranate, Solapur-413255 (Maharashtra), India, pp170.
14.	Singh, N.V., Babu, K.D. and Sharma, J. 2021. Pomegranate. In: Subtropical fruit crops: theory to practical (Ghosh, S.N. and Sharma, R.R. eds.), Jaya Publishing House, New Delhi, Pp. 454-523.
15.	Patil PG, Singh NV, Shilpa P, Sowjanya R, Jyotsana S, Marathe RA 2021. Recent Advances in Pomegranate Genomics: Status and Prospects (Book: Omics in Horticulture crops, Elsevier publisher). (Accepted).
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6.	K. D. Babu, NV Singh, R. Chandra, A.Maity, J Sharma, VT Jadhav, RK Pal, RA Marathe, Shilpa P, N.Gaikwad, PG Patil, R Damale, SH Jalkiop, BNS Murthy & PS Kumar. 2021. Solapur Lal : A bio-fortified HYV of pomegranate, International Webinar on Pomegranate : Ancient fruit in Modern Horticulture, NRCP & SARP, Aug 25-27, 2021 (Poster).
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9.	<i>In-vitro</i> evaluation of endophytes against fungal pathogens of pomegranate. In: International Webinar on Pomegranate: Ancient Fruit in Modern Horticulture, 25 th -27 th August, 2021
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14.	NV Singh, Shweta Bute, AS Shinde, DM Mudewadikar, Shilpa Parashuram, Roopa Sowjanya P, PG Patil and RA Marathe. 2021. Strategies to manage phenolic browning for efficient <i>in vitro</i> culture establishment in pomegranate cv. Bhagwa. In: International Webinar on Pomegranate: Ancient Fruit in Modern Horticulture organised by ICAR-NRCP, Solapur; ICAR-CIAH, Rajasthan and SARP, Solapur August 25-27, 2021, pp 60.
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17.	Prakash G. Patil, Shivani M. Jamma, Singh N. V., Manjunatha N., Dhinesh Babu K. and Marathe R. A. 2021. Hybridity and heterozygosity analysis of putative F1s using genome-wide SSR markers in pomegranate. In: International Webinar on Pomegranate: Ancient Fruit in Modern Horticulture organised by ICAR-NRCP, Solapur; ICAR-CIAH, Rajasthan and SARP, Solapur August 25-27, 2021, pp. 107.



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21.	Shilpa P., Maity, A., Babu K. D., Singh N. V., Roopa Sowjanya, P. and Jyotsana S. 2021. Pomegranate – Varieties and their Role in Health Security. In: National E-Conference “Biodynamic Calendar and Technological Intervention for Horticulture Sustainability and Health Security in Changing Climate” organised by College of Horticulture, Bidar, Karnataka. p. 97.
22.	Shilpa, P., Sharma, J., Gaikwad, N. G., Singh, N. V., Roopa Sowjanya, P., and Babu, K. D. 2021. Identification of fruit morphological and biochemical traits correlated to bacterial blight disease in Pomegranate. In: National Virtual Conference (NVC-2021) on ‘Genomics to Phenomics: A New Horizon in Plant Science Research’ organized by Department of Botany, University of Calcutta from 28 th February to 1 st March, 2021.
23.	Shilpa, P., Sharma, J., Maity, A., Babu, K. D., Gaikwad, N. N., Singh, N. V., Patil, P. G., Roopa Sowjanya, P. and Marathe, R. A. 2021. Study of correlation between fruit quantitative traits and bacterial blight disease in Pomegranate. In: International Webinar on Pomegranate: Ancient Fruit in Modern Horticulture organised by ICAR-NRCP, Solapur; ICAR-CIAH, Rajasthan and SARP, Solapur August 25-27, 2021. pp. 108-109.
24.	Shilpa, P., Babu, K. D., Singh, N. V., Gaikwad, N. N., Roopa Sowjanya, P., Kade, R. A., Jadhav, D. C. and Sharma, J. 2021. DUS characterization of new candidate varieties of Pomegranate. In: International Webinar on Pomegranate: Ancient Fruit in Modern Horticulture organised by ICAR-NRCP, Solapur; ICAR-CIAH, Rajasthan and SARP, Solapur August 25-27, 2021. pp. 109.
25.	Chakranarayan, M. G., Shilpa Parashuram, Singh, N.V., Patil, P. G., Roopa Sowjanya, P., Babu, K. D., Sangnure V. R., Mundewadikar, D. M. and Godhale, C. H. 2021. Utilization of Simple Sequence Repeats (SSRs) markers for cultivar identification in Pomegranate. In: International Webinar on Pomegranate: Ancient Fruit in Modern Horticulture organised by ICAR-NRCP, Solapur; ICAR-CIAH, Rajasthan and SARP, Solapur August 25-27, 2021. pp. 110.
26.	Patil PG, Jamma SM, Singh NV, Manjunatha N, Babu KD and Marathe RA 2021. Hybridity and heterozygosity analysis of putative F ₁ s using genome-wide SSR markers in Pomegranate. International Webinar on ‘Pomegranate: Ancient fruit in modern horticulture’. Organized by SARP, ICAR-NRCP, Solapur, (M.S) 25-27 th Aug, 2021.
27.	Roopa Sowjanya P., Kiran Gudaghe, Sangnure VR, Singh N.V., Ajinkya Mandave, Shilpa P., Sharma J. and R.A. Marathe. 2021. Standardization of SRAP markers for assessing pomegranate (<i>Punica granatum</i> L.) genetic diversity. In: International Webinar on Pomegranate: Ancient Fruit in Modern Horticulture organised by ICAR-NRCP, Solapur; ICAR-CIAH, Rajasthan and SARP, Solapur August 25-27, 2021. pp. 106-107.



S.No.	POSTERS
28.	Rahul D. Damalea, Banerjee K., Shaikha, N. I., Khana, Z and Babub, K. D. 2021. Profiling of bioactive phytochemicals in pomegranate variety Solapur Lal by LC-HRMS. Organised by ICAR-NRCP, Solapur; ICAR-CIAH, Rajasthan and SARP, Solapur August 25-27, 2021.
29.	Rahul D. Damale, Banerjee K., Anirban D., Shaikh, N. I., Khan, Z., Babu, K. D and Gaikwad, N. N.2021. 2. Evaluation of matrix effect on pesticide residues quantified using matrix matched calibration of four different pomegranate (<i>Punica granatum</i>) varieties by GC-MS/MS and LC-MS/MS. Organised by ICAR-NRCP, Solapur; ICAR-CIAH, Rajasthan and SARP, Solapur August 25-27, 2021.
30.	Anuradha Sane, B.N.S. Murthy, Chandrakant Awachare, Anushma P.L. and Linta Vincent. 2021. Assessment of open pollinated progenies of Pomegranate for the yield and quality. In: International webinar on "Pomegranate: An ancient Fruit in Modern Horticulture" Organized by Society for Advancement of Research on Pomegranate (SARP) and ICAR- NRC on Pomegranate, Solapur during August 25-27, 2021.

S.No.	ANNUAL REPORT
1	Maity, A., Babu, K.D., Singh, N.V., Patil, P.G. and Gaikwad, N. 2020. ICAR-NRCP Annual Report 2020, ICAR-National Research Centre on Pomegranate, Solapur-413255, Maharashtra, p. 1-193.

S.No.	MANUAL / COMPENDIUM/ OTHERS/ Scientific/ teaching reviews
1.	Basak, B.B., Maity, A., Ray, P., Biswas, D.R. and Roy, S., 2022. Potassium supply in agriculture through biological potassium fertilizer: A promising and sustainable option for developing countries. <i>Achieves in Agronomy and Soil Science</i> , 68(1), 101-114. DOI: 10.1080/03650340.2020.1821191.
3.	Somnath S. Pokhare, Manjunath N., Jyotsana Sharma, Mallikarjun M.H. and Prakash Patil (2021). Good Management Practices in Pomegranate, Technical Manual No.1/NRCP/2021 ICAR-National Research Centre on Pomegranate, Solapur-413255 (Maharashtra), India, pp170.
4.	M. H. Mallikarjun, N. Manjunatha, Jyotsana Sharma, K. Dhinesh Babu, P.S. Shirgure, Ashis Maity, N.V. Singh, N. Gaikwad, S. S. Pokhare, P. Shilpa, Roopa Sowjanya, Gunwant Garad, Govind Hande, K.N. Rao and Shalendra. 'Course Compendium of Lectures for Training Programme on "Modern practices for export quality pomegranate production and value addition" for Extension Officers from July 28 th -31 st 2021 at ICAR-National Research Centre on Pomegranate, Solapur, Maharashtra, India.pp89.
5.	Souvenir of International webinar on Pomegranate: ancient fruit in Modern Horticulture.
6.	Nripendra Vikram Singh, Shilpa Parashuram, Roopa Sowjanya P., Jyotsana Sharma, Mallikarjun M.H, Ashis Maity, Nilesh Gaikwad, KD Babu, Somnath Pokhare, Manjunatha N. and Rajiv Marathe 2021. Promotion of ICAR-NRCP Technologies under SCSP programme. Technical Bulletin No. NRCP/2022/1, ICAR-National Research Centre on Pomegranate, Solapur. p.36.
7.	Somnath Pokhare, Nilesh Gaikwad, Namrata Giri and Rahul Damale. 2022. Tribal Sub Plan (STC) Report for Three Days' Workshop on Awareness and Promotion of Good Agricultural Practices; Demonstration of ICAR-NRCP Technologies and Distribution of Farm Inputs to Tribal Farmers of Gadchiroli District for the period of 2021-22.
8.	Singh, N.V., Roopa Sowjanya, P., Shilpa, P., Sharma, J., Mallikarjun, M.H., Manjunatha, N., Babu, K.D., Pokhare, S., Maity, A., Shirgure, P.S., Gaikwad, N.N., Giri, N. and Marathe, R.A.2021. Course Compendium of Lectures for Training Programme on Model Propagation and Orchard management Practices for Sustainable pomegranate production -SCSP farmers and coordinating agencies. October 26- 29 th , 2021 at ICAR-National Research Centre on Pomegranate, Solapur, Maharashtra, India, 93p.



S.No.	Technical Bulletin/ Folders
1.	Mallikarjun H. Jyotsana Sharma Somnath S. Pokhare Manjunatha, N. Rajiv Marathe 2021. Pomegranate Shot hole borer Management. ICAR-NRCP/EXTN/2022/1. Published under CROPSAP.
2.	Mallikarjun H. Jyotsana Sharma Somnath S. Pokhare Manjunatha, N. Rajiv Marathe 2021. Dalimb Pikaavaril khod keed (Bhungera) vyavstapan. ICAR-NRCP/Vistar Patrika/2022/1. Published under CROPSAP.
3.	Manjunatha, N, Somnath S. Pokhare, Jyotsana sharma, Mallikarjun M.H., and Siddalingayya S. Salimath 2021. Dalimbe Beyela Beru Gantu Jantuhulu Roga mattu adar samagra nirvahane. NRCP. Extension- 2021/3. p. 04.
4.	Mallikarjun 2022. Dalimb pikaavaril khod Kidiche (Pin hole borer) Ekatmik Vyavstapan. Published as Krushi Salla by Department of Agriculture- Solapur 04.03.2022.
5.	Singh, N.V., Sharma, J., Shilpa, P., Roopa Sowjanya, P., Marathe, R.A. 2021, Outreach Programmes of ICAR-NRCP under SCSP and STC to disseminate pomegranate production technologies. Technical Bulletin No. NRCP/2021/2, ICAR- National Research Centre on Pomegranate, Solapur, p. 33.
6.	Singh NV, Shilpa P., Roopa Sowjanya P., Sharma J., Mallikarjun MH., Maity A., Gaikwad NN., Babu KD., Pokhare S., Manjunatha N. and Marathe RA, 2022, Promotion of ICAR-NRCP technologies under SCSP programme. Technical Bulletin No. NRCP/2022/1, ICAR-National Research Centre on Pomegranate, Solapur, p. 36.

S.No.	E-NEWSLETTER / E-PUBLICATIONS
1.	Mallikarjun, Rajiv Marathe and Dinkar Chaudhari 2021. Advisory for pomegranate shot hole borer management (September-2021)
2.	Mallikarjun, Rajiv Marathe and Dinkar Chaudhari 2021. Dalimb pikaavaril khod keed (Bhungera) vyavstapan (September-2021).
3.	Mallikarjun 2021. Fruit Piercing Moths Management Advisory August 2021.
4.	Jyotsana Sharma, Ashis Maity, N V Singh, Somnatha Pokhare, Mallikarjun and Dinkar Chaudhari, 2021. Bimonthly Pomegranate Advisory (English) for bearing orchards of April-May 2021.
5.	Jyotsana Sharma, Ashis Maity, N V Singh, Somnatha Pokhare, Mallikarjun and Dinkar Chaudhari, 2021. Annar fasal ki diwimasik salah (Hindi) for April-May 2021.
6.	Jyotsana Sharma, Ashis Maity, N V Singh, Somnatha Pokhare, Mallikarjun and Dinkar Chaudhari, 2021. Dalimba pikasatil salla (Marathi) for April-May 2021.
7.	Jyotsana Sharma, Ashis Maity, N V Singh, Somnatha Pokhare, Mallikarjun and Dinkar Chaudhari, 2021. Dalimbae beleyalli kandubaruv samasyegalige salahegalu (Kannada) for April-May 2021.
8.	Jyotsana Sharma, Ashis Maity, NV Singh Mallikarjun H. and Somnath S Pokhar 2021. Bimonthly Pomegranate Advisory for Bearing Orchards (English) June- July 2021.
9.	Jyotsana Sharma, Ashis Maity, NV Singh Mallikarjun H. and Somnath S Pokhar 2021. Annar fasal ki diwimasik salah (Hindi) for June- July 2021.
10.	Jyotsana Sharma, Ashis Maity, NV Singh Mallikarjun H. and Somnath S Pokhar 2021. Dalimba pikasatil salla (Marathi) for June- July 2021.
11.	Jyotsana Sharma, Ashis Maity, NV Singh Mallikarjun H. and Somnath S Pokhar 2021. Dalimbae beleyalli kandubaruv samasyegalige salahegalu (Kannada) June- July 2021.
12.	Jyotsana Sharma, Ashis Maity, N V Singh, Mallikarjun, Manjunatha, N., Somnath Pokhare and Dinkar Chaudhary 2021. Bimonthly Pomegranate Advisory (English) for bearing orchards of August-September 2021.



13.	Jyotsana Sharma, Ashis Maity, N V Singh, Mallikarjun, Manjunatha, N., Somnath Pokhare and Dinkar Chaudhary 2021. Bimonthly Pomegranate Advisory (English) for bearing orchards of August-September 2021.
14.	Jyotsana Sharma, Ashis Maity, N V Singh, Mallikarjun, Manjunatha, N., Somnath Pokhare and Dinkar Chaudhary 2021. Annar fasal ki diwimasik salah (Hindi) August-September 2021.
15.	Jyotsana Sharma, Ashis Maity, N V Singh, Mallikarjun, Manjunatha, N., Somnath Pokhare and Dinkar Chaudhary 2021. Dalimba pikasatil salla (Marathi) August-September 2021.
16.	Jyotsana Sharma, Ashis Maity, N V Singh, Mallikarjun, Manjunatha, N., Somnath Pokhare and Dinkar Chaudhary 2021. Dalimbae beleyalli kandubaruv samasyegalige salahegalu (Kannada) August-September 2021.
17.	Jyotsana Sharma, Ashis Maity, N V Singh, Mallikarjun, Manjunatha N., Somnath Pokhare and Dinkar Chaudhary, 2021. Bimonthly Pomegranate Advisory (English) for bearing orchards of October-November 2021.
18.	Jyotsana Sharma, Ashis Maity, N V Singh, Mallikarjun, Manjunatha N., Somnath Pokhare and Dinkar Chaudhary, 2021. Dalimba pikasatil salla (Marathi) Oct-Nov 2021
19.	Jyotsana Sharma, Ashis Maity, N V Singh, Mallikarjun, Manjunatha N., Somnath Pokhare and Dinkar Chaudhary, 2021. Dalimbae beleyalli kandubaruv samasyegalige salahegalu (Kannada) October-November 2021.
20.	Jyotsana Sharma, Ashis Maity, N V Singh, Mallikarjun, Manjunatha N., Somnath Pokhare, 2021. Bimonthly Pomegranate Advisory for Bearing Orchards (English) Feb-Mar 2022.
21.	Jyotsana Sharma, Ashis Maity, N V Singh, Mallikarjun, Manjunatha N., Somnath Pokhare, 2021. Dalimba pikasatil salla (Marathi) February-March 2022.
22.	Somnath S. Pokhare, Manjunatha, N., Mallikarjun H., Jyotsana Sharma, Rajiv Marathe. 2022. Integrated Nematode management in Pomegranate. Advisory for Delimb Mitra social media platform.

S.No. VIDEOS

ETV programs for Farmers

1.	Technology video on SBH: Shot Hole Borer (SHB) diagnosis and management in Pomegranate on 13.03.2022 by DD Pune.
2.	Technology video on Khod Bhungera: Dalimb pikaavaril pinhole borer (Khod Bhungera) Ekamrik vyavastapan, Krishi Vibhag Sangola on 26.03.2022 (Marathi) by state Dept. of Agriculture.

S.No.	NCBI data base
1.	Different loci (ITS (OK284541- OK284570), LSU (OL377934- OL377961, OL 958630-OL 958631) sequences of <i>Ceratocystis fimbriata</i> isolates (30) are submitted NCBI database
2.	Antibiotic resistance gene (<i>rpsL</i>) sequences of <i>Xanthomonas axonopodis</i> pv. <i>punicae</i> of 15 isolates were submitted to NCBI database with accession numbers (OK483036-OK483041, OK416031- OK416035, OK 626267- OK626270)
3.	Different loci (ITS: OL662873-OL662884), LSU: OM073988-OM073999), NSU: OM 108305-OM 638736) and TEF) sequences of <i>Alternaria alternata</i> isolates (12) were submitted to NCBI database
4.	Sequenced ITS loci of <i>Colletotrichum</i> causing fruit rot in pomegranate and submitted to NCBI database with accession numbers (OM638721-OM638736)
5.	Sequences (LSU: OL440914, ITS: OL440915, NSU: OL440918) of collar rot of pomegranate pathogen were submitted to NCBI database
6.	Mallikarjun MH. 2022. Sequenced <i>Euwallacea fornicatus</i> isolate MH-SPR-001 cytochrome c oxidase subunit causing pomegranate wilting submitted to NCBI database with accession numbers (ON063908- ON063909).

**Any Other: Not covered above**

S.No.	Souvenir:
1.	Marathe R. A., Singh N. V., Roopa Sowjanya, Gaikwad N. N., Manjunath N. Shilpa P., Damale R. D., Jyotsana Sharma. 2021. International Webinar on Pomegranate: Ancient Fruit in Modern Horticulture, August 25-27, 2021, ICAR-NRCP and SARP, Solapur, Maharashtra, India, 205 p.

Crop Advisory

S.No.	Crop Advisory
1.	Dr. Jyotsana sharma, Dr. Ashis Maity, Dr. N V Singh, Dr. Somnath Pokhare, Dr. Mallikarjun and Shri. Dinkar Chaudhari. Bimonthly Pomegranate Advisory for Bearing Orchards (April- May 2021 in English). (https://nrcpomgranate.icar.gov.in/files/Advisory/92.pdf).
2.	Dr. Jyotsana sharma, Dr. Ashis Maity, Dr. N V Singh, Dr. Somnath Pokhare, Dr. Mallikarjun and Shri. Dinkar Chaudhari. Bimonthly Pomegranate Advisory for Bearing Orchards (April- May 2021 in Hindi). (https://nrcpomgranate.icar.gov.in/files/Advisory/95.pdf).
3.	Dr. Jyotsana sharma, Dr. Ashis Maity, Dr. N V Singh, Dr. Somnath Pokhare, Dr. Mallikarjun and Shri. Dinkar Chaudhari. Bimonthly Pomegranate Advisory for Bearing Orchards (April- May 2021 in Marathi). (https://nrcpomgranate.icar.gov.in/files/Advisory/93.pdf).
4.	Dr. Jyotsana sharma, Dr. Ashis Maity, Dr. N V Singh, Dr. Somnath Pokhare, Dr. Mallikarjun and Shri. Dinkar Chaudhari. Bimonthly Pomegranate Advisory for Bearing Orchards (June-July 2021 in English). (https://nrcpomgranate.icar.gov.in/files/Advisory/97.pdf).
5.	Dr. Jyotsana sharma, Dr. Ashis Maity, Dr. N V Singh, Dr. Somnath Pokhare, Dr. Mallikarjun and Shri. Dinkar Chaudhari. Bimonthly Pomegranate Advisory for Bearing Orchards (June-July 2021 in Hindi). (https://nrcpomgranate.icar.gov.in/files/Advisory/101.pdf).
6.	Dr. Jyotsana sharma, Dr. Ashis Maity, Dr. N V Singh, Dr. Somnath Pokhare, Dr. Mallikarjun and Shri. Dinkar Chaudhari. Bimonthly Pomegranate Advisory for Bearing Orchards (June-July 2021 in Marathi). (https://nrcpomgranate.icar.gov.in/files/Advisory/99.pdf). Dr. Jyotsana Sharma, Dr. Ashis Maithy, Dr. N V Singh, Dr. Mallikarjun, Dr. Manjunatha, N., Dr. Somanth Pokhare and Shri. Dinkar Chaudhari. Bimonthly Pomegranate Advisory for Bearing Orchards (August-September 2021 in English). (https://nrcpomgranate.icar.gov.in/files/Advisory/102.pdf).
7.	Dr. Jyotsana Sharma, Dr. Ashis Maithy, Dr. N V Singh, Dr. Mallikarjun, Dr. Manjunatha, N., Dr. Somanth Pokhare and Shri. Dinkar Chaudhari. Bimonthly Pomegranate Advisory for Bearing Orchards (August-September 2021 in Hindi). (https://nrcpomgranate.icar.gov.in/files/Advisory/105.pdf).
8.	Dr. Jyotsana Sharma, Dr. Ashis Maithy, Dr. N V Singh, Dr. Mallikarjun, Dr. Manjunatha, N., Dr. Somanth Pokhare and Shri. Dinkar Chaudhari. Bimonthly Pomegranate Advisory for Bearing Orchards (August-September 2021 in Hindi). (https://nrcpomgranate.icar.gov.in/files/Advisory/103.pdf).
9.	Dr. Jyotsana Sharma, Dr. Ashis Maithy, Dr. N V Singh, Dr. Mallikarjun, Dr. Manjunatha N., Dr. Somanth Pokhare and Shri. Dinkar Chaudhari. Bimonthly Pomegranate Advisory for Bearing Orchards (October-November 2021 in English). (https://nrcpomgranate.icar.gov.in/files/Advisory/109.pdf).
10.	Dr. Jyotsana Sharma, Dr. Ashis Maithy, Dr. N V Singh, Dr. Mallikarjun, Dr. Manjunatha N., Dr. Somanth Pokhare and Shri. Dinkar Chaudhari. Bimonthly Pomegranate Advisory for Bearing Orchards (October-November 2021 in Marathi). (https://nrcpomgranate.icar.gov.in/files/Advisory/112.pdf).



Awards and Recognition

AWARDS

S.No.	Name of Scientist	Name of award	Year of award	Awarding organization
Fellowship/ Associateship/Young Scientist/ other awards				
1.	Dr. R.A. Marathe	Fellow of Society for Advancement of Research on Pomegranate – 2020	2021	Society for Advancement of Research on Pomegranate (SARP), Solapur
2.	Dr. R.A. Marathe	Fellow of Indian Society for Arid Horticulture, Bikaner, Rajasthan. (FISAH-2021)	2021	Indian Society for Arid Horticulture, Bikaner
3.	Dr. K. Dhinesh Babu	Fellow of Society for Advancement of Research on Pomegranate - 2020	2021	Society for Advancement of Research on Pomegranate (SARP), Solapur
4	Dr. K. Dhinesh Babu	Fellow of Indian Society for Arid Horticulture, Bikaner, Rajasthan. (FISAH-2021)	2021	Indian Society for Arid Horticulture, Bikaner
5	Dr. K. Dhinesh Babu	Life Time Achievement Award in Fruit Science	2021	Society for Development and Advancement of Agricultural Technologies (SDAAT), Meerut
6	Dr. Ashis Maity	SARP Associateship- 2020	2021	Society for Advance Research in Pomegranate (SARP), Solapur
7	Dr. Mallikarjun M.H	Young Scientist Award-2020	2021	Society for Advancement of Research on Pomegranate (SARP) Solapur
8	Dr. Gaikwad Nilesh N.	SARP Associateship- 2020	2020	Society for Advancement of Research on Pomegranate, Solapur
9	Dr. Gaikwad Nilesh N.	Best Scientist of the year award 2020-21	2020-21	ICAR-NRCP, Solapur
10	Dr. N.V. Singh	Fellowship of the Society for Advancement of Research on Pomegranate-2021	2021	Society for Advancement of Research on Pomegranate, Solapur
11.	Dr. N.V. Singh	Fellowship of the Confederation of Horticulture Associations of India-2021 (FCHAI)	2021	Confederation of Horticulture Association of India (CHAI), New Delhi
12.	Dr. P. G. Patil	SARP Associateship Award-2021	2021	Society for Advancement of Research on Pomegranate, ICAR-NRCP, Solapur
13.	Dr. P. G. Patil	NESA Eminent Scientist Award -2021	2021	National Environmental Science Academy, New Delhi
14.	Dr. P. G. Patil	Excellence in Research Award -2021	2021	Society for Scientific development in Agriculture and Technology, UP



S.No.	Name of Scientist	Name of award	Year of award	Awarding organization
15.	Dr. P. G. Patil	Best research publication of the Year 2020-21 Award	2021	ICAR-National Research Centre on Pomegranate, Solapur
16.	Dr. Shilpa Parashuram	Young Scientist Award-2020	2021-22	Society for Advancement of Research on Pomegranate (SARP), Solapur
17.	Dr. Shilpa Parashuram	Young Scientist Award-2021	2021-22	Environment and Social Development Association (ESDA), New Delhi
18.	Mr. Rahul Damale	Young Scientist Award-2021	2021	Society for Scientific Development in Agriculture & Technology (SSDAT), Meerut, India
Best poster awards				
1.	K. Dhinesh Babu, N.V. Singh, R. Chandra, A. Maity, J. Sharma, V.T. Jadhav, R.K. Pal, R.A. Marathe, Shilpa P, N. Gaikwad, P.G. Patil, R. Dhamale, S.H. Jalikop, B.N.S. Murthy, P.S. Kumar and P.L. Saroj	Best Poster Award	2021	Indian Academy of Horticultural Science (IAHS)
2.	K. Dhinesh Babu, N.V. Singh, R. Chandra, A. Maity, J. Sharma, V.T. Jadhav, R.K. Pal, R.A. Marathe, Shilpa P, N. Gaikwad, P.G. Patil, R. Damale, S.H. Jalikop, B.N.S. Murthy and P.S. Kumar	Best Poster Award	2021	Society for Advancement of Research on Pomegranate (SARP)
3.	Gaikwad N.N., Kadam A., Giri, N.A. and Suryavanshi S.K	Best poster presentation Award	25-27 th August 2021	ICAR-NRCP, Solapur
4.	K. D. Babu, NV Singh, R. Chandra, A.Maity, J Sharma, VT Jadhav, RK Pal, RA Marathe, Shilpa P, N.Gaikwad, PG Patil, R Damale, SH Jalkiop, BNS Murthy & PS Kumar.	Solapur Lal : A bio-fortified HYV of pomegranate, International Webinar on Pomegranate : Ancient fruit in Modern Horticulture,	2021	NRCP & SARP, Aug 25-27, 2021.
5.	K. D. Babu, NV Singh, R. Chandra, A.Maity, J Sharma, VT Jadhav, RK Pal, RA Marathe, Shilpa P, N.Gaikwad, PG Patil, R Damale, SH Jalkiop, BNS Murthy & PS Kumar, PL Saroj.	Solapur Lal: A bio-fortified HYV of pomegranate for nutrition & livelihood. 9th Indian Horticulture Congress-2021: Horticulture for Health, Livelihoods and Economy,	2021	IAHS, CSUA&T, Kanpur, Nov 18-21, 2021



S.No.	Name of Scientist	Name of award	Year of award	Awarding organization
6.	Manjunatha N	<i>In-vitro</i> evaluation of endophytes against fungal pathogens of pomegranate. In: International Webinar on Pomegranate: Ancient Fruit in Modern Horticulture, 25 th -27 th August, 2021	2021	SARP, Solapur
7.	Mallikarjun M.H	Best Poster Award	2021	Society for Advancement of Research on Pomegranate (SARP) Solapur
8.	NV Singh, Shweta Bute, AS Shinde, DM Mudewadikar, Shilpa Parashuram, Roopa Sowjanya P, PG Patil and RA Marathe	Best Poster Award- Strategies to manage phenolic browning for efficient <i>in vitro</i> culture establishment in pomegranate cv. Bhagwa. In: International Webinar on Pomegranate: Ancient Fruit in Modern Horticulture	2021	ICAR-NRCP & ICAR-CIAH and SARP, Solapur August 25-27, 2021.
9.	Unnati Salutgi, NV Singh, VR Sangnure, Shilpa Parashuram, Roopa Sowjanya P, PG Patil, VA Gargade and RA Marathe	Best Poster Award-. 2021. Standardizing micropropagation protocol and genetic fidelity testing of micropropagated clones of pomegranate cv. Super Bhagwa. In: International Webinar on Pomegranate: Ancient Fruit in Modern Horticulture organized by ICAR-NRCP, Solapur; ICAR-CIAH and SARP, Solapur August 25-27, 2021.	2021	ICAR-NRCP & SARP
10.	Raghavendra Gunnaiah, Dattatraya Hegde Radhika, M. Nandan, Pushpa Doddaraju, Pavan Dumble, Girigowda Manjunatha and Nripendra Singh.	Best Poster Award- 2021. Genome-wide analysis of resistance gene analogues (RGAs) in pomegranate. In: International Webinar on Pomegranate: Ancient Fruit in Modern Horticulture organised by ICAR-NRCP, Solapur; ICAR-CIAH and SARP, Solapur August 25-27, 2021.	2021	ICAR-NRCP & SARP
11.	Prakash G. Patil, Shivani M. Jamma, Singh N. V., Manjunatha N., Dhinesh Babu K. and Marathe R. A.	Best Poster Award- 2021. Hybridity and heterozygosity analysis of putative F1s using genome-wide SSR markers in pomegranate. In: International Webinar on Pomegranate: Ancient Fruit in Modern Horticulture organised by ICAR-NRCP, Solapur; ICAR-CIAH and SARP, Solapur August 25-27, 2021.	2021	ICAR-NRCP & SARP



S.No.	Name of Scientist	Name of award	Year of award	Awarding organization
12.	Roopa Sowjanya P, Kiran Gudaghe, Vipul R Sangnure, Singh N. V, Ajinkya Mandave, Shilpa Parashuram, Sharma J. and Marathe R. A.	Best Poster Award- 2021. Standardization of SRAP markers for assessing pomegranate (<i>Punica granatum</i> L.) genetic diversity. In: International Webinar on Pomegranate: Ancient Fruit in Modern Horticulture	2021	ICAR-NRCP, Solapur; ICAR-CIAH and SARP, Solapur August 25-27, 2021
13.	Shilpa P, Babu KD, Singh NV, Gaikwad, NN, Roopa Sowjanya, P, Kade KR, Jadhav D. C. and Sharma J.	Best Poster Award for the poster on DUS Characterization of New candidate varieties of Pomegranate, in International webinar on Pomegranate: Ancient Fruit in Modern Horticulture. during 25-27 th Aug, 2021	2021	ICAR-NRCP & SARP
14.	Dr. Somnath S. Pokhare	Best poster award 'In-vitro bio-efficacy of bactronol against fungal pathogens of pomegranate' in the international webinar on Pomegranate: Ancient Fruit in Modern Horticulture	2021	SARP, Solapur
Best oral presentation awards				
1.	Ashis Maity	Best oral presentation award	2021	Society for Advancement of Research on Pomegranate (SARP)
2.	Ashis Maity	Best oral presentation award	2021	Hi-Tech Horticulture Society and Prerna Foundation
3.	Dr. Namrata Giri	Best oral presentation award	18-20 August 2021	ICAR-IARI, New Delhi.
4.	Gaikwad N.N., Giri, N.A. and Marathe, R.A. 2021.	Best Invited oral presentation paper Value Added products and dietary supplements from pomegranate in International webinar on Pomegranate ancient fruit in modern horticulture, ICAR-NRCP, Solpaur, 25-27 th August 2021 p. 158.	2021	SARP and ICAR-NRCP Solapur, (M.S)
5.	Gaikwad N.N., Kadam A., Giri, N.A. and Suryavanshi S.K. 2021.	Best poster presentation Award. Foam mat drying of pomegranate juice using whey protein isolate and carboxy methyl cellulose in International webinar on Pomegranate ancient fruit in modern horticulture, ICAR-NRCP, Solpaur, 25-27 th August 2021 p. 167.	2021	SARP and ICAR-NRCP Solapur, (M.S)



S.No.	Name of Scientist	Name of award	Year of award	Awarding organization
6.	Singh, N.V., Sharma, J., Maity, A., Manjunatha, N., Parashuram, S., Patil, P.G., Marathe, R.A. 2021.	Best Oral Award -2021. Bio-priming and innovative propagation techniques for climate smart pomegranate production. In: International Webinar on Pomegranate: Ancient Fruit in Modern Horticulture organised by ICAR-NRCP, Solapur; ICAR-CIAH and SARP, Solapur August 25-27, 2021.	2021	ICAR-NRCP & SARP Solapur, (M.S)
7.	Dr. P. G. Patil	Best invited oral presentation award for the topic entitled 'Genomics Assisted Breeding for accelerated crop improvement in pomegranate' presented in International Webinar on ' <i>Pomegranate: Ancient fruit in modern horticulture</i> '.	2021	SARP, ICAR-NRCP, Solapur, (M.S)
8.	Shilpa P., Roopa Sowjanya P., Singh N. V., Patil, P. G., Babu, K. D., Sharma, J. and Marathe, R. A.	Best invited oral presentation entitled "promising germplasm resources for pomegranate improvement	2021-22	Jointly by ICAR-NRCP, Solapur; ICAR-CIAH, Rajasthan and SARP, Solapur.



Budget Estimate

Table 1: Financial outlay in 2021-22

Head of account	Rupees (in lakhs)	
	2021-22	
	Govt. Grant	
	RE	Expenditure
(A) Recurring		
Establishment charge	458.61	458.59
T.A.	5.60	5.60
Other charges	292.05	292.04
Total A	756.26	756.23
(B) Non-recurring		
Equipment	73.81	73.81
Minor works	18.91	18.91
Library	0.00	0.00
Furniture	2.50	2.50
Information technology	8.01	8.01
Total B	103.23	103.23
(C) Loan & advances	0.00	0.00
(D) Pension	0.00	0.00
(E) Vehicles & vessels	2.27	2.27
Grand total (A+B+C+D)	861.76	861.73

Table 2: Revenue receipt in 2021-22

S. No.	Items	Amount (Rs.)
1.	Income from farm produce	1566131.00
2.	Income from royalty and publications	23838.00
3.	Income from other sources	565166.00
4.	Interest on loans and advances	9438.00
5.	Interest earned on short term deposits	213220.00
6.	Recovery of loans and advances	356510.00
7.	Training programs	390000.00
8.	Analytical testing fee	11896.00
9.	License fee/ Guest house	70504.00
	Total revenue receipt	3206703.00



Staff position & Personnel Joining/Promotion/Relieving

Category	Sanctioned during XIIIth Plan	Staff position	Vacant
RMP	1	1	0
Scientific	22	16	6
Technical	6	6	0
Administrative	11	5	6
Supporting	2	2	0
Total	42	30	12

PERSONNEL

RMP		
Dr. R.A. Marathe Director		
Scientific staff	Technical staff	Administrative staff
Dr. Jyotsana Sharma , Principal Scientist (Plant Pathology)	Sh. D.T. Chaudhari Technical Officer	Sh. R.B. Rai AAO
Dr. P.S. Shirgure Principal Scientist (Land and Water Management Engg.)	Sh. Yuvaraj Shinde Technical Officer	Sh. V.A. Shinde Finance & Account Officer (FAO)
Dr. K. Dhinesh Babu Principal Scientist (Hort.-Fruit Science)	Sh. Bhausaheb Naikwadi Sr.Technical Assistant	Sh. Kiran Khatmode UDC
Dr. Ashis Maity Senior Scientist (Soil Science-Pedology)	Sh. Mahadev Gogaon Senior Technician	Sh. A.S. Babar LDC
Dr. N.V. Singh Senior Scientist (Fruit Science)	Sh. Govind Salunke Senior Technician	Sh. Vipin Dagar LDC
Dr. Prakash G. Patil Senior Scientist (Plant Biotechnology)	Sh. Vijay Lokhande Technical Assistant	Supporting staff
Dr. N.N. Gaikwad Senior Scientist (Agrl. Structures and Process Engg.)		Sh. Shailesh Bayas SSS
Dr. Shilpa P. Scientist (Genetics & Plant Breeding)		Sh. Vishal Gangane SSS
Dr. Mallikarjun Scientist (Agrl. Entomology)		
Dr. Roopa Sowjanya P. Scientist (Genetics & Plant Breeding)		
Dr. Somnath Pokhare , Scientist (Nematology)		
Dr. Manjunatha , Scientist (Plant Pathology)		
Dr. Namrata Ankhush Giri , Scientist (Food Technology)		



Mr. Rahul Damale , Scientist (Biochemistry)		
Dr. Pinky Raigond , Senior Scientist (Plant Physiology)		
Mr. Chandrakant Awachare , Scientist, (Fruit Science)		

JOINING:

Dr. Pinky Raigond, Senior Scientist (Plant Physiology) joined ICAR-NRCP, Solapur on 04.10.2021 due to transfer from ICAR-Central Potato Research Institute, Shimla.

Dr. Chandrakant Awachare, Scientist (Fruit Science) joined ICAR-NRCP, Solapur on 04.10.2021 due to transfer from Central Horticultural Experiment Station, Chettalli, ICAR- IIHR, Bengaluru.

Mr. Bhausaheb V Naikwadi, Sr. Technical Assistant (T-4) joined ICAR-NRCP, Solapur on 24.02.2021 due to transfer from ICAR-Central Institute for Cotton Research, Nagpur.

PROMOTION

Mr. Bhausaheb V Naikwadi, Technical Assistant promoted to Sr. Technical Assistant wef. 24.02.2020.

RELIEVING

Nil

75
Azadi Ka
Amrit Mahotsav



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भारतीय कृषि अनुसंधान परिषद

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ICAR – National Research Centre on Pomegranate

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